International Business Management 7 (6): 516-526, 2013
ISSN: 1993-5250

Theory of Constraints in Increasing the Profit of an Organization: A Case Study on a Quarry from Turkey

Enver Bozdemir
Faculty of Business, University of Duzce, Duzce, Turkey

Abstract: In modern age, the foremost objective of organizations is to obtain maximum profit during the period they actively operate. In assisting the organizations to reach their profit objective, the salient factor is providing cost efficient and timely products to customers. Theory of Constraints bears great significance in achieving this particular goal. Theory of Constraints advocates that constraints in stages of production adversely impact organizational capacity and profitability. This study, thus aims with the intent of enhancing the profitability of organizations to conduct a research to detect the effect of eliminating the constraints emerging during production stage. Within that context the first step shall be analyzing Theory of Constraints theoretically and second step shall be examining within the scope of a Turkish Quarry model the effect of capacity constraint which is a type of constraint-in terms of organizational profit.

Key words: Constraint, bottleneck, Theory of Constraints, turkey quarry, profit

INTRODUCTION

In this increasingly globalizing world of modern day, owing to the new competition conditions traditional accounting systems fail to be effective in assisting organizations to increase their profits by gaining competitive advantage in both national and international markets. Consequently in addition to several new approaches, such as target costing, kaizen costing, value engineering, Theory of Constraints has also emerged as a major approach amidst strategic cost management systems in decreasing organizational costs and increasing profitability. As a novel approach, the Theory of Constraints (TOC) has been developed during the 1980s by Eliyahu M. Goldratt. TOC is a method which has a well-developed research apparatus referred to as the thinking process. The mechanism makes it possible to analyse systems and to identify and remove any constraints which act like obstacles preventing the company from achieving its goals. Constraints also include bottlenecks, i.e., weakest links within an enterprise which in critical situations are first to become sources of problems.

At this point, it is worth remembering that each production system has 1 constraint as least and any constraint arising in 1 specific point in the system can by disrupting the effectiveness of the whole system adversely affect the profitability of the organization. Theory of Constraints advocates that to the aim of increasing the profitability of organizations the organizational administration needs to focus on detecting and eliminating such constraints. By detecting and eliminating the constraint or constraints during production step, the manufacturing process of organizations shall become even further smooth, extreme semi-product stocks shall minimize which in turn shall dwarf the expenses paid for stocks.

The purpose of present research is to conduct a research which towards the aim of increasing the profitability of organizations, supports the detection and elimination of constraint or constraints emerging during production stage. Accordingly by focusing on a case study in Turkey, Erzurum Andesite Quarry Company, the constraints limiting the effectiveness of an organization in production stage shall be identified, the ways to eliminate existing obstacles and the effect of eliminating these obstacles on the profitability of organization shall be detailed. In present study, the first step shall be elaborating the Theory of Constraints. As a second step of Theory of Constraints obtained from mentioned quarry organization shall be put forth with respect to the case study findings and these findings shall be examined at length.

MATERIALS AND METHODS

Methodology of Theory of Constraints: In the early 1980s, a novel was published which has subsequently been read by many hundreds of thousands of executives, production planners and shop floor workers. The goal sets out Eli Goldratt's ideas on how production should be planned. The methodology was made available in the production planning system OPT (Optimised Production Technology) which was marketed by Creative Output Inc. These ideas were later broadened to encompass other areas, such as marketing and distribution in a further novel. Its not luck and the theory widened to become the Theory of Constraints (Rand, 2000).

As part of a marketing tool for the OPT system, Goldratt illustrated the concepts of OPT in the form of a novel. The goal (Goldratt and Cox, 1984) in which the theory is gradually unravelled through the context of an everyday production situation. A second book, titled the race (Goldratt and Fox, 1986) was written to overcome difficulties encountered in the implementations and gradually, the focus of the concept has moved from the production floor to encompass all aspects of business. By 1987, the overall concept became known as TOC which Goldratt (1988) viewed as an overall theory for running an organisation.

Theory of Constraints, known as TOC can be defined as a procedure for managing factors, production processes, organizational decisions and situations in which there are constraints in the present state. TOC is a business management tool that links all the manufacturing techniques. It is a scientific methodology that makes it possible to relate the solutions to a firm's critical problems (regardless of its size) to ensure that its ongoing improvement process continues unabated.

TOC claims that a real-world system with >3 constraints is extremely unlikely. This claim is based on linear programming models which are capable of solving optimization problems for systems with many 100 of constraints. Researchers found that all but a few such solutions were so unstable that they would be completely impractical amid the noise of a real-world system. Stability had a strong correlation to the number of constraints the more constraints, the less stability. TOC practitioners claim that in practice 3 constraints is the realistic maximum (Hamilton *et al.*, 2009).

In the words of Mabin and Balderstone (2003), TOC is a systemic problem structuring and problem-solving methodology which can be used to develop solutions with both intuitive power and analytical rigour in any environment. Goldratt himself refers to TOC as a generic management theory for running an entire organization (Goldratt, 1988). The management concept delivered by the Theory of Constraints may be summarized by means of the following 2 fundamental principles (Rahman, 1998):

- Every system is equipped with at least 1 constraint
- The systemic constraints represent opportunities for improvement

The central idea of TOC lies in the identification and exploitation of the system constraint in improving a system. TOC is based on the assumption that the performance of a system is determined by the system constraint which is anything that blocks the system from accomplishing its stated goal or in achieving a higher level of performance with respect to this goal. As the first step in improving a system, managers need to determine what constrains the system from reaching its goal. Constraints can be physical or nonphysical. When the constraints are physical, such as resources, raw materials or supplies, they can be relatively easily identified by undertaking a capacity analysis. However, if constraints are nonphysical, such as policies, behaviors or measures, they are harder to identify (Choe and Herman, 2004).

