



Applying Theory of Constraints in Administrative Process: An Experiment from the U.S. Government

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Abstract: U.S. Federal Government contracting has continually been assailed for waste and inefficiency. After a failed technological solution from Enterprise Resource Planning (ERP) procurement, and several insufficient operational solutions such as Lean Six Sigma to improve process efficiency, senior management at United States Supply Services¹ (USSS) turned to the Theory of Constraints (TOC) after learning about its success in manufacturing. Over a two year period of 2008-2010, for the thirteen TOC implemented procurement divisions there was an average of a 46% improvement in contract award rates while in the three control divisions the improvement was only 8%. It was also found that information transparency, the ability to see how a product is transformed in the supply chain, is a key element of TOC success. This research adds to the TOC body of knowledge by showing its effectiveness in an administrative system in one of the largest Federal Government contracting organizations and the results can be generalizable to other public and private sectors.

Keywords: theory of constraints, administrative process, supply chain management, enterprise resource planning, information transparency

1 Introduction

Procurement managers at the United State Supply Services (USSS) in a military supply chain were left in a quandary when a long anticipated procurement implementation of Enterprise Resource Planning (ERP) had not delivered what was desired. This commercial-off-the-shelf product had been altered to fit specialized government needs, but the mismatch between the commercial product and Federal contracting legal requirements was so large that it was not cost-effective to continue with this ERP-based procurement solution. This left managers with a working but unimproved legacy procurement system based on COBOL. Upon determination that any possible software remedy was

many years off, procurement executives turned to an internal process improvement orientation.

Tools such as Total Quality Management (TQM), Just-in-Time (JIT), Material Requirement Planning (MRP), and Lean Six Sigma (LSS) had often resulted in short-term improvement, but disappointing long-term results, due to unsolved underlying issues. It was decided to conduct an experiment using the Theory of Constraints (TOC) to improve contracting workflow and output. There was a desire to understand if TOC could be applied to a complex administrative and transaction based procurement process that requires plenty of legal oversight. It was hoped that if TOC experiment was successful it could be replicated throughout the larger procurement organization achieving at least some of the benefits lost through failure to implement ERP procurement.

USSS is a government entity that supplies parts and equipment primarily to the U.S. military services. USSS and its customer base plus contractors are collectively known as a particular supply chain of the military. USSS employs 2800 personnel worldwide providing demand planning, purchasing, engineering and other customer services. Approximately 900 of USSS' employees are in procurement which operates within a rigorously regulated electronic and manual process that awards 480,000 contracts a year to as many as 60,000 different suppliers. There are 8,000 individual customer activities that submit 1.4 million orders a year to USSS resulting in a sales volume of just over \$5B a year. There is a complex system of formal and informal inter-relationships between USSS with its customer and supplier base.

USSS' contracting operation has been a source of concern for decades. Contracts are often awarded late to the customer's requirement and productivity, in terms of contracts awarded per employee, has been stalled or is declining. The amount of workload in queue rarely improves and information transparency of workload in process is poor despite numerous attempts at improving workload tracking. Current measures and procedures are inadequate to help management understand workflow

¹ USSS is a pseudonym for an actual U.S. Government organization.

and why there seems to be large quantities of consistent rework. Purchasing officers are frustrated by the myriad of changing priorities and time interference away from their primary function of contracting. There is no match between workload capacity in USSS and the workload either directly received from customers or produced by USSS' demand planning and inventory system. This failure to match workload capacity has been further exacerbated by inputs from USSS' implemented but failed ERP system.

