SYNCHRONIZING THE 3M CUSHION

MOUNT PLUS SUPPLY CHAIN

By

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ABSTRACT

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Synchronizing the 3M Cushion Mount Plus™ Supply Chain

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The main objective of the study at the 3M St. Paul Tape Plant Cushion Mount Plus focus factory was to develop a detailed plan to apply Synchronous Management and Theory of Constraints techniques to the Cushion Mount Plus™ multi-plant supply chain. The plan was developed using the Theory of Constraints tool: The Prerequisite Tree. In order to assure that the project addressed the most significant problems in the Cushion Mount Plus supply chain the root core problem was identified using a Current Reality Tree. Further analysis of the core problem was done using a cloud diagram. The Current Reality Tree analysis results where used to direct the development of the Prerequisite Tree.

ACKNOWLEDGMENTS

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<u>TABLE OF CONTENTS</u>

Chapter IV: Conclusions and Recommendations

Appendix

LIST OF FIGURES

Figures

<u>LIST OF TABLES</u>

Tables

Chapter I

PROJECT SUMMARY

Project Objectives

The main objective of the study at the 3M St. Paul Tape Plant Cushion Mount Plus focus factory was to develop a detailed plan to apply Synchronous Management and Theory of Constraints techniques to the Cushion Mount Plus multi-plant supply chain. The study accomplished the following objectives:

1. Identify the root core problem of the Cushion Mount Plus Supply Chain using Current Reality Tree analysis.
2. Develop a detailed plan to address the core problem of the supply chain.
3. Achieve buy-in with the key people in the supply chain needed to implement the plan

Significance of the Study

There is a steadily growing interest in Theory of Constraints in 3M. Eli Goldratt's book The Goal: *A Process of Ongoing Improvements* (Goldratt, 1984) is almost required reading in the manufacturing arm of the business and some very good classes are offered in an effort to help turn the information in the book into common practice. As a result there are expanding pockets of knowledge and interest spread throughout 3M.

The 3M St. Paul Tape plant is one of these pockets of TOC knowledge. At the beginning of this project they had already implemented the Theory of Constraints scheduling technique called Drum-Buffer- Rope throughout the St. Paul Tape plant and had seen significant benefits as a result. Inventory levels where down and customer service improved.

The problem facing the St. Paul Tape plant is how to continue the improvement process. Most of the products that flow through the St. Paul plant are started at other 3M plants. A large number also travel to additional 3M plants for further processing after leaving the St. Paul plant. It is not unusual for a product to travel between 3 and 5 plants before being sent to the final customer. Often these plants are in distant locations, and often they are owned and operated by other divisions of 3M. Multi plant and often multi division supply chain limited the ability for any one piece of the supply chain to implement improvements to the entire supply chain. The question was how do you get similar results as those seen at that St. Paul plant throughout the supply chain? In order to answer this question it was decided that a single supply chain would be used as a pilot. The Cushion Mount Plus supply chain was selected because it was having difficulty meeting its customer service targets.

Report Overview

This report is divided into four chapters. Chapter I details the objective of the study, discusses the significance of the study and provides an overview of the report.

Chapter II contains a review of Theory of Constraints, the definition of terms used in this report, background information about the Cushion Mount Plus™ supply chain, and a summary of the collection, treatment and validity and reliability of the data.

Chapter III includes an analysis of the data including, identification of the core problem using a Current Reality Tree. Examination of the core problem using a cloud diagram and a detailed action plan in the form of a Prerequisite Tree.

Chapter IV contains a summary of the study, findings and personal observations.

Chapter II

DESIGN OF THE STUDY

Review of the Theory of Constraints

Theory of Constraints was developed primarily be Dr. Eli Goldratt, an Israeli born Physicist. In 1984 Dr. Goldratt wrote the book The Goal: *A Process of Ongoing Improvements* (Goldratt, 1984) in order to explain the logic behind his successful, but often misunderstood and misapplied scheduling software. Named Optimized Production Technology (OPT)

The Goal focused on solutions for managing and improving the performance of manufacturing. The ideas in the book challenged many common practices used in manufacturing. The application of the ideas in the book allowed significant improvement very quickly.

Since 1984 Dr. Goldratt has focused on expanding and extending the Theory of Constraints solutions into other areas of the business including distribution, sales, marketing, and project management as well as providing a frame work for tying all of these areas together called strategy and tactics. Along with developing general solutions for each of these areas, a tool kit has been developed to guide the change process. These tools are called The Theory of Constraints thinking process. The addition of these solutions and tools has transformed Theory of Constraints from simply a manufacturing tool into a new overall management philosophy. The goal of this philosophy is to move the entire organization towards rapid and continuous improvement.

The rest of this chapter can be divided into two parts. The first is a description of the Thinking Process tools, what each is used for and how they are read. The second is a brief description of Drum- Buffer- Rope production scheduling.

I. Theory of Constraints Thinking Process Tools

" There are really only two TOC Thinking Processes: Sufficient Cause and Necessary Condition. As of this writing there are five applications of these two thinking processes:

The Sufficient Cause Application Tools	**The Necessary Condition Application Tools**
• Current Reality Tree (CRT)	• Evaporating Cloud
• Future Reality Tree (FRT)	• Prerequisite Tree (PRT)
• Transition Tree	

(Scheinkopf p6)"

The Thinking Process Tools where developed under the assumption that people have very good intuition about the systems that they work and live in. This intuition should allow people to develop creative solutions that address the problems that exist in these systems. Unfortunately something often prevents the development and implementation of these solutions.

> " We grossly underestimate our intuition. Intuitively we do know the solutions. What is unfortunately not emphasized enough, is the vast importance of verbalizing our own intuition. As long as we will not verbalize our intuition, as long as we do

> not learn to cast clearly into words, not only will we be unable to convince others; we will not even be able to convince ourselves of what we already know to be right. If we don't verbalize our intuition, we ourselves will do the opposite of what we believe in." (What is this thing called TOC p3)

The various Thinking Process tools, and the rules for constructing them, allow the user to clarify their intuition and encourage the examination of underlying assumptions. These assumptions are often erroneous, left from situations when things where different. Challenging these assumptions allows the change process to begin.

The change process is often described in TOC texts using the following three questions.

What to change?
To what to change?
How to cause the change

All three questions need to be answered in order to change an organization. Different thinking process tools are used to find answers for each of these three questions.

What to change?

Current Reality Tree

> "The Current Reality Tree (CRT) is a problem-analysis tool. It helps us examine the cause-and- effect logic behind our current situation. " (Dettmer, 1997 p.22)

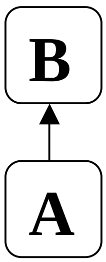
The Current Reality Tree provides Focus. It is used to sift through the many problems that we face in the systems that surround us and identify the one problem that drives the others. Once the Current Reality Tree is constructed it is relatively easy to identify the problem to address first.

A Current Reality Tree is constructed by linking a selection of problems you face by using sufficiency logic or effect- cause- effect.

> "Sufficient cause is the thought pattern of effect-cause-effect. When we assume that something, simply because is exists, causes something else to exist, we are using sufficient cause thinking. Another way of saying this is that we are using sufficient cause thinking when we assume that something is the inevitable result of the mere existence of something else." (Scheinkopf p.31)

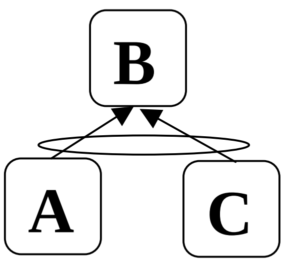
Here are some examples of the structure of a sufficient cause tree. Each Box in the diagram contains a statement about reality. The arrow represents the connection between the statements.

1.



In the first diagram Box A is the cause of Box B. The diagram is read if A then B. In all of the Thinking Process tools that use effect- cause- effect logic the Box or entity at the point of the arrow is caused by the Box or entity at the base of the arrow.

2.



In diagram number two both Box A and Box C are necessary for Box B to exist. The oval shape functions as an "and" sign. This diagram is read If A and if C then B.

3.