The systems constraint is that part of the system that constrains the objective of the system. For money making organisations, Goldratt defines the objective as being to make more money, now and in the future. In production planning terms, the systems constraint is the bottleneck (Rand, 2000).

In the Theory of Constraints, the components of any system is viewed not as independent processes but rather as complementary stages of a whole. System is a unity and all its components are interlinked. Theory of Constraints is based on the principle the weakest link. The components of a system are regarded as the links in a chain. The power of chain symbolizes the power of in other terms success of the system. Yet any system is powerful to the extent its weakest link is durable (Dettmer, 1997). This corresponds to the saying that any system is powerful and successful to the extent of power and success its weakest link possesses. The weakest link is the constraint of system. This is the element blocking the improvement and high-performance of the system. Hence, the objective is to identify the weakest link or links in the system and provide the kind of solutions to eliminiate the existing obstacles. To achieve that it is necessary to focus on not the components but the whole system and pay attention to the mission and interrelations of every component in the system. Theory of Constraints gears towards improving the performance in any system by directing the attention of organizational administarion to the constraints of the system (Reid and Cormier, 2003). The TOC can serve as a unifying theory, providing new insights for researchers and an organizing principle for teachers (Gupta and Boyd, 2008).

TOC views an organisation as a chain composed of many links or networks of chains. Viewed as a constrained system a chais links all contribute to the goal and each link is strongly dependant on the other links. The chain, however is only as strong as its weakest link. Goldratts

TOC states that the overall performance of an organisation is limited by its weakest link. He states that if an organisation wants to improve its performance, the first step must be to identify the systems weakest link or constraint (Dettmer, 1997).

The approach was first used in a manufacturing environment and reported at an APICS conference in 1980. TOC is now used worldwide by companies of all sizes. Many managers who routinely use TOC believe, they understand their businesses for the first time. From this understanding, they gain a sense of control and of being able to act proactively. This is because TOC empowers managers by providing a consistent framework for diagnosing problems (Mabin, 1999).

TOC is perhaps not normally considered by systems modelers to be part of the systems literature but it is a systems methodology in that it strives to ensure that any changes undertaken as part of an ongoing process of improvement will benefit the system as a whole rather than just part of the system. At its most basic level, TOC provides managers with a set of tools that guide the user to find answers to the basic questions relating to change, namely (Goldratt, 1990).

What needs to change?: Not everything needs to be changed, most things are good enough as they are or alternatively, the profit resulting from changing them does not justify the cost.

Why change?: Often it is obvious that a process needs to be changed but it is unclear why it should be changed.

How to cause change?: Even if one knows exactly what to change and why this should be changed, one still faces the difficult task of getting the firm to fully implement the change.

A survey of the change management literature shows that people become less resistant to change when they participate in the process of defining the change and developing road maps and plans for the change. When the main sources of resistance to change in an organization are the lack of agreement among organizations members on the core problem and the direction for a solution, TOC can provide an effective set of tools for understanding and coping with the forces of resistance (Choe and Herman, 2004).

Types of Theory of Constraints: Constraints can be either internal or external. External constraints are governed by market characteristics and therefore are often beyond the control of management. However, it still is important to consider them as it affects the demand and thus the firms product mix and the utilisation of resources. Internal constraints, on the other hand comes in many forms and in summary, it is just any resource that prevents the system from obtaining continuously higher levels of performance. Constraints can also be classified into 5 categories (Atwater and Gagne, 1997).

First a company faces market constraints which include demands of the market on the assortment, absorption capacity of the market, the influence of the price on the demand and the chance to lose an order by not meeting a delivery-agreement (Chase *et al*., 1998). Newbold (1998) also refers to response time, the quality of a product, the features and options a company offers and the image of the company.

Second a company faces capacity constraints, among those the maximum orders a company can handle with its capacity to produce products.

Third a company faces financial constraints. The amount of money a company can use to produce products is restricted, departments are, therefore restricted by budgets and so on.

The fourth set of constraints are resource constraints, for example the amount of raw material or specific human skill is restricted.

The last type of constraints is policy constraints. The following statements can hint at policy constraints (Newbold, 1998):

- Researchers can not sell below cost
- It makes no sense to hire someone if they won not even be half utilised
- Everyone should have enough work on their desks to keep busy
- People who are overloaded with work are more valuable
- Researchers won not start anything researchers do not intend to finish
- Get rid of the buffers, they reflect that researchers will fail the intended deadline
- Researchers just want employees to do what they are told
- Follow the schedules exactly

Profitability valuation and tools in the Theory of Constraints: Based on earliar explained Theory of Constraints certain types of performance measurements for organizations have been developed. According to Theory of Constraints, performance measurements are classified as financial measurements and activity measurements (Chase *et al*., 1998). Financial measurements include net profit, investment profitability and cash flow while activity measurements integrate process (througput), stock and activity costs.

Measurements are required to determine whether or not the system is accomplishing its goal of making money (Simatupang *et al*., 2004). These can be defined as follows (Goldratt and Fox, 1986; Chase *et al*., 1998; Dugdale and Jones, 1997; Cyplik *et al*., 2009).