While the vast majority of procurement workload passes between electronic systems and personnel using those systems, the problems being experienced by USSS appear to mirror exactly those that have plagued manufacturing operations that have successfully used a concept called Theory of Constraints [11,12]. TOC is a popular philosophy fathered primarily by Goldratt [10,11,12] who proposes that virtually all problems can be described, and solved, in terms of managing constraints. TOC proposes that any organization, or sub-segment thereof, must have an overarching goal that transcends any other objective in the organization. To meet this objective (or achieve it efficiently) the primary constraint must be identified and eliminated. The theory proposes five distinct phases [2]: 1) Identify the constraint; 2) Decide how to exploit the constraint; 3) Subordinate all other processes to above decision; 4) Elevate the constraint; and 5) If the constraint has moved, return to Step 1.

TOC has been successfully applied almost exclusively in manufacturing production environments [1]. There is little evidence that TOC has thrived anywhere in large scale administrative processes. A proof of concept is desired by USSS through a highly original and unique experiment that can add to the body of supply chain related knowledge and help validate, modify or reject TOC as it relates to non-manufacturing oriented processes. It will also provide a test-bed to potentially solve a real world process issue with promise of

replication across similarly tasked public and private sector organizations

The paper proceeds as follows. Section 2 provides more background information of USSS and its need for process improvement. Section 3 and 4 discuss why the technological solution from ERP failed and the previous operational solutions such as Lean Six Sigma were insufficient. Section 5 discusses TOC in detail, why USSS examines TOC for its potential fit for process improvement, and what the potential challenges are for managing such a change in process. Section 6 introduces USSS' TOC experiment and its results. Section 7 concludes with contributions and limitations.

2 USSS administrative process and its need for improvement

Fig. 1 shows the USSS major administrative processes. In simple terms, customers place orders into USSS' *Order Management*. These orders can come directly from individual end users or intermediate retail activities depending on established supply chain procedures. *Order Management* either fills the order immediately out of on-hand stocks or back-orders the materials. In either case, a message is sent to *Demand Planning* recording the demand. *Demand Planning* determines forecasts of current and future requirements and then forwards that information to *Supply Planning* where a timing plan and buy quantity for procurement is developed. This buying timing is normally immediately for out-of-stock items, but also includes planning for large buys to fill worldwide inventories. Depending on approval of *Technical/Quality* requirements (not required in all cases), *Procurement* then solicits the buy from *Suppliers*, awards the contract, and then tracks the buy until completion. This completion results in material being sent directly to the customer or onto one of 37 USSS partnered supply depots throughout the world.

