ABSTRACT

The Bullwhip Effect: Recognizing the Phenomenon and Mitigating It Using the Theory of Constraints Illustrated by a Case Study from British Petroleum

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Many companies experience reoccurring problems that seem to grow increasingly worse throughout time. Attempts to fix these problems may prove temporary. These efforts are usually directed towards the symptom of the problem instead of the core problem, creating a cycle as the result of the bullwhip effect. This thesis introduces the phenomenon from academic approach and includes a business element via a case study and discussion of the Theory of Constraints. The opening section includes a definition of the effect and its four causes referred to throughout the text. The next section involves the environment, or a multi-variable system, where the phenomenon occurs. Following is a case study derived from observations of British Petroleum first-hand. Last, tools from the Theory of Constraints are introduced as one approach to mitigating the bullwhip effect.

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THE BULLWHIP EFFECT: RECOGNIZING THE PHENOMENON AND MITIGATING IT USING THE THEORY OF CONSTRAINTS ILLUSTRATED BY A CASE STUDY FROM BRITISH PETROLEUM

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CHAPTER ONE

Introduction

The first time I witnessed the bullwhip effect was during the summer of 2012 when I was a Logistics Coordinator intern with British Petroleum (BP). I was assigned a continuous improvement project concerning vessel scheduling. After studying data, I noticed that vessel capacity was underutilized. It seemed that many vessels used approximately 10% of capacity on average while traveling to and from assets, primarily production platforms in the Gulf of Mexico. However, during meetings with BP employees, many said they needed more vessels to provide additional capacity. One meeting in particular stood out because of a heated argument where one department argued that BP needed more vessels while another claimed the opposite.

I observed that both sides were arguing about symptoms of the problem rather than the root cause. I knew the problem was not the number of vessels because the data showed that there was available capacity. While watching the departments bicker, it dawned on me that the bullwhip effect was causing this symptom.

After the meeting, I recalled learning about the bullwhip effect during my junior year at Baylor University. While I was enrolled in a course in Distribution Management, the class was required to play The Beer Game, a simulation used throughout the world to demonstrate the effect by illustrating the results of demand variation in a supply chain. Prior to the simulation, the class had not studied the effect so we were not familiar with it. After a few cycles of the game, it became obvious that the supply chain was not working properly. I grew frustrated and immediately assumed that the other students were responsible for the problem. The class discussion following the game, though, showed me that the class had experienced a real-life phenomenon that occurred despite our behavior. The class, including myself, had created the bullwhip effect.

This paper is an elaboration of what I learned during the simulation and internship using what I learned in the course and subsequent research. It begins with an academic study of the phenomenon followed by a business example. Tools that can mitigate the effect in a system environment are described and demonstrated.

The first chapter defines the bullwhip effect and its four causes. These include demand variation, order batching, price fluctuations, and gaming. The second chapter defines the systemic environment where this particular study of the bullwhip effect occurs, including a description of five common characteristics occurring in many such systems. The third chapter presents the real-life, business scenario in which I experienced first-hand the phenomenon and its effects. Chapter Four is dedicated to applying the Theory of Constraints to resolve the bullwhip effect.

Many businesses encounter problems ranging from small and innocuous to potentially disastrous. It is not uncommon to have employees spend significant amounts of time and resources reacting to such problems, often indiscriminately. Sometimes they successfully identify the cause and resolve the problem before it grows out of control, but usually the situations are not this simple. Often, employees believe they are fixing the problem when they are actually working on the symptoms. When the perceived problem resurfaces at a later time, they try to fix it again. This cycle can reoccur indefinitely unless the root cause is found. Unfortunately, there is no equation or tool that can easily direct employees to the cause and even if they found the cause of the problems, they may not have the solution.

The bullwhip effect is a well-known phenomenon where a reoccurring problem grows uncontrollably. Its cause is subtle and consequently it is often overlooked when problem-solving. However, consideration of it can help identify the root causes of the observed problem and point the way to a solution.

The bullwhip effect causes excess inventory in the pipeline, backlogs, and stock-outs. It is found where a change in the demand for a product results in increasingly large oscillations of product orders. The effect occurs in a forecast-driven environment that may resemble a supply chain. A way to visualize it is to picture a bullwhip and the fluctuations that occur when it is cracked. The fluctuations nearest the person's hand are relatively small, but they increase exponentially the further away from the hand.

Demand occurs at the start of the bullwhip effect where a consumer orders a product. A change in consumer demand, or a flick of the bullwhip, occurs at the retailer. The retailer's order travels upstream. The supply chain uses the order to forecast future demand, resulting in oscillating inventory. The effect's definition and example may make it appear easy to identify, but finding it in a business environment is difficult because it may cause multiple problems simultaneously. The Beer Game is a classic example that portrays this phenomenon in a supply chain.

Created by MIT professors, The Beer Game is a simulation of a supply chain that experiences the bullwhip effect. The simulation incorporates four entities, or partners, which are played by students. The entities include a retailer, distributor, manufacturer, and factory.

Each partner is responsible for ordering beer from their upstream supplier and filling the demand of their downstream customer. The simulation consists of cycles where each student must complete these actions. The purpose of the simulation is to show the results of one of the bullwhip effect's causes – demand variation. Consumer demand in The Beer Game may fluctuate in small or large degrees throughout the game. Note the following example where the consumers' demand increases.

The cycle begins when the consumer places an order for beer with the retailer. The retailer then places an order for the amount of inventory that they need from the distributor. Assuming that several cycles have passed and the distributor has available inventory, the distributor fills the retailer's order from existing inventory and places an order with the manufacturer to replenish its inventory. The manufacturer fills this order and places one with the factory to maintain a certain level of inventory. The cycle is completed after the factory receives and fills the manufacturer's order. If at any time a student does not have sufficient inventory to fill an order, the amount of unfilled inventory is added to the backlog.

The bullwhip effect begins when the consumer increases their demand for beer. The retailer places an order with the distributor that is larger than the one at the first cycle. When the distributor places an order with the manufacturer, they request the amount of inventory needed to fill the retailer's demand plus additional inventory. This becomes safety stock in case the retailer demands even more inventory during the next cycle. When the manufacturer receives the distributor's order, the manufacturer places a significantly larger order with the factory. This order must fill the distributor's inflated demand as well as provide safety stock for the manufacturer. As the game progresses, the additional inventory grows exponentially as each entity tries to have sufficient beer to fill orders.

The game has several parameters that allow the effect to take place. The first is the flow of information and material. The information, or the inventory order, travels upstream to the factory whereas the material, or inventory, moves downstream to the retailer. Participants only receive orders from their immediate downstream partner, so no partner except the retailer knows the consumers' demand.

In order to simulate a realistic supply chain, delays occur between when an order is placed and when it is received. There are also delays between when inventory is shipped and when it is received. These delays may or may not be equal between each partner or on each order. A condition of play is that students may not exchange information except through the game itself.

The Beer Game showed that the bullwhip effect can cause significant inventory problems. Demand variation caused excess inventory to accumulate in the pipeline because of increasingly large orders that included safety stock. During most of the cycles, demand was less than the ordered inventory so partners had growing amounts of the product. However, the fluctuating level of inventory was only a symptom of the bullwhip effect. When students play The Beer Game, many do not realize that there is an underlying cause of the inventory fluctuations.

The bullwhip effect is the generic problem affecting the supply chain in The Beer Game, but it can be related to four discrete and independent causes. These are demand variation, order batching, price fluctuations, and gaming. Demand variation causes the orders to grow exponentially as they travel upstream. Order batching occurs when orders are sent in large groups to reduce transaction costs. Price fluctuations are the changes in prices due to functions such as advertising that can temporarily inflate demand and subsequently drive demand variation. Gaming occurs when entities inflate their orders beyond what is actually needed in an effort to secure what they need from a limited amount of available inventory.

Demand variation is the primary cause of the bullwhip effect in The Beer Game. In the game, there is a slight change in demand when the customer ordered more beer than usual during one cycle. However, the results of this slight change amplify as the order travels upstream. The reason this small change led to increasing order size lies in each entity's use of forecasting. A forecast is a tool that helps determine the future demand for a product. Each entity updates their forecast based solely on the order, or the demand, from their immediate downstream partner. According to Lee's thoughts in the article "Information Distortion in a Supply Chain: The Bullwhip Effect", using only one entity's demand to update a forecast, "…will cause the supplier to lose track of the true demand pattern at the retail end" (p. 1879). As the order travels upstream, each entity orders more inventory than necessary to meet demand so they can have extra inventory, or safety stock, in case of an emergency. The inflated order increasingly distorts demand the further the order travels upstream. By the time the order arrives at the factory, it is so distorted that the true demand is masked.

The second cause is order batching. This occurs when entities wait to send orders upstream until several are combined instead of sending individual orders as they become available. Entities batch orders in order to reduce transaction costs and save time that would otherwise be spent on preparing and sending the orders. Since The Beer Game disregards costs, this component was not an issue. However, if entities were allowed to batch orders to minimize costs, the bullwhip effect would have occurred.

Order batching results in entities perceiving a sudden surge of orders indicative of an increase in true demand. As a result of this perception, each entity increases production to fill their customers' demand while placing large orders with their suppliers. As orders and inventory travel throughout the supply chain, each grows exponentially. However, partners realize there is a problem when orders drop significantly as the batching process starts over. The problem is realized too late since each entity has increased capacity and produced excess amounts of inventory.

The third cause, price fluctuations, is the temporary change in a product's price that can alter demand for that product. Lee states that the effects of fluctuating prices depend on the frequency of the price changes and the depth of the price discount (p. 1884). Many companies temporarily decrease the price of a product in order to sell excess inventory or boost demand. When the product's price is reduced, consumers purchase more resulting in an increase in demand. At the end of the discount period, the entity offering the discount increases the price to its original level, hopefully causing demand to return to normal. During the discount period, the other partners in the supply chain are usually not aware of the discounting. They perceive the increased demand during the discount period as a permanent change requiring additional capacity and inventory. As the sudden increase in demand travels upstream, each entity reacts by ordering more inventory than necessary.

The fourth cause, gaming, is a partner's deliberate attempt to secure inventory when there is a limited amount available. There is pressure to game because every entity in the supply chain must fill orders for their downstream customer. In order to do this, partners must receive the inventory ordered from their suppliers at the prescribed time. If the suppliers cannot meet the demand, entities may find it attractive to game the ordering process. Instead of ordering what is needed to fill demand, the entities increase their orders beyond what is actually needed. The rationale is that entities will receive less than what they requested but enough to fill the actual demand.

These four causes, demand variation, order batching, price fluctuations, and gaming, are primary causes of the bullwhip effect. This is a critical problem because its results, such as excess inventory and distorted decision making, are noticeable and expensive, yet the four causes are subtle. Entities which experience the bullwhip effect, such as the ones in The Beer Game, may try to mitigate the problem by focusing on inventory or forecasting. However, this usually provides only temporary relief. Understanding the causes of the bullwhip effect and the environment in which it takes place is critical to resolving the issue.

The environment of The Beer Game was characterized by several factors (e.g. time delays, information and material flows). Within this system, the four entities had to place and fill orders while forecasting demand. Their interactions in and response to the system compounded the bullwhip effect. Thus, system environment is an important concept that can help one understand why the bullwhip effect occurred in the supply chain. The system is a complex environment with several characteristics.

These characteristics combine to produce the environment where the bullwhip effect is likely to occur.

CHAPTER TWO

Systems Thinking

The bullwhip effect may occur in a system, a structural concept that applies to many environments (e.g. businesses, schools, churches). The four causes can occur within the system so it is beneficial to study. While each environment has unique characteristics that define the system's purpose, there are several common characteristics that are applicable to most systems.

First, a system is a dynamic environment that is continuously changing. Second, a system has feedback and delays where information is cycled at a certain rate depending on the amount of time in the cycling process. Third, the system is multivariate in that the values of variables interact and produce new values. Fourth, the system is often non-linear, in that its inputs are not proportional to its outputs. Fifth, there is a limited amount of information in a system. These common characteristics apply to most systems and their environments.

