# APPLICATION OF THE THEORY OF CONSTRAINTS TO AN ELECTIVE COURSE REGISTRATION SYSTEM

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## ABSTRACT

APPLICATION OF THE THEORY OF CONSTRAINTS TO AN ELECTIVE COURSE REGISTRATION SYSTEM

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The Theory of Constraints (TOC) is a holistic management philosophy put forward by Eliyahu Goldratt in 1984. The thinking process and improvement tools discussed in this theory are mainly geared to manufacturing environments, however their applicability to service environments has also been shown for private professional service organizations. This study demonstrates that the steps and principles of the TOC can also be applied to non-profit services, such as the elective course registration process described in this thesis. In the case of non-profit organizations, the challenge is to define the performance measures of the TOC, which are Throughput, Inventory, and Operating Expense. This study offers a novel definition for these measurements, and using the principles of the TOC, it identifies the bottleneck and constraints of the elective course registration process. Using this analysis, the study then redesigns the system in order to improve the performance measures of the system.



Keywords: Theory of Constraints, Performance Measures

# ÖZ

KISITLAR TEORİSİ'NİN BİR SEÇMELİ DERS KAYIT SİSTEMİNE UYGULANMASI

Üstün, Pınar
Yüksek Lisans, İşletme Bölümü
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Kısıtlar Teorisi (KT), 1984 yılında Eliyahu Goldratt tarafından geliştirilen bir bütünsel yönetim felsefesidir. Bu teori dahilinde tartışılan düşünce süreçleri ve iyileştirme araçları çoğunlukla üretim ortamları için uygulanmıştır; ancak bu teorinin özel hizmet şirketleri için gerçekleştirilen uygulamaları da mevcuttur. Bu çalışmanın amacı, bu tez içerisinde anlatılan bir üniverisitenin seçmeli ders kayıt sistemi gibi kâr-odaklı olmayan bir hizmet sistemine de KT'nin adım ve prensiplerinin uygulanabileceğini göstermektir. Kâr-odaklı olmayan organizasyonlar için zorlayıcı olan, KT'nin performans ölçütlerini, yani Çıktı, Envanter ve Faaliyet Giderleri'ni tanımlamaktır. Bu çalışma, bu performans ölçütleri için orjinal tanımlar ortaya koyar ve KT'nin prensiplerine dayanarak seçmeli ders kayıt sisteminin kısıt ve darboğazlarını tanımlar. Daha sonrasında, sistemin performans ölçütlerini iyileştirmek için öneriler sunar ve sistemi yeniden tasarlar.

Anahtar Kelimeler: Kısıtlar Teorisi, Performans Ölçütleri

To Can Ünver

and

The Department of Business Administration

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# CHAPTER 1

## INTRODUCTION

One of the characteristics of today's post-industrial society is undoubtedly the dominance of service industries. The service sector has been on the rise for over twenty years and the value created by service industries account for most of the national income of developed countries. This not only shows the current status of the service sector, but also suggests the future growth of service operations all around the world. As people's needs and expectations change, the service sector has to respond quickly in order to meet the individual requirements of large populations, and this increases the complexity of service processes significantly.

To meet the ever-increasing and ever-changing demands of the society, some management tools and techniques must be devised and applied to service environments in order to streamline and improve services on a continuous basis. Even though significant research has been carried out about the classification and characteristics of service processes, the improvement methods and techniques have mostly been borrowed from the manufacturing literature and adapted to services. However, the distinctive characteristics of service processes, such as simultaneity, perishability, intangibility and customer presence (Fitzsimmons and Fitzsimmons, 2006), make it challenging to transfer the terms and methodologies of management techniques that are specifically designed for manufacturing operations to services. While product inventories act as a buffer between the customer and the manufacturing environment, this is not possible for service processes and the de-coupling can only occur through customer waiting. Since services are delivered right where and when the customer dictates, there is little room for quality checks before the actual delivery of the service. Such properties of services are examples of the distinctive characteristics that set services quite apart from the more controllable

environment of manufacturing. Therefore, a whole new approach is needed for the management and improvement of services.