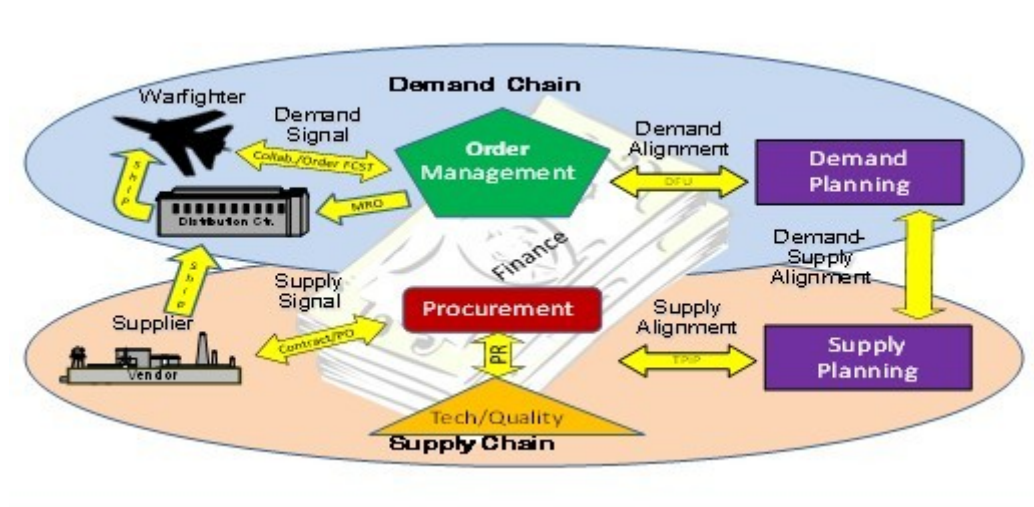


Fig.1 USSS major processes

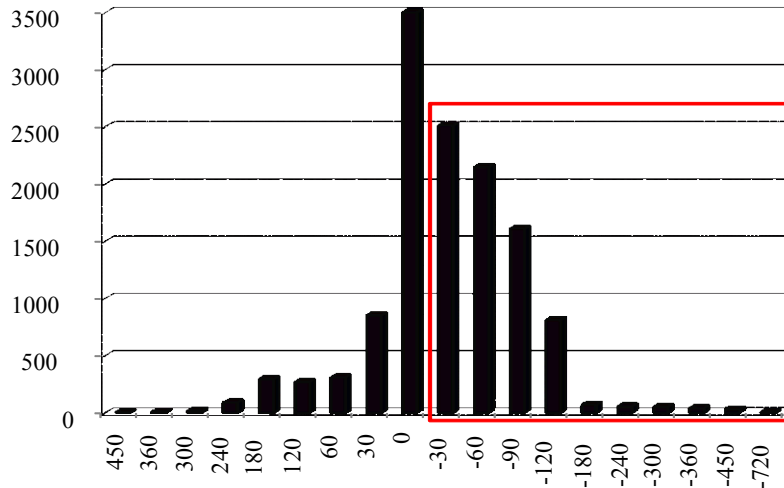


Fig.2 Days early/late for USSS contract award in 2006

Historically, over many years, the ability for USSS to meet the procurement workload coming from customers had been poor. On average 15% of customer requests had to go on backorder for some period of time. While some of this failure was explainable due to funding, customer forecast issues, and supplier delinquencies, almost 50% of backorders were caused by execution problems in the procurement process. The variability in USSS' ability to award contracts on-time was wide ranging. Fig. 2 shows the days early or late the contract was awarded based upon a machine-generated timeline called Administrative Lead-Time (ALT) which is calculated to maintain a full pipeline of supplies for expected demand. It is a snapshot of the USSS buying process in late 2006.

Optimally, all contracts should be awarded no more than 30 days early and no more than 30 days late to prevent backorders. As noted by the drawn square around the data in Fig. 2, all these buys were made more than 30 days late over the required ALT. This virtually guarantees future backorders and potential lost sales. It should be recognized that ordering early, while the lesser of two evils to customers, is also a problem since it ties up capital, increases inventory, and decreases stock turn. To make the entire supply chain of suppliers and customers work efficiently, contracts must be awarded on time to match requirements – not early and not late.

The administrative lead time discrepancy issue in awarding contracts clearly highlighted to USSS as a problem in keeping up with buying requirements and that the number of average buys made by a buyer (award rates) would have to improve significantly.

3 Failed technological solution of ERP procurement

After many years of preparation and beta testing, USSS introduced a comprehensive SAP-based Enterprise Resource Planning (ERP) to handle, in an integrated manner, all supply chain functions in USSS. This system

was intended to replace a forty-year-old COBOL-based system which was becoming difficult to maintain, document, and alter. The objective of this new information technology changeover was to establish a commercial look, feel and efficiency into USSS systems. Despite the desire for absolute private sector modernity, this new ERP development still had to maintain legacy transactional relationships with customers and suppliers as illustrated in Fig. 1. This was required because USSS' considerable customer base would continue to operate with their current transactional software interfaces for many years to come. This information technology limitation was also reflected in some large supplying manufacturers as well as in many small businesses.

The institution of the ERP dramatically altered the content, look and feel of user job roles within USSS. Notwithstanding years of prototyping, this ERP system introduced significant complexity into the working environment. Not surprisingly, change management issues were difficult and followed traditional paths of resistance [3,24]. The ERP system also experienced significant initial downtime and software related problems. Almost 2,000 system change requests were generated in the first year of operation.