Many systems do not have a steady state where there is little change in outcome. Instead, systems change frequently as its inputs interact and consequently result in new values. Change creates the system's dynamic environment. The process starts when individual inputs come into contact with other input values, combining to produce a new value. This process of interaction is continuously occurring within the dynamic environment.

As a result of this change in values, one cannot easily predict the direction or outcome of the system. Furthermore, it is difficult to control since this process is continually causing change. Thus there is little transparency, but stakeholders can influence the direction of the system using a feedback loop.

Information feedback and delays occur in the feedback loop. Information cycles throughout the system's environment and can influence its direction towards the outcome. The cycle starts with a stakeholder acquiring available information from the system's current state. After he collects this information, he uses it to make a decision about what action is necessary to reach his intended goal. When the decision is made, it results in an action that changes the current state of the system and produces new information. The latter can be used to make further decisions. In this cycle information can travel and influence actions within the system.

The described feedback loop consists of decisions, but the cycle does not necessarily need a decision to produce an action. The value of variables continuously interacting can cause an action to occur without a stakeholder making a decision. The interactions of the dynamic environment ensure that the system progresses without stakeholder decisions in order for every action to occur. The decision step only applies when a stakeholder is deliberately acquiring information to make a decision.

There is another potentially important characteristic of the feedback loop. A delay may occur between any steps of the cycle. A delay is a realistic characteristic because the feedback loop cannot complete each step instantaneously. There is some degree of delay as stakeholders gather information. The amount of time depends on the complexity of the decision to be made and the amount of information needed to make the decision. When the decision is made, there may be some time before the effects of the resulting action are felt. Once the action occurs, stakeholders gather the information again during a period of time until the next decision. The delay affects the rate at which the system progresses. The delay also makes the rate difficult to gauge since pauses between steps may not be equal or may change over time.

The system is multivariate where each variable has a unique value distinct from other variables. Within a dynamic environment, variables interact and produce values derived from multiple individual variables. The individual initial values of the variables are important, but a more crucial aspect is the new value achieved by interacting variables. This process of transforming individual values into a different value is another reason why the system is dynamic. Since it is difficult to gauge the values of individual variables and the new resulting value, the system is difficult to understand. Predicting the outcome becomes even more difficult.

This system is non-linear. Non-linearity is when the value of its inputs are not proportional to its outputs. When the values of the inputs change, the non-linearity becomes noticeable. Because of the change, the outcome becomes difficult to predict and control. A small change in the inputs can cause a drastic change in the outcome. The outcome may even appear chaotic at times. The feedback loop, especially the decision step, provides stakeholders the opportunity to influence the system's direction. This is not the same as control of the system.

Systems have a limited amount of information. This characteristic exists because stakeholders usually have incomplete information. As systems become complex, data accumulates, making it difficult to discover useful information apart from the data. The system does not appear transparent because the stakeholders cannot fully comprehend all of the information. They can understand the system to some degree, but they do not have all of the information necessary to fully understand the system and its behavior.

As dynamic systems change, there is potential that a limiting factor, or constraint, will inhibit growth. This limiting factor can negatively affect one or more of the five system elements described above.

A management tool that can both identify problems and restore the system's growth is the Theory of Constraints (TOC). TOC can aid in defining goals and the steps needed to attain them. TOC states that a business will experience a lack of growth unless its weakest operation, activity, etc. is made more efficient. According to Bushong, "TOC emphasizes the maximization of profit by assuring that the factor that limits production is used most efficiently," (p. 1).

The effort to improve this constraint does not stop, however, once the operation is made more efficient. Instead, TOC is a continuous improvement effort that strives to enhance the least efficient activity. This is because the constraint and the system where it occurs are not static elements. The constraint can change once the least efficient operation is made more efficient. Since this change can happen at any time, stakeholders must always be aware of the constraint's current location.

TOC addresses constraints that prevent optimal performance while providing ways to continuously improve. TOC was first described in Eliyahu Goldratt's book *The Goal* in 1984. Since its introduction, TOC has grown in popularity as managers strive to improve efficiencies and stay ahead of their competitors. While TOC is descriptive, it is also prescriptive because it provides managers with six logical thinking processes.

According to Dettmer, TOC uses logic that is not automatically understood by all. This is why the processes are necessary in order to understand the logical nature of the theory (p. 22). The process includes three tools, the Intermediate Objectives Map (IO Map), Current Reality Tree (CRT), and Evaporating Cloud (EC).

The Intermediate Objectives Map is the first of the logical thinking process tools. It consists of necessary conditions (NCs), critical success factors (CSFs), and a goal. This tool describes the conditions that one must have in order to achieve the CSFs and consequently the goal. The author builds the map starting from the top. The goal is the most abstract component that defines the reason for conducting business. If stakeholders cannot agree on the same goal, they will not be able to agree on the CSFs and NCs. Two to three CSFs are placed below the goal. CSFs are important milestones that groups must achieve in order to reach the goal. The bottom may consist of two layers of NCs. NCs are typically less abstract than the CSFs and the goal. Since this map is the foundation for other tools, agreement is crucial.

The second tool, the Current Reality Tree (CRT), shows the gaps between the present situation and the goal in the IO Map. It also reveals a core problem or root causes responsible for the gaps. The root causes result in the majority of undesirable effects (UDEs) that prevent groups from attaining the goal. UDEs are existing problems that stakeholders consider as negative. Unlike the IO Map, the CRT is a sufficiency tree that shows the relationship between causes and effects. It is created by connecting UDEs while following the Categories of Legitimate Reservations (CLRs). These are rules that ensure a coherent, structured tree. They also provide instructions on how to review the tools that scrutinizers can use. Scrutinizers may not always agree, though, on how to resolve the core problem. Fortunately, the last tool is available to handle disagreements.

The Evaporating Cloud (EC) is a conflict-management tool that results in win-win situations. According to Dettmer, compromise and win-lose situations lead to dissatisfying results for all those involved. However, the EC provides a third alternative pleasing to everybody (p. 164). This tool that incorporates necessity logic uses components found in the IO Map to address conflict revealed in the CRT. These components are one objective, two requirements, two prerequisites, and at least one injection, which terms are defined below.

The objective is the goal that stakeholders want to achieve. The requirements are those necessary to reach the goal. The prerequisites are needed in order to meet the requirements. The objective and requirements are usually the IO Map's goal and CSFs respectively. There are arrows connecting each of these components that may include assumptions. Thus, one should construct the IO Map prior to the EC. After construction, the hidden assumptions underlying each arrow are revealed. The invalid assumptions are used to create injections, or breakthrough solutions. Only the invalid assumptions are important while using this tool. The EC is especially helpful when resolving long-lasting conflict.

These TOC tools are useful when trying to understand how the system can be influenced. A system structure is complex, and its outcome is hard to determine, but stakeholders have some degree of influence. Using TOC tools can focus stakeholders' efforts on a common goal while also making sure that conflicts and undesirable effects are handled appropriately. The tools are especially helpful in a system's dynamic environment since each tool can be updated to reflect the system's current state. A flexible system with complex characteristics needs tools that can accommodate the system's behavior.

CHAPTER THREE

Case Study

We can apply the above tools and concepts by analyzing how three BP stakeholders complete a specific process. Stakeholders have varying degrees of control in this process that cause demand variation and gaming. Their actions explain why the effect occurred and continues to exist. Addressing this process involves a discussion of communication bandwidths and amplifies the role of communication between stakeholders. Both are vital and can potentially reduce or exacerbate the bullwhip effect**.** An introduction of BP's structure and stakeholders' roles follows.

BP consists of three segments, including Upstream, Downstream, and Alternative Energy. Each segment has several businesses. Upstream contains Exploration, Developments, and Production. This segment is responsible for finding, producing, and transporting the company's oil and gas. Downstream involves refining and marketing fuels, lubricants, and petrochemicals using refineries and petrochemical plants. Alternative Energy is a new segment dedicated to bio-energy, electrification, and carbon solutions. In addition, BP has Corporate Functions and Integrated Supply and Trading (IST). Corporate Functions creates strategies while IST oversees assets.

Each segment has several job categories. For example, the Upstream segment contains Subservice, Engineering, Operations, Wells, and more. All stakeholders in this analysis, including Marine Logistics, Shore Base, and Drilling & Completions, work in this segment. The first two work in Operations while the latter works in Wells. Marine

Logistics oversees BP's vessels. Shore Base loads and unloads vessels that operate in the Gulf of Mexico (GoM). Drilling & Completions oversees rigs and ensures that they operate successfully.

Marine Logistics and Drilling & Completions are located at the Houston, TX, campus. The Westlake campus houses employees working for the Gulf of Mexico region. Shore Base works at C-Port in Fourchon, LA. The port opened in 1996 and is capable of handling each type of BP's vessel. The port has 18 slips, 37 overhead cranes, 25 foot drafts, and dockside services that BP shares with other oil and gas companies. Shore Base employees visit the Westlake Campus on occasion to troubleshoot problems and share information with employees.

BP established three distinct teams within Logistics, including Marine Logistics, Aviation, and Performance Management. Marine Logistics is the primary focus of the Logistics group that manages the vessels used for the GoM operations. These employees manage the fleet and ensure that each asset has the required vessel capacity. Each vessel's operation relies on the Shore Base team located at C-Port. The team loads and off-loads vessels and maintains them. Last, Drilling & Completions manages asset development and production.

Marine Logistics has one manager overseeing the entire Logistics group. He works directly with the team leads stationed underneath him. There is one team lead per team. They report to management on a daily basis and are expected to have a firm understanding of their team and how it interacts with the others. Team leads oversee full-time employees and contractors on their team. Since the manager's time is limited, many full-time employees and contractors must communicate problems and concerns through their team lead.

Besides these duties, team leads are responsible for maintaining a wide communication bandwidth and reducing workplace noise. Noise consists of anything that disrupts the stakeholders. This may include different projects that stakeholders must work on rather than the issue at hand, distracting them from concentrating on the problem. The team lead must also communicate information to his team, manager, and colleagues in other stakeholder groups. Since he serves as the gateway to the top manager, his position requires that he knows the amount and quality of the information passing from employees to management. If problems or discrepancies arise, he must handle the situation and prevent the communication bandwidth from contracting. He must also eliminate noise that is produced as the result of tension between teams. Communication bandwidth and noise level within each group is vital to understanding the bullwhip effect.

Besides working with colleagues and management, Marine Logistics must regularly correspond with Drilling & Completions and Shore Base. While Marine employees hold weekly meetings with Shore Base, the latter group rarely meets with Drilling & Completions unless a meeting is requested several times and planned far in advance. The reluctance for each group to meet is due to friction that has occurred throughout the years. As a result, the groups have developed clashing objectives.

Marine Logistics' major objectives include decreasing operating costs associated with fast supply vessels (FSVs) and offshore supply vessels (OSVs), preventing the fleet size from increasing unnecessarily, and decreasing the risk of vessel collision in the

GoM. These objectives differ dramatically from those of Drilling & Completions which focuses on the management of constructing and operating rigs.

BP experiences the bullwhip effect because of these stakeholders and their interacting processes. A large number of stakeholders require many channels of communication to share information. Each channel is susceptible to noise created by tension between stakeholder groups, in that the available bandwidth contracts when noise increases. Without a wide bandwidth to disperse information, stakeholders have difficulty understanding how their actions affect the system. This focus on local optima allows the bullwhip effect to go unnoticed. When the effect starts to spread through the system, the problem grows exponentially.

Tension is one of two major concerns that preoccupy Marine Logistics. Drilling & Completions insists that the GoM needs more vessels if each asset is to continue operating. As a result, this pressure often leads Marine Logistics to acquire more vessels than necessary even though this is counter to their objectives. Marine Logistics is unwilling to ignore the budget by acquiring more vessels because they face increasing pressure from top-level management who demands cost reductions. Relevant costs include the price paid to rent a vessel for a specified period of time. Since the cost of renting a vessel comes directly from the Logistics budget, the manager is wary of increasing the fleet size. These disagreements create a tense environment with the complexities and poor communication bandwidth necessary to cause the bullwhip effect.