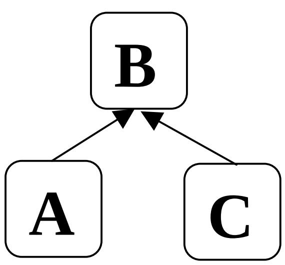


Diagram number three is just a variation on diagram number 1. Though it look similar to diagram number two there is no and symbol. This means that Box A alone is sufficient to cause Box B to exist. Box C alone is also sufficient to cause Box B to exist. It is read if A then B or if C then B.

In any Current Reality Tree many of each of these structures will be linked together. (See fig. 9) This linking will show how the existence of one of the entities is the cause or driver of all or most of the others. This root cause entity and the problem or conflict that causes it to exist is the place to start when answering the question, "<u>What to change?</u>"

> " The CRT tells us *what to change*-the one simplest change to make that will have the greatest positive effect on our system." (Dettmer p.23)

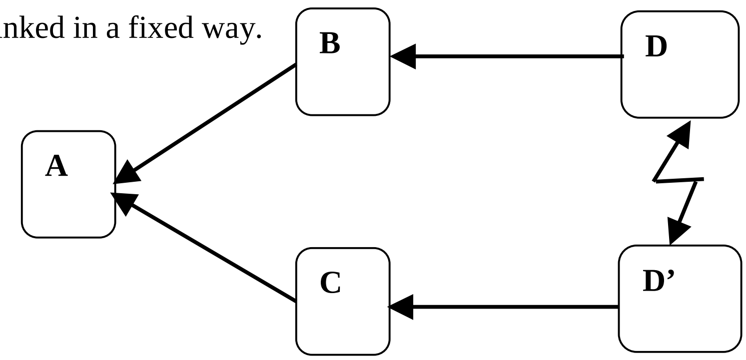
To what to change

Often the root core problem is not a new problem. Many people in the organization realize that it is a problem but most have decided that there is no solution or are attempting to us an unacceptable compromise to address the problem. In order to address a conflict without compromise the Evaporating Cloud diagram is used.

Evaporating Cloud Diagram

The Evaporating Cloud Diagram is one of the most used tools. It is a very concise way to show the conflict that is behind a problem. It can be used to analyze any problem that can be described as a conflict. Like the Current Reality Tree the Cloud is used to focus intuition and to raise erroneous assumptions about reality.

Compared to the Current Reality Tree the cloud is a simple structure. It contains only five Boxes linked in a fixed way.



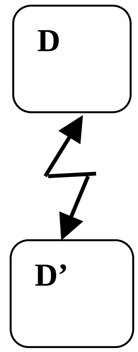
The Cloud diagram is a necessary condition tool.

> "Necessary Condition is the thought pattern we use when we are thinking in terms of *requirements*. When we think that something *must* exist before we are able to achieve something else, we are using necessary condition thinking." (Scheinkopf p. 69)

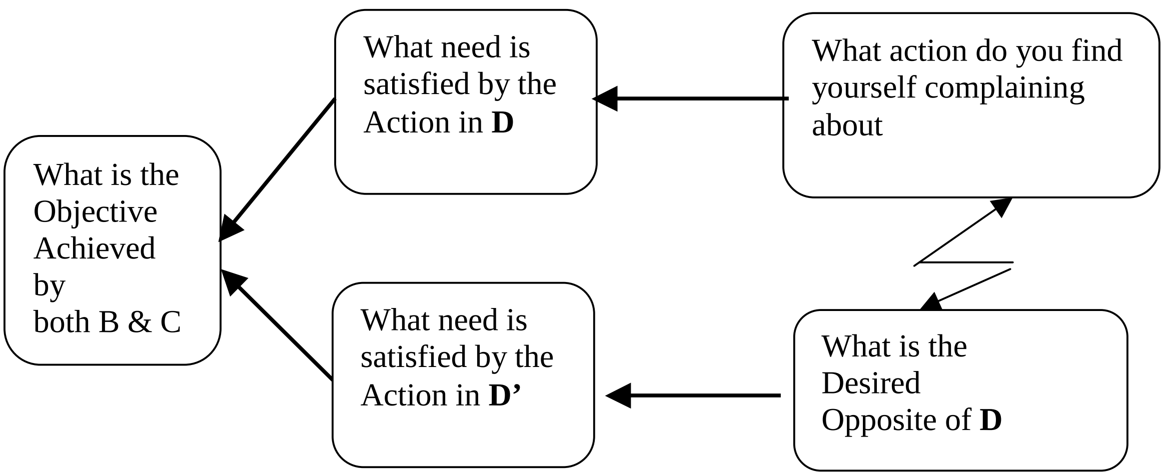
This thinking differs from sufficient cause thinking in a very fundamental way. If the cloud above where a sufficient cause diagram we would be able to say Box A is caused by Box B and the simple existence of Box B will inevitably cause Box A to exist. In a necessary condition diagram Box B is necessary to have Box A, but the fact that Box B exists may not be sufficient for Box A to exist. There may be other necessary conditions.

Reading a cloud

A necessary condition diagram such as the cloud can be read in one of two ways. Either by stating that in order to have Box A I must have Box B or by stating the same relationship but in reverse order I must have Box B in order to have Box A. The one exception is the Boxes connected by the jagged double-headed arrow. This is the conflict arrow and it is read I cannot have Box D and have Box D'.



Box D and D' are considered mutually exclusive, you cannot have both; often they are polar opposites of each other. Box B is the underlying reason that we want Box D and Box C has the same relationship with Box D'. The A Box is the underlying reason for wanting both Box B and Box C. The fact that you need both Box B and Box C in order to achieve Box A is the reason that the conflict exists.



In order to evaporate the cloud and eliminate the conflict we must invalidate one of the necessary condition relationships. In other words we must challenge the fact that we cannot have the entity at the point of the arrow without having the entity at the base of the arrow. Challenging the fact that we cannot have both the D and D' Boxes.

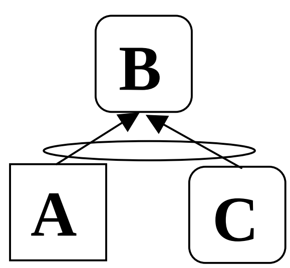
> "Our interpretations of necessary condition relationships shape our perception of what we are and are not able to do. Often, we limit our opportunities by believing strongly in necessary conditions that aren't, or don't need to be. As a result, we block ourselves from seeing and acting upon many simple, practical, creative, and speedy ways to achieve our objectives." (Scheinkopf p 70)

If we can invalidate one of the arrows in the diagram then we will no longer be in conflict because we will be able to achieve our objective. If the problem that has been eliminated is the one that is at the base of the Current Reality Tree then we have taken the first step towards identifying, to what to change. This step is often not sufficient. The root core problem usually has existed for an extended period of time and our organizations will have developed policies and procedures in an attempt to deal with the consequences. These policies and procedures in themselves may drive other negative things in our organization. In order to address these issues and develop a comprehensive solution a Future Reality Tree diagram is used.

Future Reality Tree diagram

As the name implies the Future Reality Tree diagram is used in an attempt to predict the future. In many ways it is the mirror of the Current Reality Tree. It uses the same sufficient cause logic and is read using the same if…then language. The Current Reality Tree is focused on the problems that the organization is facing with the root cause problem at the base. In contrast the Future Reality Tree has the solution derived from the cloud at the base as well as any other changes to the organization needed in order for all of the original problems to no longer effect the organization. These changes are called injections.

> "**Injections** are entities that do not exist in the system's current reality, and are distinguished from other entities by their squared corners. Why the term injection? Think of getting a shot in the arm. The idea is that once you've received that injection, the illness will be cured, and the ugly symptoms will disappear." (Scheinkopf p.110)



In the diagram above Box A would be the injection.