Net Profit (NP): The net profit is equivalent to throughput minus operating expense for a particular period:

$$NP = T - OE$$

Return on Investment (ROI): The return on investment can be defined as the ratio of net profit to investment (in materials and others):

$$ROI = \frac{NP}{Investment}$$

Capital Flow (CF): The capital flow is equal to net profit plus/minus changes in investment for the respective period:

$$CF = NP + \Delta I$$

Throughput (T): Throughput is determined as sales minus sales discounts, expenditure and actual variable costs. As a result:

$$\text{Unit throughput} = \text{Unit sale} - \text{Expenditure} - \text{Variable cost}$$

or;

$$\text{Total throughput} = \text{Unit throughput} \times \text{No. of units sold}$$

Inventory (I): Inventory corresponds to all capital that a company invests to its purchases bought for sale. Stocks on hand are analyzed only with respect to their raw material costs, craftsmanship and total production costs are excluded.

Operating Expense (OE): A total of financial resources spent to transform investment into throughput. They refer directly to labour, overhead costs and fixed expenditure (independent of production volume). All the factors listed earliar are interdependent. Any change occurring in any of them affects the others. Consequently, according to TOC assumptions in order to improve the efficiency of operation of the system as a whole efforts should be made to increase as far as possible the value of sold production based on optimisation of stock levels and maximum reduction of operating expense.

$$\text{Return on investment} = \frac{\left(\begin{array}{c}\text{Throughput} - \\ \text{Operating expense}\end{array}\right)}{\text{Inventory}}$$

Implementation process of Theory of Constraints: Management of constraint which constitutes the scope of analysis in current study and plays vital role in increasing the organizational profit takes place in 5 stages and this continuous improvement procedure emerges in the form of a cycle (Louderback and Patterson, 1996). Indeed the primary argument of Theory of Constraints is that each system has at least 1 constraint. Thus, upon identification and elimination of 1 particular constraint a new 1 emerges again and the cycle goes on this way.

The Theory of Constraints as a way of thinking aims at constantly increasing the efficiency of the system. Each supply chain is targeted at generating profits, however its inherent constraints (there is always at least one constraint present) make it impossible for all participants of the chain to reap unlimited benefits. In order to resolve the problem, all links in the chain should, first and foremost, recognise a constraint and then focus all activities and decisions on managing the constraint in such a way as to increase current and future gains. However, the decisive factor determining the implementation of efforts aimed at improving the operation of the supply chain is consensus as to the type and location of constraints (Cyplik *et al*., 2009).

In the constraint-focused process of supply chain improvement, the profitability of the entire supply chain is defined and determined by the constraint existing in a given supply chain. If the constraint is permanently removed, the supply chain can increase its profitability until another constraint comes up. Consequently to increase the efficiency of the whole system, the TOC provides management tools in the form of a 5 step procedure which provided that it is followed consistently, yields beneficial outcomes. This 5 step constraint management procedure is as explained hereinafter (Reid and Cormier, 2003; Goldratt, 1990; Cyplik *et al*., 2009).

Step 1; identification of system constraint: Identification of constraints that may occur both within and outside the supply chain is of vital importance. Supply chain constraints markedly reduce the throughput of the chain. Consequently, members of the supply chain should coordinate their efforts on removing the constraint, as that the outcome of chain operations as a whole depends on impact exerted by the constraint. It frequently happens that constraints develop because of local rules imposing reductions of production, distribution and marketing costs. The 1 example is the min-max principle used in defining stock levels. Under the method, as soon as the stock level falls below a predefined minimum level, an order is placed to replenish the stock up to the maximum level. The method seeks to reduce transportation costs, however in many cases a retailer has the same suppliers delivering different products to the warehouse. In this case, both the retailer and the supplier should review their stock replenishment policy to satisfy customer requirements.

Step 2; decision to exploit the constraint: This stage comes down to deciding what actions should be taken to pool out the maximum benefits out of the constraint or in other words, how to exploit the constraint to ensure the maximum capital flow for the company. This means optimisation of the capacity of the constraint which is not properly exploited by producing and selling unsuitable product sets and by inappropriate principles of constraint planning and controlling. The constraint should be subject to ongoing monitoring to make sure there is no downtime. At the same time, all activities should be scheduled to bring maximum gains: The focus should be on those products which in the bottleneck analysis, generate the highest profits.

Step 3; subordination of the entire system to the constraint: This means that every other component of the system (non-constraints) must be adjusted to support the maximum effectiveness of the constraint. Because constraints dictate a firm's throughput, resource synchronisation with the constraint will lead to more effective resource utilisation.

Step 4; reinforcement of the constraint: This step consists of increasing the constraint's capacity, i.e., improving its action. For example, the supplier can increase the capacity of the constraint by redesigning products, increasing stock or enhancing production capacity which enables quick response to changing customer's demands.

Step 5; return to step one: TOC is a continuous process and no policy (or solution) will be appropriate (or correct) for all time or in every situation. It is critical for the organisation to recognise that as the business environment changes, business policy has to be refined to take account of those changes.

The implementation of the 5 focusing steps to a typical production environment can yield rapid and substantial improvements in operations, as well as profits (Noreen *et al*., 1995). However, this process of continuous improvement will eventually shift constraints from factory floor to the market. Insufficient demand is a managerial or policy constraint rather than a physical constraint. Policy constraints are generally difficult to identify and evaluate and frequently require involvement and cooperation across functional areas (Table 1).

The 5 focusing steps assist with identifying the largest constraint that overshadows all of the others. These steps constitute an iterative process. As soon as 1 constraint is strengthened, the next weakest link becomes the priority constraint and should be addressed. Thus, a process of ongoing system improvement is applied to the business practice of the firm.