When Eliyahu Goldratt first developed the concept of the Theory of Constraints (TOC), he foresaw the applicability of the underlying principles of his theory to service processes. Although he explained the thinking processes behind his theory mainly with examples from a production environment in his novel *The Goal* (Goldratt, 1984) where the concept was first introduced, he refrained from using heavy manufacturing jargon and managed to put forward a systems-based, holistic approach to management which was applicable to many organizations, be it goods or services-oriented. In *What is this thing called Theory of Constraints and how should it be implemented?* (Goldratt, 1990), he elaborated on the details and principles of this management philosophy and he specifically underlined the fact that he had not designed the TOC just for use in the manufacturing arena, because his teachings and methodologies are applicable to any business which has a goal, and the service industry is undoubtedly included. After more than twenty years of successful implementations, the theory gained significant credibility as an essential tool for continuous improvement, not only in the manufacturing sector but also in services. However, in order to apply Goldratt's principles to a service setting, there is still a need for re-wording and re-interpretation in order to reflect his principles to the characteristics of service processes. Once the TOC is transferred to the service instance, the focusing steps and thinking processes of the theory provide clear guidance to diagnose the areas that need attention and to come up with ideas that significantly improve the current system performance. However, the applications of the TOC in service environments have been largely concentrated on profit-seeking organizations. Defining the performance measures for non-profit systems presents an additional challenge in the application of the TOC to such service instances, since these measures cannot be defined in monetary terms. Therefore, a different approach needs to be taken.

This study aims to demonstrate the applicability of Goldratt's Theory of Constraints and thinking process to a non-profit service environment which consists of the interactive elective registration process of third and fourth year Business Administration (BA) students at Middle East Technical University (METU). The study adapts the tools and principles of the TOC to this service and defines the performance measures of the system, which are Throughput, Inventory and Operating Expense. The study presents simple yet effective recommendations and modifications to improve the current system performance, and shows that the Theory of Constraints can be applied to a service setting such as a university's registration system.

In this thesis, Chapter 2 presents an overview of the Theory of Constraints and introduces its principles and tools, followed by applications of the TOC to service environments given in Chapter 3. Chapter 4 discusses the registration system of METU and the elective course registration process of the Department of Business Administration in detail and presents the performance measures of the system. In Chapter 5, factors affecting the performance measures of the system are discussed and several recommendations are put forward. Using the analyses in Chapters 4 and 5, Chapter 6 presents the proposed system and discusses improvements. Chapter 7 concludes by discussing the results of the study and mentioning its limitations as well as implications for future research.

# CHAPTER 2

# THE THEORY OF CONSTRAINTS

This chapter introduces and discusses Eliyahu Goldratt's Theory of Constraints and its fundamental elements. The sections under this chapter discuss the nomenclature, mechanisms and main principles of the theory, drawing parallels from the service industry where appropriate. The analysis presented in this chapter is later used in Chapters 4 and 5 to adapt the interactive elective registration system of METU Business Administration students to the steps and guidelines of the Theory of Constraints.

## 2.1 Overview of the Theory of Constraints

The term Theory of Constraints was first coined, although implicitly, in 1984 when the first edition of *The Goal* was introduced into the market. In this management novel, Eli Goldratt (1992) guides the reader along with the hero of the story through the steps of the Socratic thinking process to solve the problems that the characters face on the factory shop floor. The guide-teacher in the story Jonah, who reflects Goldratt's own personality, slowly puts forward a set of intuitive guidelines that are aimed at taking a company closer to its goal and helping it exploit its constraints, whatever they may be. It is due to this holistic approach that the TOC is applicable for both manufacturing and service environments, because every system is built for a purpose and every system is bound to be subject to certain constraints. According to Goldratt (1990), "anything that limits a system from achieving higher performance versus its goal" is a constraint, and "any system in reality must have at least one constraint."