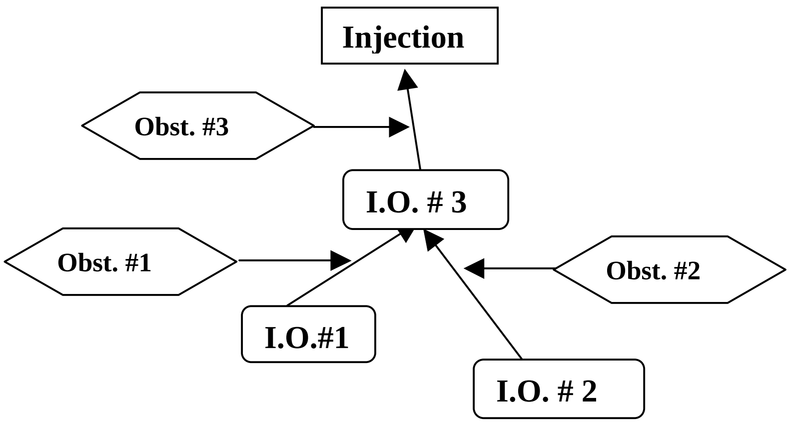
Many times when adding injections the FRT new problems will be created. Often the existence of these new problems is the reason that the solution has not been applied before. These new problems cannot be ignored but if they are added to the Future Reality Tree we end up with a confusing mess. In order to avoid this problem the negatives are diagrammed on a separate Future Reality Tree called a negative branch. Then the various tools and techniques are applied to eliminate or trim the Negative Branch. This requires additional injections. These injections are then added to the original FRT. In this way a list of injections are created to address many of the problems faced by the organization. This list becomes the answer to the question, "To what to change?"

How to cause the change?

Prerequisite Tree

We now have a list of injections that need to be put in place in order to eliminate our selected problems faced by our organization, but some of these injections will seem impossible to achieve. The Prerequisite Tree was developed in order to facilitate achieving difficult to reach goals. The Prerequisite Tree is constructed using necessary condition logic

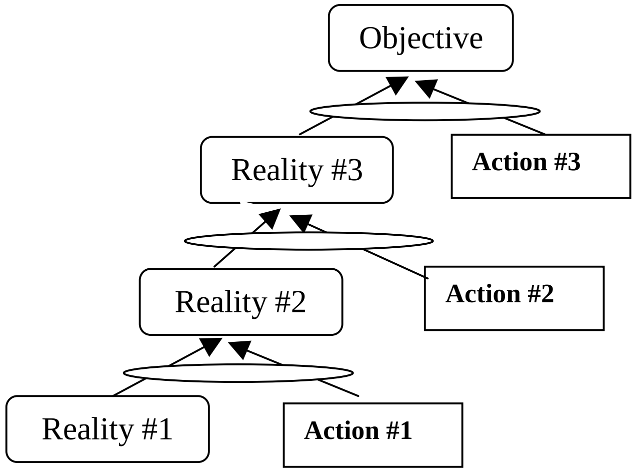
The prerequisite tree structure has the desired outcome in a Box at the top of the page. Underneath are all of the obstacles that block achieving the desired outcome as well as the necessary condition to overcome each obstacle. The necessary conditions are often called intermediate objectives (I.O.). These are the milestones that need to be achieved in order to reach the injection. The obstacles at the base of the tree must be addressed before those at the top of the tree can be addressed. Here is an example of the prerequisite tree structure.



This structure is read as follows. In order to have I.O. #3 I must have I.O. #1 because of Obst. #1. . I have used a modified Prerequisite tree for this project because it is easier to read and present in a group. The modified prerequisite does not show the obstacles**.**

Transition Tree

The transition tree is used to develop a detailed action plan. Its structure is based on sufficient logic. Lowest level of this tree contains a statement about current reality. This statement is paired with an action. Once the action is taken this will cause a change in reality resulting in a new reality. This structure repeats itself until the final desired outcome is achieved.



This structure is read as follows. If “ Reality #1” and If “Action #2” Then “Reality #2”

The various TOC Thinking Process tools can be used in sequence to address a very complex problem or individually to address particular situations. An example would be to use a cloud diagram to address a conflict between two employees.

Theory of Constraints manufacturing applications

In the book The Goal (1984) Dr. Goldratt describes a dramatic transformation of the way to run the manufacturing arm of an organization. Since The Goal was written specific applications for distribution, marketing & sales and project management have been developed. An area called strategy and tactics has also been developed to assist managers in their efforts to lead their companies along a path of continuous improvement.

Manufacturing

In the book Critical Chain (1997 p 87) Dr. Goldratt uses the analogy of a chain to describe the manufacturing process. In this analogy each link in the chain is a step in the manufacturing process. In this analogy as in real life the strength of the chain is determined by the weakest link. In a chain the weakest link is the first link that will break under pressure.

> "Let's say you keep increasing the force you apply to this chain. Can you do this indefinitely? Of course not. If you do, eventually the chain will break. But where? At what point? The chain will fail at the weakest link. How many "weakest links" does a chain like this have? One- only one. It will fail at only one point, and that weakest link is the constraint that prevents the chain (system) from doing any better at achieving its goal." (Dettmer p. 8)

In manufacturing the weakest link is the operation that has the least capacity. This weakest link is called the bottleneck or constraint. The bottleneck, in each manufacturing process, dictates the maximum output of the system. As long as the market demand for the company's product exceeds the potential output of the bottleneck the output of the bottleneck will dictate the maximum profits. This means that in order to improve profits the output of the bottleneck must be increased. This can be achieved by increasing the quantity the constraint produces, by focusing on products that yield more profit per time on the constraint or a combination of the two.

Constraint vs. Non-constrained resources

The fact that the entire system is limited by the capacity of the constraint means that producing more anywhere in the system than is needed by the constraint will only inflate the inventory in the system and will not result in increased profits. In order to avoid this it necessary to restrict production on all non-constrained resources below their individual maximum capacity. The decision to limit production on all non-constrained resources has a negative impact on traditional efficiency and unit cost measures. The fact that this decision is the right decision for the system, but traditional measures would lead to the exact opposite decision reveals a flaw in traditional cost measures. In order to address this flaw Dr. Goldratt has developed new measures for making decisions and evaluating local performance. These measures are Throughput, Inventory and Operating expense. These three measures play a key roll in the decision-making process.

Throughput is defined as the rate at which the system generates money through sales. In this definition only sales results in throughput. Hence, an increase in production without an increase in sales will not show a fictitious increase in profits. Throughput is equal to sales dollars minus the material cost of goods sold.

Inventory is defined as all the money the system invests in purchasing things the system intends to sell. This definition implies that the value of inventory is always equal to the money paid for materials. The inventory value does not include any allocated costs. Nor does the inventory increase in value as it undergoes additional steps in the manufacturing process.

Operating expense is defined as all the money the system spends in turning inventory into throughput. Operating expense includes all money accept that spent to purchase inventory.

There are three ways to improve the performance of an organization, Throughput dollars go up, Inventory dollars go down and Operating Expense dollars go down. In an ideal situation all three measures would improve simultaneously, but any improvement in one measure while the others remain relatively unchanged is an improvement.

There are practical limits to the improvements that can be made in each category. Efforts to reduce Inventory and Operating Expense are limited by zero. Efforts to increase Throughput cannot result in infinite profits but the potential gain is much larger. Consequently the more focussed a system is on increasing Throughput rather than reducing Inventory or Operating Expense the greater the potential improvements. The Drum- Buffer- Rope scheduling system can be used to increase the throughput of a manufacturing system.

Drum- Buffer- Rope scheduling technique

The Drum- Buffer- Rope (DBR) scheduling technique was developed to move material quickly and smoothly through the manufacturing system in concert with market demand. Material must flow quickly through the system in order to minimize the inventory in the system as well as to allow more rapid adaptation to changes in the market. The drum in the system sets the pace for the entire system. The drum is either an internal constraint if one exists or market demand. The initial schedule for the system is developed based on market demand. This schedule is then modified to fit the capabilities of any constraints in the system.

In order to achieve this schedule the constraint must be protected from disruption. The constraint is protected from disruption by establishing a buffer at the constraint. This buffer consists of all of the materials needed by the constraint for a set time period. Once this buffer is established any disruption up stream from the constraint will not affect the constraint as long as the disruption is eliminated before the buffer is exhausted and as long as the process that experienced the disruption has sufficient protective capacity to replenish the buffer before further disruption. Buffers are also placed before shipping and at assembly points. The shipping buffer is used to protect the promised due date to the customer. The assembly buffer is used to assure rapid flow of materials from the constraint to the shipping buffer. An assembly buffer is placed before any assembly point down stream from the constraint. The assembly buffer consists of all non-constraint materials for the assembly step. Releasing material into the system before it is theoretically necessary creates all buffers. The rope refers to the process of tying the release of materials into the system to the various buffers.