Tension and resulting conflict exists primarily between Marine Logistics and Drilling & Completions. This conflict is best shown using an Evaporating Cloud from the Theory of Constraints. The EC was described in Chapter Two as a tool that can clearly show the reasoning behind the conflict. Figure 1 shows the EC that corresponds with the preceding paragraph. The top portion of the EC represents the objectives of Marine Logistics while the bottom represents that of Drilling & Completions. The EC is read as follows: In order to have profitable rigs, Marine Logistics must decrease cost. In order to decrease costs, they must decrease the fleet size. On the other hand, in order to have profitable rigs, Drilling & Completions must have immediate access to vessels. To have immediate access to vessels, they must increase the fleet size. The conflict is that the groups cannot agree about the appropriate size of the fleet.

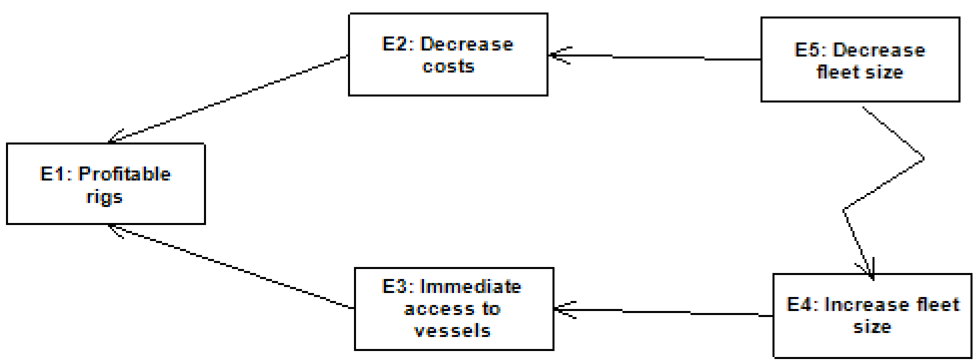


Figure 1

Shore Base in Fourchon, LA works with Marine Logistics. Shore Base employees consist of managers, team leads, and dock workers. The port requires a manager on site to maintain an efficient level of operations. While this manager confers with Houston management on occasion, the high level of activity in the port requires a manager responsible for making decisions in emergencies, such as weather. This division of labor allows both Houston and Fourchon employees to concentrate on their own work.

Nevertheless, this separation can harm the communication bandwidth and introduce noise into the system.

The physical distance between employees in Houston and Fourchon is sufficient to harm communication. Employees do not have immediate access to ask each other questions or resolve problems. Even though both teams have working phones, internet, and video conferencing, setting time to meet is difficult.

Marine Logistics and Shore Base meet via video conference once a week, but this is not sufficient to update each other. The teams need a wider communication bandwidth to update the groups on important information such as maintenance, incidents arising on the dock or vessels, and assets' requests for more vessels. Without rich communication, Marine Logistics remains somewhat unaware of Shore Base operations.

Lack of communication exacerbates the schism between Marine Logistics and Shore Base employees. Even though both teams work for the same company and department, neither focuses on a common goal. Marine Logistics emphasizes cost cutting because management is continuously demanding cost reductions. Shore Base employees concentrate on safely handling vessels. Since Shore Base continues to successfully achieve this objective, it is safe to assume that the current number of vessels is optimal for this group. The objective of Marine Logistics is to decrease the fleet size while that of the Shore Base is to maintain the existing fleet size. This slight difference in objectives can lead to conflict. The following EC represents this conflict and is read the same way as the preceding example. However, the conflict represents an alternative instead of an opposition. The top portion represents Marine Logistics while the bottom represents the

Shore Base. Please note that the objective for Marine Logistics is the same as that in Figure 1.

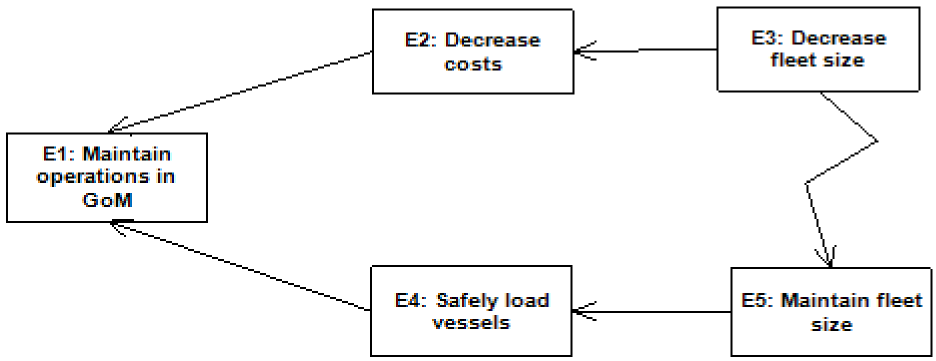


Figure 2

Another reason for conflict is prevailing assumptions in Houston and Fourchon. Over the years, both teams have developed assumptions of each other. For example, Shore Base workers consider Houston employees, like Marine Logistics and Drilling & Completions, to be ignorant regarding vessel maintenance and upkeep. This assumption leads Shore Base employees to withhold some technical information because they do not think their Houston counterparts will understand it. On the other hand, Houston employees regard Fourchon dock workers as hardened and unwilling to take advice.

In the past, Shore Base has complied with Marine Logistics on certain initiatives only to stop cooperating after a short time. They stop cooperating because they know Marine Logistics will not enforce the initiatives in the future since they have not done so in the past.

While these differences may seem trivial, they are instrumental in understanding why communication between the groups is so poor. The assumption that certain stakeholders are ignorant has led to worsening relationships.

Besides Marine Logistics and Shore Base, Drilling & Completions also plays an important role in this process. This particular group rarely works alongside the other stakeholders. However, due to the quick addition of new assets in the GoM, a relationship has recently been established between the three groups. Already Drilling & Completions and Marine Logistics have developed negative assumptions about one another. One example of these assumptions held by Drilling & Completions is that Marine Logistics does not care whether or not the rigs operate as long as Marine Logistics can maintain or reduce vessel costs. These assumptions have promoted ill-will between the groups. The assumptions further contribute to the worsening communication established between all of the stakeholders.

Drilling & Completions oversees new wells and ensures that the wells' activities are running smoothly. Employees in the Houston office coordinate efforts with the offshore installation managers (OIMs) located on each rig. The OIMs oversee the daily operations since they are located directly on the asset. Very few difficulties arise in this relationship since both parties have the same objectives. The groups focus on developing profitable assets that can cover the high operational expenses associated with drilling. However, the same camaraderie is not evident in Drilling & Completions' relationship with Marine Logistics.

Historically, Drilling & Completions was rarely concerned with having the available vessels to service their assets. However, during the last few years, this concern has materialized even though Drilling & Completions admits that Marine Logistics has been able to supply the necessary vessels when needed. Drilling & Completions still worry that the wells could be shut down if the vessels fail to transport vital materials on time. This concern is justified by the potential $1 million/ day cost of losing production.

Throughout the remainder of this chapter, these descriptions and different objectives are used to explain why the bullwhip effect exists in BP's system, concluding with an analysis of how demand variation and gaming occur within and between the stakeholder groups. Also, the extent of each effect is used to show the problematic nature of the effect, laying the foundation for the following chapter in which BP-specific solutions are discussed.

Demand variation and gaming are of particular concern when examining the bullwhip effect at BP. The next step includes analyzing one BP process and how stakeholders create demand variation and gaming using this process. Their actions help explain how extensive the bullwhip effect has become within this subsystem.

Each stakeholder group, Marine Logistics, Shore Base, and Drilling & Completions, is responsible for completing specific processes. They work within the system using established processes, and have the ability to influence the system by communicating and sharing information. The system has flexibility because stakeholders can only influence, not control, the system. The processes and communication bandwidth deserve considerable attention when addressing demand variation and gaming.

The primary process observed at BP is the operation of part of the Marine Team's fleet referred to as fast supply vessels. FSVs are used in conjunction with larger vessels in the fleet. They are used to transport materials and equipment to assets located in the

GoM. Stakeholders contribute to this transportation process to varying degrees. Using the communication bandwidth, stakeholders collaborate while working, which has proven difficult during the past few years.

The process where a FSV delivers the appropriate materials to the correct assets on time requires collaboration and communication. The process is initiated when the asset's OIM calls the Shore Base to request materials. They explain what and how much they will need and when. They must call each time to ask for materials because there is not a schedule that they can use to determine when an FSV will arrive with materials. After receiving this request, Shore Base employees load an available FSV with the needed materials. Shortly after, the vessel leaves C-Port and embarks on a voyage to the asset where employees unload the vessel. While the process appears relatively straightforward, it is difficult due to the relationship between Marine Logistics and Drilling & Completions.

Teams have differing objectives relating to this process. Drilling & Completions insists that Marine Logistics increase the size of the FSV fleet because Wells employees want an available vessel at C-Port in case of emergencies out of concern that operations may shut down due to lacking the necessary tools, equipment, materials, etc. While the vessels have rarely failed to deliver materials to the right location and on time, including in emergency situations, Drilling & Completions demands more vessels. On the other hand, Marine Logistics cannot justify renting more vessels when this would require the approval of a budget increase. Houston management oftentimes agrees with Marine Logistics because management is responsible for keeping costs low. The EC in Figure 1 shows this conflict.

Completing this process is difficult even with a wide communication bandwidth because stakeholders may act in a manner that leads to a contracting bandwidth. A contracting bandwidth occurs when stakeholders stop communication entirely or when they withhold rich information while still maintaining a small degree of communication. Stakeholders unconsciously trim the bandwidth by allowing tension to obstruct open communication and consequently shrink it. Without rich communication, stakeholders are left to their own intuition and perspective. Instead of assisting one another, stakeholders must do their best regarding what they can directly control. Focusing on the local optimum prevents stakeholders from perceiving the system as a whole. This limited view negatively affects each stakeholder group involved in the FSV process.

The lack of communication and growing tension results in the first cause of the bullwhip effect – demand variation. Variation occurs when stakeholders misinterpret the end consumer's demand for a product. In this particular process, the end consumer is the asset that requests a vessel to bring materials and equipment. The product is the demand for items transported by FSVs resulting in an amplified demand for FSVs. The end consumer is unlike the typical example, retailers, found in academic papers, but the principle is similar because the asset is demanding and consuming materials brought by the FSVs.

The stakeholders are distributed throughout the system and have varying degrees of communication with the OIMs. The distance between each stakeholder group and the asset is discussed. Only after visualizing these distances can one understand demand variation in BP's process.

According to the principles of demand variation the group furthest away from the end consumer experiences the most pronounced variation in demand. This concept is validated when the stakeholder located the furthest has the largest demand for vessels relative to the asset. The group with the highest degree of involvement with the asset may experience little to no variation. Note that this distance is not measured in literal terms but by the stakeholder's level of involvement. Drilling & Completions is the most involved group. They drive the demand for items since they are the most affected by whether or not assets receive items on time. They bear the costs of lost production if materials are not delivered on time. They convey their concerns to other stakeholders by requesting more vessels. Instead of asking for available capacity or acceptable scheduling, they ask for more vessels. This is the start of the increasing demand for FSVs. As the discussion turns towards the remaining stakeholders, demand for FVS begins to oscillate.

The location where demand variation becomes apparent is Marine Logistics. They communicate directly with Drilling & Completions, but rarely does the team communicate with the end consumer, or the asset. Instead of asking asset OIMs for demand forecasts, Marine Logistics must interpret Drilling & Completions' requests and convey this information to the Shore Base. The latter group may misinterpret this request as a demand for more vessels. Consequently, Marine Logistics assumes that the fleet must increase to meet the Shore Base's needs. Marine Logistics initiates the vessel renting process in order to acquire more FSVs. Even though this process is unintentional and due to misunderstanding, the end result is a cost increase. Demand variation continues to oscillate in pronounced ways.