Prior to the 5 focusing steps, Goldratt (1990) prescribes 2 extra steps which Coman and Ronen (1995) include in the focusing steps, redefining them as a 7 step method. The 2 extra steps inserted at the start are:

- Define the system's goal
- Determine proper, global and simple measures of performance

Scheinkopf (1999) describes these as prerequisite steps for any improvement process. As can be seen from the earliar, one of the central tenets of TOC is that any system has constraints that prevent it from achieving its goal. The place to focus efforts is on making those constraints produce more, either by acting on the constraints directly or on other operations interacting with them. The 5 focusing steps of TOC provide a simple but effective approach to continuous improvement in cases where the constraint is fairly clearly identifiable. However, where the constraint is caused by policies or behaviours or in other more complex and messy situations, the constraint may be harder to pinpoint and what should be done to rectify it is not as clear-cut.

Goldratt accentuates the importance of regularly reviewing the rules that have been derived from the existence of constraints. Not paying sufficient attention to questioning the validity of instituted policies may result in policy constraints being the greatest limiting factors of the system. To sum up, due emphasis must be placed on not allowing inertia to bring about a system constraint (Westerlund, 2004).

How to find a bottleneck or constraint in practice: A bottleneck is defined, as any resource whose capacity is less than the demand placed on it. A bottleneck can be, for example a machine, scarce or highly skilled labour or a specialised tool. A non-bottleneck is any resource whose capacity is greater than the demand placed on it. A non bottleneck, therefore should not be working constantly because it can produce more than is needed (Chase *et al*., 1998).

Table 1: The 5 steps of focusing

The 5 focusing steps	Steps expressed in terms of continuous improvement	How to implement
Identify the system's constraints	What to change?	Use the effect-cause-ffect method to identify constraints
Decide how to exploit the system's constraints	What to change to? Construct simple practical solutions	Use the evaporating cloud method to invent simple solutions
Subordinate everything else to the above decision	How to change? How to overcome the emotional resistance to change	Use the socratic method to induce people to invent solutions The Socratic approach reduces or eliminates the emotional resistance to change and allows the inventor to take ownership of the idea
Elevate the systems constraints If a constraint has been broken, go back to step 1 but do not allow inertia to cause a systems constraint		

Goldratt (1990)

Goldratt along with the help of APICS-The Association for Operations Management (formerly the American Production and Inventory Control Society) has been successful in re-emphasizing the importance of process bottlenecks. While the role of bottlenecks in process management has been recognized for a long time, Goldratt has been successful in translating these bottleneck issues into principles that can be understood by any audience. Arguably, he had done so by gross oversimplification but there is no question that he had done so effectively (Balakrishnan *et al*., 2008).

The symptoms of a bottleneck are high stock in front of the bottleneck, a work pressure above 100%, bottleneck parts that are missing at the assembly and the bottleneck gets special attention (due to the constant fire fighting) (Aertsen *et al*., 1996). In order to identify a bottleneck, you could, for example count the stock in front of every resource and look for any other symptoms mentioned. It's therefore better to identify a bottleneck by interviewing operators (Aertsen *et al*., 1996) than by interviewing higher level managers because the latter will not have a clue of the real inventory waiting to be processed. The symptoms are easier to identify when one deals with visible bottlenecks, such as a machine with the lowest capacity. When one has to deal with invisible constraints, such as policies, training and measurement, it becomes more difficult to identify them. These constraints, however can cause a person to undertake an action that makes the company lose Money (Kendall, 1998).

The core of TOC is that for any given system at any given time, there will be at least 1 constraint on that system, determining how quickly the system can produce. TOC, applied to manufacturing, seeks to identify bottlenecks in the production line. The underlying assumption is that a production facility is only as fast, as the slowest process in the chain. As a general rule, TOC assumes that a value chain is only as strong, as the weakest link in the chain. The capacity of the weakest link is the current system constraint (Anderson, 2006).

Case study of the application of Theory of Constraints at the Turkey quarry

Method and objective of research: The objective of present study is with the intent of increasing the profitability of organizations to conduct a study to detect and eliminate the constraint or constraints emerging during production stage. Accordingly, through analyzing an application in an Andesite Quarry Company operating in Turkey, Erzurum and of which researchers personally conduct public accounting, the constraints limiting the effectiveness of organization during production stage shall be identified, the ways to eliminate existing obstacles and the effect of eliminating these obstacles on the profitability of organization shall be detailed. Towards this aim an explorative and descriptive case study has been conducted in this Quarry Company.

The implementation part of the study which has been conducted in an andesite stone manufacturing organization operating within Erzurum city reflects the actual financial figures, thus the real title of organization shall be unmentioned and the company shall be referred as X andesite quarry throughout this study.

Data required to implement the implementation part has been provided personally by the company, since researchers possess all relevant financial data and also comprehensive face-to-face interview conducted with production manager. To the purpose of meeting research objective, case study method has been the favored method in gathering financial data, analyzing extensively the capacity of each machine in production stage in conducting face-to-face interviews with the operators of machines.

RESULTS AND DISCUSSION

Case study findings: The 6 key products manufactured from a stone named Anzetit in X andesite quarry organization:

- Andesite curb (10×15×50 cm bevelled curb) (A)
- Andesite flooring (3×30×30 cm andesite flooring) (B)

- Andesite downspout (6×30×50 cm downspout) (C)
- Andesite wall papering (3×30×30 cm wall papering) (D)
- Andesite kingpost and caps (double profiled handrail)
- Andesite capstone and andesite special application

In addition to these key products tens of different derivatives are being manufactured in different sizes from every single product. In order to obtain the desired effect in this research the first 4 products explained here in above shall be utilized. These 4 key products shall be titled as products A-D in this study so as to use minimum space for their titles within table.

