THEORY OF CONSTRAINTS AS A TACTIC COST MANAGEMENT TECHNIQUE AND AN IMPLEMENTATION IN A PRODUCTION COMPANY

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(Master's Thesis)

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TAKTİK MALİYET YÖNETİM TEKNİĞİ OLARAK KISITLAR TEORİSİ VE BİR ÜRETİM İŞLETMESİNDE UYGULAMA

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ESKİŞEHİR OSMANGAZİ ÜNİVERSİTESİ

SOSYAL BİLİMLER ENSTİTİSÜ MÜDÜRLÜĞÜNE

Hajdina IBRAKOVIĆ tarafından hazırlanan Taktik Maliyet Yönetim Tekniği Olarak Kısıtlar Teorisi ve Bir Üretim İşletmesinde Uygulama başlıklı bu çalışma 19/06/2016 tarihinde Eskişehir Sosyal Bilimler Enstitüsü Lisansüstü Eğitim ve Öğretim Yönetmeliğinin ilgili maddesi uyarınca yapılan savunma sınavı sonucunda başarılı bulunarak, Jürimiz tarafından İşletme Anabilim Dalında Yüksek Lisans tezi olarak kabul edilmiştir.

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ETİK İLKE VE KURALLARA UYGUNLUK BEYANNAMESİ

Bu tezin/projenin Eskişehir Osmangazi Üniversitesi Bilimsel Araştırma ve Yayın Etiği Yönergesi hükümlerine göre hazırlandığını; bana ait, özgün bir çalışma olduğunu; çalışmanın hazırlık, veri toplama, analiz ve bilgilerin sunumu aşamalarında bilimsel etik ilke ve kurallara uygun davrandığımı; bu çalışma kapsamında elde edilen tüm veri ve bilgiler için kaynak gösterdiğimi ve bu kaynaklara kaynakçada yer verdiğimi; bu çalışmanın Eskişehir Osmangazi Üniversitesi tarafından kullanılan bilimsel intihal tespit programıyla taranmasını kabul ettiğimi ve hiçbir şekilde intihal içermediğini beyan ederim. Yaptığım bu beyana aykırı bir durumun saptanması halinde ortaya çıkacak tüm ahlaki ve hukuki sonuçlara razı olduğumu bildiririm.

Hajdina IBRAKOVIĆ

İMZA

ABSTRACT

THEORY OF CONSTRAINTS AS A TACTIC COST MANAGEMENT TECHNIQUE AND AN IMPLEMENTATION IN A PRODUCTION COMPANY

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In 1979, the introduction of the Optimized Production Timetables scheduling software brought to the development of a management philosophy, the Theory of Constraints (TOC). Through a five-step focusing process, TOC enables organisations to identify the constraints and find ways to stop them from damaging the company's performance. The purpose of this study is to examine the effects the Theory of Constraints has on a company's performance and profit through the application of the five-focusing steps in a production company. The research is based on the assumption that "each system has at least one constraint" and that "the weakest link of a system determines the whole performance of that system". By comparing the results of the Variable Cost method and the TOC method, it was concluded that by following the five-step continuous improvement process of TOC, the shoe-manufacturing company from Montenegro has benefited from higher sales profitability than according to the traditional cost accounting system.

Key words: Constraint, Bottleneck, Theory of Constraints, Throughput Accounting

ÖZET

TAKTİK MALİYET YÖNETİM TEKNİĞİ OLARAK KISITLAR TEORİSİ VE BİR ÜRETİM İŞLETMESİNDE UYGULAMA

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1979'da, Optimize edilmiş Üretim Zaman Çizelgesi çizelgeleme yazılımının tanıtımı, bir yönetim felsefesinin, Kısıtlar Teorisi'nin (KT) geliştirilmesine getirildi. Beş adım odaklanma süreci sayesinde, KT kuruluşların kısıtları belirlemelerini ve şirket performansına zarar vermelerini engellemenin yollarını bulmalarını sağlar. Bu çalışmanın amacı, bir üretim şirketindeki beş odaklanma adımının uygulanması yoluyla Kısıtlar Teorisi'nin bir şirketin performansı ve kârı üzerindeki etkilerini incelemektir. Araştırma, “her sistemin en az bir kısıta sahip olduğu” ve “bir sistemin en zayıf bağlantısının o sistemin tüm performansını belirlediği” varsayımına dayanmaktadır. Değişken Maliyet yöntemi ve KT yönteminin sonuçlarını karşılaştırarak, KT'nin beş adımlı sürekli iyileştirme sürecini takip ederek, Karadağ’daki ayakkabı üretici firması, geleneksel maliyet muhasebesine göre daha yüksek satış karlılığından yarar sağlamıştır.

Anahtar Kelimeler: Kısıt, Darboğaz, Kısıtlar Teorisi, Süreç Katkı Muhasebesi

TABLE OF CONTENTS

CHAPTER 2

TOC METHODS AND MEASURES

CHAPTER 3

IMPLEMENTATION OF TOC IN A MANUFACTURING COMPANY

LIST OF TABLES

TABLE OF FIGURES

ABBREVIATIONS

5FS	: Five Focusing Steps
ABC	: Activity Based Costing
APICS	: The American Production and Inventory Control Society
BN	: Bottleneck
CCC	: Core Conflict Cloud
CCPM	: Critical Chain Project Management
CCR	: Capacity constraint resource
CF	: Cash Flow
CM	: Contribution Margin
CPCM	: Contribution per Constraint Minute
CPM	: Critical Path
CRT	: Current Reality Tree
DBR	: Drum-Buffer-Rope
DM	: Direct Material
EC	: Evaporate Cloud
FMO	: Fixed Manufacturing Overhead
FRT	: Future Reality Tree
I	: Inventory
JIT	: Just-In-Time
LP	: Linear Programming
MRP	: Materials Requirements Planning
NP	: Net Profit
OE	: Operational Expense
OM	: Operations Management
OPT	: Optimized Production Technologies

POOGI	: Process of On-Going Improvement
PQ Problem	: Production Mix Problem
PT	: Prerequisite Tree
ROI	: Return on Investment
STT	: The Strategy and Tactic tree
T	: Throughput
TA	: Throughput Accounting
TCA	: Traditional Cost Accounting
TOC	: Theory of Constraints
TP	: Thinking Processes
TQ	: Total Quality
TQM	: Total Quality Management
UDE	: Undesirable Effects

PREFACE

I would like to thank my family who has showed me endless support in the process of writing. I also want to thank the Dizdarević family that has provided me with the necessary information without which the research implementation would have been impossible.

I would especially like to thank my husband, Džefris, who has been with me through the ups and downs during my whole studies and their finalization.

INTRODUCTION

Businesses have been forced to develop and implement cost management techniques to be able to meet customer needs and stay on the market as they are located in a rapidly changing environment. In 1979, the introduction of the Optimized Production Timetables scheduling software brought to the development of a management philosophy, the Theory of Constraints (TOC). Through a five-step focusing process, TOC enables organisations to identify the constraints and find ways to stop them from damaging the company's performance.

Companies strive to make profit by reaching high performance and efficiency levels. This applies both to the current period and the future of the company. Manufacturing companies need to maintain a fluent production flow to be able to achieve their goal. Any obstacles that restrict the production process must be treated as constraints and need to be removed or turned into an advantage for the company.

TOC is considered to be a tactical cost management technique because it has a structure that allows for the most appropriate contribution and short-term profit. It is defined as an integrated technique that sees the company as a system, determines the constraints of the system and establishes the relationship between them to achieve the objectives. The main goal of TOC is to place the continuous improvement process in a company through simultaneous production.

The purpose of this study is to examine the effects the Theory of Constraints has on a company's performance and profit through the application of the five-focusing steps in a production company. The research is based on the assumption that "each system has at least one constraint" and that "the weakest link of a system determines the whole performance of that system". By following the TOC's five-step continuous improvement process and applying it in a production company, this study will make a considerable contribution to the literature, the company's and other similar businesses' performance and profitability, and it could also provide guidelines for further studies.

The thesis will be divided into four parts. In the first part of the thesis, the theoretical background of the Theory of Constraints will be described in detail. The concept of TOC, its development, evolution, and principles will be described, and the Five-Focusing Steps will be included.

The second part will describe the methods and measures of TOC, which include the Drum-Buffer-Rope, I-V-A-T Analysis, performance measurements, the concept of Product Mix, and the basics of Throughput Accounting.

The third part will be the implementation of the Theory of Constraints in a small shoe-manufacturing company from Montenegro and its results. The last part will include the conclusion of the study.

CHAPTER 1

THEORETICAL BACKGROUND OF THE THEORY OF CONSTRAINTS

1.1.Introduction

Theory of Constraints (TOC) is a profit-improvement oriented change method. The first introductions of TOC surfaced in the late 1970's by its developer, an Israeli physicist, Dr. Eliyahu Goldratt. The main concept of TOC is that every business contains a constraint which could be defined as anything that prevents a business to reach its goals and maximum profit (Mahoney, 1997). A business can be viewed as a linked set of operations that turns inputs into sellable outputs. However, TOC considers this linked set of operations as a chain and defines the chain to be only strong as its weakest link. Goldratt delineates a five-step process that can be used to strengthen the weakest link(s) (Dettmer, 1997). With these steps organisations can identify the constraints and find ways to remove them from the system.

According to Goldratt in “The Goal”, most organisations have only a few real bottlenecks – constraints, and businesses should only focus on them. Implementing TOC can result in significant advancement after three months of effort and without incorporating a great deal of resources (Dettmer, 1997).

This chapter will include the theoretical background of the Theory of Constraints by first analysing what the duties of a manager are on the path to reach the goal of an organisation. Following, the manufacturing environment will be explained and the various definitions of the concept of constraints will be described as well as their varieties. Afterwards, by defining the concept of TOC, its development will be included, and the description of its evolution since the first introductions will be divided into the five main eras. The Theory of Constraints has rules that can help an organisation in better understanding how to approach the implementation, therefore they will be listed, and their explanations will be included. This chapter will also include the principles of TOC, and the five-step continuous improvement process. Advantages and disadvantages, as well as benefits of TOC will be analysed. Finally, the list of organisations with successful implementations will be added, and a brief literature overview will be incorporated.

1.2.The Manager and The Goal

Being a manager means being able to recognise the need for change, initiate it, control it and direct it, and solve any issues en-route. It is of essential means for businesses to be concentrating on the future instead of presence, therefore to be proactive rather than reactive (Dettmer, 1997). In his novel »*The Goal«,* Goldratt mentions that in most cases, as opposed to their beliefs, managers are running an in-efficient plant. He also suggests that struggling for high efficiencies takes managers in the opposite direction of their goal (Goldratt, 2004). A manager that does not know the answers to »What the ultimate goal is?«, »Where he or she currently stands in relation to that goal?«, »The size and the direction of the change needed to reach what he or she wants (the goal).«, cannot hope to succeed (Dettmer, 1997).

Systems are created with an intention, a goal. The goal of a service or manufacturing company is in most cases to achieve large profits now and in the future (Siha, 1999). TOC is not oriented against improving only one manufacturing department or one plant, but the entire company, therefore local optimums are not concerned with. In the novel, Goldratt explains that the goal is not to decrease operational expense (OE) by itself, nor to better one measurement separately from others. The goal is to lower OE and inventory while increasing throughput simultaneously, and to increase net profit while increasing cash flow and return on investment at the same time (Goldratt, 2004).

1.3.Manufacturing environment

Being productive translates to working on bringing the company closer to its goal, therefore any action of this kind is considered a productive action. Unless you know “what” your goal is, productivity loses its meaning (Goldratt & Cox, 2006).

As mentioned before, Goldratt explains in his novel that struggling for high efficiencies takes managers in the opposite direction of their goal. A company where everybody works all the time is inefficient and costly. Having excess manpower creates excess inventory. Most managers tend to cut short capacity wherever it is possible, so no resource is unemployed and that everybody has something to work on (Goldratt, 2004). He goes on to explain what a *balanced plant* is.

A balanced plant is a plant where capacity of each resource is balanced with the market demand. However, when capacity is equalised with the marketing demands, throughput goes down, and simultaneously inventory and the carrying cost of inventory i.e. operational expense increase (Goldratt, 2004). Efficiencies should be maximised on each operation, and TOC aims to maximise the productivity of the whole system. TOC-based scheduling "counts backwards" from the bottleneck process to determine schedules for workstations and material releases to maximise the bottleneck process's productivity. This is commonly referred to as Drum-Buffer-Rope (DBR) (Polito et al., 2006).

Goldratt (2004) describes the two phenomena that can be found in every plant. One is called *dependent events* which is defined as a series of events that need to occur before the next can start; in other words: the following event depends upon the ones before it. If a company has dependency going through ten to fifteen operations with different sets of fluctuations just to make one part, then *"the fluctuations of the variables down the line will fluctuate around the maximum deviation established by any preceding variables"* (Goldratt & Cox, 2006).

1.4.System Constraints

A business can be considered as a connected set of operations that turns inputs into sellable outputs. However, TOC considers this linked set of operations as a chain and defines the chain to be only strong as its weakest link is (Dettmer, 1997). With the five-focusing steps TOC helps identify the constraint within the system, and then strengthen that constraint to the level where it no longer delimits the strength of the chain. Despite eliminating the constraint, the chain will still have at least one link that will not be as strong as other links in the chain. Wherefore, with the use of the TOC steps again, the new constraint can be identified and eliminated. This demonstrated that TOC can be viewed as a continuous improvement method (Watrous & Pegels, 2005). The efficiency of the whole chain cannot improve unless the weakest link is strengthened. Consequently, the »chain is only as strong as its weakest link«.

The American Production and Inventory Control Society (APICS) dictionary defines the term constraint as *"any element or factor that prevents a system from achieving a higher level of performance with respect to its goal"* (Blackstone & Cox, 2004). Constraints have three forms in general: physical (resource capacity less than demand), market (demand less than resource capacity), and policy (formal or informal rules that limit productive capacity of the system), whereas DBR is meant to address physical and market constraints (Watson et al., 2006).

1.4.1. The Concept of Constraints

The performance of the whole system depends on the weakest link's capacity, therefore to improve the performance, the weakest link needs to be strengthened. The focus must be only on constraints because strengthening any other link will not result in improving the whole system. It is essential to understand that by identifying the one constraint and eliminating it will not bring an improvement for an unlimited period. Very soon new links can turn into weak links and limit the chain's strength. This means that the system is still constraint however the constraint has moved to another link (Dettmer, 1997).

A constraint is any particle that limits the system form reaching its goal (Goldratt & Cox, 1992), and the goal of every business is to make money (Simatupang et al., 2004). If the example of a plant is considered: The resource that has equal or lower capacity than the demand is a *bottleneck resource*, and the resource that has greater capacity than the demand is a *non-bottleneck resource*. Thus, to increase capacity of the plant, bottleneck capacity needs to become more equal to the demand. If an hour is lost at a bottleneck it cannot be recovered anywhere else in the system. Consequently, throughput for the entire plant becomes lower by the amount the bottleneck would produce in that time (Goldratt, 2004).

Constraints can be divided into physical and non-physical, and their location can be internal or external. Physical constraints surface in forms of raw material shortages, limited capacity resources, limited distribution capacity, and lack of customer demand. They are usually human-behaviour driven actions, decisions, and habits. Non-physical constraints include outdated rules, procedures, measures, training and operating policies that guide the way in which decisions are made. In terms of location: Internal constraints, which incorporate raw material, capacity and distribution constraints, are within the supply chain, whereas external constraints include market constraints (Simatupang et al., 2004). Even when all the internal constraints are eliminated, they then move outside of the system, however with a different set of task skills and knowledge, they can also be ousted (Dettmer, 1997).

Inadequate demand is considered a managerial or policy constraint rather than a physical constraint. It is usually hard to recognise and evaluate, and very often it requires cooperation between the functional areas. Goldratt created the Thinking Process (TP) methodology that uses common sense, intuitive knowledge and logic to address the policy constraint and create breakthrough solutions (Rahman, 2002).

1.4.2. Constraints and Continuous Improvement

Cooperation is essential for success; formal improvement efforts include team work in the process. TOC helps identify the constraint within the system, and then strengthen that constraint to the level where it no longer delimits the strength of the chain. Despite eliminating the constraint, the chain will still have at least one link that will not be as strong as other links in the chain. Wherefore, with the use of the TOC steps again, the new constraint can be identified and eliminated. TOC was developed as an approach to continuous improvement (Dettmer,1997), and it was increasingly accepted as a newer Operations Management (OM) concept (Polito et al., 2006).

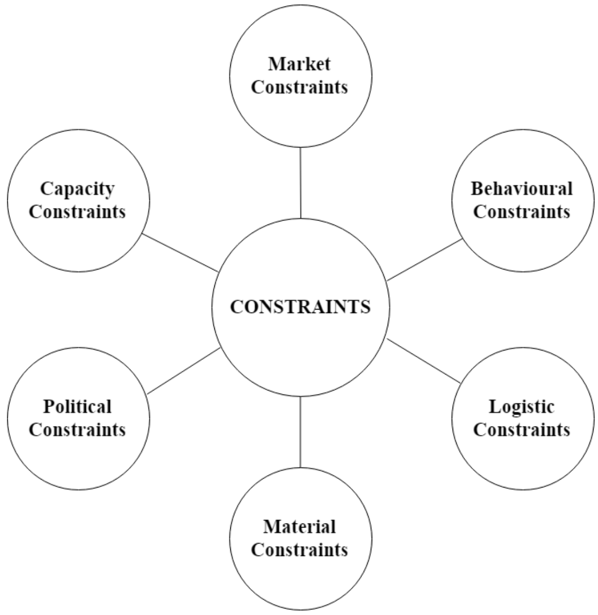
Changing how people manage organisations and their projects is equivalent to changing the structure of the business. It is important to incorporate the right people at the right time whenever these changes are addressed. Simultaneously, to identify the necessary changes and not to lose the momentum which is vital to sustain continued progress, the whole process should move at just the right pace – not to fast nor to slow (Jacob & McClelland, 2001).

An organisation that desires to achieve continuous improvement must ensure consistent addressing of the correct problems at the right time.

1.4.3. Classification of Constraints

A constraint is any particle that limits the system form reaching its goal (Goldratt & Cox, 1992), and the goal of every business is to make money (Simatupang et al., 2004). Any problem that negatively affects the flow can be referred to as a constraint. There are several different internal and external factors that can influence the system performance; internal factors being labour force, machinery capacity, storage area, inability to deliver on certain days of the week, business policies, for instance the inability of a worker to have more than six hours of overtime in a week, raw material or energy availability, and external being, for example, insufficient demand. Thus, it is possible to divide the concept of constraints as follows:

Figure 1: Types of Constraints



Source: Kaygusuz, 2005: 138

Market constraints: The market constraints represent one of the most important constraints for any business, since they are constantly looking for a market to offer their products or services to. With the changing world economy conjuncture, businesses try to offer products or services that they can sell instead of selling what they produce, to avoid the difficulties that come up in the search of a market. Considering the market as a determinative and an unavoidable feature for businesses increases its importance among all the constraints. If a business wants to continue operating, there must be a market demand for the product it produces or the service it offers. Therefore, market demand is crucial for an organisation's sustainability. Market demand is the significant factor in regulating the production quantities, quality standards and production times (Dettmer, 1997: 81; Karamaraş, 2002: 62).

To address market constraints, management should look for new markets and new opportunities by increasing the demand in the current market or by developing new products and services. Increasing demand for the market-constrained businesses' products requires gaining the competitive advantage elements of the company. It is possible to increase competitive advantage by harmonising the production flow. This allows the process to increase, and the inventory and operational expenses to decrease (Rezaee & Elmore, 1997: 12).

Market constraints are considered to be entirely external, therefore they are not a result of the operations within the company. Even though there are many reasons for market constraints, most of them are the result of management policies.

Capacity constraints: They can be delineated as the inability to meet the demand. This type of a constraint has a negative effect on the system flow and results in a decrease in the sales revenues of the business. Capacity constraints can include machines or people, and they limit the creation of output (Chase et al., 1998: 52).

In the system, there are primary capacity constraints and secondary capacity constraints. Primary capacity constraints are constraints that limit the production of output for the whole company. Secondary capacity constraints are constraints that do not provide a sufficient amount of parts for the primary constraint. In other words, a secondary constraint occurs when there is an increase in the demand for resources up to the level where the primary constraint is not able to feed at the desired level (Tezcan, 2001: 12).

There are two main reasons for occurrence of capacity constraints; the first is a raw material supply problem, whereas the second is when capacity represents inadequate capacity. Here, capacity limited and non-capacity limited resources play an important role. Limited resources require production to be carried out inside certain limits. A capacity constraint is present when the demand for a resource exceeds the capacity of the resource. When referring to non-capacity limited resources, capacity in terms of demand is expressed (Chase et al., 1998: 52; Karamaraş, 2002: 3).

Capacity constraints can significantly restrict the performance as bottlenecks or non-bottlenecks.

Bottleneck resource: This type of resource is a subject to a higher demand than its capacity. Bottleneck is a constraint that limits the system’s income. In case there is no bottleneck, there is excess capacity, and the system creates a bottleneck itself (Chase & Aquilano, 1995: 760).

Non-bottleneck resource: These resources have more capacity than demand. Non-bottlenecks should not be subjected to a continuous production. Goldratt clearly stated in *The Goal* that 'excess manpower creates excess inventory'. Thus, if the use of a non-bottleneck and its efficiency is increased, this leads to an increase in inventory and operational expenses, which furthermore affects the speed of money creation in the company. Due to having excess capacity, it is normal for non-bottlenecks to have idle time (Umble, 2000: 36-41).

If a certain activity is a bottleneck activity, processes and products will most probably not be completed on time. Even in cases when there is no bottleneck resource, there is usually one or more resources that have the potential of causing significant blockages during the product flow. These are usually referred to as *capacity constraint resources* (Ilhan, 2014: 13-14).

Capacity constraint resource (CCR): It is the resource that can become a bottleneck when demand and capacity are very close or equal. If the material input is not carefully scheduled, a resource can easily become a bottleneck. For example, the CCR can be a resource that waits for work from many different resources. If these awaited resources cause the CCR to have idle time by waiting for the intermediate product, then inertia occurs in the CCR and it becomes a bottleneck.

The efficiency of a production system depends on the use of resources within the planned framework that minimizes losses (Karamaraş, 2002: 52). Some companies face issues in managing and scheduling of these resources (Umble & Srikanth, 1995: 83).

Inadequate management of bottlenecks or capacity constraint resources in the production process could result in long-term damage to the company in form of long lead times, production level limitations, inability to meet the deadlines, and losing the competitive advantage of the company. The fundamental solution for improving performance in production-constraint companies is to take bottlenecks into account, and harmonise the production flow, therefore to synchronise it, and consequently increase the process (Ilhan, 2014: 14).

Managerial constraints: In the literature, they are usually referred to as policy constraints. Managerial constraints are caused by the poor decisions that the company executives, i.e. managers, make. The company's management is to make decisions and policies in a way that they will not have an unfavourable effect on the production. Businesses tend to lose the ability to respond to opportunities due to poor policy choices. Managerial constraints are very hard to detect and repair or compensate for. They can affect the business partially or entirely (Teceren, 2002: 24-25).