Shore Base is located the furthest away from demand for FSVs. The team's demand for FSVs is the most exaggerated because the team's objectives are the least correlated with those of Drilling & Completions. Shore Base is not as impacted if assets do not receive necessary items. Shore Base focuses primarily on the operational duties of preparing vessels for voyages. The team relies on Marine Logistics to determine how many vessels are needed. Marine Logistics rents more FSVs causing Shore Base to manage a larger fleet size. By the time Shore Base must send vessels to assets, the demand for FSVs is much higher than what was originally demanded. Stakeholders start to believe that additional FSVs are the only solution to meeting asset demand. Although the assets' original demand did not fluctuate much, stakeholders misinterpreted demand and proposed renting more FSVs.

The distance from the stakeholder to the end consumer directly correlates with the extent that demand deviates from initial order quantity. This may be due to a lack of communication or a lack of quality information. Without a clear, transparent communication channel spanning the distance from Drilling & Completions to the asset OIMs via the Shore Base, demand variation continues. Distance results in the other primary cause of the bullwhip effect in this case - gaming.

Gaming can imply that individuals skew data to benefit themselves at the expense of others, but this research focuses on those who game without realizing the consequences. In particular, Drilling & Completions is the primary participant who games. Gaming occurs when individuals demand more than is necessary to protect individual interests. Using the process discussed above, gaming is a harmful activity resulting from a focus on a local optimum instead of the system.

Drilling & Completions is the closest to the source of demand and can benefit by gaming the process because they are concerned that assets will not receive materials on time. Drilling & Completions believes that Marine Logistics will not be able to provide enough FSVs to deliver materials on time. This belief is not supported by past data though. Gaming starts when Drilling & Completions demands more vessels than those they originally requested.

The difference between this situation and demand variation is that Drilling & Completions does not intend on using the extra vessels. By demanding more than necessary, they assume that they will receive what they actually need and not the inflated request. They do not game with bad intentions in mind, but their actions prompt Marine Logistics to rent more vessels than necessary. This behavior is the foundation of gaming observed in Drilling & Completions and is one of the causes of the poor communication between these stakeholder groups.

Communication suffers when stakeholders withhold rich information. Gaming is an example of stakeholders withholding information and damaging communication. This negatively affects parties as they must turn to focusing on their local optima instead of the process's subsystem and BP's overall system. While Drilling & Completions does not game deliberately, the result remains the same. Historically, gaming produced the desired results so Drilling & Completions continues to game because they want to receive similar results. This forces teams to rely on their narrow perspective to complete a process requiring a fully-operational focus on system dynamics.

Understanding the causes' ramifications is necessary but not sufficient. It is also important to understand the bullwhip effect's significance on the entire system. This includes financial losses, heightened risk, and the effect's self-perpetuating nature. Self-perpetuation relates closely to the communication problems. Following paragraphs include the results of demand variation and gaming. They also explain how and the extent to which the system is affected.

Prior to explaining each ramification, the negative results are categorized by tangibility. Categorizing provides a basis for measuring the issues' importance. As shown in preceding pages, the systemic problems have varying degrees of significance. The most significant problem is the financial loss incurred from demand variation and gaming. The issue is highly tangible since financial losses have a direct impact on budgets and BP's bottom line. Risk is the remaining distinction. There is a high degree of risk when operating FSVs that can lead to damages and repairs. Self-perpetuation of demand variation and gaming is the least tangible item, partly explaining why they have proven impossible to eliminate.

Financial losses are incurred as a result of purchasing more vessels than are necessary. Since the causes of the bullwhip effect lead to an increasing fleet size, the financial losses are directly correlated with the effect. These losses can prove significant when considering the annual dollar amount required to finance voyages and to keep the FSVs in operating condition. One FSV costs BP approximately $5 million per year. The financial losses increase significantly when the fleet size grows. These costs are financed largely by Marine Logistics. This is why the team is more averse to adding vessels than their colleagues. The millions of dollars spent renting additional FSVs is the most significant financial loss, but there are lesser expenses (e.g. fuel costs) impacting the company.

Fuel is an operational cost that rapidly accumulates. Each FSV requires approximately $15,000 worth of fuel per voyage. This price can fluctuate depending on current pricing. Marine Logistics and their management are less likely to be concerned with fuel since the cost is relatively small, but the cost increases to a significant amount at the end of each year. As more fuel is used to power each additional FSV, costs increase.

Management is aware of the vessel and fuel costs, but they seem to be unaware of the causes – demand variation and gaming. Without acknowledging the real, systemic causes of these costs, the stakeholders focus their cost-cutting efforts on other, less significant areas. These insignificant costs are examples of noise that plagues systems and causes stakeholders to ignore more pressing concerns. Neglecting to recognize and mitigate noise can lead to the bullwhip effect.

Besides the financial losses, there is risk inherent in adding FSVs to the fleet. As the fleet size increases, the risk of vessels hitting other vessels in the GoM increases. Since the GoM is a highly active oil and gas area, the number of vessels operating in the area is large. Vessels occasionally come into contact with one another. Contact may require maintenance, repairs, or a complete vessel replacement. Employees on damaged vessels are liable to be injured which can prove costly for BP. Vessel collision requires costly remedies which may increase significantly. A growing fleet size can simultaneously increase risk to vessels and employees.

The effect's systemic nature shows why past efforts to correct the situation have not been successful. The different objectives, assumptions, and tension between the stakeholder groups decrease the richness of communication and introduce noise into the system. When stakeholders lack needed information, they focus on local optima to their own detriment. They do not recognize how their actions affect the system and cause the bullwhip effect. The effect becomes progressively problematic as stakeholders become entrenched in their duties instead of recognizing the cycle and taking measures to eliminate the root causes.

The bullwhip effect results in problems that are difficult to solve without identifying the core problem. BP's stakeholders could mitigate the financial losses and risk, but this is difficult due to their relationship with each other. Stakeholder groups can take measures over time to unravel the causes. Chapter Four includes suggestions concerning ways to mitigate the bullwhip effect without incurring high costs. General solutions covering the remaining two causes, price fluctuation and order batching, are included. The suggestions are not exhaustive, but they represent a starting point for BP and other companies interested in resolving the bullwhip effect.

CHAPTER FOUR

Solutions

It is difficult to identify and mitigate the bullwhip effect. The problems are typically symptoms of a more serious core problem. When stakeholders do not recognize this problem, they focus on finding temporary solutions that can fail to provide a lasting remedy. The efforts cause unnecessary tension between stakeholders because the solutions rarely work. The resulting conflict prevents them from collaborating and further entrenches each in their assumptions, but this unproductive cycle can be broken with tools and dialogue. Eliminating years of tension and developing a shared vision are difficult, but the reward of resolving the systemic issue is worthwhile.

BP is a system where some stakeholders address peripheral issues instead of the core problem. The result is employees who have unsuccessfully tried to resolve the problem involving the FSV process. They are unaware of how demand variation and gaming are affecting the system and the ultimate reason why each cause exists. Historically, they have not incorporated enough tools and conflict management while solving problems. These are necessary if employees want to eliminate the process's root cause and develop a solution. The BP case study is representative of many systems experiencing problems and provides the foundation for specific solutions.

This chapter discusses what I see to be the core problem and solutions at BP. Stakeholders are assumed to have identified the bullwhip effect and the causes in the FSV process but have yet to understand why the causes exist and how to solve the problem.

Stakeholders can use tools to identify and solve the core problem. Tools include the Theory of Constraints (TOC) thinking processes – the Intermediate Objectives (IO) Map, Current Reality Tree (CRT) and Future Reality Tree (FRT). These are built sequentially to establish a common goal, understand the gap preventing the achievement of the goal, and create a simulation of desired future performance.

BP's stakeholders struggle with identifying a common goal. Without consensus they pursue individual goals at the expense of others. Stakeholders must agree on the goal before they can discover and resolve the core problem. Building a shared vision by identifying a common goal is possible when parties are open to dialogue. According to Senge, "The discipline of team learning starts with 'dialogue,' the capacity of members of a team to suspend assumptions and enter into a genuine 'thinking together,' (p. 10). Identifying a goal requires that stakeholders talk with each other. This is the foundation of BP's solutions and is necessary for TOC to be effective. The following tools are used after stakeholders have agreed to open, unbiased dialogue.

Once dialogue begins, the stakeholders can use the TOC tools. First, the IO Map is used to build consensus. Stakeholders must forego individual goals and work towards one that benefits the company and resolves the FSV dilemma. This goal should be undisputed and representative of the stakeholders' values. Many for-profit corporations choose a goal that includes maintaining a profitable company which rewards stakeholders and enriches employees. Most stakeholders can agree to this goal, but this analysis involves a process requiring a specific goal. BP stakeholders can agree on the following: Provide assets with sufficient capacity to meet demand. It is unlikely to be debatable because these groups want to satisfy the need.

The next step is to establish the critical success factors (CSFs) and necessary conditions (NCs). Certain conditions are critical in order to reach the goal. These include an optimal fleet size, available vessel capacity, and an accurate schedule. These are BP's CSFs. The NCs must support the CSFs because they are necessary to obtain the CSFs. A few examples of NCs include a sufficient number of vessels, an updated Cargo Manifest System, and available deck space. Figure 3 shows the relationship between the IO Map's elements. Read it by stating, 'In order to provide assets with enough capacity to meet demand, we must have an optimal fleet size, available vessel capacity, and an accurate schedule.' The rest of the map is read the same way.

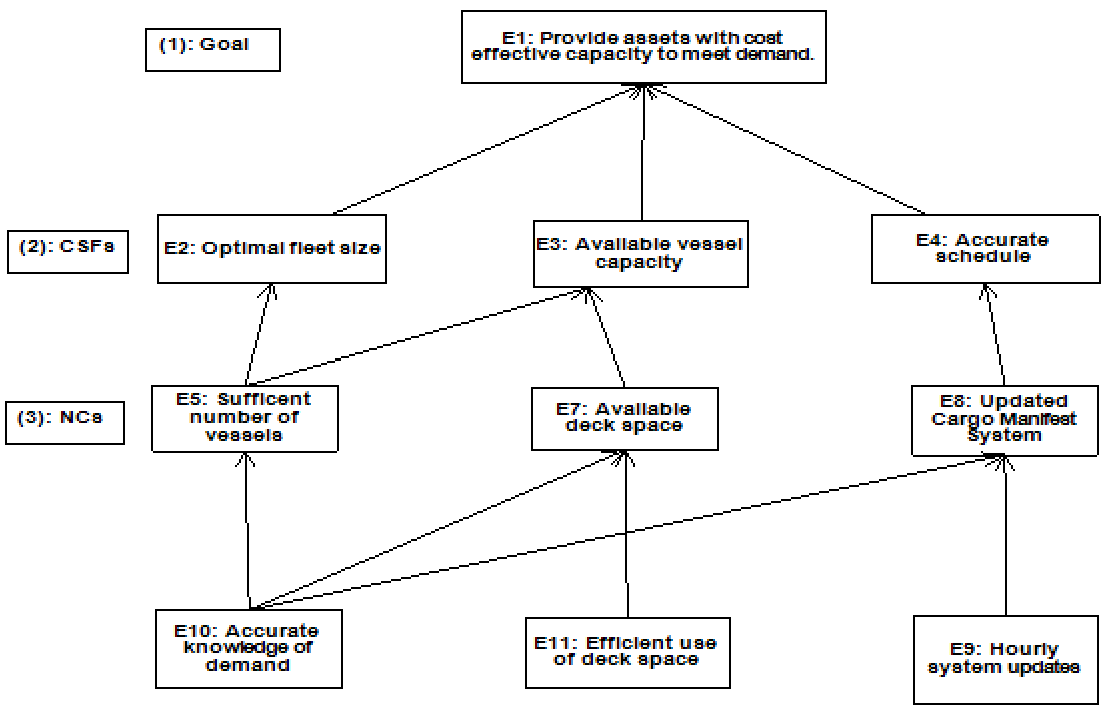


Figure 3

This logical progression leads stakeholders to their ultimate goal, but this is not the end of the process. An additional tool, the CRT, explains why the bullwhip effect's causes exist. This sufficiency tool uses cause-effect relationships to determine the cause of most, if not all, undesirable effects (UDEs). UDEs are problems affecting the system which stakeholders want to mitigate or eliminate. The primary UDEs described in Chapter Three include tension between stakeholders, rising costs, increasing collision risk, and increasing fleet size. Demand variation and gaming are related to UDEs, but they are not considered UDEs. Demand variation and gaming are the derived causes of UDEs. There are deeper causes other than the UDEs that affect demand variation and gaming. Figure 4 shows the CRT and the deductive logic used to reveal the core problem leading to the UDEs. This core problem is the reason why most of BP's UDEs exist.