The length of the rope is calculated by estimating the time it would take for material to reach the buffer if no disruptions occur plus adding in an estimate of how long it would take to overcome most disruptions. As long as the drum, buffer and rope are applied correctly the system should by protected from disruptions with a minimum of inventory.

Definition of Terms

Cloud diagram	A necessary condition TOC tool developed to solve conflicts
Constraint	Anything that prevents a system from achieving a higher level of performance relative to its goal
Current Reality Tree	A sufficient cause TOC tool used to analyze complex situations and identify high leverage points for change
Drum- Buffer- Rope	A scheduling system used to manage a manufacturing environments
Future Reality Tree	A sufficient cause based TOC tool used to project the consequences of change
Inventory (I)	All of the money the system invests in purchasing things the system intends to sell
Necessary Condition Logic	The thought pattern used when thinking in terms of *requirements.* "A" must exist before "B" can exist.
Negative Branch	A version of a Current Reality Tree used to eliminate potential consequences of a proposed action
Obstacle	A condition that may prevent successful application of an injection
Operating Expense (OE)	All the money the system spends in turning inventory (I) into Throughput (T)
Prerequisite Tree (PRT)	A necessary condition based TOC tool used to identify the intermediate goals necessary to achieve a desired outcome.
Sufficiency logic	The thought pattern when we assume that something, simply because it exists, causes something else to exist.
Throughput (T)	The rate at which the system generates money through sales.
Transition Tree	A sufficient cause TOC tool used to sequence events to achieve a desired outcome.

Supply Chain Background

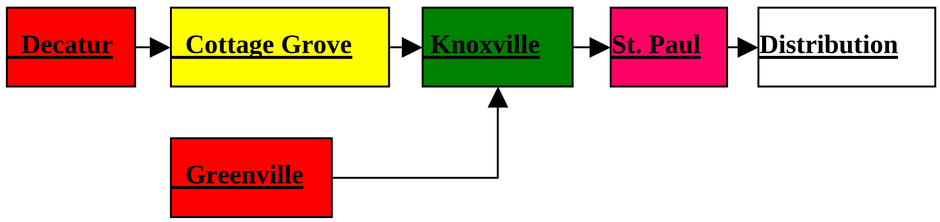
The term supply chain can be defined as every step from the point where naturally existing materials are gathered through the point where the ultimate customer consumes the final resulting product. For use in this project the term supply chain is defined as all of the operations necessary to transform materials purchased from non-3M suppliers into a product purchased by a non-3M customer. This limited view of the supply chain focuses on the areas that are under 3M's direct control.

Cushion Mount Plus™ Supply Chain

The Cushion Mount Plus™ supply chain involves five different 3M factories.

Plant Name	Plant Location
Decatur Specialty Film Plant	Decatur, Alabama
Cottage Grove Specialty Chemical Plant	Cottage Grove, Minnesota
Greenville Specialty Film Plant	Greenville, South Carolina
Knoxville Tape Plant	Knoxville, Iowa
St. Paul Tape Plant	St. Paul, Minnesota

The finished product is sent either direct to a customer or to a distribution center.



For a more in-depth picture of the supply chain see Appendix D.

There are a total of 17 operations involved in production of CM+, involving ten different pieces of equipment. The following table lists the number of operations and machines at each plant.

Location	# of operations	# of machines
Decatur	2	2
Cottage Grove	1	1
Knoxville	11	4
Greenville	1	1

St. Paul	2	2
Total	**17**	**10**

Cushion Mount Plus™ Products

The Cushion Mount Plus ™ Tapes are used in the flexographic printing industry. This industry provides the printed packaging for many consume goods. One example would be the pictures and wording on bags of chips and other snacks. The Cushion Mount Plus™ Tape is used to mount the photopolymer plate to the plat cylinder in the printing process.

Data Collection

Two sets of data where collected for this study. The first consists of undesirable effects as reported by different individuals involved with the Cushion Mount Plus™ supply chain. The undesirable effects where collected in individual interviews with a selection of employees involved in this supply chain.

The second set of data consists of obstacles and intermediate objectives used in creating the Prerequisite Tree analysis. This data was collected in group meetings with a cross section of the people involved in the supply chain. The individuals involved where selected to represent the different functions and the different locations involved in the Cushion Mount Plus™ supply chain.

Data Treatment

The data collected for this project was analyzed two ways. The first set of data was used to create a Current Reality Tree and to identify a root core problem in the supply chain. The second set of data was used to construct a Prerequisite Tree. A detailed discussion of the data and its treatment was included in Chapter III.

Validity and Reliability

The data collected for this project is considered to be valid because it was collected from people intimately involved in the Cushion Mount Plus™ supply chain and it has been reviewed and validated by many people working in the supply chain.

CHAPTER III

ANALYSIS OF DATA

Chapter Overview

In this chapter three of the TOC Thinking Process tools where applied to analyze the Cushion Mount Plus™ supply chain. A Current Reality Tree was developed using Effect-Cause- Effect analysis on Undesirable Effects (UDE's) that existed in the supply chain environment. The UDE's where collected from the individuals directly involved in the supply chain. The root problem identified by the Current Reality Tree analysis was converted into a cloud to better expose the cause of the problem. This analysis was used to answer the question "WHAT TO CHANGE?" The evaporating cloud analysis and the resulting injection also indicated a firm direction for the answer to "WHAT TO CHANGE TO?" This direction was clarified with the entire supply chain team using a modified Prerequisite Tree.

The Current Reality Tree

The Current Reality Tree was used to identify the problem that once addressed would minimize or eliminate many other problems in the system. The following Undesirable Effects (UDE's) where used as the starting point for the Current Reality Tree Analysis.

1. There are frequent changes in the production plan (#230)
2. Excess time is spent coordinating supply chain activities (250)

3. It takes significant time and effort to rush material through the supply chain to replace defective material (#300)
4. Inventory levels are too high (#135)
5. We have only 2.3 inventory turns per year #109)
6. The output quantity from the supply chain is unpredictable (#180)

The Current Reality Tree is shown in Figure 10 with the original UDE's outlined in blue. The Boxes with bold outlines indicate that they appear in multiple locations on the tree.

Core Problem

The steps for identifying the root core problem are:

1. Develop the CRT
2. Highlight all entities that are by there existence negative. Do not include entities that are just negative because of what results from them.
3. Highlight connections between all Highlighted entities.
4. Identify the entity lowest in the tree that leads to the majority of the highlighted entities. This should be the root core problem in the CRT.

The lowest level driver in the tree is Box #3; Each planner does their best to optimize the portion of the supply chain that they are responsible for. If this is addressed then all the UDE's in the tree would be eliminated or at least their impact would be reduced. In order to add clarity to the problem the supply chain cloud in was created See figure 11. In the cloud the Box D is a restatement of the core problem from the Current Reality Tree, Take actions that optimize their portion of the supply chain. Under the current situation they must take these actions in order to, achieve Box B, meet their local goals. They must meet their local goals in order to, achieve Box A, and do their jobs well. On the other side of the cloud is, Box D', Not take actions that optimize their portion of the supply chain. They must comply with Box D' in order to, Box C; Do what is best for the entire supply chain. Box C is also necessary in order to accomplish Box A. The conflict is clearly between Box D and D'. The planner can not both take actions that optimize their portion of the supply chain and not take these same actions. In order to evaporate a cloud an assumption about the cloud that is incorrect must be found. In order to do this the connection between Box B, meet their local goals and Box D, take actions that optimize their portion of the supply chain was targeted. The assumption challenged was:

> In order to meet their local goals they must take actions that optimize their portion of the supply chain because their local goals focus on local optimization.

If local measures could be changed to drive optimization of the entire supply chain rather than local optimization the cloud would no longer exist. With this solution in mind the modified Prerequisite Tree was developed.

The goal for the Prerequisite Tree was to optimize or synchronize the entire supply chain with a focus towards maximizing the output of the supply chain rather than maximizing any one part. A synchronization process would be complete when the following had been accomplished.

1. The constraint in the supply chain has been identified.
2. Necessary buffers and procedures are in place for exploiting the constraint

3. Procedures for subordinating all other operations in the supply chain to the pace of the constraint are in place.
4. Procedures are in place to monitor progress.