People in general tend to preserve old situations over emerging innovation. Managerial constraint can be considered to exist in case when the slightest benefit after all the improvement work, which is an outcome of all the decisions and changes made by a manager, is not provided. When we increase the capacity of a source where the constraint cannot be observed, the occurrence of a new constraint can be given as an example of the situation described above (Umble & Spode, 1991: 27).

Usually, policy constraints are more common than physical constraints in companies. Identifying and eliminating managerial constraints tends to take more effort in comparison to physical constraints, however the results have a larger contribution to the business. Managerial or policy constraints generally emerge in marketing, accounting and finance.

Raw material and Material constraints: They involve shortcomings of one or more crucial substance required in the long or short-term to produce a product (Okumuş, 2002: 29). In other words, material constraints occur when there are insufficient quantities of materials and raw materials needed for the production. Production cannot take place without a sufficient amount of materials and raw materials. A company can self-provide materials and raw materials by means of its own production or by the help of their suppliers. If a company relies on their suppliers, problems with them can be manifested as a constraint during production (Umble & Srikarth, 1995: 82).

Short-term constraints usually occur when the suppliers do not deliver the product on time or when the product becomes defective, which can be the main cause for imbalance in the production flow. Raw material shortages in the market can be considered as long-term raw material constraints. When scheduling the main table for the production, it is necessary to take issues, such as access to quality material and the supply time for obtaining the raw material into consideration (Umble & Srikarth, 1995: 82-83).

To eliminate raw material constraints, management should find new suppliers or increase the prices for raw materials that they present to their existing suppliers (Ilhan, 2014: 15).

Logistics constraints: These constraints can be defined as all the difficulties encountered in the process of transportation of materials and raw materials to the production area, to the final product, and the delivery to the end user. Late deliveries to customers can really damage the company's reputation. More than any other, logistical constraints are very common for manufacturing companies. It is easier to recognise distribution constraints when the distribution network is more complicated (Umble & Srikarth, 1995: 84).

Logistic constraints exist when problems that arise from the planning and control system occur. Inability to supply the raw materials on time, supply of incomplete materials, and not shipping the materials in time for production will keep the company from making a profit (Kaygusuz, 2005: 139).

In other words, logistic constraints are the disruptions that occur in the process from the introduction of materials used by the company to the exit from the operation. Significant failures can disrupt the flow of production. This prevents the company from making planned, on-time deliveries (Teceren, 2002: 24-25).

To achieve the targeted goals, these types of constraints require special type of investigation and analysis to eliminate them since they are easily invisible. They usually occur in the production system and are difficult to replace.

Behavioural constraints: Behaviour is expressed as a response to specific situations encountered in a given environment. Behaviours vary according to education, experience and logical understanding (Kaygusuz, 2005: 139).

A behavioural constraint occurs when reality and behaviour are in conflict and end up affecting the organisation's global measurements in a negative way. Behavioural patterns mostly arise from the style of managing. Therefore, management is partly responsible for some behavioural constraints in the organisation. An example of this type of constraints can be seen in the behaviour of many employees and managers. It is especially obvious when the managers keep employees constantly working with the concern of losing their jobs. Similarly, the employees share the concern, and therefore allow this push towards constant work. One of the most difficult things to change is the approach of keeping the resources busy. The idea of keeping the employees busy at all time comes from the assumption that all resources must be used at a high rate, otherwise the business will be damaged. This concept is for the same reason accepted by both the management and the employees. As a consequence, to the above-mentioned type of behaviour, inventory increases, product mixes become unbalanced, charts shift, and material gaps occur (Umble & Srikarth, 1995: 178).

Behavioural constraints might not be the main cause of problems in the company, however if they are present, finding a solution is difficult. Accordingly, behavioural constraints can be a major obstacle to improving the production process (Ilhan, 2014: 16).

1.5.The Concept of TOC

Theory of Constraints has been progressing steadily since the early 1980s. TOC was developed as a system-based approach to continuous improvement management (Reid, 2007). Besides being systematically-oriented TOC has the Thinking Process (TP), a generic set of logic tools that assist in finding the problem's origin, create improvement strategies, and apply the wanted changes (Reid & Cormier, 2003).

Reid (2007) defined three interconnected assumptions that TOC is based on:

- Every system has its goal and a set of important requirements that need to be completed if the goal is reached;
- The general system's performance is more than just the sum of its component performances;
- A system's performance is limited by at least one constraint at any given time.

1.5.1. TOC Development

Companies have implemented various operations management principles and strategies such as Materials Requirements Planning (MRPI and MRPII) (Orlicky, 1975), Just-In-Time (JIT) (Monden, 1981), Total Quality Management (TQM) (Deming, 1986; Juran, 1992), Toyota Production System (TPS) (Ohno, 1988), Lean Thinking (Womack & Jones, 1996), Six Sigma (developed by Bill Smith in 1985), and Theory of Constraints (TOC) (Goldratt, 1988), that have over the last four decades helped to reduce manufacturing costs to a minimum (Rahman, 2002).

The alikeness and dissimilarity along with the relative applicability in different types of organisations of these management principles has been discussed a lot between practitioners and academicians. TQM usually uses many of the data summarization and team assistance Total Quality (TQ) tools for describing and analysing problems that are encapsulated in organisational processes, and it is applied by using the Deming Plan-Do-Check-Act cycle. Before TQM, JIT and TPS were developed and used for process improvements in Japan. Similarly, the same tool set is used for applying a new five-step process variability reduction effort, called Six Sigma. The historical links to TPS allow Lean Thinking the use of same tools to improve the entire system's general performance. Besides being systematically-oriented TOC has the Thinking Process (TP), a generic set of logic tools that assist in finding the problem's origin, create improvement strategies, and apply the wanted changes (Reid & Cormier, 2003).

To summarize, TQM, JIT, TPS, and Six Sigma are generally focused on making the organisation's work-performing processes better and perform best when the process goal is aligned with the organisational goal. Whereas Lean is about reducing cost by minimizing waste and non-value-added in every system activity or process, TOC aims to manage the only activity or process that constrains the system's throughput (Reid & Cormier, 2003). In addition, TOC offers a convenient framework for maintenance management in manufacturing environments and concentrates on capacity-constrained resources (CCR) as the machines/operations that define the performance of the manufacturing system (Ribeiro et. al., 2005).

1.5.2. TOC Evolution

As a strategic management philosophy, managers can use TOC to identify constraints in their system. Constraints prevent the system from achieving maximum performance which allows to reach its goal of making larger profits now and in the future (Siha, 1999).

The first introductions of TOC surfaced in the late 1970's by its developer, an Israeli physicist, Dr. Eliyahu Goldratt. However, TOC's reputation arose with Goldratt's business novel *The Goal* in 1984 (Goldratt & Cox, 1984). The novel demonstrated the application of most of TOC concepts on an example of a medium-sized manufacturing plant that had three months of time to make a change or the plant would shut down (Reid & Cormier, 2003).

TOC was initially progressed from the Optimized Production Timetables (OPT) systems (Goldratt, 1980), which later evolved into Optimized Production Technologies (OPT). OPT concepts were explained in form of a novel, *The Goal*

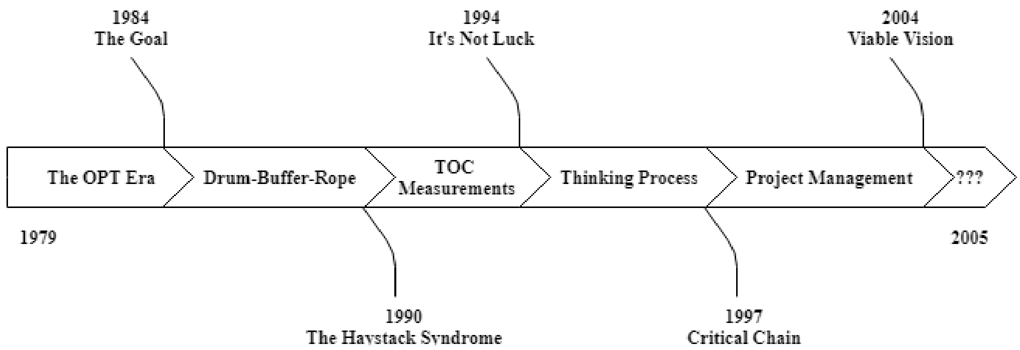
(Goldratt & Cox, 1984) and *The Race* (Goldratt & Fox, 1986). *The Goal* describes the theory through an example of an everyday production situation, whereas *The Race* goes deeper by helping overcome the obstacles faced in the implementation. It also spreads the concentration from the production floor to all elements of business. The complete idea became known as TOC by 1987 and was viewed as »an overall theory for running an organisation« by Goldratt (Rahman, 2002).

TOC comprises two branches – logistics (every day operations) and continuous improvement (Siha, 1999). Simultaneously it comprises three separate still interrelated areas – logistics, performance measurement, and logical thinking. TOC applications to logistics include the DBR scheduling method, buffer management, and VAT analysis. Operating and local performance measures are required to ensure that the system is operating towards its goal – making money. Operating measures include throughput, inventory, and operational expenses, whereas local performance measures include throughput-dollar-days and inventory-dollar-days). Logical thinking involves the process of the five focusing steps and the thinking process (Simatupang et al., 2004).

Watson et al. (2006: 388) segmented the TOC evolution into five eras:

1) The Optimized Production Technology Era – the secret algorithm;
2) The Goal Era – articulating DBR scheduling;
3) The Haystack Syndrome Era – articulating the TOC measures;
4) The It's Not Luck Era – thinking processes applied to various topics;
5) The Critical Chain Era – TOC project management.

Figure 2: The Timeline of the Major Eras in the Development of TOC



Source: Watson et al. (2006: 388)

1.5.2.1.Era 1: Optimized Production Technology

One of the distinctive traits of OPT/TOC is that the operation requires some type of a bottleneck around which to focus its efficiencies. The bottleneck is usually some type of a machine with limited capacity. According to OPT philosophy, optimising the usage of the bottleneck optimises the throughput and profitability of the whole plant, however this was not satisfactorily proven (Plenert, 1988).

Since the capacity on non-bottlenecks is greater than the demand, idle time on them is acceptable (Goldratt, 2004), however, in the attempt to stay occupied and avoid negative performance estimations workers would sometimes ignore the schedule and produce parts for inventory. This conduct creates uncoordinated material flows in the plant, rushing the schedule and putting in danger the success of OPT. To avoid this type of activity, Goldratt decided to educate managers and workers by explaining the misconception about efficiency as the main measure of worker productivity. According to Goldratt (2004), a plant where everybody is working all the time is very inefficient, because excess manpower creates excess inventory. Occupying non-bottlenecks at a hundred percent of their capacity does not increase output, it only creates excess inventory (Watson et al., 2006).

1.5.2.2.Era 2: The Goal

When conducting presentations at industry meetings, Goldratt was unsuccessful at eliciting a response, thus he changed tactics. In cooperation with Jeff Cox, he wrote The Goal in 1984. The book was written in form of a novel in which the protagonist, Alex Rogo, rescues his plant with the help of his mentor, Jonah. The main purpose of The Goal was to teach workers at facilities employing OPT in the attempt to have them follow OPT schedules. Nevertheless, it became a business best seller with many companies trying to implement the concepts from the book. The above-mentioned Five Focusing Steps (5FS) are an important part of The Goal, since they represent the process by which TOC is implemented. The 5FS have evolved into Process of On-Going Improvement (POOGI), a combination of the 5FS and the two preconditions for implementation. The first precondition for implementation is to delineate the system that is being examined and to identify its purpose. After defining the purpose of the system, the second precondition is to delineate measurements that line up to that purpose. While decreasing inventory, manufacturing lead time, and the standard deviation of cycle time, TOC systems generate larger numbers of product (Watson et al., 2006).

1.5.2.3.Era 3: The Haystack Syndrome

According to Goldratt, “cost accounting is public enemy number one to productivity”. When traditional cost accounting (TCA) principles are applied to local performance measurements, product cost, and capital investment decisions, they provide deceptive or wrong information to decision makers. This could cause an implementation of policies which are discrepant with the company goals (Watson et al., 2006).

Watson et al. (2006) quote by Smith (2000) that ‘‘the theory behind financial accounting is valid for the purpose of reporting past activities; however, the actions necessary to maximize throughput and cash flow now and in the future are not the same as minimizing local unit cost and maximizing short-run reported net income’’.

Making money now and in the future is the most important goal of a TOC system. To prove whether an organisation is acquiring that goal, three global performance measures have been engaged: Net Profit (NP), Return on Investment (ROI), and Cash Flow (CF). Simultaneously, Goldratt and Cox present three plant level performance measurements: throughput (T), inventory (I), and operational expense (OE) (Watson et al., 2006). These measurements strengthen the goal of maximizing corporate profits by accentuating revenue generation while concurrently reducing inventory and operational expense (Cox et al., 1997).

An important philosophical difference is present between TOC and traditional accounting. Cost reduction is important for TOC, and the focus is on increasing throughput. In contrast to the traditional environment, operational expense in TOC plants is not as stressed. Second, Throughput Accounting (TA) is conservative in recognising throughput, since revenue is only acknowledged when a sale to the consumer and not a downstream member of the supply chain occurs. Third, producing »apparent profits« is restraint by carrying material inventories at the raw material purchase price (Noreen et al., 1995; Corbett, 1998), and fourth, OE is treated as fixed during a specific, usually short, period of time which prevents distribution of wrong information based on the allocation of indirect or non-variable costs (Watson et al., 2006).

The most important TA concept is contribution per constraint minute (CPCM) (Gardiner & Blackstone, 1991), whereas Fox (1987) introduces CPCM in the context of the PQ problem. Throughput accounting is used to select products that should be processed by the constraint in a given period of time. This problem is known in the literature as Production mix problem, usually identified with the name of the PQ problem (Wojakowski, 2016: 84). The PQ problem remarks the failure of cost accounting to recognise the disproportionate impact of the constraint by calculating the opportunity cost of production of a specific product at the constraint. This provides a trustworthy measure for taking advantage of the constrained resource. PQ, and CPCM are most commonly applied to the make-or-buy decision; however it has also been used to (1) determine retail product mix based on opportunity cost of limited shelf space (Gardiner, 1993), (2) identify strategic linkages between the operations and purchasing functions (Low, 1993), (3) direct preventative maintenance efforts (Chakravorty & Atwater, 1994; Atwater & Chakravorty, 1995), and (4) prioritize set up time improvement efforts (Chakravorty & Sessum, 1995).

TA is sufficient for directing activities within a company. However, to direct increases in throughput, management must have measures of customer satisfaction and competitive position (Watson et al., 2006).

1.5.2.4.Era 4: It's Not Luck

As a sequel to *The Goal,* which identifies management policies as the biggest source of potential constraints, *Goldratt* published *It's Not Luck* in 1994. The novel presents a guide for discovering solutions to perplexing unstructured problems – the Thinking Processes (TP). Most academicians believed TOC to be synonymous with the drum-buffer-rope (Watson et al., 2006).

The TP tools were first developed in 1987 and were introduced through the Jonah courses offered by the Goldratt Institute, however they gained more attention in 1992 (Noreen et al., 1995). The Thinking Processes tools specify the precise and systematic ways to approach identification and resolution of unstructured business problems connected to the management policies (Schragenheim & Dettmer, 2000). They consist of two logic categories, the first is the *sufficient cause or effect-cause-effect logic* which influences the current reality tree (CRT), future reality tree (FRT), and transition tree (TT), the second is the *necessary condition logic* which is used by the evaporating cloud (EC) and prerequisite tree (PRT) to reveal the hidden assumptions that prevent the identification of the effective solutions to specific core problems (Scheinkopf, 1999).

1.5.2.5.Era 5: The Critical Chain

Critical chain project management (CCPM) was introduced at the 1990 International Jonah Conference. CCPM is a method for scheduling and controlling projects based on TOC logic. However, the concept of critical chain remained unstudied until 1997 when Goldratt published the *Critical Chain.*

The best explanation of the logic behind CCPM is in Newbold's (1998) *Project Management in the Fast Lane*. CCPM is the application of the FFS to project management, utilizing buffers at critical control points to influence better project performance by protecting against task completion time variation and proactively managing it. There are three major differences between CCPM and critical path project management: the method of assigning activity times, the use of buffers, and the elimination of resource conflicts (Watson et al., 2006).

To insure the project due date against surplus in carrying out individual tasks, a project buffer is placed at the end of the project network. Non-critical activities should not impact the start of critical chain tasks, therefore »feeding« buffers must occur where the non-critical and critical activities merge. CCPM insists on considerably shorter task durations. Traditional project management techniques such as critical path (CPM) are based on infinite capacity logic, and do not consider resource conflicts. Therefore, it is possible that CPM schedules include at least one resource planned to carry out two different activities at the same time, making the project schedule impossible. CCPM uses a Gantt chart approach to avoid and resolve resource problems. According to Watson et al. (2006), this enables the critical chain to »jump between linear project paths to reflect resource contention«. Leach (2000) describes CCPM successes in the information technology sector and states that ‘‘companies such as Texas Instruments, Lucent Technologies, Honeywell and Harris Semiconductor complete projects in one half or less the time of previous or concurrent similar projects, or as compared to industry standards.’’

1.6.TOC Rules

TOC was initially progressed from the Optimized Production Timetables (OPT) systems (Goldratt, 1980), which later evolved into Optimized Production Technologies (OPT). OPT concepts were explained in form of a novel, *The Goal* (Goldratt & Cox, 1984) and *The Race* (Goldratt & Fox, 1986).

Goldratt bases the foundation of TOC on nine fundamental rules of OPT. These nine rules do not need to follow a certain order during the TOC implementation. In his novel, *The Goal*, Goldratt implemented this feature to a boys' scout tour in the forest. The main character in the book, Mr. Rogo, joins his son's boys scout tour through the forest and there he was able to associate his observations with the way his factory operates. He becomes aware of the fact that the children's walking is a series of interdependent events that are subject to statistical fluctuations. This translates to the children not being able to maintain the same average speed and that is the reason that the scout group slows down.

Mr. Rogo manages to translate his observations into terms used in a production. Therefore, the distance between the first and last scout walking becomes inventory, the effort to run during the walk is considered as an operational expense, and the last person in the walking line is considered as flow. All the changes in the distances between the first and last child in the line reflects the inventory status. If the slowing down of the line replaces statistical fluctuations, a delay in the flow if unavoidable (Goldratt & Cox, 2007: 160).

Goldratt argues that during production the resource capacity must be balanced against the market demand, which is opposite to what is always accepted. Goldratt explains the theorem of TOC, which is based on OPT, with the help of nine rules (Goldratt & Fox, 1986).

Balance flow not capacity: Market demand and flow should be equal. Most commonly, managers care more about capacity utilisation rate of machines, however they usually neglect the changes that occur. Although some resources in the system (non- bottlenecks) will have idle capacity, the other resources (bottlenecks) should be employed to its maximum capacity. It is important to employ the bottlenecks to their maximum because they determine the continuity of the production.

Anything negative that could prevent the continuous work of a resource that is a bottleneck, such as employee absenteeism, low-quality materials, preparation processes, and inadequate employee education or training, needs to be eliminated. If for some reason a bottleneck resource stops operating, it must be brought back to the system as soon as possible so the flow would not be affected.

At times, the constraint resource cannot adapt to the process variabilities. Thus, the inability to »feed« a resource can be seen in cases when the to-be-processed parts cannot be found. This interrupts the flow. Even when there are sufficient amounts of raw materials, if there is no area to store the processed parts, the constraint gets blocked.

Constraints determine the use of non-bottlenecks: Non-bottleneck machines affect bottleneck machines. As Goldratt (2004) explained in *The Goal*, when a business has limited market demand, a non-stop production will create excess inventory. The company then needs to organise a storage area to store their finished products. TOC aims to minimise inventory and operational expense while maximising throughput. Therefore, TOC slows down the production according to the capacity of the bottlenecks, to equalise it with the demand. Slowing down the production can create a cost burden, however, as a way out it is important to impose drastic changes that will have an affect the inventory cycle and output.

The use and mobilisation of a source is not the same: If an operating machine has an increase in the number of outputs, it can be considered that the machine is used. However, if there is no increase in output, the machine can be considered as not used.

An hour lost at the bottleneck is an hour lost for the whole system: During a production, if a worker leaves the bottleneck machine, for example, to go on a lunch break, the machine should have a substitute supervisor that would maintain the continuous operating of the machine. The possible substitutes need to have been provided with sufficient quality training to use the machine. As the name indicates, a unit lost in the bottleneck will affect the whole system.

An hour gained at the non-bottleneck is just an illusion: Improvements made on non-bottlenecks do not provide benefits. Time spent on a bottleneck and time spent on a non-bottleneck is not the same. On-time reductions on non-bottlenecks affect their idle times, however reducing preparation time brings bigger earnings.

Bottlenecks manage the system output and inventory: The importance of bottlenecks has been mentioned above. If a bottleneck is not fully employed, the flow is affected. Running both bottlenecks and non-bottlenecks can cause an increase in inventory. A bottleneck affects both the output and the non-bottlenecks. In other words, a bottleneck controls both output and inventory quantity.

Batch transfer size surely does not have to be equal to process batch size: This applies under the assumption that the non-bottleneck is placed in front of the bottleneck, and that there is a large batch being processed in the non-bottleneck. It is desirable that at least a part of the batch that is being processed, requires to be processed by the bottleneck (Umble & Srikanth, 1990: 116). Therefore, as the guideline implies, it is not necessary for the whole process batch size to match the transfer batch size.

The process batch size is not fixed: The bigger batch size at the bottleneck in comparison with the batch size at the non-bottleneck, reduces the loss of time spent at the bottleneck. In other words, the transfer of the batch from the non-bottleneck to the bottleneck is supposed to be on time.

The total of the local optimum is not equal to the optimum of the whole system: Each department in a company defines their own goal they want to reach. Most of the times the gaps in communication cause problems to reappear throughout the company. It is possible to ensure optimisation by focusing on the main goal.