Another important characteristic of the TOC is commitment to continuous improvement. The set of intuitive guidelines put forward by Goldratt are constructed in a cyclic fashion, so that the improvement process is designed to continue after each successful attempt. However, according to the TOC, trying to improve a system's components separately, without taking the global goal of the organization into consideration almost always fails. This can also be explained with the principles of assembly-line balancing, where it does not make sense to maximize the output on a machine without trying to improve the output of the bottleneck to which that machine feeds. This is also analogous to the fact that a chain is only as strong as its weakest link. Consequently, it is evident that the TOC does not consider a change in the system to be an improvement unless it works for the benefit of the global optima. In his novel *The Goal* (1992), Goldratt repeatedly underlines the importance of refraining from focusing only on local goals and improvements, because in the end, a local improvement that adds nothing to the actual global goal is a waste of time and resources. This constant emphasis on the global goal is what actually sets the TOC apart from management techniques such as Total Quality Management (TQM) and Just-In-Time (JIT). According to Motwani, Klein, and Harowitz (1996a), TQM and JIT "philosophies are solidly rooted in the concept that any improvement, anywhere in the process, improves the performance of the whole organization" whereas the TOC believes that improvement efforts should only focus on the weakest links of a system. Therefore, it could be said that the primary purpose of the TOC is to alleviate the weight on bottlenecks that prohibit an organization from reaching its goal. These bottlenecks do not necessarily comprise physical constraints, such as the insufficiency of raw materials and machines, the unavailability of shop-floor space, or even the absence of workers. The policies of an organization or its culture may well be equally destructive constraints that can be named as bottlenecks. In fact, Goldratt (1990) argues that most of the constraints that organizations battle against are operating procedures and policy constraints that have been embedded within the structure of the organization for many years. The fact that the TOC strives for ongoing improvement is because whenever the capacity of a bottleneck is increased

and it starts to perform synchronously with other components of the system, another constraint will eventually arise in another part of the system, limiting the organization. Therefore, one must continuously be on the watch.

### 2.2 The Five Steps of Focusing

The intuitive set of guidelines that were mentioned in the previous section is composed of five steps, which Goldratt (1990) names as "the Five Steps of Focusing". These five steps are as follows: 1. Identify the system's constraints, 2. Decide how to exploit the system's constraints, 3. Subordinate everything else to the above decision, 4. Elevate the system's constraints and 5. If in the previous steps a constraint has been broken, go back to Step 1, but do not allow inertia to cause a system constraint.

***Identifying the system's constraints*** constitutes the backbone of the whole process. It is at this step that the limiting element or elements in the system are diagnosed. Several constraints may arise and they may have to be prioritized according to their overall impact on the organization's goal. As discussed before, constraints may come in the form of physical or labor-related constraints as well as limitations rooting from organizational procedures, policies, market regulations, or money. The correct diagnosis of the system's constraints is crucial because the remaining steps in the focusing process heavily depend on it.

***Exploiting the system's constraints*** simply calls for seeking ways to get the most out of the specified constraints without spending a significant amount of money. Since the whole system will be tuned to function synchronously with the constraints, it is firstly important to get the maximum possible performance from the constraints and make sure that all the activities carried out at the constraint resource are productive and value-adding. Therefore, improvement efforts should firstly be aimed at the bottlenecks. It is possible to extract more from the bottlenecks by trying to find the

actual reasons behind the limitations and devising ways to remove those limitations. For example, the utilization of a bottleneck machine may be enhanced by carrying out a quality inspection prior to the process on the bottleneck machine. This ensures that the bottleneck will not waste time on defective products and therefore it produces more quality-ensured products in a given time. In a service environment, this could mean the cross-training of employees so that the performance of a specific task is not limited to the ability of a single server/employee.

***Subordinating everything else to the above decision*** requires balancing the rest of the system, namely the non-constraints so as to perform harmoniously with the bottlenecks. Subordination has two major requirements. Firstly, it should be ensured that a constraint always has what it needs exactly when it needs it and this can only be achieved by managing the non-constraints properly. The second important point is that the non-constraints should not work beyond what the constraint can process at any given time. The driving factor behind these principles is to keep the bottleneck as busy as possible, and make sure that it is never left idle. It is however acceptable for non-constraints to stay idle, as opposed to what is generally practiced. Goldratt (1992) has continuously tried to teach that an idle resource is not a complete waste and in fact, some machines *do* need to stay idle in order to create a protective capacity for the bottlenecks and to increase the overall performance of the system, however contradictory to conventional methods it may seem.

***Elevating the system's constraints*** means trying other ways to improve the productivity of a bottleneck, after all internal exploitations and subordinations have been carried out. This could simply mean outsourcing the needed resource or purchasing another machine that can carry out the job of the bottleneck. In a service environment, the time constraint on a specific process may be relieved by hiring additional servers such as part-time employees, or even by implementing a computerized system that reduces the actual time of the service. Carrying out special marketing strategies to increase the exposure of the service to customers may be another way to elevate a market-related demand constraint. What is common about

these possible solutions is that these are all strategic decisions and they typically require more investment in the constraint than what the preliminary subordination efforts carried out in Step 2 require.