With this goal in mind the team created a list of obstacles blocking the goal. Each obstacle was then paired with a target condition that once in place would eliminate the obstacle as well as a person who would be responsible for putting the necessary condition in place. See Table 6. The target conditions where used to create the modified prerequisite tree. See Appendix F Prerequisite Tree

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Summary

The main objective of this study was to develop a detailed plan to improve the performance of the Cushion Mount plus supply chain. The plan needed to address the core problem faced by the supply chain and have the support of the people necessary to implement the needed changes. The following steps where used to accomplish the objectives of the study.

1. The core problem was identified using effect- cause- effect logic in the form of a Current Reality Tree. The Current Reality Tree was constructed from Undesirable Effects collected from people directly involved in the Cushion Mount Plus supply chain.
2. The Evaporating Cloud tool was used to increase the understanding of the core problem as well as to develop a solution to the core problem.
3. A detailed action plan was created using the Prerequisite Tree tool. This was developed in concert with the people necessary to implement the plan. Each step in the plan has a volunteer who is responsible for assuring the implementation of their step in the plan.

Findings

The results for this study are summarized in the following: List of UDE's See Table 5, Core problem and Solution.

List of UDE's
1. There are frequent changes in the production plan (#230) 2. Excess time is spent coordinating supply chain activities (250) 3. It takes significant time and effort to rush material through the supply chain to replace defective material (#300) 4. Inventory levels are too high (#135) 5. We have only 2.3 inventory turns per year #109) 6. The output quantity from the supply chain is unpredictable (#180)

Table 5. List of Undesirable Effects

Core Problem: Each planner does their best to optimize the portion of the supply chain that they are responsible for.

Solution: Change the local performance measures so that they are in line with the needs of the entire supply chain and subordinate local decisions to the needs of the entire supply chain.

Conclusion

The three objectives of this study of 3M Cushion Mount Plus™ supply chain where met by accomplishing the following actions.

1. The root core problem in the supply chain was identified using Current Reality Analysis.
2. The conflict behind the core problem was analyzed using the Evaporating Cloud technique
3. A detailed plan for improving the performance of the supply chain was developed and the plan has the support of the people responsible of implementing the needed changes.

Personal Observations and Recommendations

Though this project and the resulting plan have some potential for improving the performance of Cushion Mount Supply Chain there are still significant difficulties that need to be overcome before significant improvement can be realized. In my opinion the key barriers are as follows:

1. The current inventory and control systems do not provide the necessary visibility of the entire supply chain needed to assure that local decisions are in line with the needs of the entire supply chain. This lack of visibility can be overcome using analysis performed by individuals in the supply chain, but this is time consuming and would not be practical on a company wide scale. The inventory and control system needs to be updated to provide the needed information.

2. The measures used to evaluate the performance at the plant level are not in line with the needs of the supply chains. The focus almost exclusively on local performance without regard to the impact on the total supply chain involved.
3. No individual or function in 3M is responsible for the performance of the entire supply chain; consequently there is no drive to improve the performance of the supply chain. All of improvement programs are focussed at the individual links of the chain. Even the programs focussed on reducing inventory and improving customer service, both results of the supply chain performance, look at the performance of the individual links of the chain rather than the structure and performance of the whole.

Until these issues are addressed at a company wide level improvements in supply chains will be slow and will tend to atrophy.