Prior to reading the CRT, one should remember the Categories of Legitimate Reservation (CLRs) that scrutinizers may use. CLRs are tools (e.g. insufficient cause, entity existence, additional causes) used to validate the logic in the TOC diagrams. The CLRs forces scrutinizers to challenge their logic and improve the cause-effect relationships. BP stakeholders should use these when considering whether the logic is sound. It would be beneficial to request that others besides the involved stakeholders to participate in this scrutiny. The stakeholders are familiar with the problem at this point so they might need a fresh outlook. Additional participants can come from other business segments and do not need to understand the FSV process. They do not have to have experience with these tools or the CLRs, but the presenter should have sufficient experience to understand their comments and address their concerns. The product may resemble the CRT shown in Figure 4.

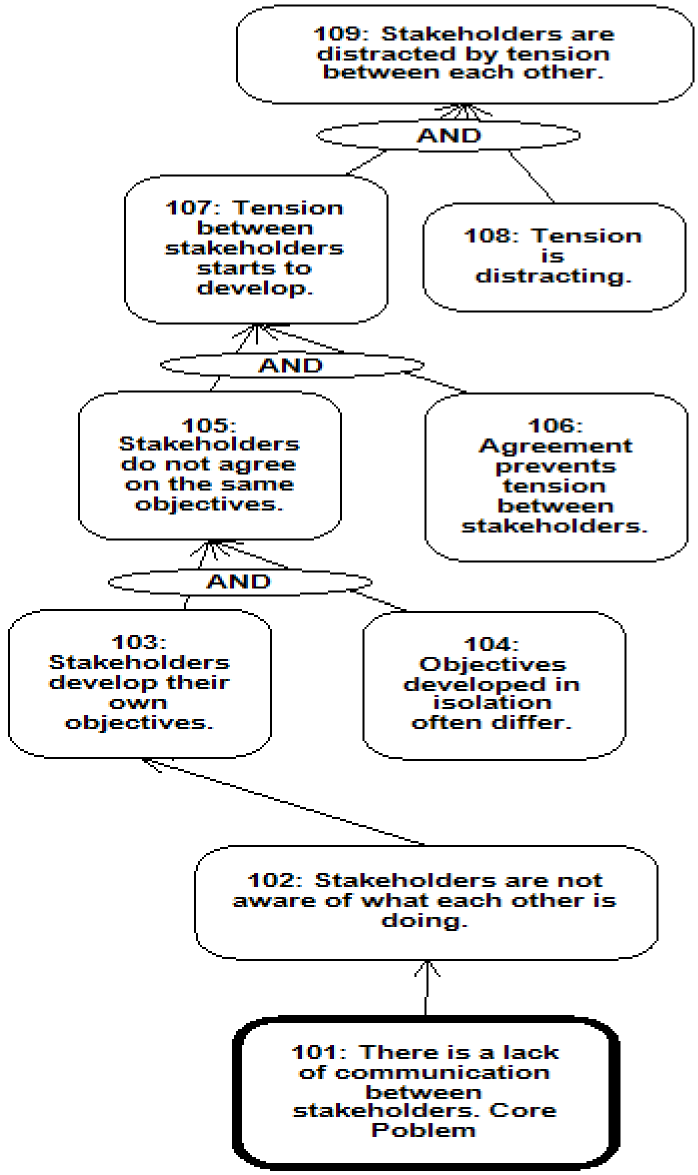

109: Stakeholders are distracted by tension between each other.
AND
107: Tension between stakeholders starts to develop.
108: Tension is distracting.
AND
105: Stakeholders do not agree on the same objectives.
106: Agreement prevents tension between stakeholders.
AND
103: Stakeholders develop their own objectives.
104: Objectives developed in isolation often differ.
102: Stakeholders are not aware of what each other is doing.
101: There is a lack of communication between stakeholders. Core Poblem

Figure 4a

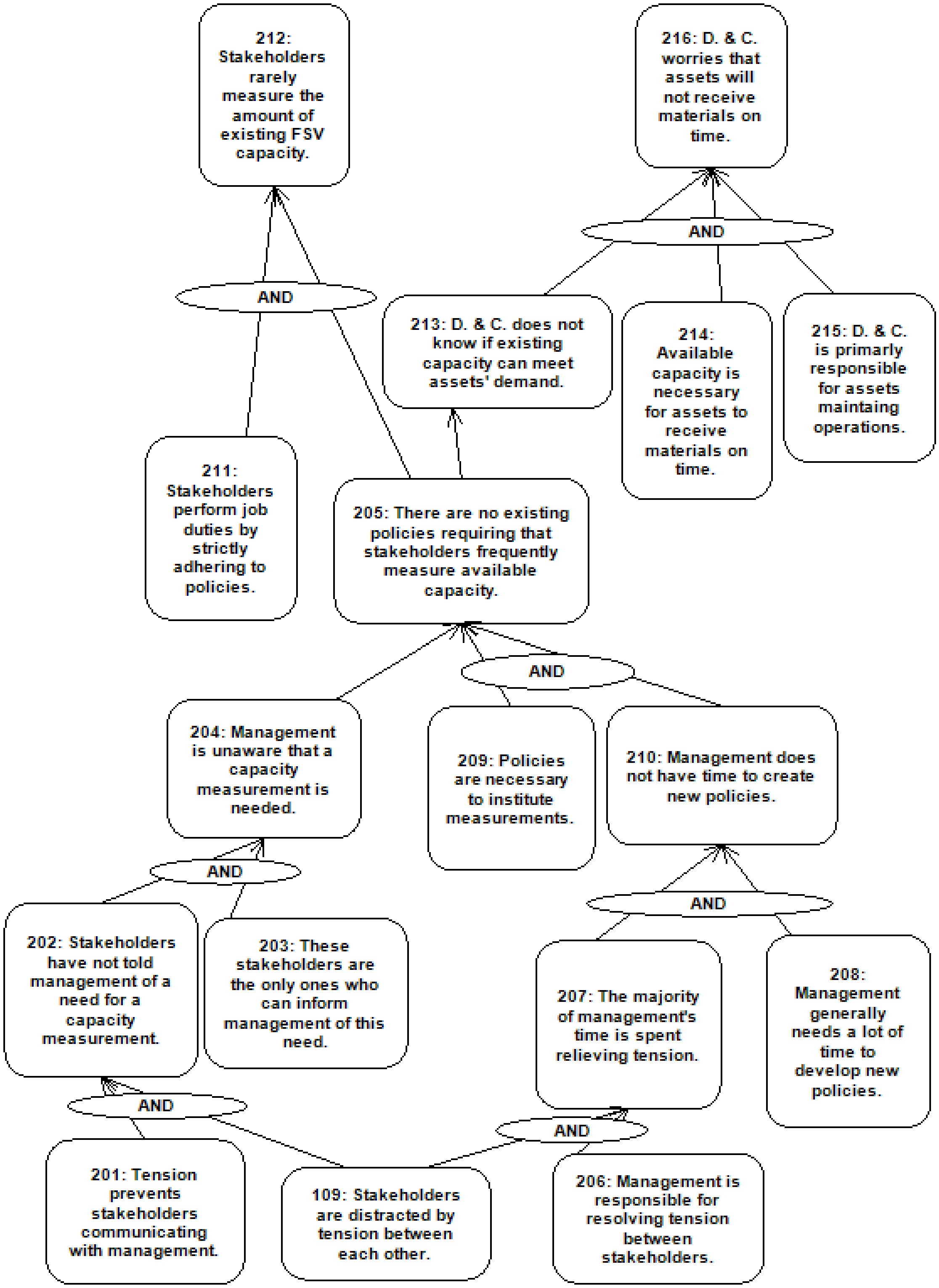
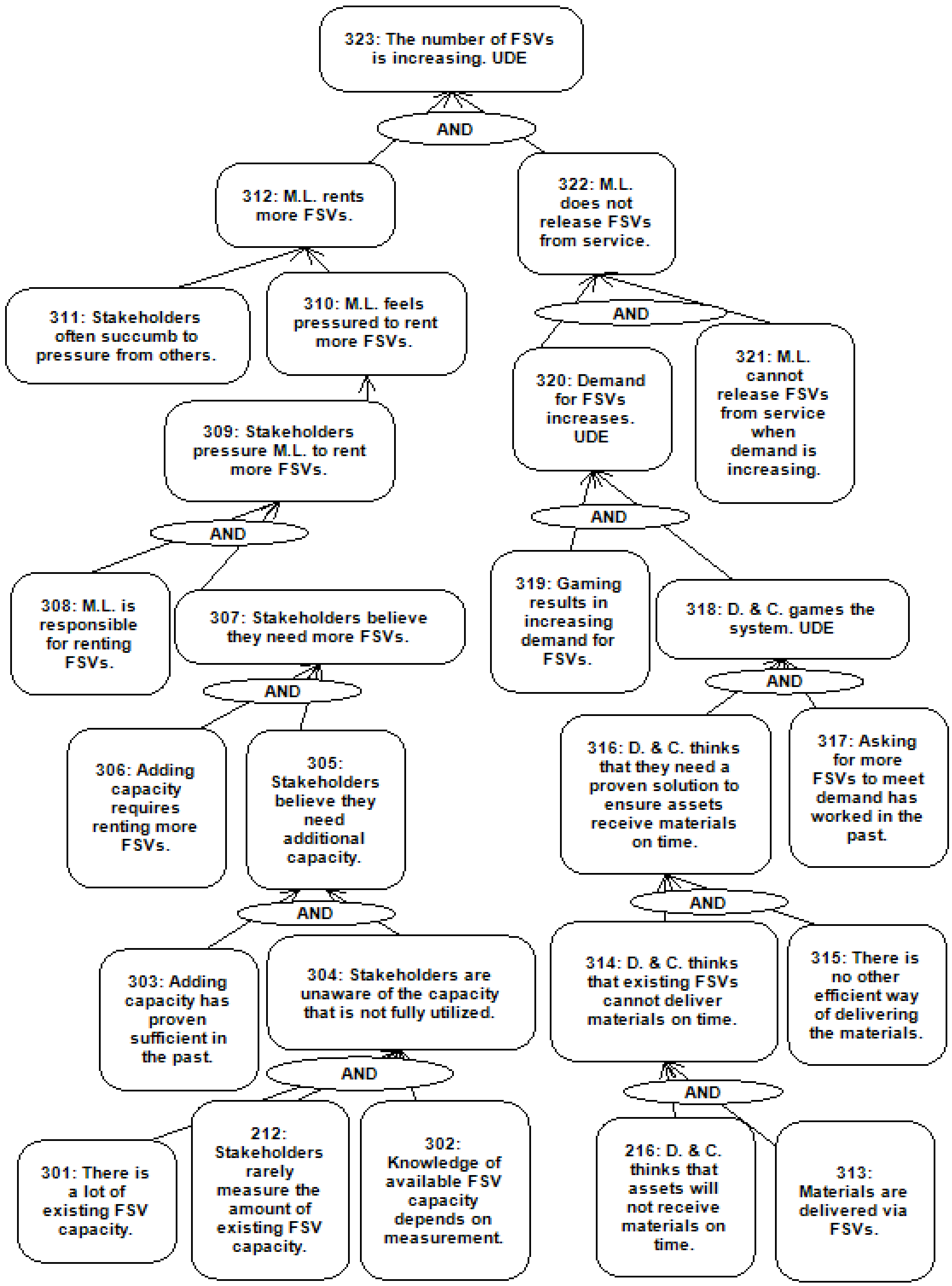

212: Stakeholders rarely measure the amount of existing FSV capacity.
216: D. & C. worries that assets will not receive materials on time.
AND
AND
213: D. & C. does not know if existing capacity can meet assets' demand.
214: Available capacity is necessary for assets to receive materials on time.
215: D. & C. is primarly responsible for assets maintaing operations.
211: Stakeholders perform job duties by strictly adhering to policies.
205: There are no existing policies requiring that stakeholders frequently measure available capacity.
AND
204: Management is unaware that a capacity measurement is needed.
209: Policies are necessary to institute measurements.
210: Management does not have time to create new policies.
AND
AND
202: Stakeholders have not told management of a need for a capacity measurement.
203: These stakeholders are the only ones who can inform management of this need.
207: The majority of management's time is spent relieving tension.
208: Management generally needs a lot of time to develop new policies.
AND
AND
201: Tension prevents stakeholders communicating with management.
109: Stakeholders are distracted by tension between each other.
206: Management is responsible for resolving tension between stakeholders.