Besides in X quarry organization, since andesite downspout (6×30×50 cm downspout), manufacturing process of C product, A product refers to manufacturing process of bevelled curb and andesite wall papering (3×30 ×30 cm wall papering) and manufacturing process of D product and manufacturing process of B product andesite flooring are identical the type of constraints likely to emerge during the manufacturing of these products shall be the same which eliminates the need to conduct a separate constraint analysis for these products. Production capacity of a quarry with 250 ha of area:

- Visible quantity of reserves 4.000.000 m^3
- Monthly obtained quantity of stones 700 m^3
- Monthly capacity amount of X andesite quarry manufacturing company
- Andesite curb (10×15×50 cm bevelled curb) (A), 16.000 running m
- Andesite flooring (3×30×30 cm andesite flooring) (B), 16.400 m^2

In X andesite quarry manufacturing company 4 units of computer controlled andesite stone cutter, 4 units of header, 1 unit of bevel (Profile) machine and 1 unit of bush hammering machine are available. Since, bush hammering machine is utilized for special orders only it shall not be mentioned in the study.

In X andesite quarry manufacturing company demand, physical production and sales data pertaining to products A and B are as exhibited in Table 2.

In order to manufacture A product bevelled curb in 10 cm thickness ×15 cm width ×50 cm height (10×15×50 cm) total lengths of process in 4 units of stone cutter machines, 4 units of header machines and 1 unit of bevel (Profile) machines are as given in Table 3.

A brief explanation of the process of manufacturing product A in X company, the stones in quarry are removed and transported to the company. As a first step scanning is performed in stone cutter machine. Then semi-product is taken to header machine and sizing is made. As a last step upon milling in stone bevel (Profile) machine it is packed as final product. To sum up, product A is prepared as a semi product in stone cutter and header machines and manufactured as a final product in bevel (Profile) machine. Weekly physical production amount of product A is 640×6 = 3.840 running m. Additionally in company X working schedule is 6 days a week.

Table 2: Amount of demand, physical production and sales data of X company

Products/Data	A	B
Weekly demand	3.900 running m weekly^{-1}	4.380 m^2 weeks^{-1}
Weekly physical production	3.840 running m weekly^{-1}	3.900 m^2 weeks^{-1}
Sales price	$24 running m^{-1}	$21 m^{-2}

Table 3: Total lengths of process spent in all machines to manufacture product A of X company

Type of machines	No. of machines	Daily operation length (min)	Daily production amount (runing meter)	Average length per unit (min running m^{-1})
Stone cutter machine	4	1.650	665	2.5
Header machine	4	1.610	650	2.5
Bevel (Profile) machine	1	420.000	640	0.6

In order to manufacture B product andesite flooring in 3 cm thickness ×30 cm width ×30 cm height (3×30×30 cm) total lengths of process are as given in Table 4.

A brief explanation of the process of manufacturing product B in X company, the stones in quarry are removed and transported to the company. As a first step scanning is performed in stone cutter machine. Then semi-product is taken to header machine and sizing and packing are made. In the manufacturing process of product B bevel (Profile) machine or similar machines are not utilized. In company X operating 6 days a week physical amount of production for product B is 650×6 = 3.900 m^2.

In X andesite quarry manufacturing company, it is required to compute the costs related to products A and B. According to Theory of Constraints while conducting performance measurement in addition to costs of direct first item and materials, production costs, such as varying labor costs and general production costs are also included in total activity costs of company X. In X company general production costs are calculated with respect to direct labor hour. Table 5 illustrates total production cost of company X.

Identification of products A and B's constraint: For product A, the average of total length per running meter spent on stone cutter machines is 2.5 min running m^{-1}. As shown in Table 6, in 2 no stone cutter machine the average of total length per running meter spent for

Table 4: Total lengths of process spent in all machines to manufacture product B of X company

Type of machines	No. of machines	Daily operation length (min)	Daily production amount (runing meter)	Average length per unit (min m^2)
Stone cutter Machine	4	1.640	720	2.3
Header Machine	4	1.610	650	2.5

Table 5: Per unit profit (loss) of company X

Products/Financial data	A	B
Direct raw material	\$4 running m^{-1}	\$4 m^{-2}
Direct labor	\$7 running m^{-1}	\$6 m^{-2}
Direct costs per unit	\$11 running m^{-1}	\$10 m^{-2}
General production cost per unit	\$9 running m^{-1}	\$8 m^{-2}
Unit production cost	\$20 running m^{-1}	\$18 m^{-2}
Number of produced units	3.840 running m $week^{-1}$	3.900 m^2 $week^{-1}$
Sales price	\$24 running m^{-1}	\$21 m^{-2}
Profit (loss) per unit	\$4 running m^{-1}	\$3 m^{-2}
Total profit	\$15.360	\$11.700

Table 6: Total lengths of process spent in each stone cutter machine to manufacture product A

Stone cutter machines	Daily operation length (min)	Daily production amount (running meter)	Average length per unit (min running m^{-1})
1 No. machine	420.00	180.00	2.3
2 No. machine	380.00	120.00	3.2
3 No. machine	430.00	190.00	2.2
4 No. machine	420.00	175.00	2.4
Average total	412.50	166.25	2.5

product A is 3.2 min running m^{-1}. Daily operation length of this machine is 380 min and amount of production is 120 running m.

For product A, the average of total length per running meter spent on header machines is 2.5 min running m^{-1}. As shown in Table 7, in 3 no header machine the average of total length per running meter spent for product A is 3.0 min running m^{-1}. Daily operation length of this machine is 360 min and amount of production is 120 running meter.

Average operation length of both machines is high whereas the produced amount of units is low, hence it has been determined that this is a capacity constraint. It has also been ascertained that for product A there is no capacity constraint in bevel (Profile) machine.