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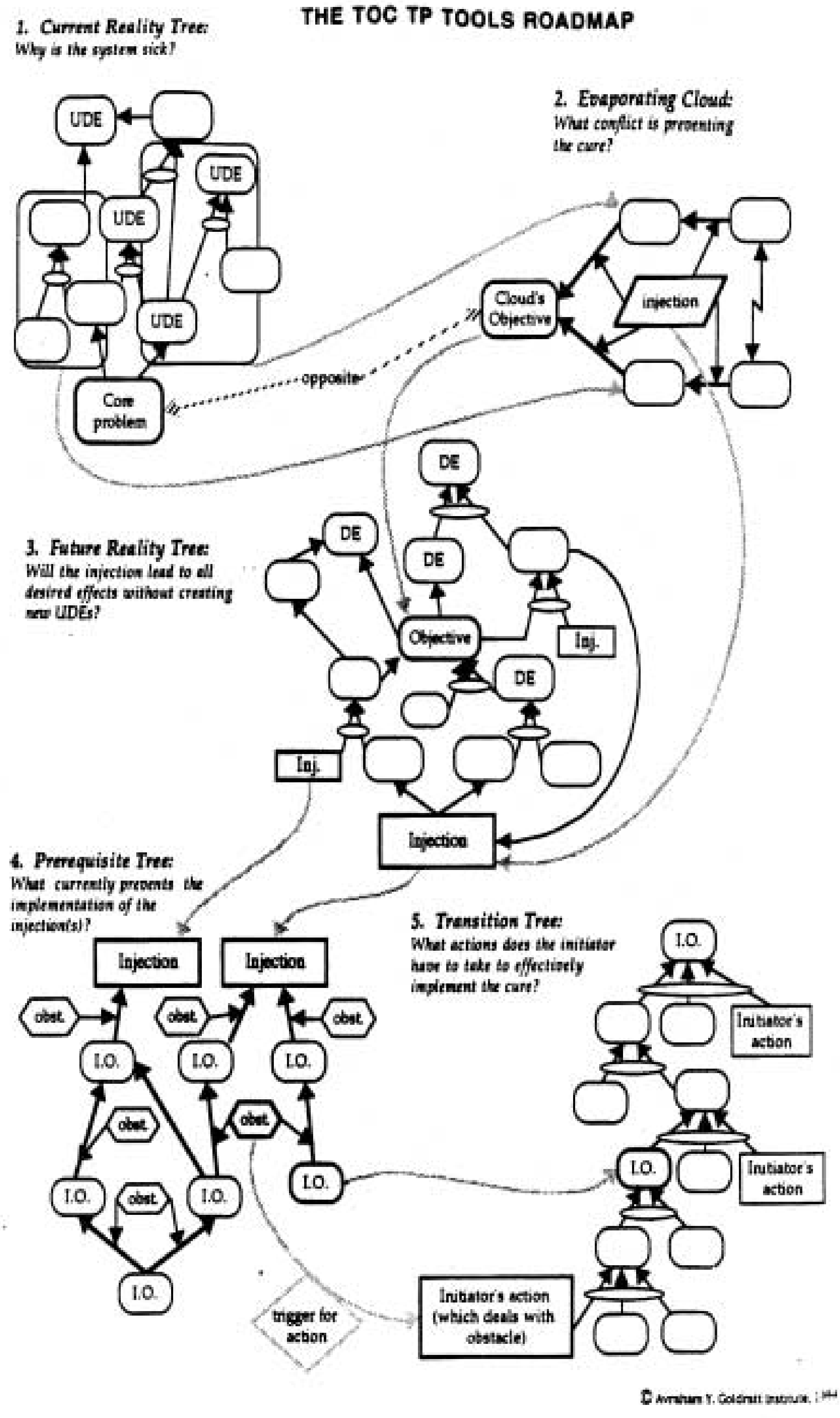
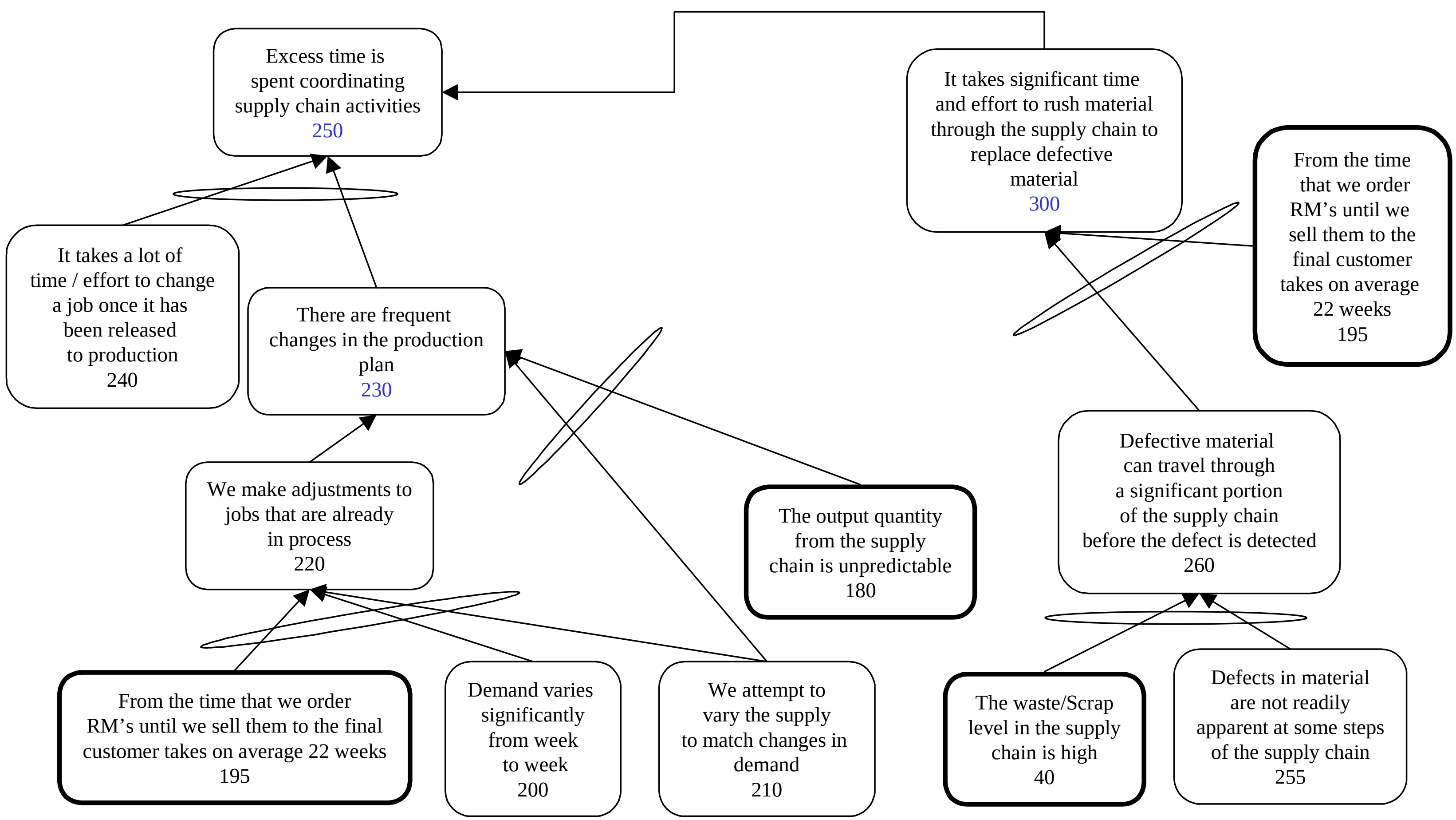
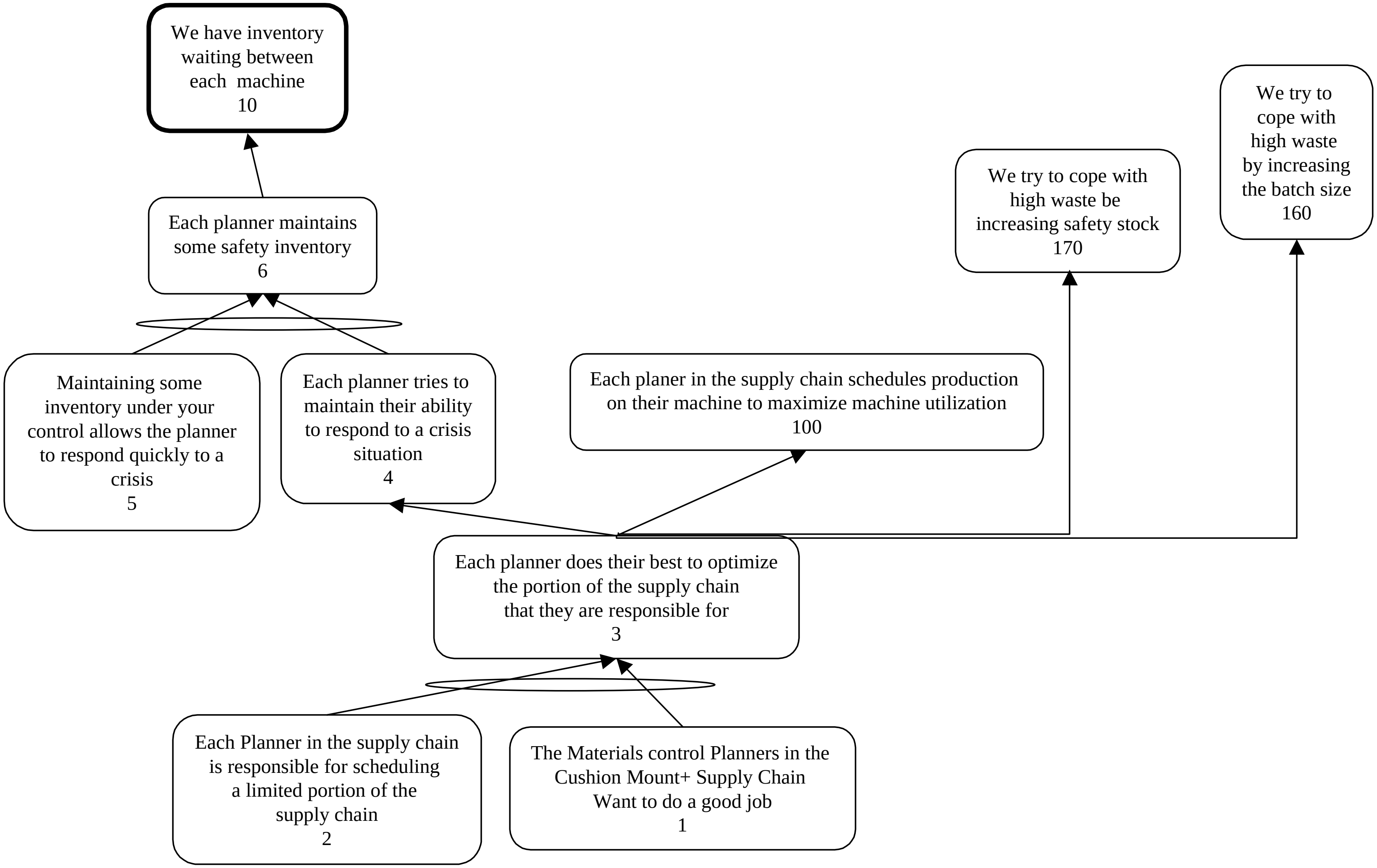
Appendix A: TOC Thinking Process Tools: Flow