1.7.TOC Principles

Theory of Constraints is a system-improvement oriented theory. Goldratt suggested several important principles which are put in order in the aspect of system's thinking (Dettmer, 2007):

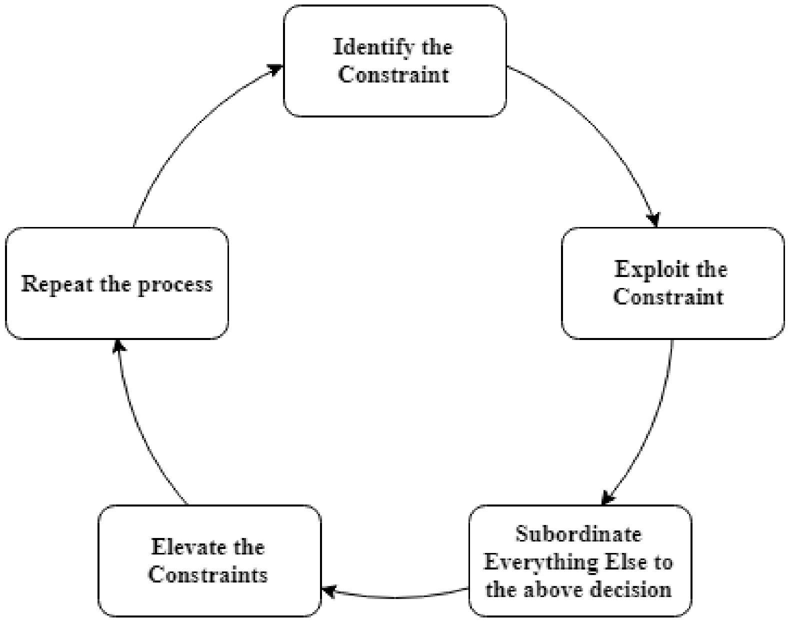
- Systems thinking is preferable to analytical thinking in managing change and solving problems.
- An optimum system solution deteriorates over time as the system's environment changes. A process of ongoing improvement is required to update and maintain the effectiveness of a solution.

- If a system is performing as well as it can, not more than one of its component parts will be. If all parts are performing as well as they can, the system will not be performing the same way entirely. The system optimum is not the sum of the local optimum.
- Systems are analogous to chains. Each system has a “weakest link” (constraint) that ultimately limits the success of the entire system.
- Strengthening any link in a chain other than the weakest one does nothing to improve the strength of the whole chain.
- Knowing what to change requires a thorough understanding of the system's current reality, its goal, and the magnitude and direction of the difference between the two.
- Most of the undesirable effects within a system are caused by a few core problems.
- Core problems are almost never superficially apparent. They manifest themselves through several undesirable effects (UDEs) linked by a network of cause and effect.
- Elimination of individual UDEs gives a false sense of security while ignoring the underlying core problem. Solution that do this are likely to be short-lived. Solution of a core problem simultaneously eliminates all resulting UDEs.
- Core problems are usually perpetuated by a hidden or underlying conflict. Solution of core problems requires challenging the assumptions underlying the conflict and invalidating at least one.
- System constraints can be either physical or policy. Physical constraints are relatively easy to identify and simple to eliminate. Policy constraints are usually more difficult to identify and eliminate, however removing them normally results in a more powerful system improvement than the elimination of a physical constraint.
- Inertia is the worst enemy of a process of ongoing improvement. Solutions tend to assume a mass of their own that resists further change.
- Ideas are not solutions.

1.8.Managing the Constraints - The Five Focusing Steps

The TOC method of improvement consists of five focusing steps to analyse and enhance any company comprehensively (Goldratt 1990, Goldratt & Cox 1992). The FFS are represented in Figure 3.

Figure 3: The Process of Ongoing Improvement



1.8.1. Identify the System Constraint

The main concept of TOC is that every business contains a constraint which could be defined as anything that prevents a business to reach its goals and maximum profit (Mahoney, 1997). Managers need to determine whether the constraint is a physical constraint (e.g. materials, machines, people, and demand level) or a policy/managerial constraint. Therefore, the question is: Which part of the system constitutes the weakest link? (Dettmer, 1997). Besides identifying the constraints, prioritising them according to their effect on the organisation's goal is of great importance (Rahman, 2002).

A business can be viewed as a linked set of operations that turns inputs into sellable outputs. Since TOC considers this linked set of operations as a chain and defines *the chain to be only strong as its weakest link.* A system consists of a combination of resources. It is important that their capacities are calculated separately. These calculations can provide us with the information about how much load a certain resource is able to process. Whether a certain resource is a constraint or not can be determined by the ratio between capacity and market demand. If capacity is lower than or equal to the market demand, the resource is a bottleneck for the system, otherwise it can be expressed as a non-bottleneck (Dettmer, 1998: 5). Once the constraint is identified, the control mechanisms need to be designed according to the constraints, otherwise the system cannot maintain the maximum performance (Siha, 1999).

1.8.2. Decide How to Exploit the Constraint

In this step, Goldratt emphasizes the word »exploit« by which he means to take advantage of every bit of capability and/or capacity in a physical constraint with using the existing resources. According to Dettmer (1997), managers should figure out the answer to this question: "What can we do to get the most out of this constraint without committing to potentially expensive changes or upgrades?”. The intention of this step is to show how to use the constraint. By using the bottleneck, the produced products’ profitability is calculated. It is then determined which products need to use the bottleneck and how often will the use occur (Rahman, 2002). According to the reached amount of product produced in the bottleneck, the capacity of the bottleneck is determined by ranking the profitability values. Hence, the product mix is determined by concluding the type and amount of the product that needs to be produced. By the end of the production, the company is able to determine how much it will earn by means of their sales. TOC emphasises that the bottleneck output is equal to the system output. Net profit is calculated by deducting operational expense from the system throughput (Rahman, 1998: 337).

After the profit values for each product produced have been calculated, it is important to determine the time spent for the products produced. The ratio of the system throughput to the time spent for the products produced determines the product mix (Rahman, 1998: 337). The capacity of bottlenecks must always be used to the maximum, because an hour lost at a bottleneck is an hour lost for the whole system. Managerial constraints should rather than exploited be eliminated and replaced with a new policy that will support increased throughput (Rahman, 2002).

1.8.3. Subordinate Everything Else to the Above Decision

After identifying the constraint and deciding on how the constraint will be tackled, the decision about the next step is up to the system. It important to adjust everything in the system according to these decisions. This will enable the constraint to perform at its maximum. These decisions might cause some parts of the system (non-bottlenecks) to have more idle time, while other (bottlenecks) will be employed to its maximum capacity. It is crucial not to employ resources that do not have to be processed by the bottleneck if not necessary (Rahman, 1998: 338).

This step aims to demonstrate that the functioning of the non-bottlenecks is dependent on the functioning of the bottlenecks. In other words, by keeping the bottlenecks under observation, the aim is to carry out studies that will, with the right decisions and the right timing, prevent the increase of operational expenses, and the accumulation of inventory (Rahman, 1998: 338). Once this has been completed, the results must be evaluated, and it is necessary to figure out whether the constraint is still present. If not, the constraint has been successfully eliminated, therefore we can skip to Step 5. If the constraint has not been eliminated after these steps, we must continue with Step 4 (Dettmer, 1997).

1.8.4. Elevate the Constraints

In case the constraint could not have been eliminated through Steps 2 and 3, the company needs to make bigger changes to its existing system, such as reorganisation, divestiture, capital improvements, or other important system modifications. In case the constraint is the business centre, supplementary preventive maintenance can be applied for the constraint to be eliminated, additional machines can be purchased to increase capacity. The company must be sure that the existing constraint cannot be eliminated through the first three steps, because Step 4 can include abundant investment in time, energy, money, or other resources. "Elevating" the constraint means that the company takes whatever action is required to eliminate the constraint (Dettmer, 1997), therefore to improve the performance of the system according to its aim (Yüksel, 2009: 200). When this step is completed, the constraint is broken (Dettmer, 1997). When performance of the constraints improves, performance of other, non-constraint resources, can also improve. Accordingly, the whole system-performance benefits. However, eventually, the system will encounter a new constraint (Rahman, 2002).

1.8.5. Go Back to Step 1, But Beware of “Inertia”

In case the existing constraint has not been eliminated, it is necessary to go repeat the process until the constraint is fully eliminated (Mabin et al., 2001: 172). If in a previous step a constraint was broken, inertia must not become the system constraint, and we need to go back to Step 1 (Goldratt & Cox, 1992). In case there is another constraint, by going back to Step 1 we can repeat the process of identifying and eliminating it, so our system performance does not drop.

According to Dettmer (1997), the FFS have a direct connection with the three management questions referring to change: what to change, what to change to, and how to cause the change. The FFS help us answer those questions. To determine what to change, we look for the constraint. To determine what to change to, we decide how to exploit the constraint and subordinate the rest of the system to that decision. If that does not do the complete job, we elevate the constraint. The subordinate and elevate steps also answer the question "how to cause the change".

1.9.Advantages and Disadvantages of TOC

TOC incorporates management style and approaches that contribute to a continuous improvement through focusing on constraints that restrain the overall system performance. Rather than concentrating on the inputs and outputs of the system, TOC provides a process-oriented understanding. Some of the main objectives are increasing throughput and net profit by minimising the time between the supply, production, and distribution. The constraints and process-oriented management approach of Theory of Constraints allows for on-time production and delivery of customer orders. TOC aims to minimise the stock of raw materials, semi-finished/work-in-process, and finished goods in the production process, and therefore the costs decrease while profitability increases. Its low cost and easy-to-understand characteristics increase the success of the application. TOC provides several advantages for a business, such as shorter supply and production times, increase in product and service quality, increase in profitability, decrease in stock levels, reducing the number of bottlenecks, constraints management, developing the competitive position, enabling strategic marketing and operational decisions, and continuous improvement in supply chain (Ilhan, 2014: 4-5).

In literature, most of the criticism is oriented to TOC providing short-term solutions. The main reasons for this criticism are that TOC focuses on eliminating the constraints, and that except for direct material and material costs, all other costs should be accepted as fixed costs. On the other hand, Thomas Corbett argues that TOC and accordingly Throughput Accounting concentrate on long-term profitability as well as short-term analysis. Similarly, Robert Kee states that if TOC and therefore Throughput Accounting are integrated with Activity-Based-Accounting and implemented together in a company, the TOC’s short-term analysis will become long-term analysis, and the mentioned negativities can be overcome. Another criticism that has been addressed to TOC is that the theory views businesses as organisations that aim to make money. This criticism is connected to the ‘modern’ businesses that incorporate different goals and missions which include social responsibilities and social benefit. In other words, businesses are not only profit-making organisations as TOC presumes (Kırlı & Kayalı, 2010: 105).

1.10. Benefits of TOC

TOC offers a lot of advantages in terms of businesses, and some of them have been mentioned in the section above. However, this section will concentrate on a brief introduction of the advantages of TOC in terms of the company’s most important issues – cost, on-time production, and system integrity.

The goal of every company is to reduce their costs and increase their profit. Accordingly, it can be said that the aggregation of work-in-process stock, which is a significant cost factor for the company, is prevented by eliminating the bottlenecks. This triggers a cost reduction, and in addition to the production time improvements, orders are completed on time. The most important short-term problems are shortages of semi-finished products and the inability to meet the deadlines. Since TOC performance criteria are throughput and inventory, it can be said that the theory focuses on costs (Ilhan, 2014: 5-6).

Throughput accounting reports, which take practice in TOC applications, are relatively easy to understand and by comparison less costly than other cost reports. Shareholders and business employees particularly can easily comprehend the identified goals and recognise what their obligations that will bring them closer to the goal are. This represents a significant development for a system to be able to perform as a whole (Büyükyılmaz & Gürkan, 2009: 189).

1.11. Successful Applications

Since its emergence in the 1980s, TOC has been applied in many manufacturing companies as well as service companies. Below are some of the successful applications and their results (Adopt a New Approach to Business Management, Online: 07 December 2018):

Dow Corning Corporation: In a six months long improvement process, the company managed to achieve an 85 % cycle time reduction, 70 % work-in-process and finished goods reduction, an increase in on-time delivery from 50 % to 90 %, and number of material handling steps was cut by over half.

TBS Furniture: Operational Expenses 40 %, decrease in stock levels for £2 million, increased capital turnover from £13 million to £17 million. 40% sales increase, 97% delivery performance increase. Order fulfilment dropped from 6-8 weeks to 7 days.

General Motors: After identifying the system constraint, the teams started working together on eliminating it. By using TOC, the teams developed a new work schedule without too much overtime work. At the end of the process, the company managed to increase the throughput ratio.

Avery Dennison: After a 1,5-yearlong improvement process, the market share was between 17% and 25 %, net sales came up to 23 %, order fulfilment increased up to 80 %, new products' sales rose to 50 %, customer satisfaction became 47 %, waste material dropped to 32 %.

Boeing: The length of time of delivery dropped for 75 %. Inventory levels dropped for 60 %, throughput increased for 50 %. On-time delivery rate reached almost 100 %.

Motorola: Throughput increased for 150 % and their production time decreased for 20 %. By using more technology, the possibility of capacity increase was provided.

Rockwell International: Costs dropped for 25 %, time that was spent to check for mistakes on outputs has dropped for 44 %. Nonconcurrences in the production decreased for 20 %.

Ford Motor Company: Quality faults decreased for 50 %, order delivery time decreased between 60 % – 80 %, therefore the orders could reach the customers in a shorter time. Investment productivity increased for 20 %, on-time distribution came up to 38 %. Before the improvement, Ford Motor Company needed 10,6 days for order fulfilment, by implementing JIT it dropped to 8,5 days, however after implementing TOC, it dropped to 2,2 days. Customer satisfaction increased to 75 %.

Pharmacia: In a very short time, the order delivery time decreased by over 60%, which resulted in saving a lot of time. Throughput rate increased, and over 90% of orders were delivered on time. The packaging rate increased from 20% to 50% for one month.

Table 1: Successful TOC Implementation Examples

Company	Constraint	Results
General Electric	Managerial restrictions	The transformation time for direct labour decreased.
American Lighting Standard Corporation	Division from the system goals due to over-focusing on standard costs and capabilities.	The business managed to reach a 40 % profit increase and 60 % increase in cash flow.
Southwestern Ohio Steel	Variable capacity connected to the constraints.	Constraints have significantly improved by using TOC in pricing and development.
General Motors	Due to excess work, excess batches were formed in the system.	Delay time has been reduced by 30 %, quality has increased, and batch sizes have decreased.
Naval Aviation Depot	Because of the way the schedule was developed, the available resource application did not make sense.	The turnaround time dropped from 240 days to 135.
Thomson-Shore	Besides having problems with on-time deliveries, a department-type mentality was present.	On-time deliveries went from 70% to 95%

Source: Louderback & Patterson (1996: 191); Goldratt (2004: 343-372).

Besides the above-mentioned enterprises, many other have adopted and implemented TOC. Accordingly, all of them share a specific place in the world literature; for example: ABB Corporation, AT&T Bell Laboratories, Baxter, Delco Products, Delta Airlines, Harris Semiconductor, Hewlett Packard Puerto Rico, Intel International, IPL, National Semiconductor, Naval Aviation Depot, Pratt &Whitney Government Engines, Procter & Gamble, Samsonite S.A., United States Air Force, United States Coast Guard.

Goldratt's Theory of Constraints has managed to reach businesses world-wide. Some universities and institutes have also adopted TOC and include it in their curriculum; for example: Colorado State University, Iowa State University, University of Richmond, University of Washington, USAF Defence Systems Management College, Virginia Military Institute and Washington & Lee University (Saatçıoğlu, 1999: 81).

1.12. Literature Review

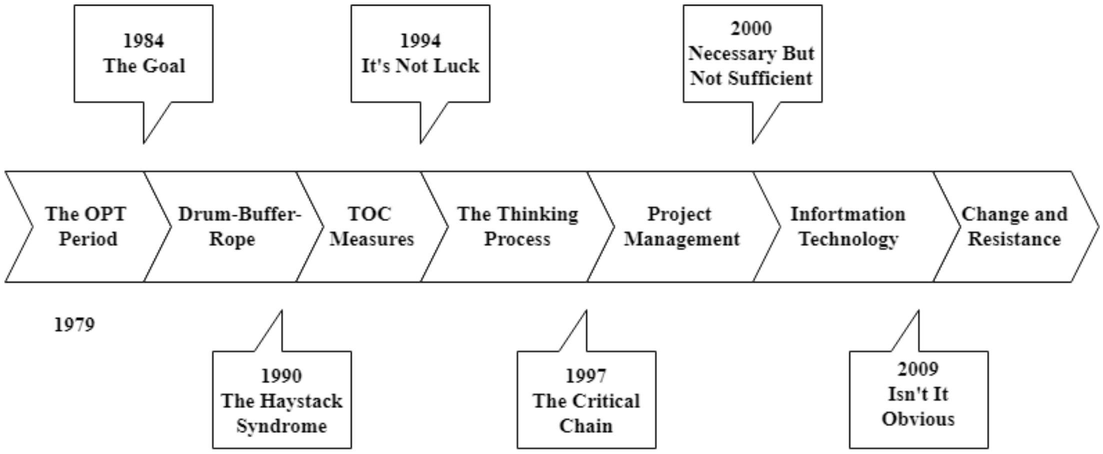
Through the examination of the TOC literature, it can be seen that numerous studies have been conducted as well as implementations of the theory. It is also notable that although TOC has had its first introduction in the late 1970s, it is still a well-known technique, which provided many businesses with competitive advantage. Implementations are more common in the manufacturing sector, however, there are also many studies that have been conducted in the service sector. By following the TOC's five-step continuous improvement process and applying it in a production company, it is believed that this study will make a considerable contribution to the literature, the company's and other similar businesses' performance and profitability, and it could also provide guidelines for further studies.

In 1979, the introduction of the Optimized Production Timetables scheduling software brought to the development of a management philosophy, the Theory of Constraints (TOC). Goldratt developed the theory as a problem-solving approach, that can be applied in different business fields (Unal et al., 2007: 24). The TOC can also be viewed as a continuous improvement process, which through a five focusing step process enables organisations to identify the constraints and find ways to stop them from damaging the company's performance.

Goldratt defines the purpose of a business as »to make money now and in the future«, and every action of the business is considered an action towards that goal (Goldratt & Cox, 2006). TOC assumes that there is at least one performance limiting constraint present in every organisation (Sheu, Chen & Kovar, 2003: 434). A constraint is considered as anything that prevent the business from achieving its main objective to make higher profits (Siha, 1999: 255). The Theory of Constraints can be used as a set of guidelines for managers for identifying the reasons that restrict their organisations from improving (Simatupang, Wright & Sridrahan, 2004: 58).

Goldratt first published his novel *The Goal* in 1984, which documented the TOC on an example in a factory scenario (Gupta, Bhardwaj & Kanda, 2011: 134). Later he wrote his other books; *The Race* (1986), which describes the stock control management (logistics systems) used in manufacturing companies, *The Haystack Syndrome* (1990), which was about the constraints encountered in decision making, *It's Not Luck* in 1994 presented the thinking processes and the tools that need to be used in the process, *The Critical Chain* (1997) included project management constraints, *Necessary But Not Sufficient* (2000) problems encountered in the information technology were covered, and in *Isn't It Obvious* (2009), Goldratt examined how changes are made in an organisation and the resistance against these changes were addressed (Büyükyılmaz & Gürkan, 2009: 178). The developmental stages of TOC can be seen in Figure 4.

Figure 4: The Timeline of The Development Stages of TOC



Source: Watson, Blackstone & Gardiner, 2007: 388

Besides Goldratt, other scientist have also written books on the Theory of Constraints topic; Umble & Srikant (1997), Cox & Spencer (1998), Stein (1997) analysed the scope and principles in TOC process management; Lockamy & Cox (1994), Noreen et al. (1995), Srikanth & Robertson (1995), Smith (1999), Corbett (1998) analysed the TOC performance criteria and throughput accounting; Dettmer (1997), Scheinkopf (1999), Schragenheim (1999), Hutchin (2001), Kendall (1998), Newbold (1998) have published books on the problem solving / thinking process of TOC (Boyd & Gupta, 2004: 352).

Both theoretical and practical studies in the literature, that concentrate on the topic of TOC, include areas such as accounting, programming performance measurement, project management, product mix and quality, and their application areas (manufacturing, service, software, army, education) (Mabin & Balderstone, 2003: 573). When examining the previously conducted studies in the manufacturing sector, it can be said that TOC increases productivity both on an organisational as well as individual level (Lubitsh, Doyle & Valentine, 2005: 117). Mabin and Balderstone surveyed over 100 events in various sectors (automotive, electronics, semiconductor industry, furniture, apparel) in the year 2000. The research resulted in a 49% average inventory decrease, and in terms of the preparation time, turnaround time and completion date, the production process performance and the financial performance both increased by 60% (Gupta & Snyder, 2009: 3707).

In spite of the differences between a production and a service system, Siha (1999: 255-264) demonstrated the successful applicability of TOC in the service sector. Other examples of TOC application studies in the service sector include: Womack & Flowers (1999), Gupta & Kline (2008) TOC's continuous improvement process; Lubitsh, Doyle & Valentine (2005) worked on the effectiveness of TOC in the service sector by implementing its change methodology in healthcare institutions (Womack & Flowers, 1999: 397-408; Gupta & Kline, 2008: 281-294; Lubitsh, Doyle & Valentine, 2005: 116- 131). Reid (2007: 209-234) conducted a study where a service process that was limiting the overall service system of a bank was identified and eliminated. Dalci & Koşan (2012: 541-568) analysed the implementation of the TOC thinking process tools in a hotel management.

TOC has helped thousands of businesses worldwide to achieve significant improvements (Geri & Ahituv, 2008: 341). Companies such as Amazon, AVCO, 3M, Bendix, Boeing, Delta Airlines, Ford Motor Company, General Electric, General Motor, Kodak, Philips, RCA, Lucent Technologies and Westinghouse have adopted the understanding of constraints management. Accompanying them, non-profit organisations and government agencies, such as Habitat for Humanity, British National Health Service, United Nations, Israel Air Force, NASA, Pretoria Academic Hospital, and the United States Department of Defence (Air Force, Marine Corps, Navy) have also successfully implemented the Theory of Constraints in their systems (Sobreiro & Nagano, 2012: 5936; Watson et al. 2006: 388).