For product B, the average of total length per running meter spent on stone cutter machines is 2.3 min m^{-2}. As shown in Table 8 in 2 no stone cutter machine, the average of total length per running meter spent for product B is 2.9 min m^{-2}. Daily operation length of this machine is 370 min and amount of production is 130 m^2.

For product B, the average of total length per running meter spent on header machines is 2.5 min m^{-2}. As shown in Table 9 in 3 no header machine, the average of total length per running meter spent for product B is 3.0 min m^{-2}. Daily operation length of this machine is 360 min and amount of production is 120 m^2.

Table 7: Total lengths of process spent in each header machine to manufacture Product A

Header machines	Daily operation length (min)	Daily production amount (running meter)	Average length per unit (min running m^{-1})
1 No. machine	400.00	175.00	2.3
2 No. machine	420.00	190.00	2.2
3 No. machine	360.00	120.00	3.0
4 No. machine	400.00	165.00	2.4
Average total	402.50	162.50	2.5

Table 8: Total lengths of process spent in each Stone Cutter machine to manufacture product B

Stone cutter machines	Daily operation length (min)	Daily production amount (m^2)	Average length per unit (min m^2)
1 No. machine	420	200	2.1
2 No. machine	370	130	2.9
3 No. machine	430	210	2.0
4 No. machine	420	180	2.3
Average total	410	180	2.3

Table 9: Total lengths of process spent in each Header machine to manufacture product B

Header machines	Daily operation length (min)	Daily production amount (m^2)	Average length per unit (min m^2)
1 No. machine	400.00	175.00	2.3
2 No. machine	420.00	190.00	2.2
3 No. machine	360.00	120.00	3.0
4 No. machine	400.00	165.00	2.4
Average total	402.50	162.50	2.5

In the manufacturing of product B, it has been detected that 2 no stone cutter machine and 3 no header machines have compared to other machines lower production capacity per unit.

Correcting the detected constraints: The factors triggering a capacity constraint in 2 no stone cutter machine are detected as the oldness of this machine and the resulting malfunctions related to the datedness of this machine. These malfunctions are prevalent in belt, center and bearing balls. These defects are continuously fixed. At the end of conducted analyses, the center and bearing balls of the machine have been replaced with domestic industry products and defects have been corrected.

The factor bringing about a capacity constraint in 3 no header machine is the constant engine problem of this machine. It has been identified that this engine used to be a domestic product which constantly malfunctioned hence it has been replaced with an import product.

Also some of the laborers working in 2 no stone cutter machine have operated bevel (Profile) machine more effectively. Hence, a change has been made between some workers operating bevel (Profile) machine and laborers operating this machine so as to prevent potential defects related to the misuse of this machine (Table 10).

In that case to manufacture product A total lengths of process spent on stone cutter machine has been

Table 10: At the end of constraint, total lengths of process spent to manufacture product A

Machines	Daily operation length (min)	Daily production amount (m^2)	Average length per unit (min m^2)
2 No. stone cutter machine	420	185	2.3
3 No. Header machine	420	180	2.3

Table 11: Total lengths of process spent in all machines to manufacture product A

Type of machines	No. of machines	Daily operation length (min)	Daily production amount (runing m)	Average length per unit (min running m^{-1})
Stone cutter	4	1.690	730	2.3
Header	4	1.670	710	2.3
Bevel (Profile)	1	430.000	650	0.6

average daily operation length 422.50 min, daily production amount 182.50 running meter and average length per unit 2.3 min running m^{-1}.

Total lengths of process spent on header machine; average daily operation length 410 min, daily production amount 177.50 running m and average length per unit 2.3 min running m^{-1} (Table 11). In X company operating 6 days a week physical manufacturing amount of A product 650×6 = 3.900 running m.

In that case to manufacture product B total lengths of process spent on stone cutter machine has been; average daily operation length 425 min, daily production amount 200 m^2 and average length per unit 2.1 min m^{-2}.

Total lengths of process spent on header machine; average daily operation length 410 min, daily production amount 182.50 m^2 and average length per unit 2.2 min m^{-2}. In X company operating 6 days a week physical manufacturing amount of B product; 730×6 = 4.380 m^2.

Evaluation of findings: At the end of analyses and researches performed on X andesite quarry company, as explained hereinabove as well it has been ascertained that during the manufacturing process of products A and B, both for product A and product B there is a capacity constraint in 2 no stone cutter machine and in 3 no header machine.

Evaluation of the findings related to the capacity constraint of product A; As illustrated with Table 12-14 given data too, prior to detecting the capacity constraint in 2 no stone cutter machine used in manufacturing product A, the amount of length spent per running meter was 3.2 min running m^{-1}. Daily operation length of this machine was 380 min and amount of production was 120 running meter. Upon correcting capacity constraint and above specified malfunctions, for product A, daily operation length of this machine increased to 430 min and amount of production rose to 230 running meter while the amount of length spent per running meter fell from 3.2-1.9 min running m^{-1}.