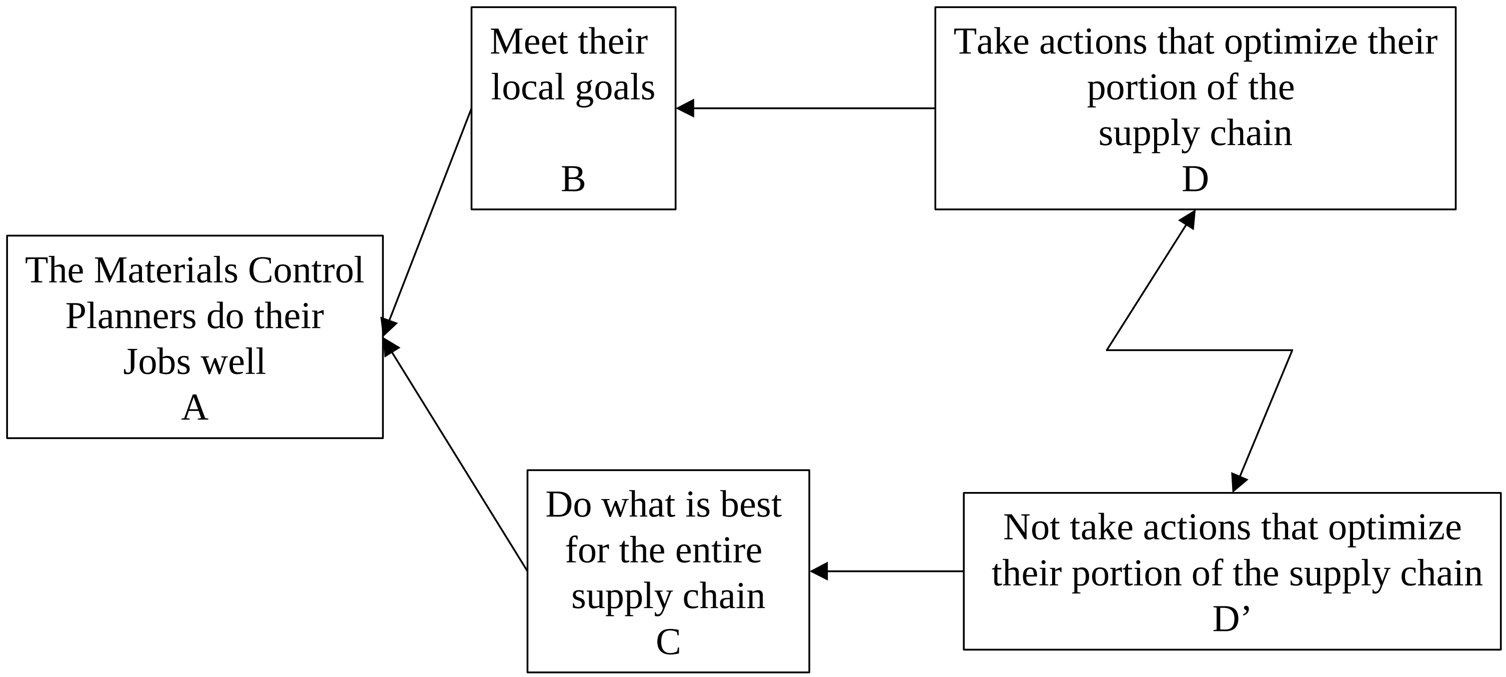
Appendix B: Supply Chain Current Reality Tree



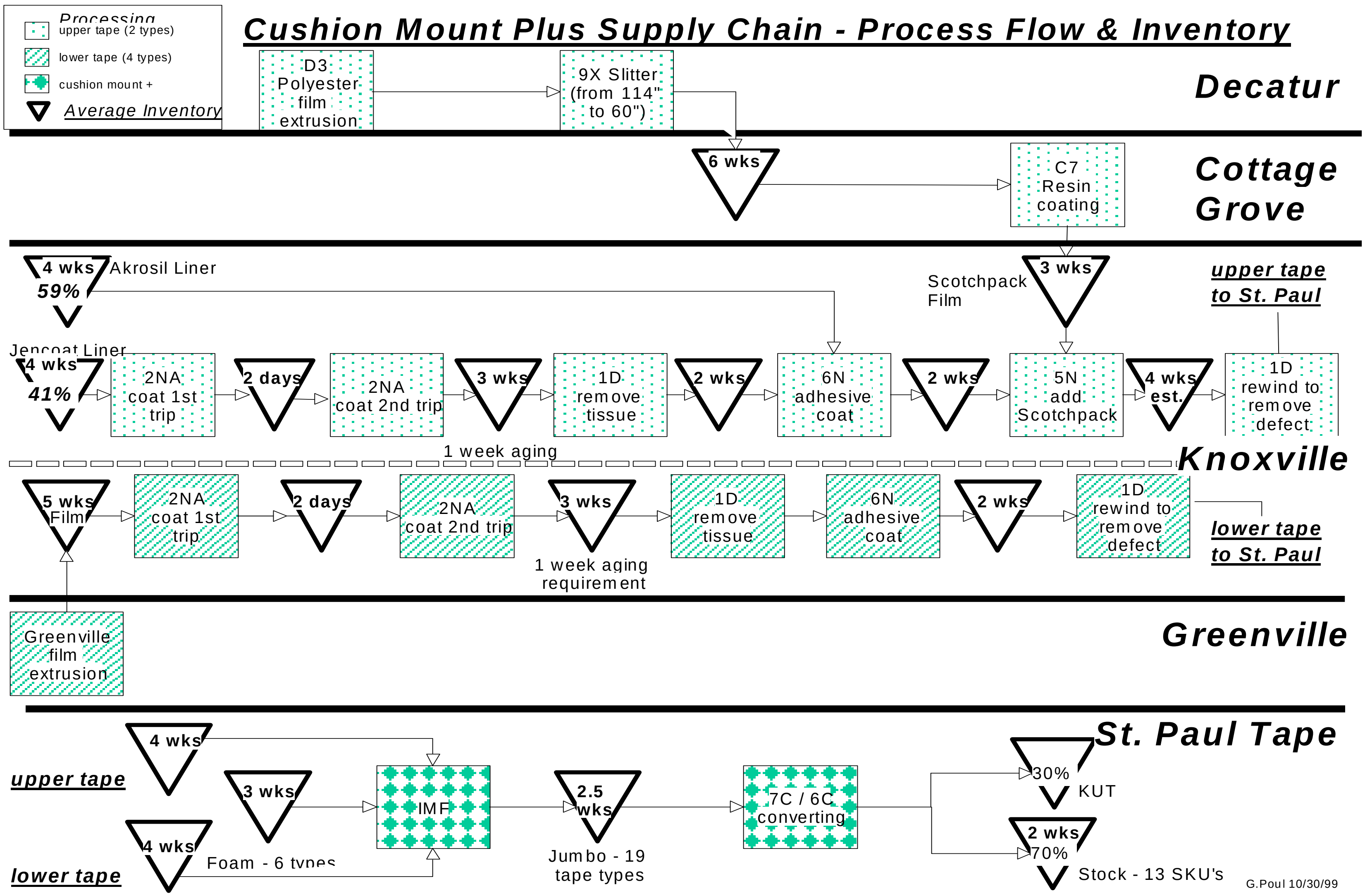
Appendix B: Supply Chain Current Reality Tree



Appendix C: Supply Chain Cloud



Appendix D Cushion Mount Plus™ Process Flow and Inventory



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Appendix E List of Obstacles and Target Conditions

The Cushion Mount + Supply Chain has been synchronized.

Definitions:

Cushion Mount + Supply Chain

Synchronized

-The constraint has been identified: 1D

-We established buffers and procedures for EXPLOITING the Constraint.

-We established procedures for subordinating everything in the supply chain to the pace of the constraint and these procedures have been implemented.

-Procedures are in place to monitor progress and target on-going improvements.

Obstacle	Target Condition	Action/ Person
	EXPLOITATION	
1. 6N adhesive tape quality is inconsistent	**(A) 6N & 5N material does not have to be rewound.**	**Andrea Penney &Matt Thatcher/Paul Gerver**
	(B) Appropriate measurements have been defined and are tracked for progress	**Andrea Penney &Matt Thatcher/Paul Gerver**
(2) Policy says 100% of output of 5N and 6N goes through 1D because it is believed that 1D is the most efficient place to do quality defect removal (most cost efficient and may not be able to see the defect further down the process stream.)	**See (1)**	**Andrea Penney &Matt Thatcher/Paul Gerver**
(3) Visual standards are weak, cannot determine what is good quality (at both 1D and 5N and 6N)	**(A) Visual standards are in place and are clearly understood by all operators (See 1)**	**Andrea Penney &Matt Thatcher & Brian Burquist/Paul Gerver**
	(B) There is a system in place to ensure that the most current visual standards are in always in place	**Brian Burquist/Kim Clark-Ferris**
(4) Quality of material coming into 1D is not consistent	**See (1)**	
(5) Customer requirements are unclear	**(A) There is a system to make sure that the supply chain understands the customer's requirements.**	**Kim Clark-Ferris**
	(B) There is a system in place to make sure that the customer requirements are current	**Kim Clark-Ferris**

(6) Have to use film from 2NA within 24 hours from rewind to consumption on 6N (why?)	**(A) We have determined why we currently rewind in 24 hours**	**Paul Gerver**
	(B) We have determined and operate within our real rewind window.	**Paul Gerver**