CHAPTER 2

TOC METHODS AND MEASURES

2.1.Methods used by TOC

The application of TOC offers the use of miscellaneous methods that can be expressed in the form of three headings and sub-headings as follows:

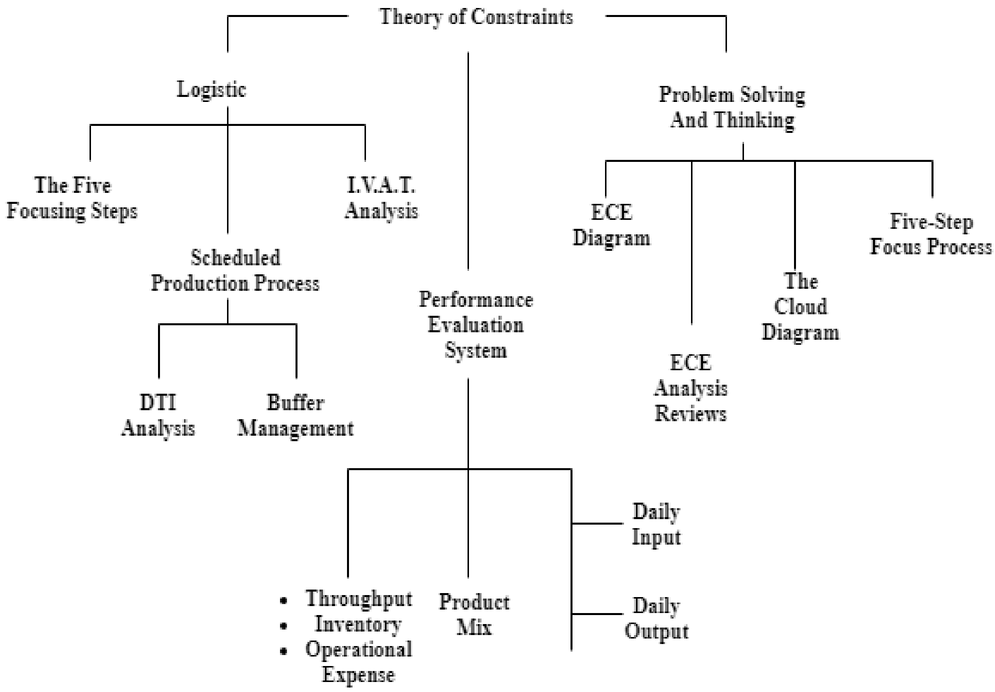
1) Logistics
- The Five Focusing Steps
- Drum-Buffer-Rope
- I-V-A-T Analysis

2) Performance Evaluation System
- Throughput
- Inventory
- Operational Expense
- Product Mix

3) Thinking process in Problem Solution
- The Cloud Diagram
- ECE (Effect – Cause – Effect) Diagram (A diagram that is made up from all of the thinking processes and is used in problem solving)

The summary of the methods is presented in the figure below:

Figure 5: TOC Methods



Source: Spencer & Cox, 1995: 1501

2.2.TOC in the Production Process

TOC is included in the production processes through miscellaneous concepts, however how the capacity is handled with varies according to other production systems. Capacity is usually evaluated in accordance with the market demand. Though, instead of capacity, TOC tries to adapt the flow to the market demand. When the market demand is put in the forefront, inventory levels increase and a decrease in flow will occur. Consequently, none of the concepts that TOC was based on, such as flow, inventory, and OE, are fulfilled and losses in earnings transpire. In *The Goal,* this situation is described and the reasons for it are disclosed. According to Goldratt (2004) the dependence of an event to the previous event and the information that has been obtained concurrently with the production process may differ. This is commonly referred to as “linked events” and “statistical fluctuations”. The two concepts must act together.

Goldratt managed to develop a new form of classification and definitions in production systems, only to eliminate the effects of the above-mentioned situations by using the I-V-A-T analysis while carrying out the classification. The classification is as follows:

Production According to The Order: This type of system produces according to the demand change, has a variety of products, decreases repeats of processes during production and accomplishes production with multi-purpose machines. Companies that choose production according to the order face many issues due to the volatile nature of the demand.

Batch Production: Customer demand and production systems do not show a wide variability; therefore, the customer group requests are placed in the beginning. When a new request of another customer group comes is, the process rearranges itself from the beginning according to the new order. According to other production systems, this type of system has an advantage in terms of cost (preparation, equipment etc.) and on-time deliveries. The length of the production time can be specified as a disadvantage.

Continuous Production: This type of production focuses on the automatization of the flow of materials in the material line and simultaneously produces high volume standard production. Continuous production contributes to lower unit cost, because the cost is spread across the volume. Therefore, any pause in the material line will cause the costs to rise. Pausing the production should not occur because continuous production has very high fixed cost (Acar, 1998: 12).

Project Type Production: Productions like this are based on specific one-of-a-kind orders, for example a ship or plane. The work that is carried out in this type of production includes, as the name indicates, a project. The volume of work that needs to be done to complete this kind of production is quite large. The requirements vary depending on the content of the project. The resources are collected only once. Special management methods have been developed for these types of productions to stay in a reasonable cost range. To develop the project on time, all activities need to be planned ahead at the desired time and place. Any problems that could be encountered before the completion of the project can cause delays, therefore, appropriate measures need to be taken (Tekin, 2006: 36).

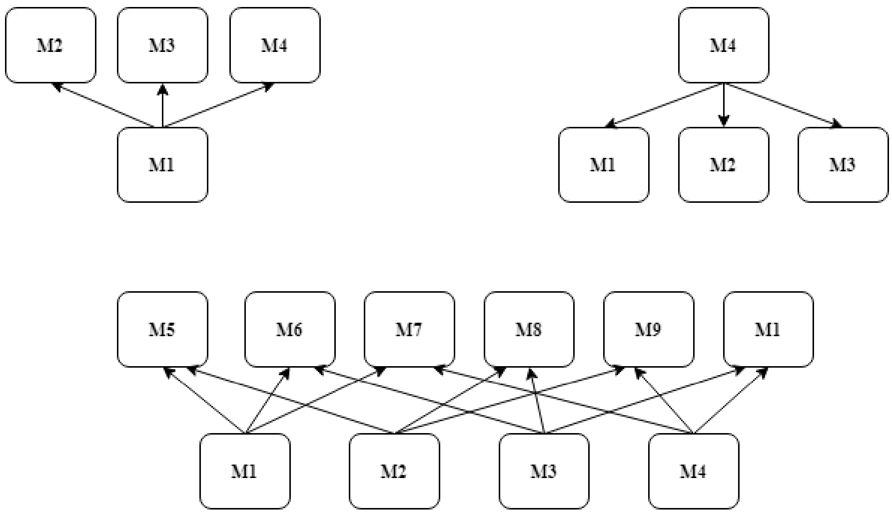
2.3.I-V-A-T Analysis

Different classifications in terms of changes in the production line can be formulated in the production process. The I-V-A-T analysis aims to better understand the process of material movements in the production line during the production.

Goldratt suggests that there are four groups a company should be examined in. These groups are the following: the I type, V type, A and T type companies (Aryanezhad & Komijon, 2004: 4221). The letters I, V, A, and T stand for the shape of the dominant product paths and the list of material structures within a manufacturing facility (Lockamy & Cox, 1991).

In the I-V-A-T analysis, the most important points are junction and separation. When referring to junction it is about combining the materials that need to be processed through the production line with the routes that the materials will follow. In other words, junction is referring to the product flow. Separation is referring to the separation of materials into different materials. When these two points are adapted to the assembly line, with junction, the assembly of two or more products can be used to make one single product. With separation, the disassembly of the common components can be used to create the main product (Tersine & Hays, 1994: 591). The figure below illustrates the assembly using junction and separation points.

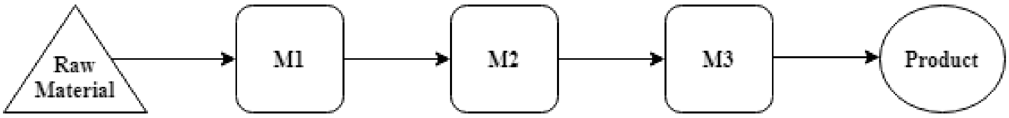
Figure 6: Separation and Junction Assembly Points



Source: Umble & Srikanth, 1990

I-Type Businesses: This type of structure is considered to be a mass production method. It holds characteristics, such as high-volume production, standard design and constant demand. The products produced adhere to a certain route. This indicates that the I Type business structure is made up of continuous or repetitive processes. The structure can be seen in the Figure below.

Figure 7: I Type Product Flow



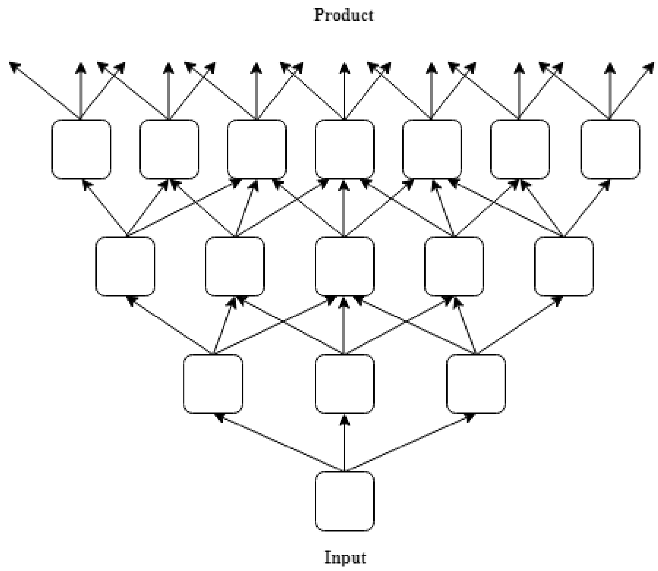
Source: Kartal, 2006: 25

V-Type Businesses: Knowing how the product flow during production works, allows for identifying the separation points. By knowing the separation points it is possible to know whether a business is a V type business. The products are obtained through the standard production process with the help of less raw materials. In the V type plant, the product inventory is available and is very weak in terms of distribution. It can be described as the sum of the I type plants where the products that follow the same routes are available with the same raw material. Examples of V type businesses would be plants with manufacturing facilities and process production (textile, chemistry, metal paper, etc.) (Karamaraş, 2002: 70).

Comparing to other types of plants, this type usually has low amounts of raw material according to the amount of product it produces. Standard production processed products are manufactured following a standard course. V type businesses have a limited number of workbenches; however, they still aim to produce abounding production in a short period of time.

As mentioned before, in the V type plant the product inventory accumulates, and it is very weak in terms of distribution. Since the production process does not occur as predicted, meeting customer demands becomes difficult. Consequently, the continuous delays in delivery to customers cause customer dissatisfaction. To achieve peace in every company, the significance of harmony is emphasised. However, although harmony is prioritised, an inter-departmental competitive element is arising. Examining the possible reasons for the above-mentioned issues, it is anticipated that the arrangement of the machines is long, the production is producing a large quantity, and, the raw material is supplied into the production line earlier than required to reach high capacities. it is possible to tackle these problems by reducing batch volume sizes, and the production time. The V type assembly phase is shaped in the form of the letter V. This is illustrated in Figure 8.

Figure 8: Production in V Type Businesses

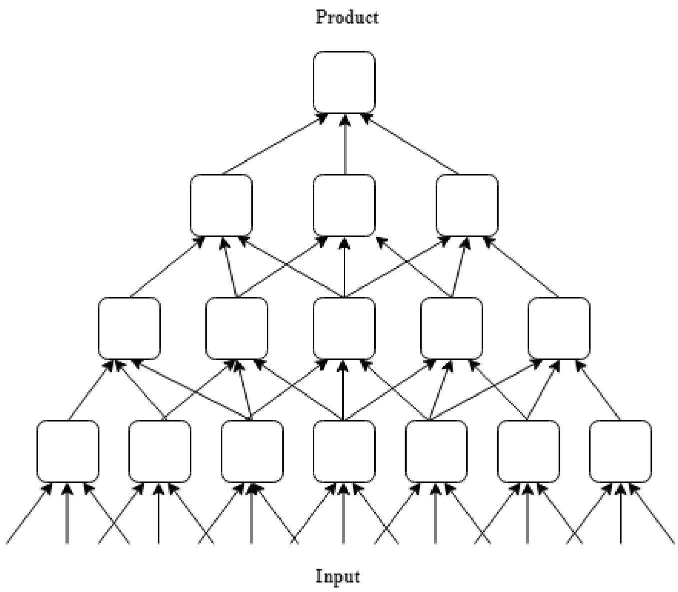


Source: Chase et al., 1998: 811

A-Type Businesses: In contrast to the V type business, it is possible to know whether a business is an A type business by knowing the junction points. In this type of business, the amount of obtained products is low. Due to overtime in production, customer demands are met on time.

The conventional features of A type businesses are long production times, inability of parts to reach the assembly points, overtime due to low efficiency, resource shortages for some parts, more than one and different resources are bottlenecks, and insufficient supply in the assembly line. Examining the possible reasons for the above-mentioned issues, it is visible that employees must do overtime due to improper arrangements of their work programmes, there is not a single bottleneck resource, in other words, there is variability of bottleneck resources according to the produced product, and the required parts do not reach the assembly point on time (Saatçıoğlu, 1999: 46). The A type assembly phase is shaped in the form of the letter A. Figure 9 illustrates the A type business assembly phase.

Figure 9: Production in A Type Businesses

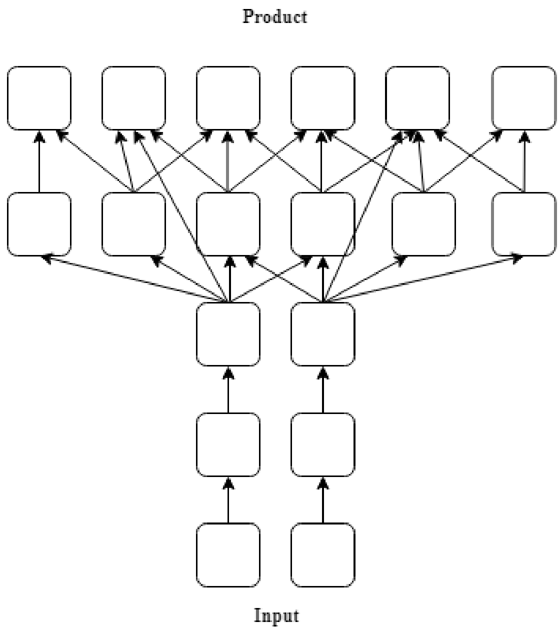


Source: Umble & Srikanth, 1990: 228

T-Type Businesses: Examining the assembly phase, the name T type businesses has been given because it resembles the letter T. The parts that await assembly are stored after they have been produced. To obtain the final product, the stored parts are brought together in the assembly line. Neither the junction points nor the separation points of the parts are related to the T type business characteristics. In this type of business, the materials pass through common assembly points in becoming the final product (Cox & Spencer, 1998: 105).

The T type business characteristics would be unspecified production process, inability to provide the parts on time, the amassing of the semi-finished products and production of large batches. Consequently, one of the most common problems encountered are delays in delivery. This problem can be resolved by reducing the batch sizes and coordinating the organisation with the customer orders. Figure 10 illustrates the production in the T type businesses.

Figure 10: Production in T Type Businesses



Source: Chase et al., 1998: 811

2.4.Drum – Buffer – Rope

TOC consists of the FFS for continuous improvement, the drum-buffer-rope (DBR) scheduling methodology, and the buffer management information system (Rahman, 2002). To preserve maximum performance in the system, it is necessary to create a system where machines with the lowest capacities within the system, i.e. bottlenecks, operate at maximum capacity. The DBR approach is used to control the flow or orders throughout the production system. The *drum* can be delineated as the flow of orders and materials to the system. It is important to coordinate the flow according to the capacity of the system constraint. The drum represents the capacity constraint, i.e. bottleneck. In other words, the bottleneck determines the tempo for the system in a way as a drum determines the pace for marching soldiers. If the materials start coming in too fast or in too big quantities than the bottleneck can process, the amount of inventory in the flow will increase and therefore the costs will increase too. Consequently, the system flow will decrease. In contrast, if the materials arrive to the flow too slow than the bottleneck can process, then the company will experience losses in sales, because the bottleneck capacity has been wasted. *Buffers* are used in order to divide or eliminate the dependencies between some resources. In other words, the buffer shields the bottleneck from unfavourable effects from the rest of the system.

The *rope* has influence on all parts of the system which must be connected to each other. It connects raw material release to the bottleneck buffer to ensure that inventory levels are at minimum. The rope is the information flow between the constraints and the rest of the system (Siha, 1999; Watson et al., 2006; Yüksel, 2009: 203).

The drum determines the tempo of the production, and the rope acts as a material release mechanism. Buffers are cleverly inserted to protect shipment dates and to prevent starvation. They could be associated with work-in-process; however, TOC most commonly uses three buffer types: time, shipping, and capacity. Material releases are delayed by using time buffers, or in other words a fixed amount of time. Shipping buffers uphold a small amount of inventory of finished goods to protect the due dates. They also allow businesses to have a bigger responsiveness to market demand by being able to deliver an item in less than the manufacturing lead time. Capacity buffers are present in TOC to the extent that non-bottlenecks have extra capacity, because material release is done according to the bottleneck capacity. The »length« of the rope, i.e. the amount of material released to the production, is determined by the buffer that provides protection to the constraint (Watson et al., 2006).

It is essential to have control points in the production system to be able to control the flow of the system. If a system has bottlenecks, they can be considered as control points. It is important to balance the system flow according to the bottleneck. Any agglomerations that could occur in the bottleneck are to be blocked by establishing connections between them. Control points are described as drums and the established connection as rope (Ünal, 2000: 51).

The DBR approach was introduced and described in *The* Goal through an example of Alex Rogo's plant. As he is faced with the closure of his factory in three months' time if its performance does not improve, he turns to Jonah, his old college professor. Jonah leads Alex to the answers that he needs for improving his plant. Trying to find a way to improve throughput and to make more money, Alex figures out that the throughput of the plant must be limited by the potential output of the machine(s) with the least capacity. He then manages to identify two machines as bottlenecks.

To achieve maximum throughput, the focus must be on managing the bottlenecks. The occupancy of the bottlenecks must be maximized; hence, the bottlenecks should not have idle time. This means they require a *buffer* of parts sitting in front of them to prevent the possible »starvation« of the machine, therefore for the machine not to have parts to process. The quality control should be moved in front of the bottlenecks, to stop rejects from being processed by the bottleneck and therefore taking up constraint time. Alternative routes for some parts should be investigated, so the bottleneck does not process parts unnecessarily.

Managing non-bottlenecks is different. In contrast to bottlenecks, non-bottlenecks have excess capacity, however they do not need to be run constantly. If the non-bottlenecks are continuously run, they will produce excess inventory which the bottlenecks will not be able to process. It is important to schedule the non-bottlenecks according to the bottlenecks. This allows for inventory to increase only in the buffers and decrease in the rest of the production plant (Dugdale & Jones, 1998: 75 – 76).

Applying all his new knowledge in his plant, Alex and his team managed to achieve increases in throughput, however the system needed continuous improvements. With his team, they learn to run the new system. With the new learnings, Alex summarizes the approach into Five Focusing Steps. By following these steps, the production system requires the beat of the production flow to be dictated by the beat of the bottlenecks ("Drum"). They are then given a time-margin before them ("Buffer"), as they draw or block the release of materials according to customer orders ("Rope") (Dugdale & Jones, 1998: 75 – 76).

2.5.The Thinking Processes

The first thinking processes (TP) tools were developed in 1987. Goldratt created the TP methodology that uses common sense, intuitive knowledge and logic to address the policy constraint and create breakthrough solutions (Rahman, 2002). The TP provide exact and orderly means to address identification and solution of unorganised business problems related to management policies (Schragenheim & Dettmer, 2000). With all the research done within an organisation's production area, by eliminating the constraints the company strives to be more productive. To achieve all the organisation's goals, it is necessary for the management to make the valuable decisions. When the board addresses change, three very important questions need to be answered; what will change, what will it change to, and how is the change going to be caused.

Applying the TP tools usually starts with identifying of the main problem(s) by developing the Current Reality Tree (CRT). An augmentation to the traditional method permits the main problems to be derived from the so-called three-cloud method, which starts by creating the three evaporating clouds. The production of the core conflict cloud (CCC) is allowed by the commonness in the cloud elements. The CCC provides an important understanding to the underlying conflict, simplifying production of the CRT (Button, 1999, 2000; Smith, 2000; Chaudhari & Mukhopadhyay, 2003; Reid & Cormier, 2003).

Essentially, Theory of Constraints is about change. According to Dettmer (1997), applying TOC principles and tools answers the three management questions referring to change: what to change, what to change to, and how to cause the change. These questions are not process-level questions but rather system-level questions.

Table 2: Thinking Process Tools and Their Roles

Basic questions	Purpose	TP tools
What to change?	Identify main problems	Current reality tree
What to change to?	Develop simple, practical solutions	Evaporate cloud Future reality tree
How to cause the change?	Implement solutions	Prerequisite tree Transition tree

Source: Mabin et al., 2001: 171

Many organisations have come to a conclusion that a process of on-going improvement is absolutely necessary. If an organisation wants to achieve a process of on-going improvement, the above-mentioned basic questions need to be answered faster and more efficiently (Burton-Houle, 2001). Dettmer (1997) rephrases the questions to:

- Where is the constraint? (What to change?)
- What should we do with the constraint? (What to change to?)
- How do we implement the change? (How to cause the change?)

2.5.1. What to change?

Organisational development requires a change, which does not always result in progress. It is possible for change to cause bad results, if the focus is on wrong components. Therefore, determining what is to be changed is very important. This question identifies the wrong policies and factors that restrict the performance of an organisation. Hence, the cause-effect technique is used for this. The above-mentioned conditions that would restrict an organisation's performance, can be referred to as constraints. By answering the "*what to change"* question, and through the application of TOC, organisational constraints are identified. For this purpose, the Current-Reality tree method is used (Akman & Karakoç, 2005).

With the list of apparent symptoms, cause-and-effect is used to recognise the main problem for all the symptoms. Burton-Houle (2001) describes the Core Conflict as an unresolved conflict in organisations that keeps them cornered and/or distracted in a never-ending struggle (management vs. market, short term vs. long term, centralise vs. decentralise, process vs. results).

2.5.2. What to change to?

This question refers to investigating the logical, simple and practical solutions for the underlying problem. TOC suggests that the above-mentioned types of solutions in the real world have the power to defeat problems. In this step it is determined what the policies that fail to generate any solutions need to be reconstructed into. To achieve this, the Evaporating Cloud and Future Reality tree methods are used (Akman & Karakoç, 2005).

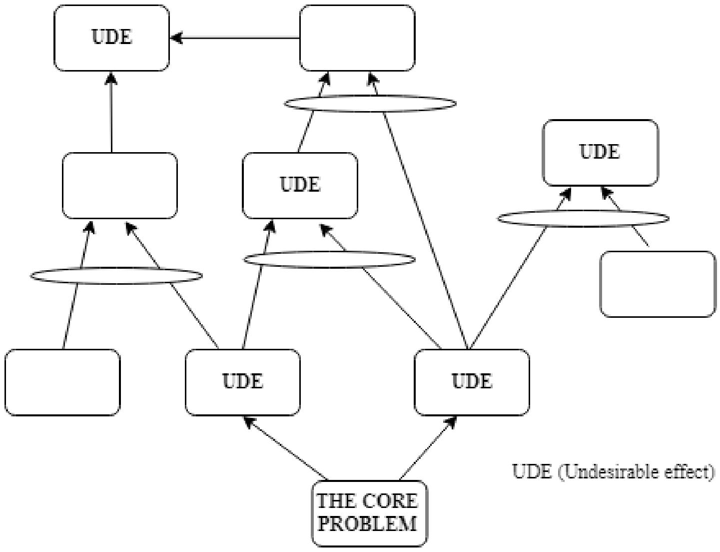
2.5.3. How to cause the change?

As the question implies, in this step, the ways of implementing the solution are investigated. For finding the right answer, this step includes the Prerequisite tree and Transition tree.

2.5.4. Current Reality Tree – CRT

The Current Reality tree is an analysis that works to resolve the issues in the company by examining the cause-effect relationship. As mentioned above, by answering the question of what to change, this analysis tries to determine the reasons for the main problem that causes unwanted results. CRT tracks all unwanted effects down to the core cause and eventually finds the main problem (Dugdale & Jones, 1996: 73). The Figure below illustrates the approach to this analysis.