The final step of the focusing process is composed of a warning about ***not letting inertia to cause a system constraint***. Keeping in mind the fact that a system must have at least one constraint, the fact that a constraint is alleviated does not keep the system from generating new limitations. For example, when a resource-related constraint is overcome, the new element limiting the system may now be the lack of demand from the market. Consequently, management must aim its efforts towards alleviating this new constraint, and the cycle of focusing must begin again, this time searching for ways to increase the market demand. When this new constraint is overcome, another internal bottleneck may arise, requiring the previously implemented changes to be reviewed and re-evaluated. This final stage is essential for the continuous improvement doctrine of the Theory of Constraints.

The analysis related to the application of the Five Steps of Focusing to the registration process of third and fourth year BA students is presented in Chapters 4 and 5. These chapters specifically discuss the constraints and factors that affect the performance measures of the registration system and provide solutions to exploit or elevate these constraints. These solutions are then used for the design of a new and improved registration process in Chapter 6.

### 2.3 The Drum-Buffer-Rope Mechanism

Aside from the application of the Five Steps of Focusing, the TOC introduces another set of thinking principles that serves as a planning and scheduling tool at the shop-floor level. This is called the Drum-Buffer-Rope (DBR). In order to understand the philosophy behind the TOC, DBR is an essential concept which needs to be analyzed thoroughly.

The DBR is based on the understanding that the time lost on a bottleneck resource is time lost for the entire system (Sivasubramanian, Selladurai, and Rajamramasamy, 2000). Therefore the bottleneck, the slowest by definition among a group of faster-performing machines, logically has to be hundred percent utilized in order to "catch up" with the faster going non-constraints. However, these constraint-free resources also have some catching up do. In fact, they have to "catch down" with the bottlenecks and tune their pace according to the slowest one in the pack, namely the bottleneck.

As opposed to Master Production Schedule (MPS) based scheduling structures that count backwards from the end of the production line to determine workstation schedules and material releases, the DBR approach advocates for counting backwards from the bottleneck resource or process to determine other workstations' schedules and material releases (Polito, Watson, and Vokurka, 2006). This is why Goldratt's TOC philosophy is used interchangeably with the term "synchronous manufacturing", because every resource on the shop-floor is in tune with each other and everything is synchronized. Therefore, the MPS should be constructed in a way that the system works at the pace which equals that of the bottleneck and no more. There is no point in using the excess capacity of non-constraint resources to the maximum and produce a pile-up of excessive inventory.

In order for the synchronization to work under all conditions, there needs to be a time buffer that "isolates" the bottleneck from the disruptions and variations that occur in upstream operations. This is done in order to keep the bottleneck busy a hundred percent of the available time, whereas other faster machines which feed to the bottleneck can and should be entitled to rest, as the pace of the drum dictates. Goldratt (1992) has continuously stressed the fact that an idle resource does not equal a forgone capacity for the overall system. In fact, in order for synchronous manufacturing to stay intact, some resources do need to stay idle in order to create a protective capacity or time buffer for the bottlenecks.

At this point, the acronym DBR becomes quite vivid. The **drum** is the bottleneck resource that is being scheduled. The **buffer** provides a protection time for the bottleneck against variations and other problems that may occur in adjacent operations. The **rope** is the imaginary mechanism that forces every element in the system to work in synchronization. With an example, if a bottleneck produces 45 units per day and the preceding resource produces 60, the non-constraint resource will have to be rescheduled so as to produce only 45 units per day, exactly the amount that the bottleneck needs to receive.

As can be seen, the DBR is an integral and essential part of the TOC. The third step of the TOC which is about the subordination of other resources according to the exploitation of the bottleneck, involves what the DBR aims to do. Although the concepts described here for the DBR mechanism seem to be based on shop-floor illustrations, it is again possible to translate them to service settings, as will be described in the following chapters.

### 2.4 Performance Measures of the Theory of Constraints

Up to this section, factors and concepts that limit an organization from achieving greater levels of performance have been discussed. In the search for exploiting or elevating constraints, there is a need for an objective measurement criteria that can be used to understand whether a certain action will work for the benefit of the primary goal of an organization or not. For this purpose, Goldratt (1990) has introduced three performance measures through which the impact of any local decision can be judged against the global goal. These measurement criteria are Throughput, Inventory and Operating Expense. The Theory of Constraints International Certification Organization has renamed Inventory as Investment (Sullivan, Reid, and Cartier, 2007).