(7) Waves of demand (both within Flexo and across product lines) cause problems exploiting 1D	**Demand variability is managed to smooth out flow through 1D**	**Paul Gerver**
(8) Shortened service expectations result in less flexibility to move product within the schedule	**See (7) See (9)**	
(9) Don't have the equipment capability on 1F slitter and #8 rewind and Hutch and 3D to offload product within the facility to free up capacity on 1D (don't know the loading on 1F slitter today)	**(A) We have optimized productivity of 1D.**	**Paul Gerver**
	(B) Equipment is available to offload slitting, rewinding and tissue removal from 1D.	**Paul Gerver**
(10) Have to remove tissue from all liner material coming off of 2NA	**This is an elevating step. We will not address in this process.**	
(11) Our other slitters have not been upgraded to meet the needs and expectations of the market in terms of what the customer wants.	**See (9) The larger market issue is not in the scope of this analysis.**	
(12) Product mix has changed that restricts the offloading of 1D to other pieces of equipment.	**See (9). The larger market issue is not in the scope of this analysis.**	
(13) Our other slitters have not been upgraded to meet the flexibility desired by internal 3M partners for experimentation and special runs.	**See (9)**	
(14) Current RM reduction goals make process flexibility difficult.	**RM buffers are maintained at sufficient levels to protect the constraint.**	**Bill Christensen, Deanna Janilla, Randy Norton & Kelley McManus**

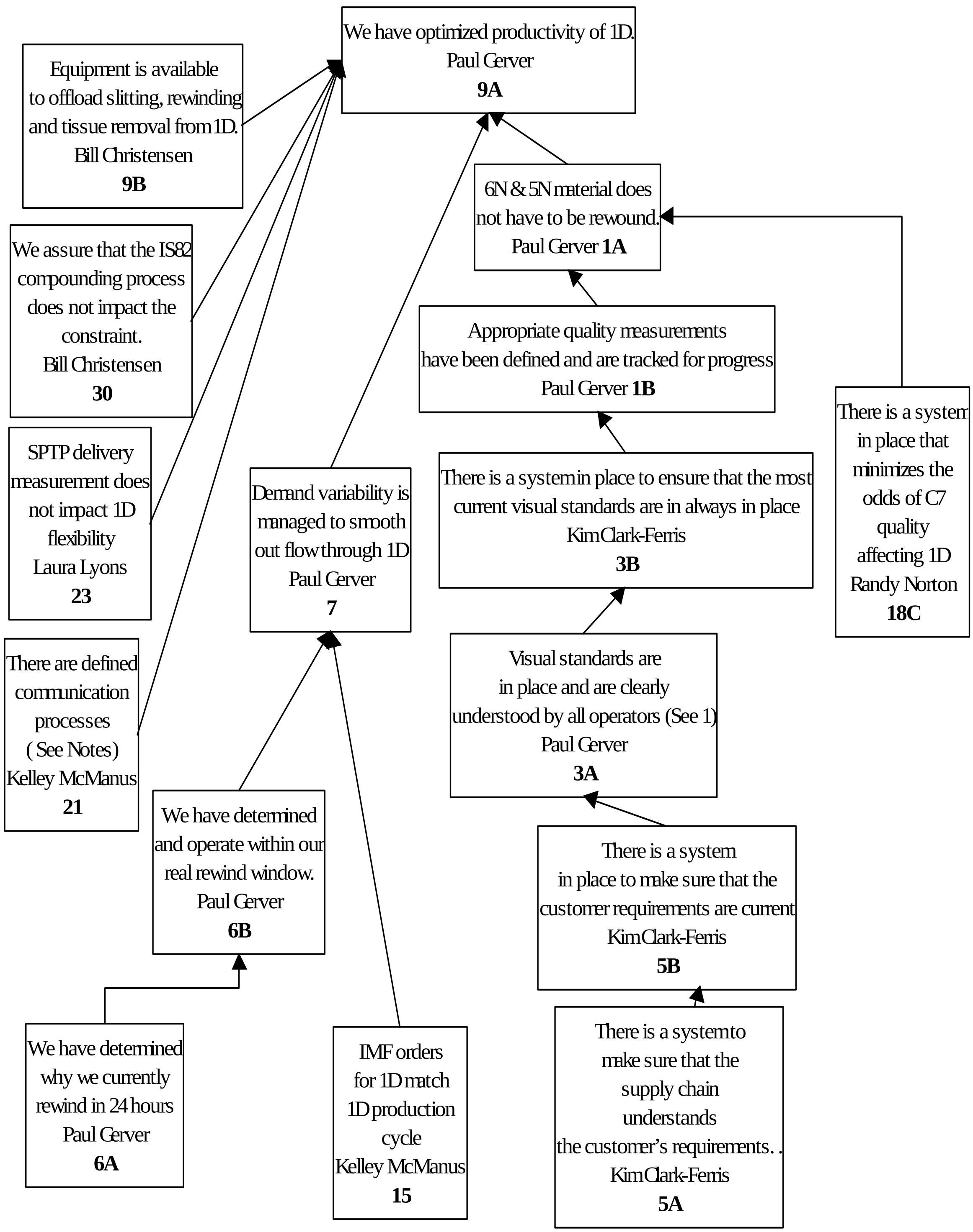
SUBORDINATION		
(15) Currently don't stagger orders for the IMF of material that comes off of 1D	**IMF orders for 1D will be matched to 1D production cycle**	Kelley McManus
(16) We can't go to weekly makes on 2NA because LM3 isn't ready to take on more product (need resources for more qualifications)	**Sufficient load has been moved off of 2NA to support weekly run cycles.**	**Bill Christensen**
(17) Changeovers and current product mix on 5N prohibit more frequent make cycles (currently run 3 to 4 weeks cycles, 2 weeks may be an option)	**5N can match 1D cycles.**	**Mike Lubinski**

(18) C7 currently runs to EOQ's per division policy to determine run sizes (results in 8 week cycles)	**(A) The EOQ and cycle for C7 is accurate and is communicated throughout the entire supply chain**	**Randy Norton**
	(B) There is an adequate buffer maintained between C7 and 5N.	**Randy Norton & Bill Christensen**
	(C) There is a system or procedure in place that minimized the odds of C7 quality issues affect 1D (May want to send a jumbo immediately through the system to check quality.)	Randy Norton
(19) There is no work being done to reduce C7 changeovers to result in reduced run sizes	**See (18) Will not work on this at this time per division policy**	
(20) Greenville will produce based on monthly order quantity (minimum) but may increase that to two month run size if loading dictates	**(A) Changes to the cycle are communicated throughout the supply chain.**	**Deanna Janilla**
	(B) See (24) Plant Loading Policy will not allow us to work on this at this time.	
(21) There is no defined communication procedure to ensure that we are consistent throughout the entire supply chain	**There are defined communication processes (see notes)**	**Kelley McManus**
(22) There exists no policy to ensure that 1D has material to run CM+ per the schedule 100% of the time.	**See (24)**	

(23) SPTP's policy of having material arrive on post date or date before has limited 1D's flexibility because KI does not have any place to store it.	**SPTP delivery measurement does not impact 1D flexibility.**	**Laura Lyons**
(24) There is no policy that states a minimum inventory buffer will be held after C7, G1 and 9X or before IMF.	**(A) There are set buffers in place as needed. See (18)**	**Kelley McManus**
	(B) Need to monitor and manage these buffers (try to do as automatically as possible.)	Kelley McManus
OTHER		
(25) A defined contingency plan does not exist in case of catastrophic failure in key areas of the supply chain	**Contingency planning is out of the scope of this analysis.**	

(26) There are no defined measurements for supporting and tracking progress (service, TI&OE, T/I, Inventory throughout the supply chain, supply chain yield, customer complaints)	**The measures for tracking and reporting progress are defined and tracked.**	**Kim Clark-Ferris**
(27) SPTP does not currently have a plant accountant assigned to the organization	**Measurement systems are defined that can continue as personnel change through positions.**	**Kim Clark-Ferris**
(28)There is no defined buffer management process	**See (24)**	
(29) The current forecast letter that SPTP sends to Knoxville does not reflect all of the information that is required to support the way that we want to manage the CM+ supply chain	**The forecast letter from SPTP to KI contains the needed information.**	**Kelley McManus & Bill Christensen**
Impact of IS82 compounding on the supply chain is undefined.	**We assure that the IS82 compounding process does not impact the constraint.**	**Bill Christensen**

Appendix F: Prerequisite Tree



Appendix F: Prerequisite Tree