Figure 11: The Current Reality Tree



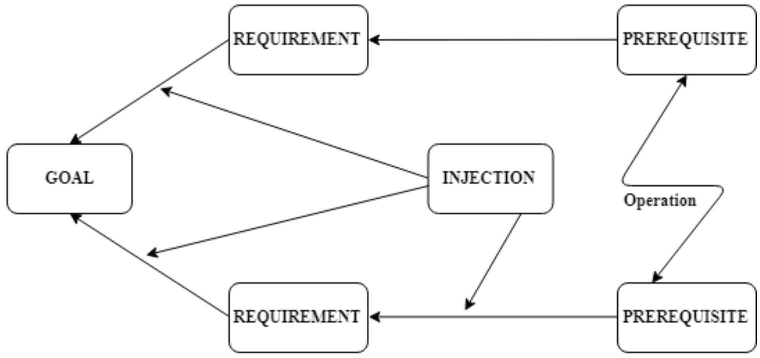
Source: Dettmer, 1997: 22

In most occasions, *brainstorming* analysis is used for CRT analysis. Brainstorming is when the board of directors comes together to examine the results of the CRT and tries to deal with the problems by focusing on ways of solution.

2.5.5. Evaporate Cloud – EC

The EC analysis falls under the question of what to change to. Therefore, it shows the need for a company to make a change towards what it needs to achieve. The EC analysis tries to oust the discrepancies that forestall the solution of the cause of the chronic problems. The Evaporating Cloud reveals the underlying conflict clearly and exposes its hidden assumptions, so that one can be revoked (Utku, 2007: 53). The Figure below illustrates the approach to this analysis.

Figure 12: The Evaporate Cloud

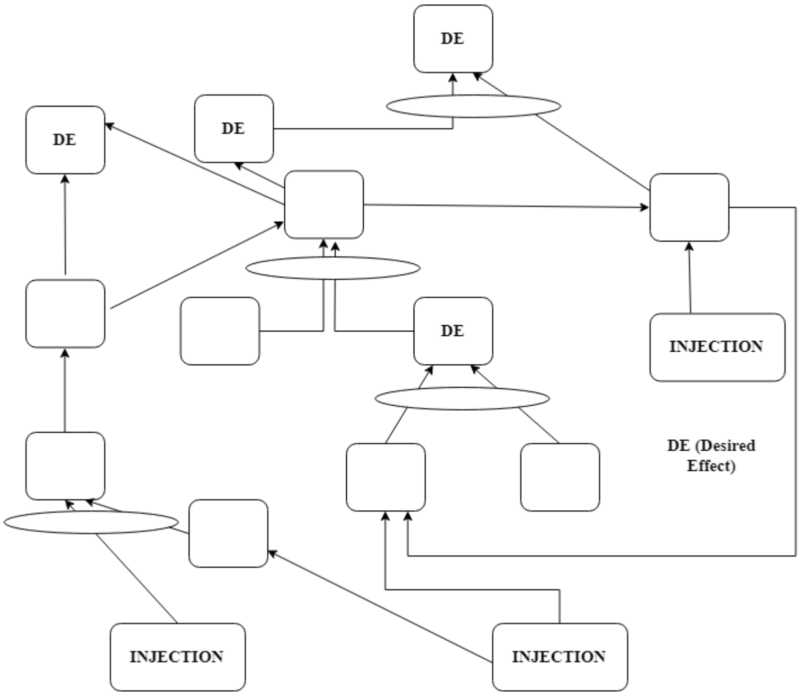


Source: Dettmer, 1997: 22

2.5.6. Future Reality Tree – FRT

As opposed to Current Reality tree analysis, the Future Reality tree analysis makes it possible to distinguish the results of the solution and try to forecast the results of the solution. The first step is to intensively examine the preferred solution, and the second is to eliminate all the elements that are causing the contradiction. The FRT shows all the consequences of the proposed injections in order to ensure that they are sufficient to solve each undesirable effect (UDE) (conflict resolution measures). Similar as for the Evaporate Cloud, the aim is to answer the question of what to change to (Utku, 2007: 55). The Figure below illustrates the FRT.

Figure 13: The Future Reality Tree

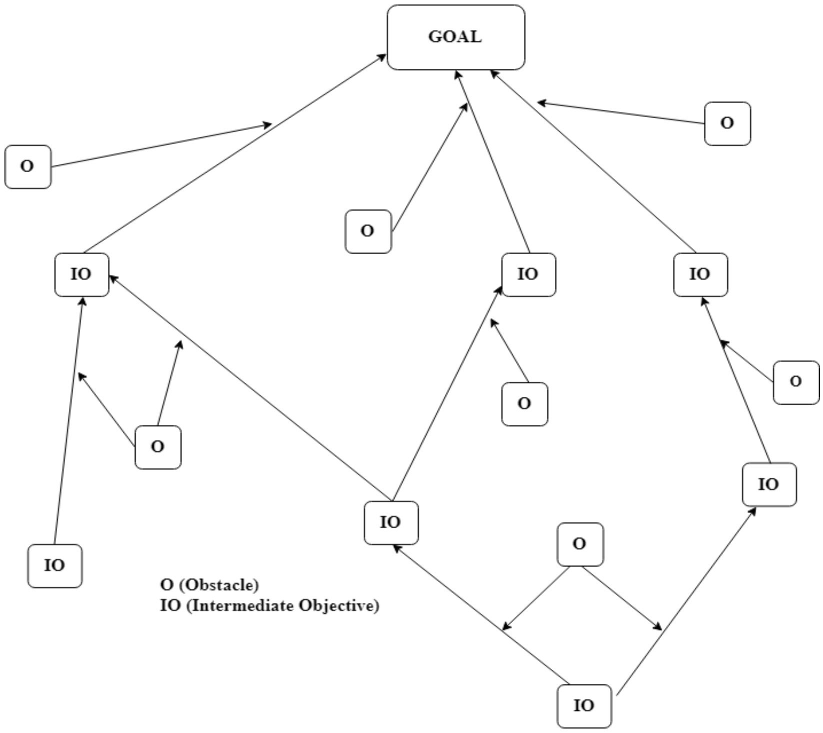


Source: Dettmer, 1997: 22

2.5.7. Prerequisite tree – PT

The Prerequisite tree analysis tries to determine the objectives that are in-between and that allow the organisation to reach its established goal. This analysis offers an insight into the path that needs to be followed to cause the change. The PRT is for more intricate undertakings (Rahman, 1998: 341). The Figure below illustrates the approach to this analysis.

Figure 14: The Prerequisite Tree

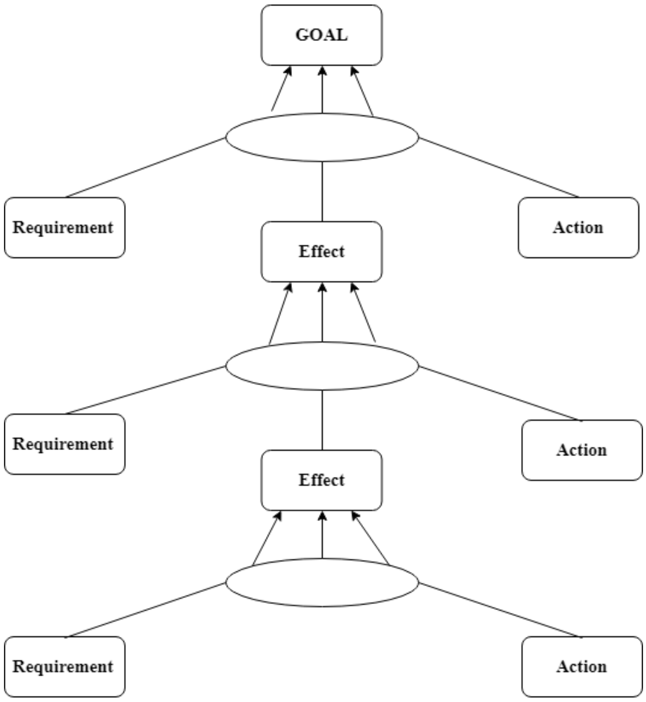


Source: Dettmer, 1997: 22

2.5.8. Transition Tree – TT

With this analysis, the point that a business wants to reach now and in the future is made clear. In other words, it is precisely defined how the business will change according to the company's purpose. The TT analysis is described as a preliminary study, and it demonstrates the reasons for what needs to be done and how much it can help to reach the goal. The Transition tree arranges a complete set of actions to get from the starting point to the final objective (Karamaraş, 2002: 88). The Figure below exhibits the Transition tree.

Figure 15: The Transition Tree



Source: Dettmer, 1997: 22

2.5.9. The 3-Cloud Method

To identify the problems and to go through the implementation faster, Goldratt developed a simplified »3-Cloud Method«. In addition, Goldratt et al. (2002) introduced a precise implementation template called »Strategy and Tactic Tree«. Combined with the 3-Cloud Method, they are remarkably effective in solving abounding business problems.

The Strategy and Tactic tree (STT) is a graphic description of the hierarchal structure between goals, objectives, intermediate objectives, and tactics (Goldratt et al. 2002). The STT is considered to be the most powerful tool of the Thinking processes. It is the formal replacement for the prerequisite tree, and it coordinates the knowledge acquired by the previous tools. Strategy provides the answer to »What for?« and tactic answers the question »How?«. The STT tree enables focusing as a logical structure. Considering the company's strategic objective, the STT tree the necessary and unnecessary actions that need to be taken, and their sequence (Cox & Schleier, 2010: 8).

2.6.TOC Performance Measurements

TOC gives priority to maximizing throughput and simultaneously reducing inventory and the carrying cost of inventory, i.e. operational expense. Besides these three performance measurements, net profit, cash flow, and investment return rate have been added to the performance measures too. TOC also focuses on identifying and eliminating the constraints which can decrease the amount of potential throughput that a company could achieve. The management's purpose of using the TOC process is to eliminate all the constraints that lie inside a system, therefore the new constraint should move outside of the system. A good example would be when a company would complete all their orders but would have a shortage of incoming orders. This means that the system's constraint is in the sales area rather than the production area (Pegels & Watrous, 2005). The Theory of Constraints has various performance measurements, which define the purpose of an enterprise.

According to Goldratt (2004) in *The Goal*, the conventional measurements that were used to express the goal did not lend themselves very well to the daily operations of the manufacturing organisation. That is why he developed a different set of measures which express the goal of making money perfectly, and they allow the development of operational rules for running a plant.

TOC implies that organisations should, for a better guidance of all employees and each unit in compliance with the main objective, and to determine if there is any progress in reaching the goal find answers to three important questions (Ilhan, 2014: 18). Instead of a collection of traditional measures, Goldratt suggested remodelling accounting from the base. In other words, managers needed to know the answers to the following questions (Goldratt, 1990: 19):

- How much money is generated by our company?
- How much money is captured by our company?
- How much money do we have to spend to operate it?

The answers to these questions can be provided by just three key measures: throughput, inventory, and operational expense. Goldratt goes on to define throughput, inventory and operational expense as follows:

Throughput, i.e. cash 'generated', is calculated as sales revenue less any materials and services purchased outside of the company that are directly connected to the product sold. *Inventory*, i.e. cash 'captured', incorporates stock, machines and buildings. *Operational Expenses* (OE), i.e. cash 'spent', consists of all the conversion costs which are all non-material costs, including all employee time – direct or indirect, operating or idle time (Dugdale & Jones, 1998: 77 – 78).

Improving one measurement alone will not improve the system's income. Improving all three measurements simultaneously will increase the incoming money, i.e. net profit. Influencing inventory, OE and throughput, impacts measurements such as net profit, cash flow, and return on investment. In effect, TOC acknowledges a relationship between local and global performance measures. According to Dettmer (1997), if the same sales revenues can be attained with less inventory and lower OE, the net profit of the company will increase. Therefore, increasing throughput while decreasing inventory and OE the system would improve. As a manager decides what action to take, Dettmer (1997) suggests these questions should be answered:

- Will it increase Throughput? If so, how?
- Will it decrease Inventory? If so, how?
- Will it decrease Operational Expense? If so, how?

If the answers to these questions are »yes«, a manager can proceed with his decision, being sure that the overall system will benefit from it. Otherwise, a re-evaluation should be considered. Essentially, if it does not end up increasing throughput, time and probably our money is being wasted (Dettmer, 1997).

2.6.1. Optimum product mix

According to TOC, when there is an existing bottleneck that is restraining a product, the best strategy for determining the product mix is based on throughput – system performance – in terms of the desired constraint (Mansouraba et al., 2013: 146).

One of the miscellaneous definitions of product mix is the following (Patterson, 1992):

»The core problem is made up of both the quantity and the identification of each product to produce. The aim of the organisation is to maximize profit or minimize loss.«

The definition summarizes the problem; however, it does not include the precise depiction of the conditions wherein this identification is valid. A more appropriate definition describes the product mix choosing as the optimum quantity of each product type in a given period and acknowledges that on the path to maximize the firm's economic results (Fredendall & Lea, 1997) products compete for a limited number of resources (Hodges & Moore, 1970).

A traditional method for product mix choosing is to give the selected products that have a higher product margin priority, regardless of considering the elapsed time (Patterson, 1992; Goldratt & Cox, 1984; Blackstone, 2001; Lea & Fredendall, 2002). This method is referred to as *traditional marginal approach*. In TOC, the objective is to choose the product line on the basis of the constraint(s) elapsed time throughput (Mansouraba et al., 2013: 146).

Product unit throughput is the result of sales revenue less total variable costs. This means that in a bottleneck, priority is given to the products that have a higher throughput and that have the lowest production time on the constraint (Roodposhti, 2007). Hence, the amount of throughput in a minute is the criteria for the manufacturing prioritization of the products (Mansouraba et al., 2013: 146).

In the process of selecting the product mix through the TOC-based method, the following steps should be taken (Mansouraba et al., 2013: 147):

1. Identifying the system constraints by calculating the needed capacity in each resource to produce all products. A constraint or a bottleneck is a resource for which the market wants to increase capacity.
2. Deciding how to handle the system constraints by:
   a) Calculating the Contribution Margin Ratio (CM) for each product by deducting raw material (RM) costs from the sales price.
   b) Calculating CM ratio for product that is produced on the bottleneck (BN) source.
   c) Making the BN capacity equal to the capacity limit of the BN to decrease the CM/BN ratio for products.
   d) Carefully planning out the manufacturing of all products which do not need to be processed by the bottleneck resource, to decrease their CM ratio (Lea & Fredendall, 1997: 1535-1536).

When that theory was suggested, TOC-based creativity for choosing the best product mix in all cases was introduced (Mansouraba et al., 2013: 146).

It is possible to determine product mix by using different approaches. The Theory of Constraints (TOC) and Activity Based Costing (ABC) present two views of relevant costs in this decision process, whereas, linear programming (LP) presents a method. The linear programming method incorporates inputs from TOC or ABC to choose the optimal product mix. Accordingly, it is able to present an alternative to several heuristics (Hájek, 2014: 435).

The product mix of the company needs to be determined correctly so the resources can be operated as efficiently as possible. The company that manages to organise the right combination of products to produce, will gain a competitive advantage. ABC and TOC represent different approaches to determine a firm's product mix (Hájek, 2014: 442).

The heuristic phrase is described officially in many publications and compilations (Patterson, 1992; Goldratt, 1990; Goldratt & Cox, 1984; Blackstone, 2001; Lea & Fredendall, 2002). Lea & Fredendall (2002) suggested selecting the product approach after Goldratt & Cox (1984).

The heuristics will not lead to the optimal solution under the circumstances when there is an addition of a new product within an existing product mix as well as the presence of multiple bottlenecks (Aryanezhad & Komijan, 2004). When multiple bottlenecks are present, TOC heuristic is usually directed the to the bottleneck that is most overloaded (Souren, Ahn & Schmitz, 2005). Besides this, another shortfall of the heuristic is when the raw material is not the only variable ("direct") cost (Louderback & Patterson, 1996).

Attempts to prove that the original TOC heuristic is able to reach optimum even when multiple bottlenecks are present have been made, however, subsequently they have been discredited by Balakrishnan (2000).

In evaluating the economic results of the decisions about production, TOC presents an alternative view to the traditional accounting (Unal, 2006). TOC connected product-mix decisions should regard considerations like the level of satisfaction of the decisionmaker to make the correct product-mix decision. According to Bhattacharya & Vasant (2006), the sensitivity of the decision made, needs to be focused on the bottleneck-free, optimal product-mix solution of TOC problem.

The traditional approach indicates that the product mix suggests how many products will be produced, which is decided by using the product addition. The product addition considers variable costs or unit contributions that identify all costs of the production. However, according to the Theory of Constraints, product mix is determined by considering the raw material costs (Unal, 2006).

When the company has a capacity constraint, producing all of the demanded products is not possible. Thus, the company is supposed to focus on producing the most profitable product or products. The product mix should be increasing the profitability, and the management should have precise knowledge about the bottleneck and the optimum product mix (Unal, 2006).

When demand is bigger than the available capacity, managers must carefully schedule which products will be produced in the given period. The product mix decision is usually an attempt to maximize the profit. However, researchers have disagreed about what the best method of determining the product mix, and what the best management accounting system is. Some researchers tend to argue that TOC product mix algorithm and TOC's accounting system (i.e., throughput accounting) perform as well or better than LP and ABC. According to Lea & Fredenhall (2002), some researchers suggest that throughput accounting should be used for short-term decisions, while ABC should be used for long-term decisions.

Similarly, as the constraint resource, other profitable products could be produced until the capacity limit, however the priority would have to be given to the maximum profitable product hourly (Unal, 2006).

2.7.TOC and Linear Programming

The correct and timely use of information in changing and renewed management accounting systems is becoming a basic understanding. To use and to process information in business decisions it is necessary to benefit from the information processing systems. The most efficient handling of business resources equals to effective capacity management. Resources should be used effectively to achieve a specific purpose. To increase the profit of the business and to achieve sustainable profitability, it is necessary to create the most suitable alternative among different alternatives (Kaygusuz, 2005: 50).

Due to the limited amount of available resources, using them in an economic way is necessary to avoid shortages. When producing goods, various resources and resource amounts can be combined to obtain the final product (Yılmaz, 2010: 29). With the linear programming technique, it is possible to create the most appropriate combination of resources among different alternatives and activities (Kaygusuz, 2005: 50). Linear Programming (LP) is an enterprise analysis method that can be used to solve problems of enterprises that use more than one product and resource.

Linear programming is a technique that allows obtaining the most appropriate distribution of resources, minimizing costs and maximizing profit (Dal, 2011: 37). LP in terms of business problems represents a series of techniques that analyse resources such as money, machinery, equipment, tools, time, and manpower in a way that provides the best use under certain restrictive conditions.

The linearity concept states that there is a constant proportional relationship between the variables in the linear programming problem. In other words, any change in a variable will cause a change in another variable. The *Programming* concept itself does not mean it is synonymous with computer programming yet is rather synonymous with planning. Accordingly, it can be said that linear programming includes planning activities that provide the optimal result among all appropriate options (Ilhan, 2014: 45).

Linear programming can be formulated in 3 steps (Afacan, 2002: 81):

- Determination of the objective function;
- Determination of the capacity and limitations;
- Equivalence of non-negative values of variables or determination of inequalities.

The linear programming model is formulated according to the maximum and minimum problem. The LP model has four elements (Kaygusuz, 2005: 51).

- The objective function
- Constraints
- Non-negative condition
- Linearity of all relations

The *Objective Function (OF)*: In LP, it is a single linear function that is formulated in a mathematical way and aims to achieve two conditions such as maximization or minimization. For example,

$$Z = C_1X_1 + C_2X_2 + ... + C_NX_N$$

Constraints: They limit the value of the objective function in a linear programming model. The constraints are the main limitations of the OF and display the available resources for the problem. The more resource limitations there are, the more constraints there may be (Sarıaslan, 1986: 59). This can be represented as below:

$$A_1X_1 + A_2X_2 + \ldots + A_NX_N < \text{Bottleneck}$$

The *non-negative condition*: Linear programming models are applied to real business problems; therefore, the variables cannot be negative. The product produced in enterprises cannot be a negative value (Toklu, 1985: 15).

$$X_N > 0$$

Linearity of all relations: This means that all relations can be expressed with linear equations, and that changes in variables will be constant. According to linearity, if a unit of product is produced for 1 Euro, 500 units will be produced for 500 Euros, and 1000 units for 1000 Euros. To formulate linear programming formulas, the above-mentioned structural features must be considered (Kaygusuz, 2005: 51).

The objectives and application areas of linear programming are summarized below (Ilhan, 2014: 46-47):

- Preparation of a production plan to meet the demand for a product, and minimisation of production and inventory costs;
- Determining the product mix that can be produced with the existing machinery and labour, to maximize the profit of the enterprise;
- Determination of raw material compositions that will produce at minimum cost (Çetindere, 2009: 31);
- Site location selection, the best location determination;
- The linear programming method is used as the evaluation of the income returns of the predicted investments.

Linear programming model's problems can be solved by the so-called Graphical or Simplex algorithm based on the number of variables involved. Since complex business problems would be time consuming and very hard or even impossible to solve manually, many computer programs have been created to provide fast solutions (Büyükkeklik, 2007: 42). The MS Office Excel program offers one of the easiest ways to solve these problems. In this study, the most suitable product mix and cost-volume-profit analysis will be created by using the MS Office Excel programme Solver analysis.

2.8.TOC Assumptions

As a theory, TOC has a few assumptions that help understand the logic behind it. TOC assumes that the goal of most manufacturing and service organisations is to make money now and in the future.

The fundamental concept of TOC is every system has at least one constraint. Goldratt delineates a five-step process that a change agent can use to improve the system's weakest link(s). TOC also presumes that the main reason a physical constraint exists is a policy constraint.

According to Reid (2007), TOC is based on three interconnected premises:

- Every system has a goal and a set of necessary conditions that must be satisfied if its goal is to be achieved;
- The overall system’s performance is more than just the sum of its component performances; and
- Very few factors or constraints, often only one, limit a system’s performance at any given time.

Considering these assumptions, TOC does not recognise the optimum performance of the system as a whole as the sum of all the local optima. Therefore, maximising the output of every machine will not bring the same results as optimising the flow of materials and value created through its connected set of activities.

As mentioned above, TOC gives priority to maximizing throughput and simultaneously reducing inventory and the carrying cost of inventory, i.e. operational expense. TOC also focuses on identifying and eliminating the constraints which can decrease the amount of potential throughput that a company could achieve. The management’s purpose of using the TOC process is to eliminate all the constraints that lie inside a system, therefore the new constraint should move outside of the system.

Throughput accounting (TA) considers direct labour cost and overhead cost irrelevant, hence it should be excluded from the purchased material cost calculations, or total variable cost calculations. TA lays on the assumption that direct labour cost and overhead cost cannot be changed, hence it will not be productive to spend our attention for such costs (Hutagalung, 2003).

Value-added concept is not relevant in TA. According to Goldratt (2004) it is better not to take the value-added concept into account. This way the confusion, whether a dollar spent is an investment or an expense, is eliminated. According to throughput, the value creation of business can only occur when a product or services have been rendered to customers and therefore create revenue for the system (Hutagalung, 2003).