Most significantly was that, even before full implementation, it was realized that the commercial SAP system modules related to contracting would not handle government procurement workload. The reasons for this were varied. These included factors such as adherence to established procurement law as well as that the volume and range of different items procured by USSS was significantly higher than that handled by most commercial entities. In addition, the types of items stocked and ordered were, on average, much slower movers in terms of requisition volume than commercial entities. As such, it was necessary to remove the procurement modules from the SAP product and continue running procurement using the previously established legacy system.

For several years the organization had put

considerable faith in the concept that the new ERP system would “cure” long-term procurement deficiencies. This resulted in enhancements to the legacy procurement system being frozen in order to commit resources to the new ERP system. The removal of the SAP-based ERP procurement modules forced USSS to operate an already problematic procurement system that was; a) not updated fully, b) now not internally integrated well with the USSS supply chain which had transitioned to the new ERP system, and c) was under increasing external pressure to produce better results. This ERP disappointment was a major catalyst in USSS’ willingness to seek new procurement solutions from non-traditional sources.

4 Insufficient operational solutions

USSS grew a reasonably mature Lean Six Sigma (LSS) program [9,35] during the period of the ERP installation. The two activities were established and executed independently, but ultimately resulted in USSS’ search for an improved procurement process. Over 200 individual LSS process improvement projects had been completed prior to year 2008. Over 60% of these projects had been executed on USSS procurement processes or accomplished jointly with USSS procurement partners of some Fortune 500 manufacturers. These process improvement projects generally showed strong gains in time, quality, or cost within the procurement sub-organization where the project was scoped. Despite these clear successes, management was disappointed that the organization’s overall bottom line metrics regarding sales, throughput, and timeliness were showing little improvement with some actually declining.

The lessons learned from the many LSS procurement projects began to point to certain common constraints that impacted the procurement process. Due to legal, policy, and personality issues these constraints were often not actionable by individual LSS process improvement projects, but were clearly impacting contracting throughput. As the LSS program matured, there was a common recognition that constraint management within the USSS procurement system had become the key improvement issue.

The bottom line is that LSS program was improving processes, but until TOC came along it became evident that LSS was not attacking the right processes. After considerable data analysis, it was determined that procurement’s failure to consistently award on time was the critical supply chain constraint for all of USSS.

There were many speculative reasons for this failure to award on time. The automated inventory generation system pushed out purchase requests to buyers far exceeding their capacity to buy. Buyers were often accused of being less efficient than their capabilities would indicate. Buyers complain that their “buying day” was often filled with routine and unnecessary tasks. It took too long (as much as three years) for buyers to achieve the certifications they need to buy the full gamut

of awarded contracts. Priorities of buys were constantly being shifted. Metrics rewarded aberrant behavior. Work in process was so large that it caused stress and “cherry picking” of easy buys at the expense of harder, but potentially more important buys. The new ERP system installed outside procurement was trying to force lower inventories in the supply depots. This increased the average number of buys per individual item. Overall lead-times for awarding contracts had grown so long that buyers and management had become desensitized to further lead-time growth. Suppliers were often non-responsive when requested to bid on contracts or their price escalation on bids submitted often exceeded government parameters. Changing customer forecasts and demand patterns caused a “see-saw” effect of buying and expediting in one month only to see contracts canceled the next month on the very same items. All these reasons were identified as potential internal obstacles to procurement efficiency that led to contracting being identified as the primary overall constraint in the ability for USSS to serve its customer base.

Looking internally at the existing procedures and resources, a fundamental conflict was identified between the supply chain (elements that procure) and demand chain (those who order). This contradiction is a typical TOC conflict and it is a problem facing USSS that must be resolved, even with the procurement constraint identified and acknowledged. Every player at USSS desires to be successful. Customer service personnel and demand planning are required to meet direct customer requirements from the military services. Meeting these customer requirements involves a continual manual interaction with procurement personnel. This interaction manifests itself through requests for contracting status as well as the expediting of awarded contracts buys to meet changing demand forecasts or emerging requirements. These actions disrupt procurement work flow. Procurement wants to be a reliable supplier. To do so, procurement must try to resist the manual disruptions that interfere with their production and throughput. This creates a “doom loop” [35], as shown in Fig. 3.