As is emphasized in the TOC, the goal of an organization is to make money now and in the future, keeping the set of non-profit organizations aside as an exception (although they too most certainly have a goal such as improving public welfare which does not keep the TOC from being suitable to be applied to them as well). Therefore the changes that a company undertakes should be directed at nothing else but its ability to realize this goal. Goldratt asserts that there are only three avenues open to increase a firm's ability for making money and those avenues are; increasing Throughput, decreasing Inventory and decreasing Operating Expense.

***Throughput (T)*** can be defined as the rate at which a system generates money through sales. It is critical to note that Throughput is not the rate at which a system manufactures a certain item at a given time period. Although it has been interchangeably used with the term *output*, Goldratt's definition of Throughput is definitely not what is generally referred to as output in a traditional manufacturing environment. According to Goldratt's accounting perspective, anything that is produced but not sold is a contribution to Inventory and it cannot be classified as part of the Throughput. Therefore, Throughput in itself is only composed of system outputs such as products or services that have *left* the system in the form of sales.

***Inventory (I)***, refers to all the money that is currently tied up in the system, which is why it is also called Investment. Contrary to traditional manufacturing frameworks, Goldratt's Inventory does not only consist of work-in-process (WIP) inventories or unsold products. Inventory is a measure of all the money that is dedicated to the system to help it generate Throughput. Therefore in a TOC environment, Inventory also consists of assets such as buildings, equipment and machinery, as well as conventional items such as raw materials, WIP and finished goods.

The final performance measure is ***Operating Expense (OE)***, which is the money spent by the system in the process of turning Inventory into Throughput. However, Operating Expense does not only encapsulate the variable costs of production, such as the purchase of raw materials or costs of outsourcing. It is composed of salaries,

rents of buildings or equipment and all other expenditures that the company undertakes in order to generate Throughput.

These performance measures are appropriate for the service industry as well. One potential difficulty may be experienced with the Inventory item, since one of the main characteristics of service operations is that they are non-inventoriable (Fitzsimmons and Fitzsimmons, 2006). However, renaming this item as Investment solves this complexity to a great extent, as service organizations also have some of their capital tied up in the system in order to generate services.

In order to put these units of performance measures into perspective and show their interdependent and simultaneous relationship with each other, Goldratt (1990) redefined them using traditional financial measures as given below, where NP stands for Net Profit and ROI stands for Return on Investment. Other conversions are also possible.

$$NP = T - OE \qquad ROI = (T - OE) / I$$

One other issue that the TOC deals with regarding these units of performance measures is their relative priority in decision making. As stated previously, these units are put forward to help an organization assess and measure its improvement attempts against its global goal. In other words, while carrying out the Five Steps of Focusing, a manager should ask questions like "Would this action increase Throughput?" or "If I pursue this method, how would Inventory be affected?" Only after being sure that the proposed actions help the company's global goal by increasing T or decreasing I and OE, then an action is valid to proceed with. However in many cases, a decision may have simultaneous effects on all of these items, sometimes even conflicting ones. In such cases, a prioritization of these measures is essential. According to Goldratt, Throughput should have the first place due to its "money making" ability. Inventory should come second due to its indirect

effects on the future Throughput of an organization, followed by Operating Expense. Therefore, the decisions that are being considered by management have to be judged against their individual impact on T, I and OE, as well as their mutual and indirect influences on these three measures according to their relative importance.

### 2.5 The Process of Change

The main emphasis of the TOC is on the process of ongoing improvement. Goldratt's Five Steps of Focusing is a tool that is designed to carry an organization closer to this goal. In other words, for an organization to realize its goal in an environment bounded by physical or procedural constraints, it needs to go through a series of steps that change how the organization has been functioning over the years. Therefore, any attempt to adopt and implement the TOC principles brings with it a challenge for managing change.

Goldratt (1990) also discusses the process of change and its impact on the organization. He identifies three guidelines that are related with change. According to Goldratt, the process of ongoing improvement firstly requires to pinpoint ***what to change***. After a major problem is identified, one must find ***what to change to***. The third and the most challenging step is finding ***how to cause the change*** in a way that will constructively affect the working environment within the organization. Goldratt states that since there will always be someone in an organization who will feel threatened by the notion of change, this sense of insecurity can only be overcome by a properly managed and nourished sense of organizational commitment.