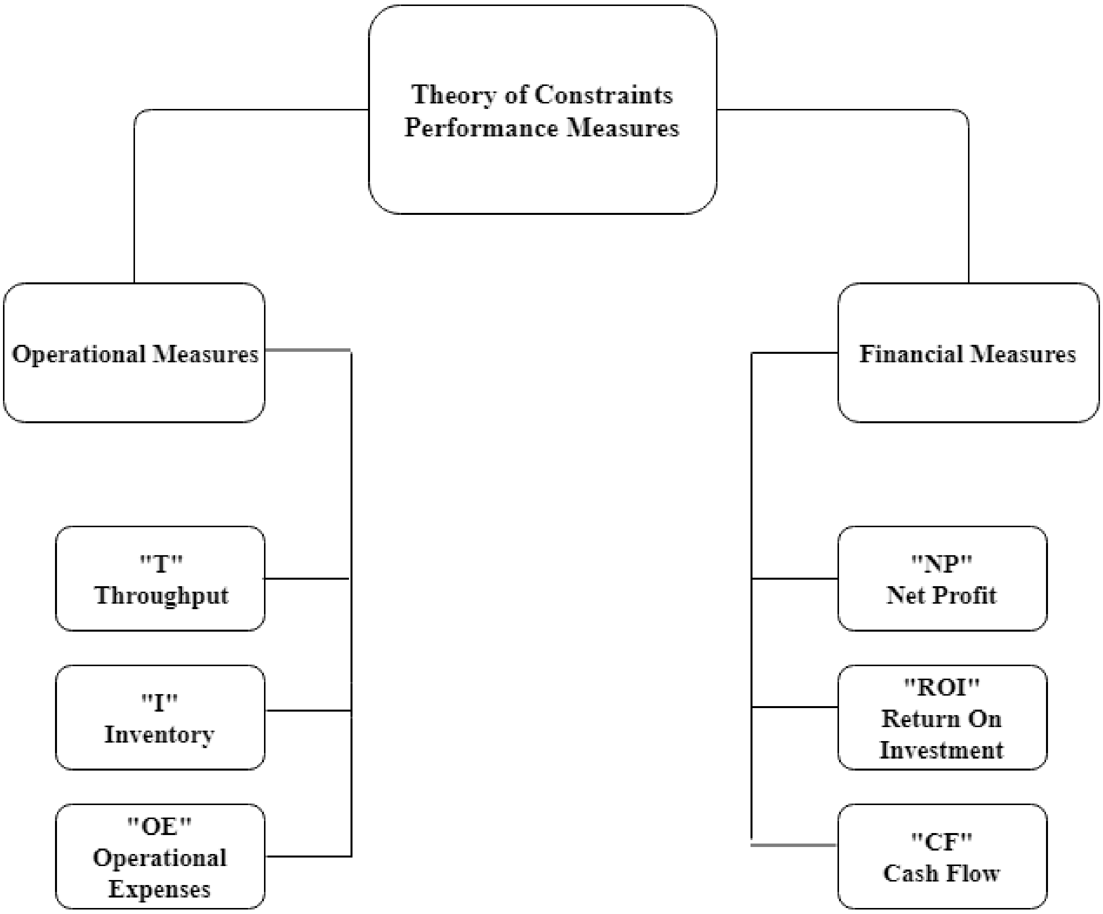
2.9.Throughput Accounting

In the 1980s, after the established management practices started being closely examined, the managers' perceptions of the problems they faced started reforming (Jones & Dugdale, 1995). Inside accountancy, Johnson & Kaplan (1987) identified the crisis and put emphasis on the inadequacy of existing accounting systems. Having different responses, some accounting academics ended up putting forward new forms of management accounting – one of them being Activity Based Costing (Cooper & Kaplan, 1988). Accounting was seen more as an important part of the problem than the solution (Miller & O'Leary, 1993: 188). In his development of TOC, Goldratt faced the challenges that came outside accountancy. In TOC, the maximisation of throughput was recognised as the most prominent determinant in increasing profitability. Since the local performance measures overshadow the goal of the organisation and obstruct the achievement of potential throughput, the cost accounting here is represented as 'enemy number one of productivity' (Goldratt & Cox, 1993).

Confronted with constant conflicts between TOC and cost accounting, Goldratt published two manuscripts (Goldratt, 1988, 1990) that incited renewed interest among TOC proponents in overhauling the cost accounting framework. His work, along with work of others (Fry & Cox, 1989; Weston, 1991; Fry, 1992; Lockamy & Cox, 1994; Srikanth & Robertson, 1995; Cox et al., 1998; Lockamy & Spencer, 1998; Smith, 2000), brought to the development of a process-focused performance measurement system which makes the organisation concentrate on actions that improve overall financial performance. This framework is called Throughput Accounting (TA). TA consists of nine interrelated measurements for use at various organisational levels which have been shown to be valid in the context of economic theory (Fry, 1992; Spencer, 1994).

TOC insists that the primary purpose of an organisation is to make money now and in the future. Businesses need measures to accurately display their performance in reaching its objectives. Pointing out the inadequacy of the measures used in cost accounting, TOC developed system-oriented performance measurements. These measurements can be divided into two groups; financial and operational measurements. Operational measurements include throughput, inventory, and operational expense, whereas financial measurements involve net profit, cash flow, and investment return rate (Ünal, 2006: 51). Figure 16 illustrates the division of the performance measurements of TOC.

Figure 16: Division of TOC Performance Measurements



Source: Kırlı & Kayalı, 2010: 105

2.9.1. Operational Measures

Goldratt & Cox (1993: 59-60) define the operational measures as follows: *Throughput* is “the rate at which the system generates money through *sales”. Inventory* is “all the money that the system has invested in purchasing things which it intends to sell”. *Operational expense* is “all the money the system spends to turn inventory into throughput”, i.e. the money going out of the system.

2.9.1.1.Throughput

It is described as the money obtained from selling the products that were produced under the TOC (Ergun & Kahramanmaraş, 2002: 99). According to Goldratt (2004), it is “the rate at which the system generates money through *sales”.* Throughput can also be viewed as “all the money coming into the system” (Dettmer, 1997). Any completed product that has not been sold yet is considered as inventory. Therefore, throughput occurs only when the product produced is »converted« into money. In effect, throughput measures the performance of a product that is derived from the sales price of raw materials. The performance of a product is connected to the performance of the organisation (Ergun & Kahramanmaraş, 2002: 99).

A profit-making company generates revenue through sales, not production. Output does not always translate to product sold, consequently, TOC does not move from the output concept. An organisation will not earn money until they sell their product. In contrast with the traditional accounting practices, inventory is not considered an asset, and therefore presents no value unless the product is sold (Utku, 2007: 33).

Throughput can be calculated by the following formula:

$T=P-DM$

In the formula, T stands for throughput, P stands for the sales price of the product, and DM represents the total direct material cost per unit. The total throughput is calculated by multiplying the unit quantity by the unit throughput. This can be seen in the following formula:

$\Sigma T=T*Q$

ΣT, total throughput and Q express the quantity of product sold.

As it can be seen, throughput has two components; sales price and variable cost. The variability in sales costs is dependent on the sales quantity, and not the production quantity. Total variable costs will increase/decrease according to the increase/decrease of the sales volume (Kaygusuz, 2005: 142).

If throughput cannot meet the operational expenses, the organisation will not be able to continue its activities for a long period of time, because they will be unable to generate profit (Demmy & Talbott, 1998: 14).

2.9.1.2.Inventory

There are two concepts that get mixed very often; stock and inventory. The concept of inventory in TOC differs from the concept of inventory in generally accepted accounting principles. In contrast with the traditional accounting practices, inventory is not considered an asset, but rather a resource (Gupta, 2003: 650). The *stock* concept is defined as the physical census and stock determination at the end of the year. It also refers to a detailed listing of the assets and wealth of a business. Stock is solid and refers to quantity, whereas inventory, which associates with the stock concept, refers to a monetary value (Ergun & Kahramanmaraş, 2002: 99).

In other words, inventory not only incorporates material, semi-finished and finished products, but also all the machinery used to produce the products, and the building where the products are being produced (Gupta, 2003: 650). Another way of defining inventory in TOC could be that anything that is directly connected to producing the items that will be sold by the company, is a part of its inventory. On account of that, instead of inventory, the concept of investment is used (Corbett, 1998: 31). Stock, on the other hand, includes all the finished products that are being sold by the company. In case a company also generates revenue from selling their raw materials to its customers, it is also considered as stock.

The traditional accounting definition of inventory is quite exclusive comparing to Goldratt's definition. Although machines and buildings might be sold later, selling them would hardly seem to be the main reason for obtaining them. Goldratt uses the term inventory where traditional accountants would refer to investments or assets (Dugdale & Jones, 1998: 77 – 78).

Inventory includes all production and labour costs, which are necessary for the production under TOC (Ergun & Kahramanmaraş, 2002: 99). Goldratt (2004) defines

Inventory as “all the money that the system has invested in purchasing things which it intends to sell”. Logically, the first things that come to mind are raw materials, unfinished goods, purchased parts, and other “hard” items intended for sale to a customer. However, inventory also includes the investment the organisation makes in equipment and facilities (Dettmer, 1997).

Inventory is expressed as all the money the business spends to buy what it needs to produce what it designs. In other words, it is the amount of money that the business invests in what it is trying to sell (Şahbaz, 2005: 23). According to TOC, excess stock prevents the organisation from achieving its purpose. The existence of excess inventory leads to an increase in expenses arising from interest, depreciation (storage space occupation), loss, deterioration, and resource management (Gupta, 2003: 650). Accordingly, the organisation should not have liquidity problems, and should be able to sell their products when needed. Inventory incorporates not only semi-finished products and finished stock, but also assets such as machinery, buildings, and vehicles (Kaygusuz, 2005: 142). In accordance with TOC, everything in the system can be sold when necessary. In contrast to the conventional classification, direct labour costs, general production costs are not included in the cost of inventory, however they are included in the operational expenses (Kaygusuz, 2006: 24).

2.9.1.3.Operational Expenses

According to Goldratt (2004) OE is “all the money the system spends to turn inventory into throughput”, i.e. the money going out of the system. Examples of OE are direct labour, utilities, consumable supplies, because it presents the value of a fixed asset dissipated or “used up”, in turning inventory into throughput (Dettmer, 1997).

It is based on the question of »how much money has been spent?« during the production activities. In some literature it can also be referred to as »period costs«. Operational expense is all expenditure made by the organisation to obtain the turnover rate by using the inventory. In other words, it expresses all the money spent to transform the company's inventory into cash. Operational expenses incorporate all direct or indirect costs related to the production, except for direct material costs (Ural, 2007: 32).

Anything other than income and inventory is administrative or managerial expenses. Examples of administrative expenses are general manager's official car, office, and telephone expenses. These fixed expenditures could have been made and accounted for in the previous fiscal period. Similarly, the product can also be pre-produced. When these expenditures are evaluated as administrative expenses, they cannot be the determinant in the unit cost of the product that is to be sold and cannot be included in the inventory. According to Goldratt, adding the fixed costs to the product cost will create a false message within the organisation, such as: »even if we will not sell it, let us produce as much as we can, so we can reduce our unit cost« (İlhan, 2014: 20).

To summarize, income is the money that enters the system, inventory is the money that it available in the system at the moment, and operational expenses are the money that exits the system. The most important point that makes Goldratt different from the traditional cost or financing approach is that earnings, inventory, and operational expenses are defined this way (Dettmer, 1998: 32).

Improving one measurement alone cannot benefit the overall system. Accordingly, it is very important to increase throughput while decreasing inventory and OE in realizing the goal of earning money or increasing the profitability. The benefits to be achieved through the reduction of costs are limited, nevertheless, the increase in profit due to an increase of sales is unlimited. Goldratt, however, suggests that the biggest acquisition could be achieved by first increasing throughput, then decreasing inventory, and finally reducing operational expenses (Ilhan, 2014: 21).

2.9.2. Financial Measures

In a production, the person in charge can decide to have overtime if he believes the throughput will increase. The production will be performed according to throughput reaching our expectations; in case it does not meet our expectations, the production will be stopped, and vice versa. If the same application was to be performed within the scope of general accounting, acting according to the operating budget would be a necessity (Tiryakigil, 2011). Goldratt produced three global financial performance measures, to obtain more meaningful and accurate results in evaluating whether the organisation is acquiring its goal of making money (Utku, 2007: 34):

- Net Profit (NP),
- Return on Investment (ROI),
- Cash Flow (CF).

The three performance measurements are formulated according to TOC, and they should, to obtain accurate results, be used together.

2.9.2.1.Net Profit

Net profit is the company's income surplus after all operational expenses have been reduced from the revenues collected through selling of products that they produced. It is a criterion that directly measures whether a business generates cash as a whole. However, this measurement alone is not sufficient. It is significant how much net profit can be achieved with an investment (İlhan, 2014: 21).

Net Profit can be calculated by the following formula:

Net Profit (NP) = Throughput – Operational Expense

As it can be seen, NP has two components; throughput and operational expense. If operational expenses remain higher than throughput, the organisation will hardly be able to continue its activities for a long period of time, because they will be unable to generate profit (Demmy & Talbott, 1998: 14). The formula can be interpreted as total sales decreased by total variable costs and operational expenses.

Net Profit = (P – DM) – Operational Expense

2.9.2.2.Return on Investments

Return on investments are the gains acquired from an investment, in comparison with the total cost of investment – a comparison of how much profit has been made according to the total amount of the capital investment. Return on Investments (ROI) criterion is a criterion that provides a relative relationship between the level of investment made and the level of earnings.

The formula for calculating ROI is as follows:

Return on Investments (ROI) = (Throughput – Operational Expense) / Inventory

As it can be seen, return on investment incorporates all three operational measurements; throughput, operational expense, and inventory. The ROI formula could be modified into the following formula:

Return on Investments (ROI) = Net Profit / Inventory

Since inventory is considered as an *investment* in TOC, and net profit is considered the incoming money, the ROI formula according to TOC actually resembles the traditional formula (ROI = Net Income / Cost of Investment). The higher the levels of inventory, the lower the return on investments will be. Therefore, high inventory levels can negatively affect the return on investments.

2.9.2.3.Cash Flow

Cash Flow (CF) is all the cash of the organisation available to cover all its financial payments.

All three measurements listed above provide adequate information about whether the entity generated cash. However, Goldratt states that these criteria are insufficient in evaluating production and investment decisions to be taken (Ilhan, 2014: 21).

Throughput, Inventory, and Operational Expense are considered as plant level performance measurements, whereas Net Profit, Return on Investment, and Cash Flow are global performance measures (Watson et al., 2006).

The development of Goldratt's ideas shows a move from a criticism of particular accounting measurements aimed at achieving local optima, to a broader concern with the overall approach adopted by cost accounting (with its under-emphasis on throughput), to an interest in providing a comprehensive 'technology of thinking' (Goldratt, 1993) which will enable accountants to apply TOC in accounting (Dugdale & Jones, 1998: 76 – 77).

To achieve their goal of maximizing the financial performance of the manufacturing company, managers need to know what to look for. Manufacturing companies consist of different subsystems. The process of producing a product does not incorporate only the assembly of the parts that construct the final product. The product itself has to be first designed, and then it has to undergo several engineering procedures, to ensure that the design translates to the exact requirements in reality. Afterward, if there are no enough amounts of raw materials or other resources needed for the production, they must be supplied. Finally, production should go through, products should be presented on the market, and obtained sales revenues should be collected. In case when the goals of each activity are not compatible with each other, these activities, which are often carried out in different environments, cannot be brought to the greatest benefit (Aksoy, 2001: 60).

CHAPTER 3

IMPLEMENTATION OF TOC IN A MANUFACTURING COMPANY

3.1.The Implementation

In this chapter, the implementation of the Theory of Constraints in a manufacturing company will be analysed. For this implementation, the manufacturing company Dambeti D. O. O. from Montenegro has been chosen. This chapter will include the basic information about the company, its production line, the determination of the constraints in the system, the creation of the most appropriate product mix according to the capacity constraint, and the effects the implementation has on the company's profit. The conclusion will evaluate the results of the implementation and suggestions for improvement will be presented.

3.2.The Problem Statement

Businesses strive to make profit by reaching high performance and efficiency levels. This applies both to the current period and the future of the company. Manufacturing companies need to maintain a fluent production flow to be able to achieve their goal. Any obstacles that restrict the production process must be treated as constraints and need to be removed or turned into an advantage for the company. According to the Theory of Constraints, every organisation has at least one constraint that limits its performance and restricts it from achieving its goal. Therefore, it is necessary for the company to concentrate on constraints management (Ünal, 2006: 86). Due to the presence of constraints, companies are unable to use their existing resources efficiently. Consequently, with the product quality and quantity decrease, the extension of the order-completion time, and an increase of the product costs, the company's profitability goes down (Tanış, 2005: 46).

TOC moves towards eliminating the constraints that are found in the system and improving the systems that the company owns. It is based on a continuous improvement process that consists of the Five-Focusing Steps, which aim to establish a permanent improvement process in the company. After identifying and eliminating the system constraint, a new constraint will appear, and the organisation needs to work on removing it through the continuous improvement process (Küçüksavaş et al., 2006: 20).

3.3.The Purpose of the Study

The purpose of this study is to examine the effects the Theory of Constraints has on the of performance and profit of a company through the application of the five-focusing steps in a production company. The research is based on the assumption that "each system has at least one constraint" and that "the weakest link of a system determines the whole performance of that system". Respectively, this study will look for answers to the following questions:

- Is there a constraint in the production area?
- Can the constraint be eliminated through the implementation of the Five-Focusing Steps?
- Will the elimination affect the profitability of the organisation and how?

3.4.About the Company

The year 1994 was a time of sanctions for the Federal Republic of Yugoslavia (SRJ) – which consisted of Serbia and Montenegro – due to the on-going war in Bosnia and Herzegovina. Consequently, there were shortages of all goods and this included the shoe supply shortages too. Starting as a small family business in a small city of Bijelo Polje in the north of Montenegro, the Independent Craftwork Shop (SZOR) soon transformed to ĆIKO D. O. O. (Ltd.) Their products were mostly hand-made, except for a few operations which required machine processing that would otherwise lower their productivity. As the demand for their products started to rise, they responded by increasing the number of employees. The founder of ĆIKO D. O. O. decided to retire, whereas his both sons continued with the business together until 2012. During that period, starting in rented facilities with just a few machines, they managed to build a production plant of 300 square meters without any loans, and they managed to establish a fully automated and machine production. Since the very first beginnings, they have been producing leather shoes, which they claim turned out to be a big advantage for them, because nowadays the market is flooded with shoes made of artificial materials. Until 2012, their main products included classic women fashion footwear. Due to some issues in cooperation between the brothers, they reach an agreement to split, and the younger brother, Damir Dizdarević becomes the founder of Dambeti D. O. O.

As a new company on the market, but with a founder that holds a good reputation, Dambeti introduces the men's programme and casual women footwear. Dambeti was immediately accepted, because it remained consistent in something that was characteristic even in the previous period for their products, and that is comfort and quality before anything. For them the design is equally important, and because they always tried to be different from others, they did not allow themselves to fall behind.

Mission: Produce and sell high quality leather shoes with the emphasis on comfort and design.

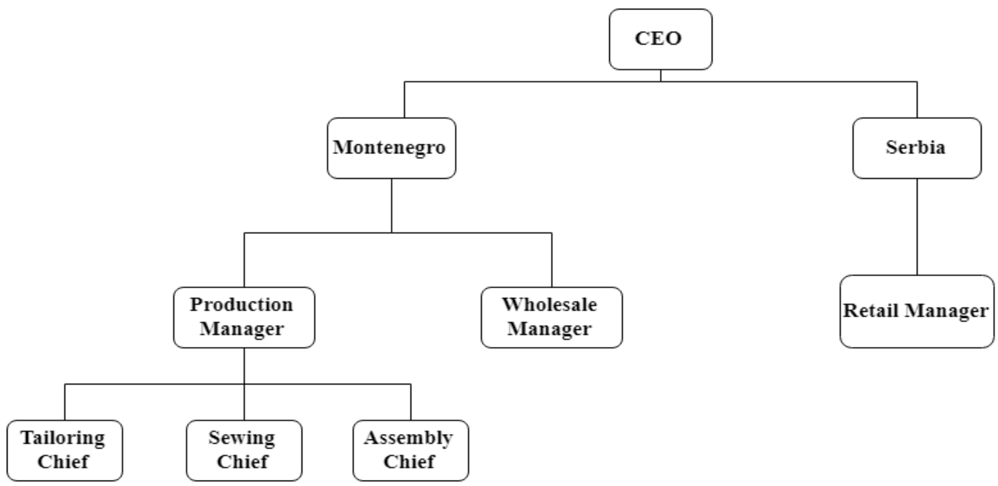
Vision: Expand retail business locally as well as in the neighbouring countries.

Until now, Dambeti has managed to expand its business to the Serbian market by opening three retail shops; two of them in the centre of Belgrade, and the third one in Novi Sad.

3.5.Organisation Scheme

The figure below illustrates the organisation scheme of Dambeti.

Figure 17: The Organisation Scheme of Dambeti



3.6.Production Plant Information

Dambeti's production plant is in Bijelo Polje in Montenegro. The company produces leather footwear which includes both women and men shoes. Women footwear can be divided into 4 groups:

1) Open shoes (Sandals, other)

2) Closed shoes (High-heel shoes, flat shoes, other)
3) Ankle boots
4) Boots

For this research, the example of Spring collection products will be taken into account, therefore men shoes, women shoes and women sandals.

As Figure 17 illustrates, Dambeti produces products both for wholesale and retail purposes. Their wholesale customers are located both in Serbia as well as Montenegro. Dambeti produces for Zupateks, Merletto, Deni Obuća, Bella Dona, Fashion Box, Grazia Vršac, Fenix, Obuća Grazia, Orange, Dambeti Retail, UNO-NK, and Madmassel.

Raw materials necessary for the production are imported on time from two different countries:

Turkey: Leather, linings, outsoles, heels, other small raw materials

Serbia: Leather, heel counters, glue, mid-soles and insoles

The autumn-winter collection raw material purchases are realised In April, whereas the spring-summer collection raw material purchases are realised in October. The average delivery times for raw materials range between 10 to 30 days.

The business week is 6 days, and the working hours are between 9 AM and 5 PM (9:00-17:00). During the 8-hour work time, there is a 30 minute "breakfast" break. Therefore, the total of hours of work in Dambeti is (7,5 hours * 6 days) 45 hours.

The plant has one production line which can be divided into three main operations; preparation, sewing, and assembly. The production line can produce all the product types (flat shoes, high heels, sandals, ankle boots, high boots). It is also possible to manufacture different types of products at the same time, for example, while sandals are being produced, the business can start manufacturing high heeled shoes by performing negligible changes on the machines. Therefore, product changes do not present any problem for the production plant. Dambeti usually never manufactures for stock, however they can cover any minimal extra demands that might arise.