At USSS this “doom loop” manifests itself in this manner. Procurement is behind, which creates unfilled orders (also termed backorders). UnFilled Orders (UFOs) result in customers demanding updates as to when their orders will be delivered. This also often causes customers to raise forecasts and priorities in hopes of spurring procurement to more speed. Procurement is then bombarded with off-line, manual requests for status as well insistence that already existing contracts be modified to add newly desired demand quantities. All this activity takes contracting away from their core procurement work which is awarding new contracts. As such, buying throughput gets further behind with UFOs increasing even more. The cycling “doom loop” then repeats faster and faster with the system gradually approaching collapse.

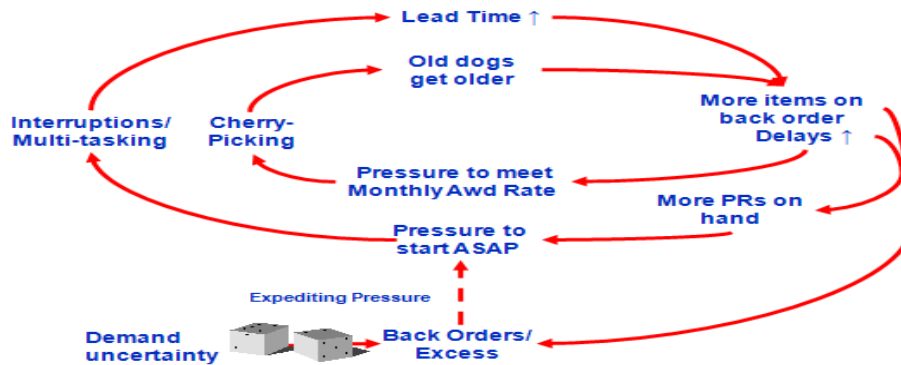


Fig.3 USSS procurement “doom loop”

Years of experimentation with tools such as LSS, TQM, JIT, and MRP had often resulted in short-term improvements, but disappointing long-term results. At USSS there was a desire to go beyond what were largely considered prescriptive toolsets [13] to a more comprehensive theory of operations management. As noted by Dirgo [4, p96] “TOC is multifaceted management philosophy . . . a systematic reexamination of some of the most fundamental beliefs in today’s management culminating in a new approach to address problems facing us today.” At USSS a proof of concept was desired to see if TOC could be applied successfully to a large and complex administrative process. After considerable discussion and analysis, USSS determined that constraint management through the use of TOC was essential to breaking the procurement “doom loop.”

5 Applying theory of constraints in USSS

The world is moving from firm to firm competition to supply chain to supply chain competition and TOC’s holistic approach to constraint management is a natural follow-on to this change in competition [19]. The theoretical basis of Theory of Constraints lies in systems theory as well as metric and culture based change management [2]. It is a Socratic based method to change management with a consistent focus on the root causes of problems and continually asking the question “why” things exist as they do [10]. Solutions to problems fall out of properly framed questions and identification of goal(s) and primary constraints that prevent attainment of goal(s) [34]. Many authors state TOC’s roots can be found in system dynamic theory from as early as 1950 and statistical process control first used in World War II [14,32]. There are also those who believe that TOC owes a heavy debt to well used management research and practices such as PERT/CPM and JIT [34].