Figure 4b



323: The number of FSVs is increasing. UDE
AND
312: M.L. rents more FSVs.
322: M.L. does not release FSVs from service.
311: Stakeholders often succumb to pressure from others.
310: M.L. feels pressured to rent more FSVs.
AND
320: Demand for FSVs increases. UDE
321: M.L. cannot release FSVs from service when demand is increasing.
309: Stakeholders pressure M.L. to rent more FSVs.
AND
AND
308: M.L. is responsible for renting FSVs.
307: Stakeholders believe they need more FSVs.
319: Gaming results in increasing demand for FSVs.
318: D. & C. games the system. UDE
AND
AND
306: Adding capacity requires renting more FSVs.
305: Stakeholders believe they need additional capacity.
316: D. & C. thinks that they need a proven solution to ensure assets receive materials on time.
317: Asking for more FSVs to meet demand has worked in the past.
AND
AND
303: Adding capacity has proven sufficient in the past.
304: Stakeholders are unaware of the capacity that is not fully utilized.
314: D. & C. thinks that existing FSVs cannot deliver materials on time.
315: There is no other efficient way of delivering the materials.
AND
AND
301: There is a lot of existing FSV capacity.
212: Stakeholders rarely measure the amount of existing FSV capacity.
302: Knowledge of available FSV capacity depends on measurement.
216: D. & C. thinks that assets will not receive materials on time.
313: Materials are delivered via FSVs.

Figure 4c

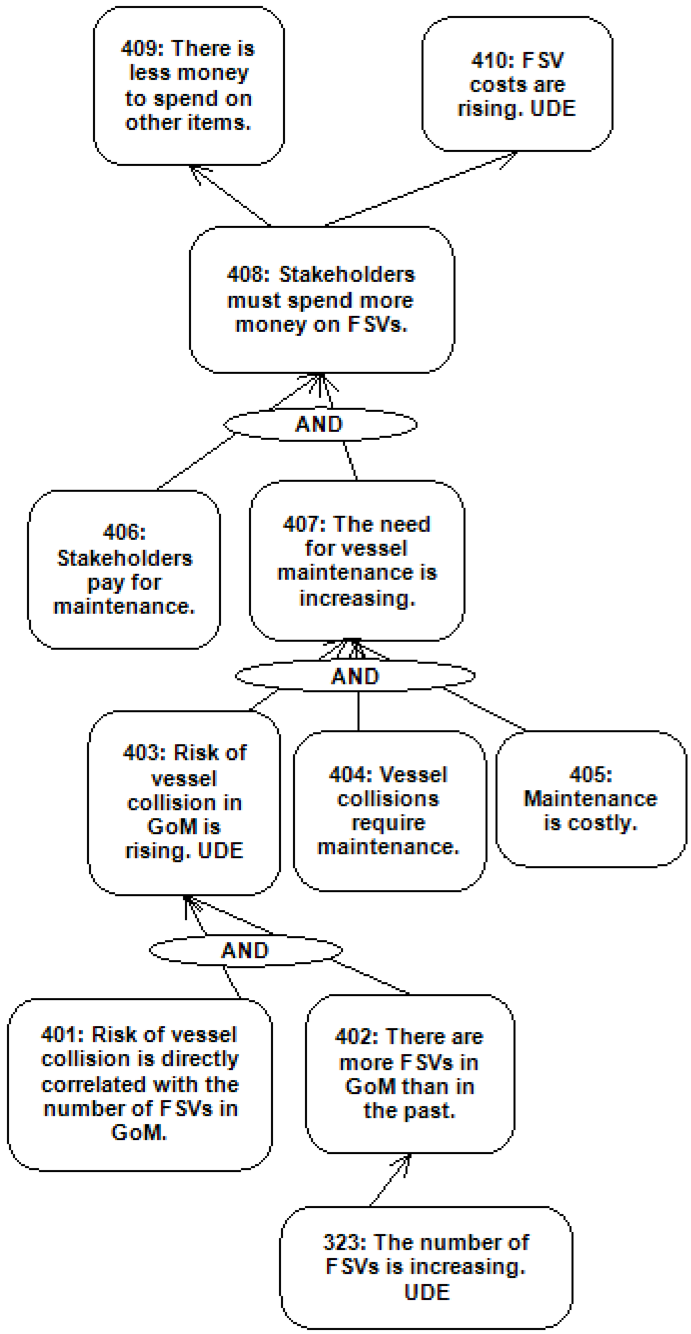


Figure 4d

Figure 4a shows the CRT starting at the bottom of the tree. It is read starting from the bottom where the explanation begins with the core problem. The core problem for this FSV process is, ‘There is a lack of communication between stakeholders.’ The problem is significant because it causes each UDE. Without proper communication stakeholders develop conflicting objectives that can cause tension. The groups' objectives are measured using different criteria.

Drilling & Completions measures their objective by counting the number of days that each rig cannot operate. This measurement is critical because of the large financial losses incurred when rigs are not operating. Marine Logistics uses a financial measure which is the cost of obtaining and operating vessels. When stakeholders must spend considerable effort handling these different objectives, they have less time to work towards achieving the goal shown in the IO map.

This logic results in two different paths seen in Figure 4b that leads to the same result. One path concerns the stakeholders while the other discusses management. Stakeholders distracted by conflict cannot easily perceive problems, such as how FSV capacity influences the fleet size. Although stakeholders know there is no measurement for capacity, tension distracts them from perceiving this as a significant problem.

Management is unaware of the need for a measurement because they are busy relieving tension. Management could address this concern by issuing a policy complete with a method of measuring, but this does not exist. Without a measurement, stakeholders cannot accurately assess the amount of capacity needed to satisfy demand.

Figure 4c shows that some groups think that available capacity is not sufficient. This thought exists because there is no measurement that can prove or disprove their assumptions. Without the measurement, some stakeholders think that additional FSVs could decrease the probability of losing days of operating. They deliberately game the system by requesting more FSVs than necessary. They recognize that they depend on

FSVs for their assets to receive supplies. Gaming has worked in the past so stakeholders naturally rely on it to get the desired results.

Figure 4d reveals the UDE, ‘The number of FSVs is increasing,’ resulting from gaming and pressure from stakeholders. This UDE causes more effects. This increase in FSVs leads to heightened risk in the GoM. Since collisions are more likely to occur when risk increases, the probability of repairs increases. Repairs can prove costly depending on the situation. Funds spent on repairs decrease the amount that could be spent on other beneficial activities.

Identifying the system’s core problem is necessary but not sufficient. Making lasting decisions requires that stakeholders create a strategy leading to desirable outcomes. The Future Reality Tree provides the structure for this strategy. BP’s FRT uses the logic seen in the CRT and has comparable branches. The UDEs are transformed into desirable effects (DEs) that stakeholders want to achieve. BP’s DEs include, first and foremost, provide assets with enough capacity to meet demand. Stakeholders must minimize demand variation, reduce costs, and decrease risk. Stakeholders should implement changes to reach these DEs. These changes are the injections. When injections are combined with entities from the CRT, the future can be altered to a more favorable outcome. Figure 5 is the FRT related to BP’s FSV process.

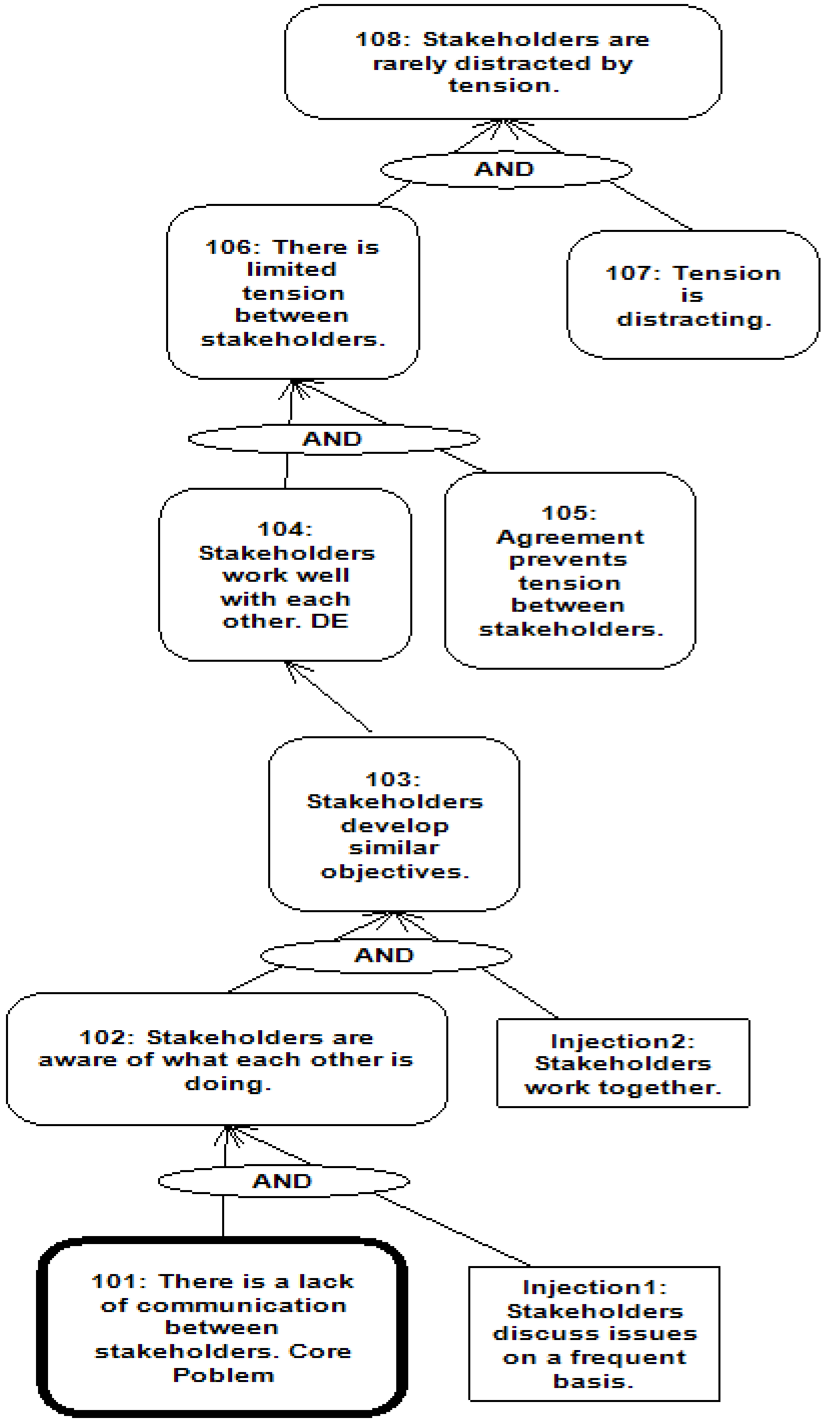

108: Stakeholders are rarely distracted by tension.
AND
106: There is limited tension between stakeholders.
107: Tension is distracting.
AND
104: Stakeholders work well with each other. DE
105: Agreement prevents tension between stakeholders.
103: Stakeholders develop similar objectives.
AND
102: Stakeholders are aware of what each other is doing.
Injection2: Stakeholders work together.
AND
101: There is a lack of communication between stakeholders. Core Poblem
Injection1: Stakeholders discuss issues on a frequent basis.