As mentioned before, Dambeti produces products for several companies in Montenegro and Serbia, as well as their own retail shops. According to the average market demand on a yearly basis, 46 % of their production is intended for Montenegro, from which 43 % of the products are sold to UNO-NK, and 3% to Madmassel. The other 54 % of the products are sold in Serbia; retail represents 17 %, 10 % of the demand comes from Grazia, 6 % from Deni Obuća, 4% each from Fenix and Zupateks, and 3 % each from Merletto, Bella Dona, Fashion Box, Grazia Vršac, and Orange.

Dambeti's product range differs according to the season. They produce men footwear, women sandals, flat and high heel shoes for the spring-summer collection, while for the autumn-winter collection, they produce men footwear, women ankle boots and high boots. The spring-summer collection products are produced in the period from November until April, whereas autumn-winter collection products are produced from May until September.

Table 3: Average 6 Months Collection Demand for Both Seasons

Product	Spring-Summer Collection Demand	Autumn-Winter Collection Demand
Men Shoes	200	185
Women Shoes	1.100	/
Women Sandals	1.230	/
Ankle Boots	/	1.130
High Boots	/	1.005
Total	2.530	2.320

3.6.1. The Process of a Creating a Product

During each of the two seasons, Dambeti starts preparing designs for the products that are intended for the next season. After all the designs have been completed, prototyping takes place. This way the business can get a better insight of what the final product should look like, and therefore if the design is appealing by considering all the aspects of it. To create a prototype, the business first checks if it has all the necessary components, such as appropriate lasts and leather samples. In cases when they do not obtain the components needed to create a prototype, they need to order them on time from their suppliers. Once they have all the needed parts, the most appropriate lasts for each model are determined. After deciding which lasts will be used, it is rather simple to determine which outsoles and/or heels will be used. The lasts are then covered with a masking tape. This allows the shoe design to be drawn onto the tape, which is then removed and laid flat on the cardboard to create the shoe pattern.

Continuing the process, the prototype is then tailored and sent to the assembly and final processing. During the creation of the prototype, any shortcomings are noted and removed by the technical service before approaching modelling by sizes. Approximately one working week is needed to realise this process.

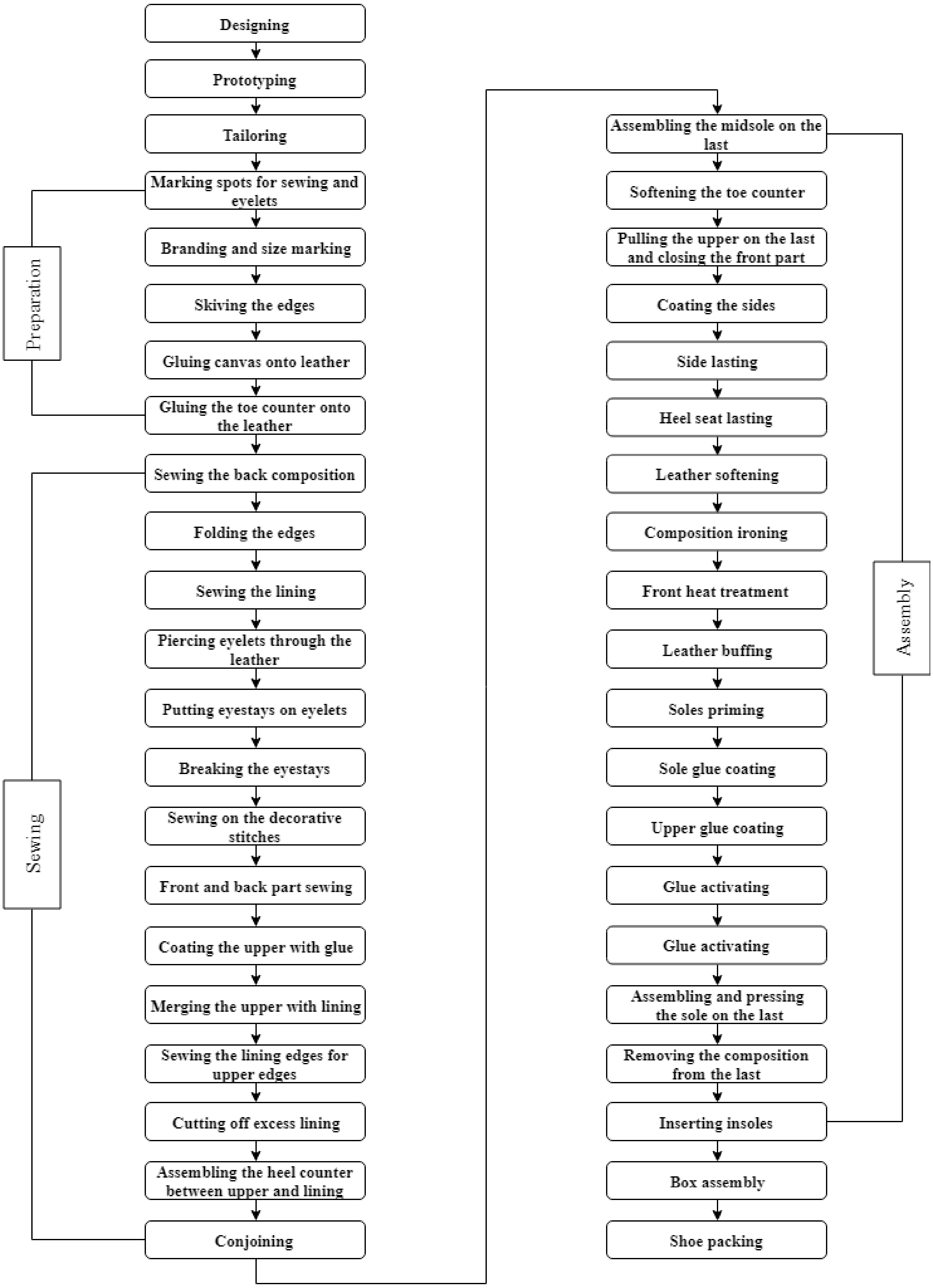
3.6.2. The Product Flow

During the production, similar operations are performed on all their products, hence their product flow can be represented as a general product flow. Figure 18 illustrates the general product flow for Dambeti's products.

After the prototypes have been approved, a production order for a specific product is prepared. According to the production order, the tailor is then able to collect the necessary materials. After tailoring, the cut material is separated into different baskets according to the size and is sent to the Preparation process. A worker approaches marking the joining spots for the upper parts. He/she then marks the article numbers and size on the lining and stamps the brand logo and name. The worker proceeds with skiving the edges and gluing canvas onto the leather with the help of a machine. As the finishing operation for the Preparation process, the toe counters are glued onto the leather to form the front part of the shoe and let it keep the shape of the last.

The work-in-process then passes on to the Sewing department, where the process starts by sewing the back composition, folding the edges, and sewing the lining. Following, eyelets are made and inside them, eyestays are placed, which then undergo a process referred to as "breaking the eyestays", as the press machine breaks them, so they stay in place. Decorative stitches are then sewn on and the front and the back part are sewn together. The upper and lining are coated with glue and joint. The lining edges are then sewn according to the upper edges and excess lining is cut off. As the final operations for the Sewing process, the heel counter is assembled between the upper and lining, and the glue is reactivated to merge all three components together.

Figure 18: General Product Flow



After this the upper is ready for the assembly with midsole and outsole. The assembly worker sets the midsoles onto the previously prepared lasts and puts every upper on its last. First the toe counters are activated (softened), then the worker performs upper lasting. After coating the sides, side and heel seat lasting is performed.

To be able to connect the shoe with the midsole and outsole, the leather is softened, the whole composition is ironed (hammered), and any existing wrinkles are straightened. Leather buffing is performed where the soles need to be glued on. For better appliance, sole priming is performed to remove any material or grease left on that would prevent proper gluing. The soles and upper are then coated with glue twice by hand, and the glue is activated to put the sole on the last. The composition is then pressed together and removed from the last. As the final operation of the Assembly process, workers insert insoles, and pack the shoes into the pre-assembled boxes.

Throughout all three processes, Dambeti makes sure that quality control is done after every operation. This means that after every operation, the worker that is sending the work-in-process to the next operation needs to make sure that there are no shortcomings. Similarly, the worker that overtakes the work-in-process needs to check if there are any existing mistakes. This is referred to as Phase Quality Control (PQC). Since every worker is highly specialised in his/her field of work, they can quickly detect flaws. In cases when minor flaws are present, for example, an eyestay has been placed incorrectly inside the eyelet, corrections are possible. However, if any more significant shortcomings would be discovered too late, interventions would be almost impossible and too costly. These products would become write-offs. Therefore, in Dambeti's case, PQC is significant to minimise waste and unnecessary costs.

3.6.3. The Process Times

Dambeti owns a total of 32 machines, however depending on the type of a certain model, all products require processing of 22 machines in general. According to the obtained information about the production process for a pair of each product type, to produce a pair of men shoes, the needed times are as follows: Swing Arm Cutting machine 9,5 min, Skiving machine 6 min, Stamping machine 2 min, Termo Fusing machine 4 min, Toe Puff Applying machine 2 min, Sewing Post Bed Single Needle machine I 0,15 min, Termo Folding machine 2 min, Sewing Post Bed Single Needle machine II 3 min, Sewing machine I 2 min, Sewing machine II 7 min, Sewing machine III 5 min, Moulding machine 5 min, Upper Steaming machine 1,5 min, Toe Lasting machine 3 min, Heel Lasting machine 3 min, Air Blower machine 1,5 min, Pounding machine 2 min, Brushing machine 2 min, Sole Activator machine 1,5 min, Sole Press machine 3 min.

According to the obtained data, to produce a pair of women shoes (high heels or flat), the following times are needed: Swing Arm Cutting machine 9,5 min, Skiving machine 6 min, Stamping machine 2 min, Termo Fusing machine 4 min, Toe Puff Applying machine 2 min, Sewing Post Bed Single Needle machine I 0,15 min, Termo Folding machine 2 min, Sewing Post Bed Single Needle machine II 3 min, Sewing machine I 4 min, Sewing machine II 7 min, Sewing machine III 5 min, Moulding machine 5 min, Upper Steaming machine 1,5 min, Toe Lasting machine 3 min, Heel Lasting machine 3 min, Air Blower machine 1,5 min, Pounding machine 2 min, Brushing machine 2 min, Sole Activator machine 1,5 min, Sole Press machine 3 min.

According to the obtained data, the following times are needed to produce a pair of women sandals: To produce a pair of women shoes (high heels or flat), the following times are needed: Swing Arm Cutting machine 6,65 min, Skiving machine 4,2 min, Stamping machine 1,4 min, Termo Fusing machine 2,8 min, Toe Puff Applying machine 1,4 min, Sewing Post Bed Single Needle machine I 0,11 min, Termo Folding machine 1,4 min, Sewing Post Bed Single Needle machine II 2,1 min, Sewing machine I 2,8 min, Sewing machine II 4,9 min, Sewing machine III 3,5 min, Moulding machine 3,5 min, Upper Steaming machine 1,05 min, Toe Lasting machine 2,1 min, Heel Lasting machine 2,1 min, Air Blower machine 1,05 min, Pounding machine 1,4 min, Brushing machine 1,4 min, Sole Activator machine 1,05 min, Sole Press machine 2,1 min.

The weekly production line capacity is shown in Table 4.

Table 4: Weekly Production Times for Products

Product	Production Time (min)
Women or Men shoes	2700 minutes

The production line can produce all the product types (flat shoes, high heels, sandals, ankle boots, high boots). It is also possible to manufacture different types of products at the same time, for example, while sandals are being produced, the business can start manufacturing high heeled shoes by performing negligible changes on the machines. Therefore, product changes do not present any problem for the production plant.

The following tables summarize the production process times on each machine for each product type.

Table 5: Production Line Times and Capacities for 1 Pair of Men Shoes

Machine	Number of Machines	Processing Time for Men Shoes (min)	Total Time (min)	Capacity (products/day)
Swing Arm Cutting Machine	1	9,50	9,50	36
Skiving Machine	1	6,00	6,00	36
Stamping Machine	2	2,00	4,00	36
Termo Fusing Machine	1	4,00	4,00	36
Toe Puff Applying Machine	1	2,00	2,00	36
Sewing Post Bed Single Needle Machine I	1	0,15	0,15	36
Termo Folding Machine	1	2,00	2,00	36
Sewing Post Bed Single Needle Machine II	1	3,00	3,00	36
Sewing Machine I	1	2,00	2,00	36
Sewing Machine II	1	7,00	7,00	36
Sewing Machine III	2	5,00	10,00	36
Moulding Machine	1	5,00	5,00	36
Upper Steaming Machine	1	1,50	1,50	36
Toe Lasting Machine	1	3,00	3,00	36
Heel Lasting Machine	1	3,00	3,00	36
Air Blower Machine	1	1,50	1,50	36
Pounding Machine	1	2,00	2,00	36
Brushing Machine	1	2,00	2,00	36
Sole Activator Machine	1	1,50	1,50	36
Sole Press Machine	1	3,00	3,00	36

Table 6: Production Line Times and Capacities for 1 Pair of Women Shoes

Machine	Number of Machines	Processing Time for Women Shoes (min)	Total Time (min)	Capacity
Swing Arm Cutting Machine	1	9,50	9,50	36
Skiving Machine	1	6,00	6,00	36
Stamping Machine	2	2,00	4,00	36
Termo Fusing Machine	1	4,00	4,00	36
Toe Puff Applying Machine	1	2,00	2,00	36
Sewing Post Bed Single Needle Machine I	1	0,15	0,15	36
Termo Folding Machine	1	2,00	2,00	36
Sewing Post Bed Single Needle Machine II	1	3,00	3,00	36
Sewing Machine I	1	4,00	4,00	36
Sewing Machine II	1	7,00	7,00	36
Sewing Machine III	2	5,00	10,00	36
Moulding Machine	1	5,00	5,00	36
Upper Steaming Machine	1	1,50	1,50	36
Toe Lasting Machine	1	3,00	3,00	36
Heel Lasting Machine	1	3,00	3,00	36
Air Blower Machine	1	1,50	1,50	36
Pounding Machine	1	2,00	2,00	36
Brushing Machine	1	2,00	2,00	36
Sole Activator Machine	1	1,50	1,50	36
Sole Press Machine	1	3,00	3,00	36

Table 7: Production Line Times and Capacities for 1 Pair of Women Sandals

Machine	Number of Machines	Process Time for Women Sandals (min)	Total Time	Capacity
Swing Arm Cutting Machine	1	6,65	6,65	36
Skiving Machine	1	4,20	4,20	36
Stamping Machine	2	1,40	2,80	36
Termo Fusing Machine	1	2,80	2,80	36
Toe Puff Applying Machine	1	1,40	1,40	36
Sewing Post Bed Single Needle Machine I	1	0,11	0,11	36
Termo Folding Machine	1	1,40	1,40	36
Sewing Post Bed Single Needle Machine II	1	2,10	2,10	36
Sewing Machine I	1	2,80	2,80	36
Sewing Machine II	1	4,90	4,90	36
Sewing Machine III	2	3,50	7,00	36
Moulding Machine	1	3,50	3,50	36
Upper Steaming Machine	1	1,05	1,05	36
Toe Lasting Machine	1	2,10	2,10	36
Heel Lasting Machine	1	2,10	2,10	36
Air Blower Machine	1	1,05	1,05	36
Pounding Machine	1	1,40	1,40	36
Brushing Machine	1	1,40	1,40	36
Sole Activator Machine	1	1,05	1,05	36
Sole Press Machine	1	2,1	2,1	36

The raw material costs per unit (a pair) of product have been calculated and are shown in Table 8.

Table 8: Raw Material Costs per Unit of Product

Raw material	Men Shoes	Women Shoes	Sandals	Ankle Boots	High Boots
Leather	5,20 €	4,30 €	3,50 €	6,50 €	14,40 €
Lining	1,90 €	1,90 €	1,45 €	2,50 €	3,50 €
Heel Counter	0,30 €	0,30 €	0,30 €	0,30 €	0,30 €
Insole	0,80 €	0,75 €	0,75 €	0,75 €	0,75 €
Outsole	3,50 €	3,50 €	3,00 €	3,50 €	3,50 €
Total Direct Material	11,70 €	10,75 €	9,00 €	13,55 €	22,45 €
Last	20,00 €	20,00 €	20,00 €	20,00 €	20,00 €

To produce a pair of product, each pair needs to have a last. Dambeti does not include last costs into the raw material costs since one last has a life span of more than one year on average.

Dambeti produces products for several companies in Montenegro and Serbia, as well as their own retail shops. Table 9 shows the wholesale unit sales prices for each product type, and the average weekly demand for the spring-summer collection products are presented in Table 10.

Table 9: Wholesale and Retail Unit Sales Price

Type Of Product	Wholesale Unit Sales Price
Men Shoes	33
Women Shoes	32
Sandals	28
Ankle Boots	38
High Boots	55

Table 10: Average Weekly Demand for the Spring-Summer Collection Products

Shoe Type	Seasonal Demand (6 months)	Weekly Demand
Men Shoes	200	8
Women Shoes	1100	42
Sandals	1230	47

3.7.Creating and Comparing the Most Suitable Product Mix According to the Theory of Constraints Method and the Variable Cost Method

This section will include the identification of a constraint or multiple constraints that might be present in the production process of the business, the creation of the most suitable product mix, and the effects that it will have on the business profit. The most suitable product mix and the effects on the business profit will be calculated according to the Variable Cost method and the TOC method.

Table 11: The Cost Locations and Process Times for a Pair of Product According to the Type of Product

	Men Shoes	Women Shoes	Sandals	Capacity (min)
Price	33	32	28	
Weekly Demand	8	42	47	
Direct Material (DM) costs	11,70 €	10,75 €	9,00 €	
Cost Location 1) Preparation (min)	26,50	26,50	18,55	2.700
2) Sewing (min)	38,90	38,90	39,10	2.700
3) Assembly (min)	42,50	42,50	29,75	2.700
Process Time of One Pair of Shoes	1+2+3= 107,9	107,9	87,40	8.100

3.7.1. Product Mix According to the Variable Cost Method

Creating the most suitable product mix will allow the business to meet the market demand in a profitable manner. The market demand will be compared to the available capacity of the business, which will show if any capacity constraints that limit the company's performance exist. The most suitable product mix will be calculated by using the Contribution Margin (CM) values.

In the Variable Cost method, by calculating the direct material costs, direct labour (DL) costs, and energy costs, unit variable costs and unit contribution margins can be calculated. All the costs related to manufacturing and sales are represented in Table 12.

Table 12: Costs Related to Production and Sales (data for 1 year)

Direct Material Costs	78.357 €		
Direct Labour Costs	48.000 €		
Electricity Costs	2.500 €		
Plant Depreciation	5.396 €		
Plant Administration Costs	15.000 €		
	Men Shoes	Women Shoes	Sandals
Sales Price	33 €	32 €	28 €
Production Amount (6 months)	200	1.100	1.230
Total Production Amount (6 months)	2.530		

Weekly fixed manufacturing overhead (FMO) costs = Plant depreciation + plant administration costs

= 5.396 + 15.000 = 20.396 €/year
= 20.396 / 52 = 393 €/week

Weekly direct labour costs = 48.000 / 52
= 923 €/week

Table 13: Weekly Production Time per Product Type

	Men Shoes	Women Shoes	Sandals	Total
Weekly Production Quantity	8	42	47	
Production Time for a Pair of Shoes (min)	107,9	107,9	87,40	
Weekly Production Time (min)	(8 x 107,9) 863,2	4.531,8	4.107,8	9.502,8

Direct labour carging rate = Weekly direct labour costs / Weekly production time
= 923 / 9.502,8 = 0,0971 €/min

Weekly electricity costs = 2.500 / 52 = 48 €/week

Electricity charging rate = Weekly electricity costs / Direct labour costs
= 48 / 923 = 0,052

Table 14: The Calculation of Direct Labour and Electricity Costs

	Men Shoes	Women Shoes	Sandals
Weekly Product Manufacturing Time (min)	863,2	4.531,8	4.107,8
Direct Labour Costs	863,2 x 0,0971 = 84	4.531,8 x 0,0971 = 440	4.107,8 x 0,0971 = 399
Electricity Costs	84 x 0,052 = 4	440 x 0,052 = 23	399 x 0,052 = 21

Table 15: Direct Labour and Electricity Costs According to the Amount of Product and Product Manufacturing Time

Shoe Type	Direct Labour Costs	Electricity Costs	Fixed FMO
Men Shoes	84	4	131
Women Shoes	440	23	131
Sandals	399	21	131
Total	923	48	393

To create the Objective Function (OF), product-based contribution margins need to be calculated.

Table 16: The Calculation of Contribution Margins According to the Variable Cost Method

	Men Shoes	Women Shoes	Sandals
Sales Price	33 €/unit	32 €/unit	28 €/unit
Unit Variable Cost	24,64 €/unit	23,69 €/unit	19,48 €/unit
Unit Direct Material Cost	11,70 €/unit	10,75 €/unit	9,00 €/unit
Unit Direct Labour Cost (A)	12,30 €/unit	12,30 €/unit	9,96 €/unit
Unit Electricity Cost (B)	0,64 €/unit	0,64 €/unit	0,52 €/unit
Contribution Margin	**8,36 €/unit**	**8,31 €/unit**	**8,52 €/unit**
(A) 107,9 min/unit x 0,1140 €/min (923 € / 8.100 min = 0,1140 €/min) (B) 107,9 min/unit x 0,0059 €/min (48 € / 8.100 min = 0,0059 €/min)			

The total of direct material costs, direct labour costs and energy costs gives the unit variable cost for one pair of the product. Contribution margin is calculated by deducting the unit variable cost from the unit sales price.

By using the Variable Cost Method, the Maximum Objective Function is as follows:

MOF: $8{,}36\,X + 8{,}31\,Y + 8{,}52\,Z$

Constraints:

Preparation $26{,}50\,X + 26{,}50\,Y + 18{,}55\,Z \leq 2700$

Sewing $38{,}90\,X + 38{,}90\,Y + 39{,}10\,Z \leq 2700$

Assembly $42{,}50\,X + 42{,}50\,Y + 29{,}75\,Z \leq 2700$

$X, Y, Z \geq 0$

Since the maximum objective function is subjected to constraints, by changing the variables, the optimal value for the MOF will be found by using the Excel Solver tool. The Excel Solver tool can be used for solving smooth nonlinear problems with the Generalised Reduced Gradient (GRG) Nonlinear algorithm method, for solving problems that are non-smooth, the Evolutionary algorithm method is used, and for linear problems, the Linear Programming (LP) Simplex algorithm method is used. The problem of this research is a linear problem; therefore, the LP Simplex algorithm will be used to find the maximum optimal value and to determine the optimal product mix.

The data of the problem has been organised into an Excel worksheet. The worksheet can be seen in Figure 19.