A specialized form of Theory of Constraints is a system described as Drum, Buffer, and Rope (DBR). DBR adds discipline to the constraint providing further controlling constructs over and above the five major stepping functions normally associated with basic Goldratt theory. These constructs are: (1) rigorously

schedule the constraint - the drum, (2) determine the buffer size and lead-time - the buffer, and (3) drive order release based on (1) and (2) - the rope [29]. While TOC appears logical for managing complex processes [23], little research has been done on DBR specifically and virtually none of that in transactional processes [26]. Nevertheless, DBR has demonstrated usefulness in production environments.

Criticisms of TOC are few. In some cases it oversimplifies very complex problems [2]. Geekie and Steyn [8] particularly bemoan the fact that users of TOC take a “cookbook” approach to TOC ignoring that real change requires mathematical discipline and expertise to balance workflows and optimize goal(s). There are those who see TOC as “less about Dogma, but more about manufacturing and business pragmatism” [33, p14]. Finally, there is even some debate as to whether TOC is actually a theory or just a set of operating procedures [2].

Nevertheless, USSS is convinced that the current procurement framework is not meeting their needs and TOC, through the use of DBR, is worth trying to apply on an experimental basis despite any risk. This opinion is based primarily upon how successful TOC has been in its traditional venue of manufacturing. In the survey research of TOC, Balderstone and Mabin [2] reported that TOC implementations reduced lead times 69%, cycle times 66%, due date performance 60%, inventory levels 50% and, most importantly, increased mean revenue 68%. Individual studies reported similar quantitative savings and qualitative improvements in workforce morale, culture change, and strategic orientation [6,9,10,17,21,25]. Especially, the specific applicability of DBR appears promising for USSS’ procurement control and capacity problems. There are inherent delays in government procurement where work on specific contract will have to wait until some other, non-USSS, actions are complete. This means buffer management will be critical in keeping the constraint(s) fully occupied. DBR offers a mathematical method to determine these buffers and flow work appropriately.

The problem for management was that research had shown that TOC had been successfully applied almost exclusively in manufacturing production environments.

TOC has had difficulty extending the conceptual and practical aspects of the theory into administrative processes. There have been limited administrative successes but the scope of activity has generally been small and often still related to movement of a physical item within an administrative process (i.e., filing paperwork) [1]. There was no evidence that TOC had thrived anywhere in large scale administrative processes [1,6,27,28,30]. Very few results have been reported on using TOC for processes where the flow of workload is almost strictly electronic with no observable physical process [9,20,36].

Goldratt [10,11,12] has stated clearly that administrative processes can be organized within the theoretical framework of TOC, but even he acknowledges the implementation issues are more problematic making success less likely. Goldratt cites the non-linear basis of electronic processes since work often does not flow in a direct single line of non-repeatable activities. He also does not believe the culture of administratively centric organizations lends itself to the discipline, metric rigor, and goal setting that is more easily framed for manufacturing processes. Finally, change management and execution is harder to control for administrative processes that often cross multiple departments easily through electronic formats. Yet, authors [17,22,32,34] who have successfully used TOC in manufacturing believe that TOC applicability in administrative processes is more a matter of will than impossibility. Generally, they argue that the problem is strictly one of vision and culture. If leaders of administrative processes can identify their products and see these products resulting from the completion of a series of repetitive production steps then the applicability of TOC is obvious.

There are other misgivings. As noted earlier, implementation of TOC can be harder than it first looks [12,17]. TOC requires a process and metric discipline throughout implementation, execution and sustainment that is not a strong attribute for many activities [2,8,22]. Also, many TOC projects do not completely cross the entire gamut of an organization's supply chain sometimes causing sub-optimization in areas [1]. Finally, there are only a couple examples so far of TOC implementations that have been in existence for greater than ten years therefore creating some potential doubt about the long-term sustainability of the theory [19]. These potential hazards have not discouraged USSS from experimenting with TOC.