Figure 5a

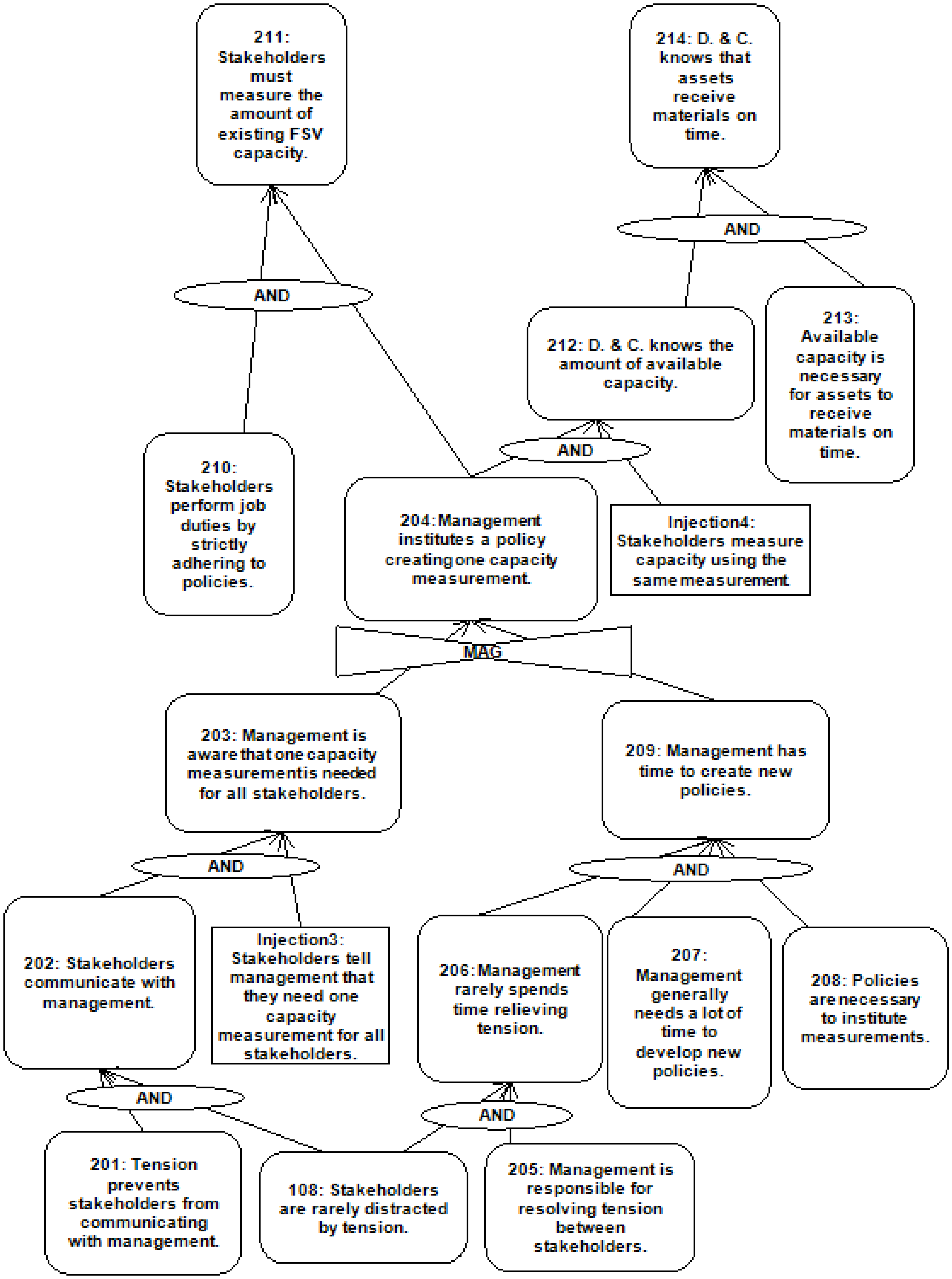

211: Stakeholders must measure the amount of existing FSV capacity.
214: D. & C. knows that assets receive materials on time.
AND
AND
212: D. & C. knows the amount of available capacity.
213: Available capacity is necessary for assets to receive materials on time.
AND
210: Stakeholders perform job duties by strictly adhering to policies.
204: Management institutes a policy creating one capacity measurement.
Injection4: Stakeholders measure capacity using the same measurement
MAG
203: Management is aware that one capacity measurement is needed for all stakeholders.
209: Management has time to create new policies.
AND
AND
202: Stakeholders communicate with management.
Injection3: Stakeholders tell management that they need one capacity measurement for all stakeholders.
206: Management rarely spends time relieving tension.
207: Management generally needs a lot of time to develop new policies.
208: Policies are necessary to institute measurements.
AND
AND
201: Tension prevents stakeholders from communicating with management.
108: Stakeholders are rarely distracted by tension.
205: Management is responsible for resolving tension between stakeholders.

Figure 5b

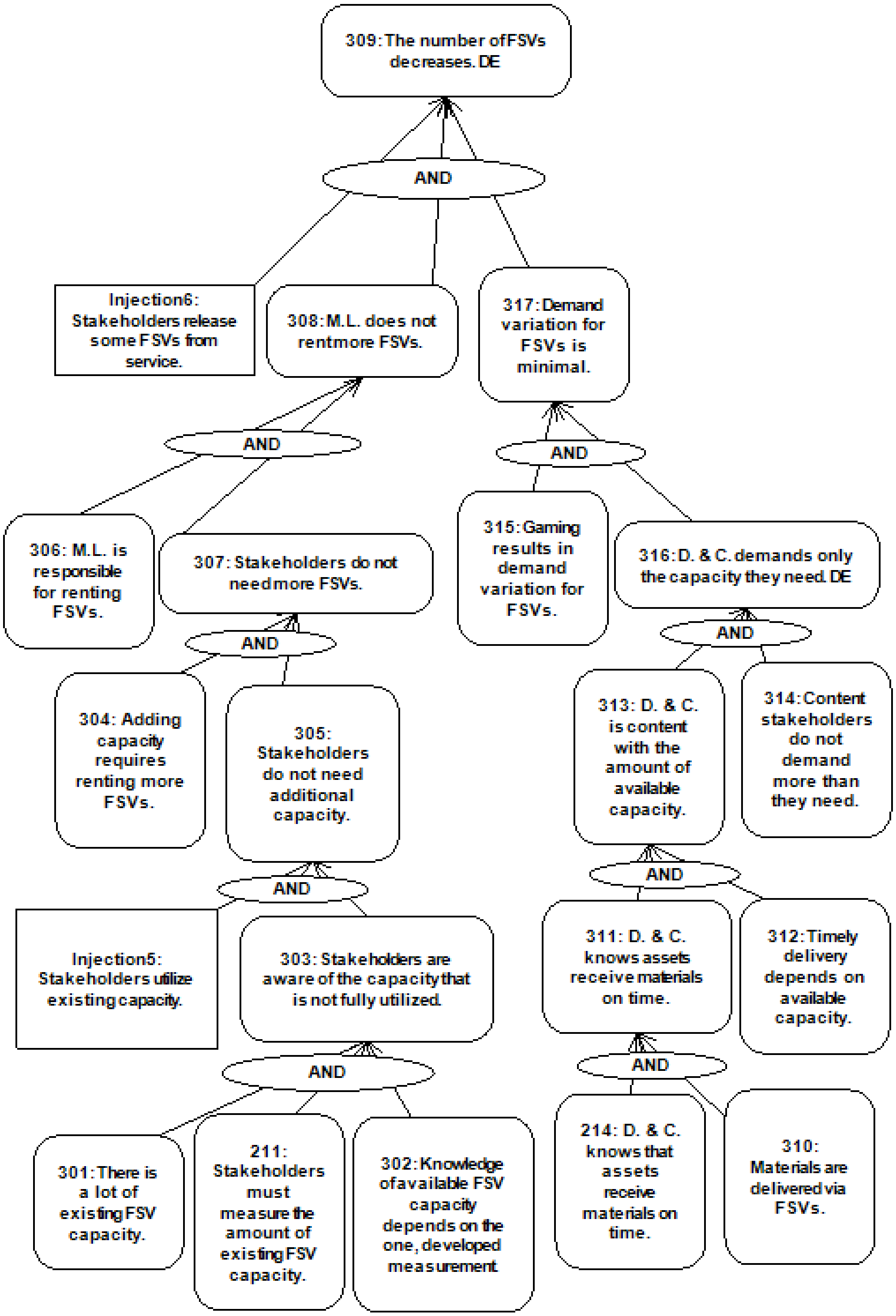

309: The number of FSVs decreases. DE
AND
Injection6: Stakeholders release some FSVs from service.
308: M.L. does not rent more FSVs.
317: Demand variation for FSVs is minimal.
AND
AND
306: M.L. is responsible for renting FSVs.
307: Stakeholders do not need more FSVs.
315: Gaming results in demand variation for FSVs.
316: D. & C. demands only the capacity they need. DE
AND
AND
304: Adding capacity requires renting more FSVs.
305: Stakeholders do not need additional capacity.
313: D. & C. is content with the amount of available capacity.
314: Content stakeholders do not demand more than they need.
AND
AND
Injection5: Stakeholders utilize existing capacity.
303: Stakeholders are aware of the capacity that is not fully utilized.
311: D. & C. knows assets receive materials on time.
312: Timely delivery depends on available capacity.
AND
AND
301: There is a lot of existing FSV capacity.
211: Stakeholders must measure the amount of existing FSV capacity.
302: Knowledge of available FSV capacity depends on the one, developed measurement
214: D. & C. knows that assets receive materials on time.
310: Materials are delivered via FSVs.

Figure 5c

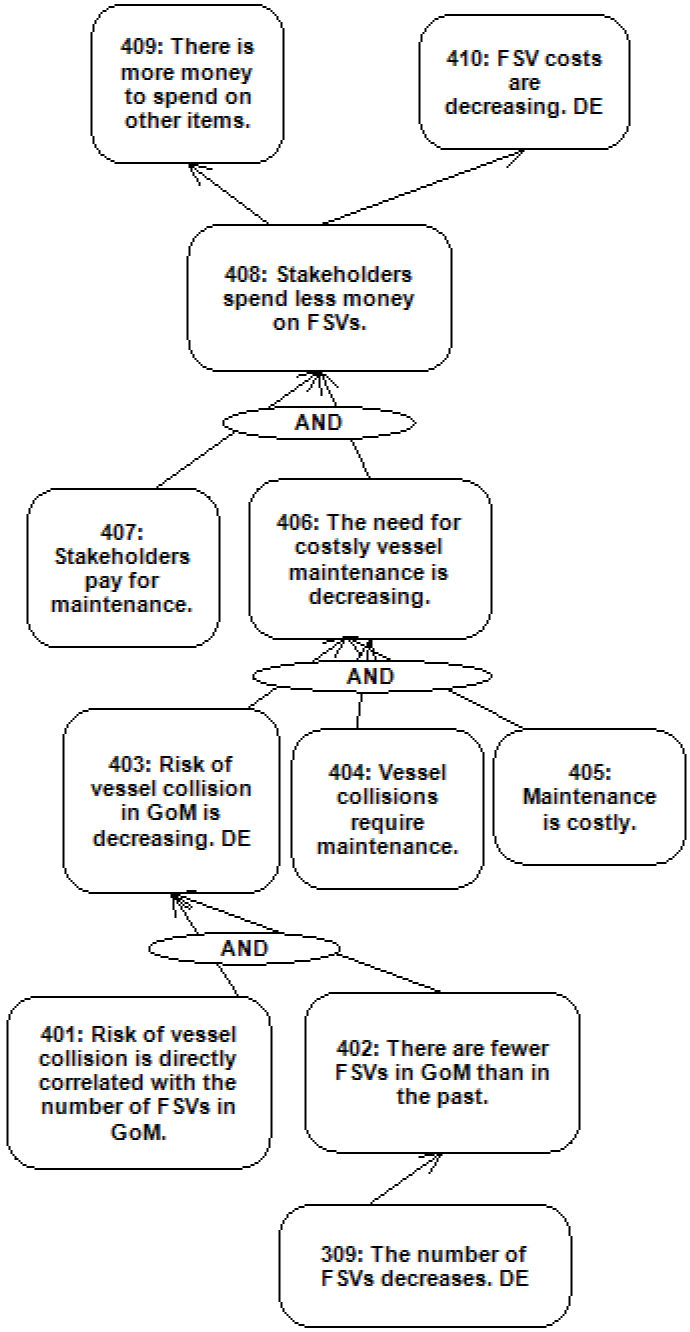

409: There is more money to spend on other items.
410: FSV costs are decreasing. DE
408: Stakeholders spend less money on FSVs.
AND
407: Stakeholders pay for maintenance.
406: The need for costly vessel maintenance is decreasing.
AND
403: Risk of vessel collision in GoM is decreasing. DE
404: Vessel collisions require maintenance.
405: Maintenance is costly.
AND
401: Risk of vessel collision is directly correlated with the number of FSVs in GoM.
402: There are fewer FSVs in GoM than in the past.
309: The number of FSVs decreases. DE