Figure 19: Data Demonstration in the Linear Programming Model According to the Variable Cost Method

	A	B	C	D	E	F	G
1	VARIABLE COST METHOD						
2		**Men Shoes**	**Women Shoes**	**Sandals**			
3		X	Y	Z	**€**		
4	**THE OBJECTIVE FUNCTION**	8,36	8,31	8,52	**816,34**		
5							
6							
7					**Total Manufacturing**		**Capacity**
8	**CONSTRAINTS**	**Men Shoes**	**Women Shoes**	**Sandals**	**Time**	**Capacity**	**Utilisation**
9	1) Preparation	26,50	26,50	18,55	2.197	2700	0,81
10	2) Sewing	38,90	38,90	39,10	3.783	2700	1,40
11	3) Assembly	42,50	42,50	29,75	3.523	2700	1,30
12							
13							
14	**Demand**	8	42	47			
15							
16	**Order of Priority**	2	3	1			

In cells B4:D4, the MOF has been entered; therefore, the unit contribution margins according to the Variable Cost method have been inserted.

Below the MOF, the constraints (preparation, sewing, and assembly) have been listed and their unit process times in minutes have been included, to calculate the total manufacturing time per constraint. After the current weekly demand per unit of product (B14:D14) has been added, the total manufacturing time (E9:E11) has been calculated:

Formula for **cell E9:** =SUMPRODUCT(B9:D9;$B$14:$D$14)

or equivalently,

Formula for cell E9: =$B$14*B9+$C$14*C9+$D$14*D9

Formula for **cell E10**: =SUMPRODUCT(B10:D10;$B$14:$D$14)

or equivalently,

Formula for cell E10: = $B$14*B10+$C$14*C10+$D$14*D10

Formula for **cell E11**: =SUMPRODUCT(B11:D11;$B$14:$D$14)

or equivalently,

Formula for cell E11: =$B$14*B11+$C$14*C11+$D$14*D11

It was then compared to the available capacity (F9:F11) per each constraint, and the Capacity Utilization (G9:G11) revealed that there are two capacity constraints present in manufacturing – sewing and assembly.

Since *sewing* exceeds its capacity limit by the most, it is therefore the Capacity Constraint Resource. This means that sewing will take priority in creating the optimal product mix. In other words, sewing processes will be equalled to the available capacity of 2.700 minutes, and the number of each type of product that can be sewn in 2.700 minutes, will represent the total output for the company.

The Solver tool is used to calculate the maximum profit and the optimal product mix. To launch the Solver tool, the objective cell (cell E4) must include a formula. The calculated value in cell E4 – before launching the Solver tool – represents the profit that the company could obtain if they would produce the demanded quantities of products, without considering the available capacity.

Formula for cell E4: =SUMPRODUCT(B4:D4;B14:D14)

or equivalently,

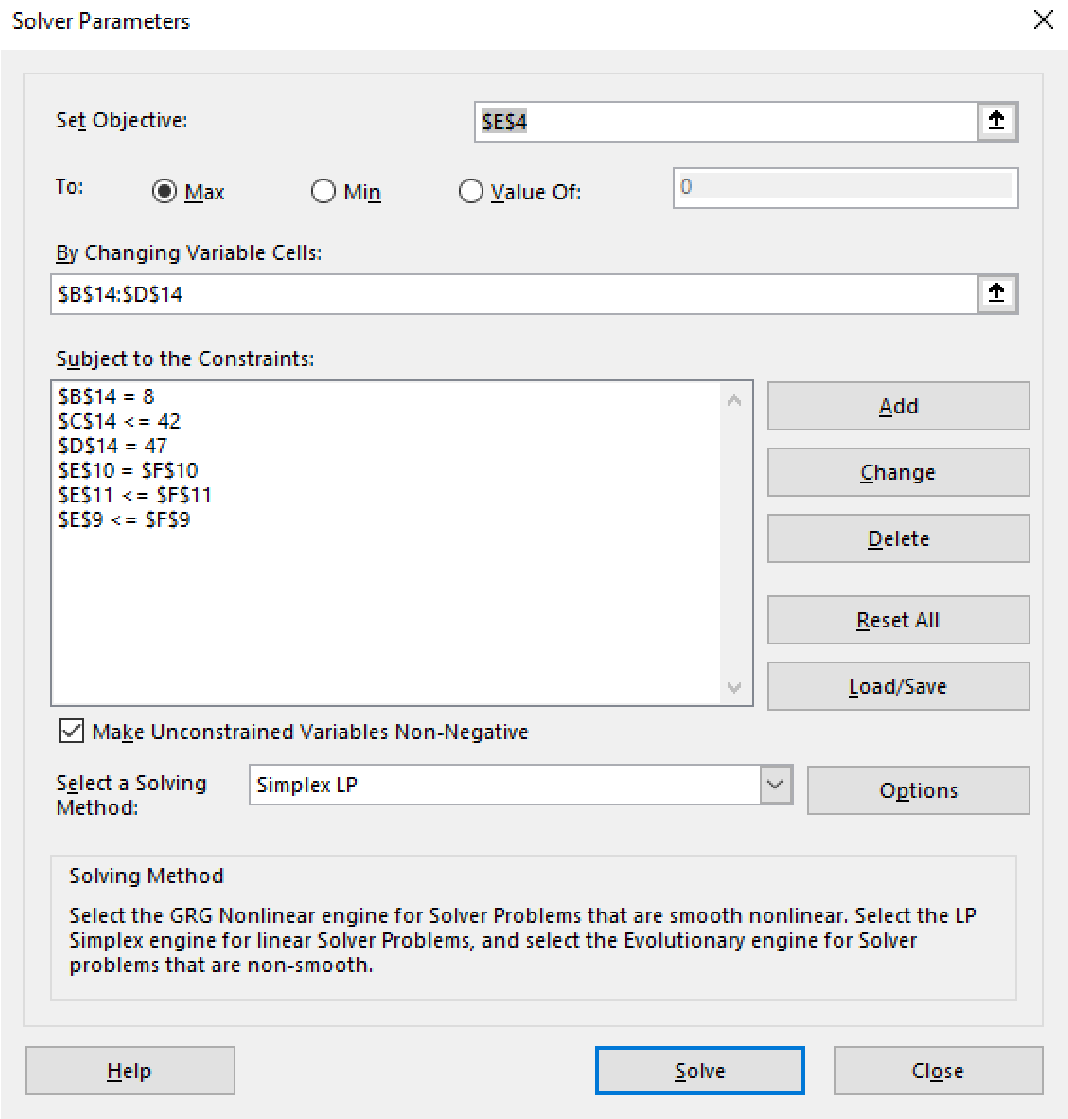
Formula for cell E4: =B4*B14+C4*C14+D4*D14

After the formula has been inserted into the objective cell (E4), the Solver tool is initiated, and the Solver parameters are set up.

The set objective is cell $E$4, which is to be maximised, therefore the “Max” option is selected. The variables in this case are the demand quantities ($B$14:$D$14), which also have their own limitations; the demand. These parameters are added in the “Subject to the Constraints” field. In the Variable Cost method, to create the most suitable product mix the products are to be produced in order by starting with the product that has the biggest unit contribution margin. Order of priority can be seen in cells B16:D16. Accordingly, the sandals need to be produced first, following with men shoes, and finally the women shoes. The parameters were adjusted accordingly (1. $D$14=47, 2. $B$14=8, 3. $C$14≤42).

There is a capacity limitation of maximum 2.700 minutes for each process (preparation, sewing, and assembly), hence the total manufacturing time for each process needs to be lower or equal (≤) to the maximum capacity. Since *sewing* exceeds its capacity limit by the most, the total manufacturing time for the sewing process is set to be equal to the maximum available capacity (2.700 minutes).

Figure 20: The Solver Parameters for the Variable Cost Method



The option to make unconstrained variables non-negative should be chosen if negative values in the changing (variable) cells want to be avoided. After establishing all the parameters, the solving method is selected – the Simplex LP method – and the set parameters are confirmed by clicking Solve.

Figure 21: The Optimal Product Mix Results According to the Variable Cost Method

	A	B	C	D	E	F	G
1	VARIABLE COST METHOD						
2		**Men Shoes**	**Women Shoes**	**Sandals**			
3		X	Y	Z	**€**		
4	**THE OBJECTIVE FUNCTION**	8.36	8.31	8.52	**585.05**		
5							
6							
7					**Total Manufacturing**		**Capacity**
8	**CONSTRAINTS**	**Men Shoes**	**Women Shoes**	**Sandals**	**Time**	**Capacity**	**Utilisation**
9	1) Preparation	26.50	26.50	18.55	1,459	2700	0.54
10	2) Sewing	38.90	38.90	39.10	2,700	2700	1.00
11	3) Assembly	42.50	42.50	29.75	2,340	2700	0.87
12							
13							
14	**Product Quantity**	8	14	47			
15							
16	**Order of Priority**	2	3	1			

The production of 8 pairs of men shoes, 14 pairs of women shoes, and 47 pairs of sandals has been determined as the most suitable product mix. With this combination of product quantities, the sewing process capacity utilisation is calculated as 100%, and the assembly process capacity utilisation has dropped to 87%.

The business management should know how much demand they are able to meet with their available capacities; therefore, it is necessary to conduct such analysis. If constraints are not identified – in this case the sewing and assembly process – the business will believe it can produce all the incoming demand. Due to this miscalculation, their sales revenue, profitability and cash flow will not reach the set goals. In other words, the business will have created its own failure.

3.7.2. Product Mix According to the TOC Method

According to TOC, throughput is calculated by deducting the unit direct material cost from the unit sales price.

Table 17: The Calculation of Unit Throughput According to TOC

	Men Shoes	Women Shoes	Sandals
Unit Sales Price	33 €/unit	32 €/unit	28 €/unit
Unit DM Cost	11,70 €/unit	10,75 €/unit	9,00 €/unit
Throughput	**21,30 €/unit**	**21,25 €/unit**	**19,00 €/unit**

The unit throughput calculated for each product type is included in the MOF, where 'x' represents men shoes, 'y' are women shoes, and 'z' are women sandals. The total manufacturing times for each process should be compared to the available capacities to determine whether there are capacity constraints in the system.

The Maximum Objective Function according to TOC:

MOF: 21,30 X + 21,25 Y + 19,00 Z

Constraints:

Preparation	26,50 X + 26,50 Y + 18,55 Z $\leq$ 2700
Sewing	38,90 X + 38,90 Y + 39,10 Z $\leq$ 2700
Assembly	42,50 X + 42,50 Y + 29,75 Z $\leq$ 2700
	X, Y, Z $\geq$ 0

As in the Variable Cost method, the data of the problem has been organised into an Excel worksheet, which can be seen in Figure 22.

Figure 22: Data Demonstration in the Linear Programming Model According to the TOC Method

	A	B	C	D	E	F	G
1	TOC METHOD						
2		Men Shoes	Women Shoes	Sandals			
3		X	Y	Z	€		
4	THE OBJECTIVE FUNCTION	21,30	21,25	19,00	1.955,90		
5							
6							
7					Total Manufacturing		Capacity
8	CONSTRAINTS	Men Shoes	Women Shoes	Sandals	Time	Capacity	Utilisation
9	1) Preparation	26,50	26,50	18,55	2.197	2700	0,81
10	2) Sewing	38,90	38,90	39,10	3.783	2700	1,40
11	3) Assembly	42,50	42,50	29,75	3.523	2700	1,30
12							
13							
14	Demand	8	42	47			
15							
16	Throughput per Constraint	0,548	0,546	0,486			
17	Time						
18	Order of Priority	1	2	3			

The set objective is cell $E$4, which is to be maximised, therefore the "Max" option is selected. The variables are the demand quantities ($B$14:$D$14), which have their own limitations; the demand. In the TOC method, to create the most suitable product mix, *throughput per constraint time* (TCT) needs to be calculated. TCT is calculated by dividing the unit throughput for each product with the unit process constraint time. In this case, the CCR is the sewing process, therefore TCT for each product type is calculated as follows:

Men shoes:	Formula for cell B16: =B4/B10
Women shoes:	Formula for cell C16: =C4/C10

Sandals: Formula for cell D16: =D4/D10

The company should start producing the product with the highest TCT value. In this case, it is men shoes which have the highest TCT value, following with women shoes, and finally sandals. The parameters in Solver were adjusted accordingly (1. $D$14=47, 2. $B$14=8, 3. $C$14≤42). The parameter settings are shown in Figure 23.

Figure 23: The Solver Parameters for the TOC Method

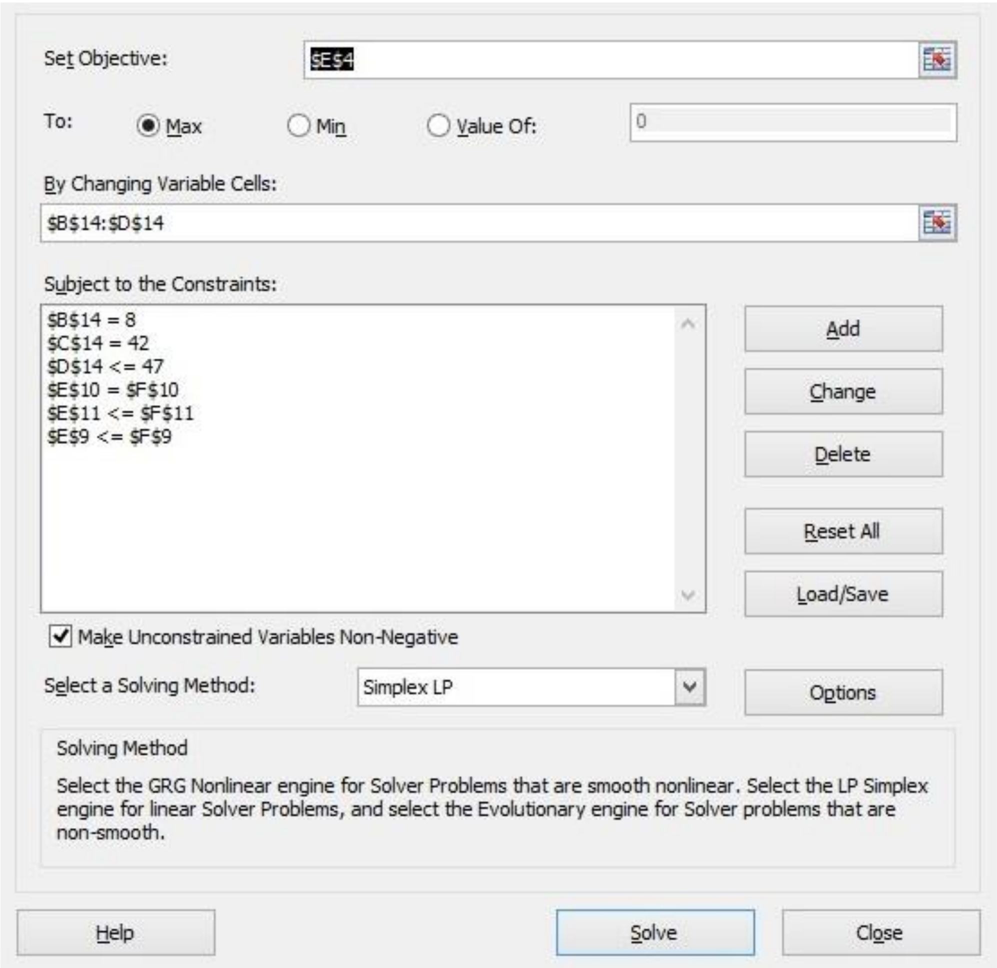


Figure 24: The Optimal Product Mix Results According to the TOC Method

	A	B	C	D	E	F	G
1	TOC METHOD						
2		Men Shoes	Women Shoes	Sandals			
3		X	Y	Z	€		
4	THE OBJECTIVE FUNCTION	21.30	21.25	19.00	1,429.78	1429.7798	
5							
6							
7					Total Manufacturing		Capacity
8	CONSTRAINTS	Men Shoes	Women Shoes	Sandals	Time	Capacity	Utilisation
9	1) Preparation	26.50	26.50	18.55	1,683	2700	0.62
10	2) Sewing	38.90	38.90	39.10	2,700	2700	1.00
11	3) Assembly	42.50	42.50	29.75	2,699	2700	1.00
12							
13							
14	Product Quantity	8	42	19			
15							
16	Throughput per Constraint						
17	Time	0.548	0.546	0.486			
18	Order of Priority	1	2	3			

According to the TOC menthod, the production of 8 pairs of men shoes, 42 pairs of women shoes, and 19 pairs of sandals has been determined as the most suitable product mix. With this combination of product quantities, both the sewing and assembly process capacity utilisation is calculated as 100%.

The pre-existing demand was unreachable because of the existence of two capacity constraints in manufacturing. Consequently, if the analysis had not been conducted, the business would be trying to meet a demand that it has no capacity for. Accepting a customer's order without considering the available capacities not only results in material value loss but also the reliability of the business as well as its brand credibility.

The effects of the created optimal product mixes on the company's profit according to the Variable Cost method and the TOC method are presented in Table 18 and Table 19.

Table 18: Sales Profitability According to the Variable Cost Method

	Men Shoes	Women Shoes	Sandals	Total
Production Quanity	8	14	47	
Unit Sales Price	33,00 €	32,00 €	28,00€	
Total Revenue	264,00 €	448,00 €	1.316,00 €	2.028,00 €
Total Variable Cost	26,64 € * 8 = 197,12 €	23,69 € * 14 = 331,66 €	19,48 € * 47 = 915,56 €	1.444,34 €
Total CM	66,88 €	116,34 €	400,44 €	583,66 €
Total Fixed Cost				392,23 €
Weekly Income				191,43 €

Table 19: Sales Profitability According to the TOC Method

	Men Shoes	Women Shoes	Sandals	Total
Production Quantity	8	42	19	
Unit Sales Price	33,00 €	32,00 €	28,00€	
Sales	264,00 €	1.344,00 €	532,00 €	2.140,00 €
Total DM Costs	11,70 € * 8 = 93,60 €	10,75 € * 42 = 451,50 €	9,00 € * 19 = 171,00 €	716,10 €
Total Throughput	170,40 €	892,50 €	361,00 €	1.423,90 €
Total Operating Expense				1.197,24 €
Weekly Income				226,66 €

Producing 8 pairs of men shoes, 14 pairs of women shoes and 47 pairs of sandals according to the variable cost method generated a weekly income of **191,43 €**. Whereas the product mix that has been created with the TOC method generated a weekly income of **226,66 €**. By using the TOC method and considering the existing opportunities of Dambeti, it is visible that the sales revenues are higher than according to the variable cost method. This reflects in a **35,23 €** per week (226,66 € - 191,43 €), i.e. 18% increase in the profit of the company.

The business was not able to meet their existing demand due to the presence of two capacity constraints in their manufacturing process. However, with the new product mix that has been created according to the Theory of Constraints, Dambeti has realised the maximisation if its profit. In case the company would like to meet any extra demand, it would be necessary to increase their manufacturing capacity by either buying new machinery or by outsourcing.

One of the basic understandings of the Theory of Constraints is that generating profit depends on the sales that a business realizes. In other words, profit will increase or decrease due to sales. This study has tested and proved the validity of this through the implementation of TOC in a small shoe manufacturing company in Montenegro. Simultaneously, the classic – Variable Cost – analysis method and the analysis made according to the Theory of Constraints brought conclusions such as:

- Managers' decision-making skills allow an organisation to realize profit, not products;
- Products do not have the potential to create profit;
- Theory of Constraints can be considered as a guide for managers in decision-making by considering that all costs except direct material are operational expenses, e.g., direct labour, factory overhead, and selling and administrative costs.

The contribution margin is the most important factor that affects decision-making in the constraint environment. Decision-making according to the contribution margin will positively influence capacity and productivity management. Managing constraints and creating the most appropriate product mix will allow businesses to form their supply policies, production or purchasing decisions, and future budgets.

4. CONCLUSION

In this study, the results of the implementation of the Theory of Constraints in a small shoe manufacturing company from Montenegro have been examined and compared to the results obtained according to the Variable Cost method.

Theory of Constraints is based on a continuous improvement process that moves towards eliminating the constraints that are found in the system and improving the systems that the company owns. With the today's economic conditions, companies are forced to reduce costs, and the existing management systems are insufficient. TOC can be considered as a systematic management method that is capable of guiding managers to run their business more efficiently. It differs from other approaches by focusing primarily on the weak points in the system, which are referred to as 'constraints'. Using the Five Focusing Steps, the business can identify and eliminate the system constraint, and when a new constraint appears, the continuous improvement process is repeated.

As making the right decision at the right time, managing constraints effectively is also important. Constraints can be internal or external, although good management of internal constraints represents a significant potential for the company. By understanding how TOC works, the company can form the problem, identifying it, build a solution, identify obstructions that need to be overcome, and apply the solution.

The purpose of this research was to identify and eliminate the system constraints using the Five Focusing Steps, and to examine how they affect the profit of the business. According to the conducted research, it was determined that the business that was chosen for the implementation had two capacity constraints in two out of three manufacturing processes – sewing and assembly.

To eliminate the existing capacity constraints, two different methods were used, and their results were compared. In the Variable Cost method, to create the most suitable product mix the products are to be produced in order by starting with the product that has the highest unit contribution margin. According to the VC method in Dambeti's case, the sandals need to be produced first, following with men shoes, and finally the women shoes. According to TOC, throughput is calculated by deducting the unit direct material costs from the unit sales price. The direct material is considered as the only variable that varies depending on the sales. In the TOC method, to create the most suitable product mix, throughput per constraint time (TCT) needs to be calculated. TCT is calculated by dividing the unit throughput for each product with the unit process constraint time. In Dambeti's case, the capacity constraint resource was the sewing process, therefore the unit TCTs were calculated according to the sewing process times.

Dambeti's pre-existing demand was unreachable because of the existence of two capacity constraints in manufacturing. Consequently, the business has been trying to meet a demand that it has no capacity for. Accepting a customer's order without considering the available capacities not only results in material value loss but also the reliability of the business as well as its brand credibility.

The effects of the created optimal product mixes on the company's profit according to the Variable Cost method and the TOC method have been compared. The Variable Cost method and the TOC method delivered different product mix results, The throughput-based TOC method proved to be a better alternative for the business, since it generates a higher profit than the variable cost method. The product mix that has been created by using the Variable Cost method generated a weekly income of 191,43 €. However, the product mix that has been created with the TOC method generated an income of 226,66 €. This reflects in a 35,23 € per week (226,66 € - 191,43 €), i.e. 18% increase in the profit of the company.

Since the business was not able to meet the current demand and would not have excess capacity to meet any additional demand, a conclusion was made that it should either increase its manufacturing capacity by purchasing new machinery, or start outsourcing its production.

According to Goldratt, systems are created with an intention, a goal, and that goal is to make money now and in the future. Theory of Constraints is defined as an integrated technique that sees the company as a system, determines the constraints of the system and establishes the relationship between them to achieve the objectives. The main goal of TOC is to place the continuous improvement process in a company.

Theory of Constraints is not oriented against improving only one manufacturing department or one plant, but the entire company, therefore local optimums are not concerned with. Managers that manage the system constraints effectively to increase the business profit are managing their business effectively.

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