Table 12: At the end of constraint, total lengths of process spent to manufacture product B

Machines	Daily operation length (min)	Daily production amount (m^2)	Average length per unit (min m^{-2})
2 No. stone cutter	430	210	2.0
3 No. header machine	420	200	2.1

Table 13: Total lengths of process spent in all machines to manufacture product B

Type of machines	No. of machines	Daily operation length (min)	Daily production amount (runing m)	Average length per unit (min running m^{-1})
Stone cutter machine	4	1.700	800	2.1
Header machine	4	1.640	730	2.2

Table 14: Per Unit profit (loss) of X Company at the end of Theory of Constraints

Products/Financial data	A	B
Direct raw material	\$4 running m^{-1}	\$4 m^2
Direct labor	\$7 running m^{-1}	\$6 m^{-2}
Direct costs per unit	\$11 running m^{-1}	\$10 m^{-2}
General production cost per unit	\$8.5 running m^{-1}	\$8.2 m^{-2}
Unit production cost	\$19.5 running m^{-1}	\$18.2 m^{-2}
Number of produced units	3.900 running m $week^{-1}$	4.380 m^2 $week^{-1}$
Sales Price	\$24 running m^{-1}	\$21 m^{-2}
Profit(loss) per unit	\$4.5 running m^{-1}	\$2.8 m^{-2}
Total profit	\$17.550	\$12.264

Prior to detecting the capacity constraint in 3 no header machine used in manufacturing product A, the amount of length spent per running meter was 3.0 min running m^{-1}. Daily operation length of this machine was 360 min and amount of production was 120 running m. Upon correcting capacity constraint and above specified malfunctions for product A, daily operation length of this machine increased to 420 min and amount of production rose to 220 running m while the amount of length spent per running meter fell from 3.0-1.9 min running m^{-1}.

As researchers analyze per unit profit (loss) table for product A, per unit production cost prior to detecting the constraint was \$20 running m^{-1}, manufactured number of units was 3.840 running m $week^{-1}$, per unit profit was \$4 running m^{-1} and total profit was \$15.360.

Upon correcting the constraint, per unit production cost is \$19.5 running m^{-1}, manufactured number of units is 3,900 running m $week^{-1}$, per unit profit is \$4.5 running m^{-1} and total profit is \$17.550.

Evaluation of the findings related to the capacity constraint of product B: Prior to detecting the capacity constraint in 2 no stone cutter machine used in manufacturing product B, the amount of length spent per square meter was 2.9 min m^{-2}. Daily operation length of this machine was 370 min and amount of production was 130 m^2. Upon correcting capacity constraint and above

Table 15: Comparative table of company X before and after the application of the Theory of Constraints

	Product A		Product B	
Theory of Constraints	Before applying Products/Financial data	After applying Theory of Constraints	Before applying Theory of Constraints	After applying Theory of Constraints
Direct raw material	\$4 running m^{-1}	\$4 running m^{-1}	\$4 m^{-2}	\$4 m^{-2}
Direct labor	\$7 running m^{-1}	\$7 running m^{-1}	\$6 m^{-2}	\$6 m^{-2}
Direct costs per unit	\$11 running m^{-1}	\$11 running m^{-1}	\$10 m^{-2}	\$10 m^{-2}
General production cost per unit	\$9 running m^{-1}	\$8.5 running m^{-1}	\$8 m^{-2}	\$8.2 m^{-2}
Unit production cost	\$20 running m^{-1}	\$19.5 running m^{-1}	\$18 m^{-2}	\$18.2 m^{-2}
No. of produced units	3.840 running m $week^{-1}$	3.900 running m $week^{-1}$	3,900 m^2 $week^{-1}$	4,380 m^2 $week^{-1}$
Sales price	\$24 running m^{-1}	\$24 running m^{-1}	\$21 m^{-2}	\$21 m^{-2}
Profit (loss) per unit	\$4 running m^{-1}	\$4.5 running m^{-1}	\$3 m^{-2}	\$2.8 m^{-2}
Total profit	\$15.360	\$17.550	\$11.700	\$12.264

specified malfunctions, for product B, daily operation length of this machine increased to 430 min and amount of production rose to 210 m^2 while the amount of length spent per square meter fell from 2.9-2.0 min m^{-2}.

Prior to detecting the capacity constraint in 3 no header machine used in manufacturing product B, the amount of length spent per running meter was 3.0 min m^{-2}. Daily operation length of this machine was 360 min and amount of production was 120 running m. Upon correcting capacity constraint and above specified malfunctions, for product B, daily operation length of this machine increased to 420 min and amount of production rose to 200 m^2 while the amount of length spent per running meter fell from 3.0-2.1 min m^{-2}.

As researchers analyze per unit profit (loss) table for product B, per unit production cost prior to detecting the constraint was \$18 m^{-2}, manufactured number of units was 3.840, 3900 m^2 $week^{-1}$, per unit profit was \$3 m^{-2} and total profit was \$11.700.

Upon correcting the constraint, per unit production cost is \$18.2 m^{-2}, manufactured number of units is 4.380 m^2 $week^{-1}$, per unit profit is \$2.8 $m^{-2}$and total profit is \$12.264.

As regards obtained profit, a comparative analysis of before and after the application of the Theory of Constraints can be illustrated, as in Table 15.

A salient finding attracting attention above is that in product A after correcting the constraints per unit cost decreased and number of manufactured units increased whereas in product B though per unit cost increased, since a parallel rise was obtained in the number of manufactured units the ratio of profit increased correspondingly.

At the end of applying Theory of Constraints total weekly amount demanded for product A-3.900 running m has been met and \$2.190 extra profit has been obtained. For product B total weekly amount demanded-4.380 m^2 has been met and \$564 extra profit has been obtained. As a result, the total weekly profit company X gains in manufacturing products A and B alone is \$2.754. Taking into account also the profit gained in manufacturing the other products it becomes obvious that Theory of Constraints is quite an essential theory that can be used effectively in raising the profit margin of an organization.

CONCLUSION

In this research, Theory of Constraints has been analyzed with respect to cost management accounting and by focusing on the constraints in production steps and eliminating these constraints effectively the objective has been to increase organizational profit of X company by meeting the total demand in a timely manner. The sample model covering X andesite quarry manufacturing company operating in Turkey, City of Erzurum the effect of correcting capacity constraint during production stage on the profit of company has been put forth. As a first step a case study in the organization has been provided to demonstrate the existing capacity of company. It has then been ascertained that in company X weekly amount of demand is not met effectively.