Figure 5d

The FRT is built starting from the bottom of the tree. The core problem in Figure 5a is combined with an injection – stakeholders discuss issues on a frequent basis. This is the foundation of the tree where positive changes take place. The entities become positive or neutral as the tree is built. Additional injections are added when entities are not sufficient to move closer to the DEs. There are five other injections, including stakeholders work together; stakeholders tell management that they need a capacity measurement; stakeholders measure capacity; stakeholders utilize existing capacity; stakeholders release some FSVs from service.

BP's primary problem is a lack of communication. The first injection in Figure 5a addresses this problem. The change prompts the groups to communicate often, but it is not sufficient. Stakeholders must also work together. This is Injection 2 in Figure 5a. Communication and frequent contact increases the groups' awareness of the FSV process. The injections promote good will and alleviate tension. Once this is established stakeholders can communicate more efficiently with management. An example is telling management that there is a need for a capacity measurement. This entity is seen in Figure 5b. Additional injections are needed to move closer to the DEs. The next injection concerns the stakeholders reacting to the new measurement.

Stakeholders are responsible for implementing the measurement. This leads to Injection 4 in Figure 5b – stakeholders measure capacity. The policy alone is not sufficient to make change. The groups must use this measurement while working together. After measuring available capacity, groups should have a better idea of whether they need to acquire more capacity. Figure 5c shows that stakeholders realize existing capacity is more than sufficient to meet current demand, but they need to use capacity more efficiently to satisfy demand. This is Injection 5 in Figure 5c where groups realize they do not need additional FSVs. On the contrary, they can release vessels.

These TOC tools show the process of identifying and resolving a logistical problem. BP's anecdote is specific to the company and logistics group, but these tools are applicable to other types of businesses, including for and non-profits. While the entities will differ, the process is the same. Builders should develop consensus by creating a goal acceptable to everybody. Then they use the CRT where they identify the core problem that inhibits their progress towards the goal. Last, they should create a simulation of the future using a FRT by defining the DEs they want to achieve.

Builders should not assume that the same goals, UDEs, etc. are applicable to all situations. Instead, builders should rely on their intrinsic knowledge of their system to create the TOC tools. For example, a non-profit company feeding the homeless might have the goal, "Feed 200 individuals per day." While this is not a financial goal, it is legitimate because it represents what the company wants to achieve. Companies in the same industry might have similar entities, but some difference is expected. Businesses should not rely solely on tools created by other companies.

Creating the TOC tools depends on one's understanding of the system and the creator's degree of influence. If neither is sufficient, builders should enlist the help of others. These individuals can provide knowledge and scrutiny while creating the tools. Overall, every company can benefit from using these tools. Whether the company has systemic problems or small problems in a specific department, such as BP's case, these tools are applicable. They can provide a competitive advantage to companies willing to invest the time and energy necessary to use TOC.

CHAPTER FIVE

Discussion and Conclusions

Many companies take a reactive approach when problems occur because solving them can be time-consuming and difficult. It is often easier to put out fires after they erupt instead of preventing the eruption, but this does not have to be the case. Companies do not have to be subject to “firefighting” if their employees look beyond the symptoms of the problem to the root cause. If employees do this, they can gain a strong competitive advantage because less time will be spent resolving problems and more time working on profitable activities. The bullwhip effect is a good starting point when problem-solving for companies experiencing reoccurring problems that seem to lack a solution.

Determining whether the bullwhip effect is occurring requires a reminder of the four causes: demand variation, order batching, price fluctuations, and gaming. Only one has to be present for the phenomenon to appear, but the presence of two or more can have a compounding effect. They are detrimental because each can cause exponentially increasing inventory as demand travels from the consumer to upstream entities. Excess inventory accumulates over time as the causes amplify the effect. Note that the phenomenon can occur regardless of the degree of the causes’ severity. A slight or large change due to one or more of the four causes can both have similar effects on the system throughout time.

The system, or the setting for this study, is the environment where the bullwhip effect takes place. It is comprised of several characteristics, such as a dynamic setting where the effect is continuously altering the system's current state. As this change occurs, information is cycled throughout the system via information channels and feedback loops. Stakeholders working in the system have limited information since the system lacks transparency. This is due partly to the system's non-linear state where its inputs are not proportional to its outputs. Another reason is the number of variables within the system that create new values as they interact. Many systems lack transparency and are difficult to control, but their characteristics provide some insight into ways to influence the system.

One example of a system is British Petroleum (BP). BP is one of the world's largest oil and gas companies. It operates in many areas, including the Gulf of Mexico where this study took place. The company's organizational structure consists of several functions (e.g. Marine Logistics, Shore Base, and Drilling & Completions). Stakeholders work together to ensure that rigs are operating efficiently and receiving supplies and equipment. This process can be difficult when stakeholders disagree.

The case showed an example of one disagreement that lead to the bullwhip effect due to demand variation and gaming. Stakeholders disagreed on the number of vessels needed to transport items to the rigs. As Drilling & Completions requested more vessels from Marine Logistics, demand variation caused an increase in the demand for vessels even though existing capacity was sufficient. Marine Logistics and Drilling & Completions debated this over a significant amount of time, yet they could not reach an agreement. This reoccurring issue was a clue that there was a more serious problem affecting the system.

Once the bullwhip effect was established as the issue, the next step was to determine the core problem driving demand variation and gaming. This problem was the lack of communication between stakeholders. Without positive communication, the stakeholders were influencing the system in a negative way. Understanding the core problem provided the opportunity to apply changes that could reverse the negative direction. A particular set of tools was used to show the process of problem-solving.

These tools were a part of the Theory of Constraints (TOC) which seems to provide many benefits that other methods lack. TOC incorporates a method applicable to all types of industries, companies, and employees. It is a relatively simple approach that all can find useful. TOC tools are useful for several reasons. These tools use a structure that prompts users to carefully work through the problem and towards a solution. This structure encourages users to do this by building consensus and eliminating disagreements in a constructive way. They allow participants to use their creativity when constructing solutions.

TOC tools provide a structured step-by-step method that prompts builders to handle each component individually. The tools, with the exception of the IO Map, use entities developed in previous TOC tools. Builders should follow the approach exactly so they can benefit from this approach. While some of the TOC tools can be used in isolation, the structured approach seems much easier. Builders do not have to recreate the entities in every tool. They can rely on information in previous tools. This saves builders the time and energy of recreating information previously shown in other TOC tools.

The case study showed that companies face problems involving multiple people and departments. People can significantly complicate and slow the process of problem-solving. Attempts to resolve problems can be futile because there is no consensus among the stakeholders. Disagreements about the problem and solutions prevent them from advancing. This can create ill will between those who disagree, but TOC tools can prevent this by using the IO Map first. Once stakeholders agree on the goal, CSFs, and NCs, they should feel that their combined efforts are capable of resolving any problem. Once they establish this foundation where the majority is satisfied, they can tackle the problem together.

The TOC tools are unique because they offer the opportunity for stakeholders to use their creativity. The tools, especially the FRT, encourage them to create ideas that are not necessarily seen in their company or department. Since consensus has been developed, employees should feel willing to experiment with creative ideas. At the same time, the tools prompt stakeholders to check the viability of their ideas. For example, the FRT uses injections to determine whether ideas will result in the DEs. It allows stakeholders to identify potentially negative consequences. This creates reasonable boundaries where stakeholders can create and validate their ideas.

These are a few examples of where the TOC tools are preferable to other thinking strategies (e.g. Six Sigma). This approach is general and can be applied to any situation, including consequential, systemic problems or irritating, daily problems. TOC tools are not limited to particular companies, individuals, or industries. The case study is one example of myriad ways where TOC tools are applicable. Individuals can learn and benefit from using this systematic approach. Learning the approach is relatively simple and does not require an extensive background in TOC, but it requires that individuals have the patience to work through each tool. It is a constructive method that focuses time, energy, and resources on resolving growth-inhibiting problems.

Whether a company is small or large, local or global, simple or complex, it may experience the bullwhip effect. This subtle phenomenon can have crippling effects on systems. One sign that the phenomenon exists is a reoccurring problem that stakeholders have unsuccessfully tried to resolve multiple times. When this sign is noted in a business, stakeholders can benefit from asking whether the reoccurring problem is due to something more serious. If the answer is yes, employees can use their knowledge of the bullwhip effect and its four causes along with TOC tools to resolve the problem.

APPENDIX

APPENDIX A

alternative energy – A segment that produces primarily low-carbon fuels.

asset – A general term that includes both platforms and rigs.

Cargo Manifest System – A system used for tracking the amount and types of each item transported via OSVs and FSVs.

Categories of Legitimate Reservation – Rules that ensure logically-sound connections in each TOC tool; also referred to as CLR.

communication bandwidth – A path where information travels; richness of information depends on width of bandwidth

critical success factors – Elements in the IO Map that are absolutely necessary in order to reach the goal; also referred to as CSFs.

Current Reality Tree – A TOC tool used to identify the system's core problem; also referred to as the CRT.

C-Port – BP's primary port that services the GoM; located in Fourchon, Louisiana.

desirable effects – Positive elements that stakeholders would like to achieve in the system; also referred to as DEs.

downstream – A segment that refines and markets products.

Drilling & Completions – A job category that operates rigs and oversees drilling projects.

fast supply vessels – Part of the fleet used to carry urgent items to and from assets; also referred to as FSVs.

Future Reality Tree – A TOC tool used to identify the desirable effects that stakeholders want to achieve; also referred to as the FRT.

goal – The ultimate outcome that all stakeholders want to achieve; shown in the IO Map.

Gulf of Mexico – The area discussed in the case study; also referred to as the GoM.

injection – Changes implemented in the FRT that help drive the system towards the DEs.

Intermediate Objectives Map – A TOC tool used to identify the system's goal; also referred to as the IO Map.

Marine Logistics – A job category that manages the fleet operating in the Gulf of Mexico.

necessary conditions – Elements in the IO Map are necessary in order to reach the CSFs.

offshore installation manager – Top manager on an asset that is responsible for its operations.

offshore supply vessels – Part of the fleet used to carry non-urgent, bulky items to and from assets; also referred to as OSVs.

platform – Produces oil by removing it from a finished oil well.

rig – Drills into ground and creates an oil well.

Shore Base – A job category that runs Port Fourchon; loads and offloads vessels.

stakeholders – All employees involved in the case study.

team lead – Employee with authority over regular employees and reports to manager

Theory of Constraints – A philosophy used to identify the system's problem(s) inhibiting growth; also referred to as TOC.

undesirable effects – Noticeable elements that negatively impact the system; also referred to as UDEs.

upstream – A segment that produces and transports products.

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