The Federal government contracting process is largely standardized nationwide and subject to a sizeable number of inflexible rules [7]. In addition, the buyers themselves are part of distinct corps of individuals whose specialty is codified in stove-piped training, advancement and a designated job series. While some procurement processes have been automated over the years, little meaningful change has occurred in the fundamental nature of how buying is conducted [15]. Procurement insiders often characterize the research,

negotiations and closing of contracts almost as an individual art form. The idea that this ingrained procurement system could be changed in some way that resembles a manufacturing production process is a foreign and somewhat repugnant possibility. To many, TOC also blurs the line between preconceptions of what is blue and what is white collar work further adding to the recalcitrance in accepting TOC experimentation.

Another problem is that many procurement professionals wholeheartedly believe that their processes are operating efficiently. In fact, traditional measurements would back them up. Productivity in terms of number of buys awarded has risen moderately throughout the years with procurement speed, in terms of average days to close an award, holding steady. The need for change or as Lewin [18] noted in his field theory, the unfreezing of change, is not apparent to the majority of contracting professionals. In addition, the management of risk is traditionally very conservative in procurement. It is believed that current contracting processes exist to minimize risk and TOC is too far removed from present practices to be safe [16]. The issue confronting procurement is that higher management, customers and the public are demanding change. This change is fueled by audits, commissions and high profile mistakes (i.e. \$500 toilet seats) creating a belief that the current processes are failing [5].

While there has been "gives and takes" on TOC over time, the positive results observed from TOC in manufacturing have been difficult to ignore for USSS' senior management. It was decided to take a subset of USSS procurement operations and experiment whether the conceptual framework of TOC/DBR could be successfully applied.

6 USSS TOC experiment and its results

The experiment was planned for and took approximately two years. The experiment proceeded in three sequential steps. First, it had to be determined if the experiment could actually be run using the TOC methodology. This meant piloting TOC in a small subset of the first experimental unit just to see if the basic flow and constructs of the theory could be inserted into work processes successfully. The pilot study was far more complex and time consuming than initially anticipated. Fortunately, the institution of general TOC flow was successful in the initial pilot study. The pilot proved that the flow of the legacy procurement system could be transformed into a general TOC structure without significant operational, customer service, or personnel show-stoppers. The pilot also collected production quantities and timings at each step in the new process flow before any actual improvements were enacted. Even though there were no specific quantitative results from the pilot, management was at the end of the pilot further assured that proposed TOC metrics could be obtained as originally proposed.

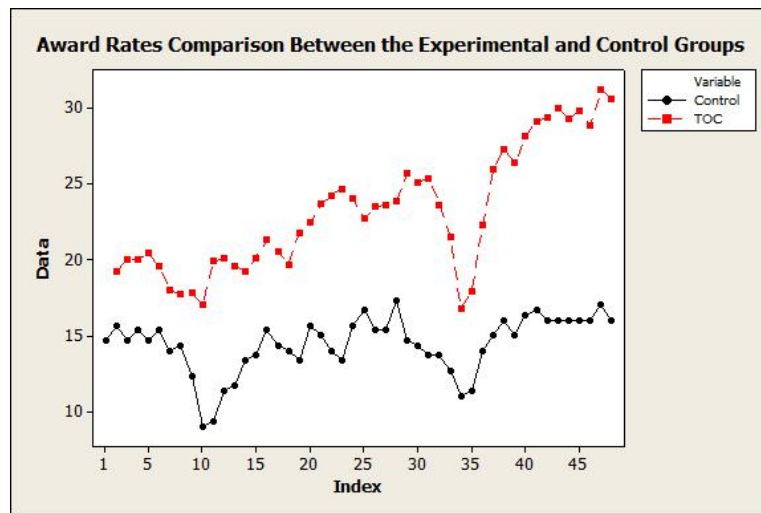


Fig.4 Contract award rates comparison between the TOC experimental and control groups (July 2008-July 2010)

With the success in the pilot study, the second phase began which introduced the TOC/DBR methodology into the first experimental division. This took the experiment beyond just proving that TOC could be implemented in procurement onto whether it could be optimized to improve performance. This objective of this phase was meant to optimize procurement production in the new TOC flow. While it was not immediately clear how each independent variable (lifting constraints, information transparency, priority compliance, buffering, etc.) affected award rates, there was an almost 6% improvement in throughput in just two months. As a result, USSS was convinced that TOC/DBR is working in procurement and has directed that two additional divisions begin their transition to the methodology. A timeline has been established for full implementation through other eleven procurement divisions once the two-division experiment becomes successful. Despite this apparent success in the first stage experiment, experimental control in the two new divisions was being maintained to ensure validity.