Since, the aim has been to apply Theory of Constraints in this company the effect of theory on company profits has been manifested. In the effective identification and elimination of the constraint or constraints emerging during production stage, capacity constraint of the companies with respect to time and production amount during the processes of manufacturing is of vital importance in terms of organization's profitability. In the implementation part of this research capacity constraint emerging in stone cutter and header machines in the production processes of X company has been identified and towards the aim of increasing organizational profit these constraints have been corrected.

The research findings have put forth that when Theory of Constraints is put into action sales and total length are increased and in turn orders are met in exact time and quantity. Besides in rising the company profit it is a must that Theory of Constraints be implemented in terms of cost management systems.

REFERENCES

Aertsen, F., A.A. Th. de Schepper and G.C.J.M. Vos, 1996. Dynamiek in Logistiek. Centraal Boekhuis, Netherlands, ISBN: 13-9789014052847, Pages: 207.

Anderson, D.J., 2006. Agile Management for Software Engineering: Applying the Theory of Constraints for Business Result. Prentice Hall, New York, USA.

Atwater, B. and M.L. Gagne, 1997. The theory of constraints versus contribution analysis for product mix decisions. J. Cost Manage., 11: 6-15.

Balakrishnan, J., C.H. Cheng and D. Trietsch, 2008. The theory of constraints in academia: Its evolution, influence, controversies and lessons. Oper. Manage. Edu. Rev., 2: 97-114.

Chase, R.B., N.J. Aquilano and F.R. Jacobs, 1998. Production and Operations Management: Manufacturing and Services. 8th Edn., Irwin/McGraw-Hill Inc., USA., ISBN: 13-9780075617105, Pages: 889.

Choe, K. and S. Herman, 2004. Using theory of constraints tools to manage organizational change: Case study of Euripa labs. Int. J. Manage. Organ. Behav., 8: 540-558.

Coman, A. and B. Ronen, 1995. Management by constraints: Coupling IS to support changes in business bottlenecks. Human Syst. Manag., 12: 65-70.

Cyplik, P., L. Hadas and R. Domanski, 2009. Implementation of the theory of constraints in the area of stock management within the supply chain-a case study. Electron. Sci. J. Logist., Vol. 5

Dettmer, H.W., 1997. Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement. ASQ Quality Press, Milwaukee, WI., USA.

Dugdale, D. and C. Jones, 1997. Accounting for throughput: Techniques for performance measurement, decisions and control. Manag. Account., 75: 52-55.

Goldratt, E.M. and J. Cox, 1984. The Goal: An Ongoing Improvement Process. North River Press, Aldershot.

Goldratt, E.M. and R.E. Fox, 1986. The Race. North River Press, Croton-on-Hudson, NY, ISBN: 0884270629.

Goldratt, E.M., 1988. Computerized shop floor scheduling. Int. J. Prod. Res., 26: 443-455.

Goldratt, E.M., 1990. What is this Thing Called Theory of Constraints and How Should it be Implemented. North River Press, Croton-on-Hudson, NY., ISBN: 9780884271666, Pages: 160.

Gupta, M.C. and L.H. Boyd, 2008. Theory of constraints: A theory for operations management. Int. J. Oper. Prod. Manage., 28: 991-1012.

Hamilton, P., T.E.T. Takeshy and P. Djair, 2009. The theory of constraints and the small firm: An alternative strategy in the manufacturing management. RAI-Revista de Administracao e Inovacao, Sao Paulo, 6: 5-27.

Kendall, G.I., 1998. Securing the Future: Strategies for Exponential Growth using the Theory of Constraints. St. Lucie Press, New York, ISBN-13: 9781574441970, Pages: 335.

Louderback, J.G. and J.W. Patterson, 1996. Theory of constraints versus traditional management accounting. Account. Educ., 1: 189-196.

Mabin, V., 1999. Goldratt's theory of constraints thinking processes: A systems methodology linking soft with hard. http://www.systemdynamics.org/conferences/1999/PAPERS/PARA104.PDF.

Mabin, V.J. and S.J. Balderstone, 2003. The performance of the theory of constraints methodology: Analysis and discussion of successful TOC applications. Int. J. Oper. Prod. Manage., 23: 568-595.

Newbold, R.C., 1998. Project Management in the Fast Lane: Applying the Theory of Constraints. St. Lucie Press, Boca Raton, Pages: 284.

Noreen, E., D. Smith and J.T. Mackey, 1995. The Theory of Constraints and its Implications for Management Accounting. North River Press, Great Barrington, MA, New York.

Rahman, S., 1998. Theory of constraints: A review of the philosophy and its applications. Int. J. Operat. Prod. Manage., 18: 336-355.

Rand, G.K., 2000. Critical chain: The theory of constraints applied to project management. Int. J. Project Manage., 18: 173-177.

Reid, R.A. and J.R. Cormier, 2003. Applying the TOC TP: A case study in the service sector. Manag. Ser. Q., 13: 349-369.

Scheinkopf, L.J., 1999. Thinking for Change: Putting the TOC Thinking Processes to use. St. Lucie Press, Boca Raton, FL., USA., Pages: 249.

Simatupang, T.M., A.C. Wright and R. Sridharan, 2004. Applying the theory of constraints to supply chain collaboration. Supply Chain Manage., 9: 57-70.

Westerlund, M.C., 2004. Theory of constraints revisited-leveraging teamwork by systems intelligence. pp: 1-29. http://sal.aalto.fi/publications/pdf-files/ewes05.pdf.