External validity of the pilot and the early phase of the experiment could only be attained if the results are generalizable to more divisions. Therefore, the experiment was further expanded to additional divisions designated for TOC experimentation. It was desired initially to introduce TOC sequentially into each division over the two year period and compare results. While all designated divisions were implemented, the sequential plan was not always followed according to the original plan. Early success in TOC created some parallel implementations as management desired to take advantage of TOC improvements earlier than planned. This created some confusion in the experimentation, but did result in more stabilized data for all divisions after the two year experimental period.

Complicated metrics are introduced to measure the improvement of contracting with TOC. Here we only focus on “award rate” to provide an overview of the

results. All the factors affecting performance are carefully operationalized and measured. Data was collected semi-monthly as early as July 2008 until the end of July 2010. Results show distinct improvement in the experimental division as compared to other procurement divisions that have not undergone the TOC process (see Fig. 4). For the thirteen TOC implemented divisions there was an average of a 46% improvement in award rates while in the control group of three divisions the improvement was only 8%. Both the TOC experiment and control groups experienced the same productivity decline over the holiday periods taking approximately the same time to recover.

Fixed effects panel regression model was used to test the impact of TOC on award rates and reached significant results. Panel data analysis used the data from March 2009 to July 2010 from thirteen divisions. The full model and comprehensive data analysis is omitted here due to the limitation of space and this paper’s emphasis on the decision making process of USSS. One significant result was that information transparency, the ability to see how a product is transformed in the supply chain, which is given in the manufacturing process but thought to be absent in administrative systems and thus rendering TOC less effective, is a major element in the TOC process.

7 Conclusion

Federal Government procurement organizations had once tied contracting improvement hopes in EPR procurement, however, the first large scale attempt of such failed. This procurement activity was forced to return to legacy software, which had gone several years without significant improvements in anticipation of the hoped for success in ERP. Realizing that improvements within contracting could not await the development of more applicable software and the traditional operations methods such as Lean Six Sigma have their own limitations, senior management at one Federal

organization turned to the Theory of Constraints (TOC) as a possible method to enhance procurement operations.

TOC, and its variant Drum, Buffer and Rope (DBR), has been successfully implemented in a complex administrative Government procurement process over a two year experimentation period across thirteen procurement divisions. This implementation supports the applicability of TOC across organizational types as theorized by TOC proponents. Many of the issues associated with manufacturing TOC efforts have been experienced and managed such as cultural resistance and workload balancing. Measures are showing distinct improvement in the experimental division as compared to other procurement divisions that have not undergone the TOC process.

USSS' contracting operation is a reasonable representation of other service sector administrative systems. Lessons learned here can contribute to the success of other administrative process improvement in both public and private sectors.

Note that TOC experimentation at USSS is a natural or quasi-experimentation because of the practicality desired by the management. For instance, it is recognized that the first implementation had significant upper management attention that might not be sustainable over the long-term. In addition, the original sequential plan was not always followed and parallel implementations were created due to the management's desire to take advantage of the success in TOC earlier than planned.

A culture of TOC discipline is still being learned within USSS and is being gradually introduced to customers and contractors. Unexpected effects have occurred that must be addressed. For instance, improvements in award rates have reduced contracting Administrative Lead Times, which in turn requires further system balancing. It is a continuous improvement process in USSS.

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