According to Goldratt, there are psychological barriers in organizations. The impact of these barriers climaxes during a suggested process of change, due to the threatening atmosphere that comes with it. Some organizations try to overcome the insecurity resulting from change, using the threat of the insecurity of what will happen if the change does not happen at once. This does not comply with the

ultimate goal of the process of ongoing improvement, because the presence of threat or manipulation brings with it a feeling of "*let's just get it over with*", and this undermines an organization's vision of ongoing improvement. Rather than enforcing such methods, Goldratt advocates the creation of a sense of ownership throughout the organization. Whenever someone comes up with an idea about *what to change* and *what to change to*, he/she will definitely have to find a way to overcome the psychological barriers of *how to cause the change* as well. If a person who tries to bring an improvement to an organization may be called an "inventor", the ultimate step is to induce in everyone else the feeling of creation and ownership about that particular idea which the inventor himself/herself has previously experienced. Therefore, it is essential to create an environment where other people in the organization will go through a process similar to that which the inventor experienced during his/her problem solving process. Those people must themselves be able to see the what and the why and the how. When the solution becomes as obvious to them as it was obvious to the inventor, only then people will start taking ownership of the idea and actually want to do something serious about it. When the emotions of the inventor can be emulated or triggered within the minds of other people, only then emotional resistance can be overcome, leaving its place to a much valued sense of organizational commitment. Such an atmosphere is where the process of ongoing improvement thrives, transforming the organization into one in which change is not an exception, but a norm (Goldratt, 1990).

# CHAPTER 3

# APPLICATIONS OF THE THEORY OF CONSTRAINTS TO SERVICE ENVIRONMENTS

This chapter aims to discuss the findings in the literature that involve applications of the TOC to various service environments. Although there are a large number of findings readily available for the manufacturing environment, the studying of service organizations has only recently been rising. There are a number of publications that deal with either conceptual or actual applications of the TOC to service firms or specific processes within service organizations. Some authors discuss the application of the TOC theoretically, following Goldratt's Five Focusing Steps framework in order to point out certain problems and demonstrate improvements for a chosen system. There are also examples of real-world applications, where the TOC is applied to an actual service environment and the factual improvements are presented. Due to this categorization, this chapter is divided in two sections that respectively deal with conceptual and actual applications of the theory to service environments.

## 3.1 Conceptual Applications of the Theory of Constraints to Service Environments

Motwani et al. (1996b) explore the applicability of the TOC to the healthcare industry, drawing a hypothetical example from a clinic that provides medical services. The authors define Throughput as revenues from selling medical services and state that it is directly related to the number of patients that have received a treatment at any given time period. Inventory is composed of those who are in need of medical care but do not use the clinic because the type of service they need is not offered. Similar to WIP, the patients who are enrolled in the clinic but not yet

checked out are also considered as Inventory. The authors define Operating Expense as the rate of money consumed to deliver the product, which the authors call wellbeing. While traditional approaches would lead the clinic management to firstly deal with and decrease operating expenses, Goldratt's approach advocates for firstly focusing on Throughput. Consequently, Motwani et al. suggest that the first step should be to identify the limiting factors that keep the clinic from attracting more patients and providing a better service; namely, factors that keep the clinic's Throughput down.

Breen, Burton-Houle, and Aron (2002) illustrate a conceptual application of the principles of the TOC on a physician's office. They identify Throughput as "all the money flowing into the practice through the variety of services provided to patients minus the totally variable costs". Inventory consists of raw material, WIP, tools, building and equipment. The WIP in the clinic's case consists of patients waiting for treatment. Operating Expense includes all expenditures that the clinic undertake such as wages, salaries, utility expenses and interest payments. In their study, rather than offering solutions, Breen et al. mention questions and problems that may be faced with during each step of the Five Steps of Focusing for the case of the physician's office. They make an important diagnosis regarding the general practice within healthcare environments, stating that most organizations prefer to cut costs by letting go of the clerical staff before physicians. This causes physicians to spend more time doing the paperwork that could have been done by the clerical staff, and less time seeing patients, which is the actual source of Throughput. Breen et al. also mention the importance of statistical fluctuations and interdependent events. According to the authors, since every organization is structured as a chain of interdependent processes where the performance of each process is dependent upon the previous processes, the system as a whole can only be as strong as its weakest link. The authors also add that the actual performance of the system may even be worse than the average performance of the weakest resource, since the time lags that occur at various steps along the chain tend to accumulate and increase further down the line. Due to these

statistical fluctuations, a buffer must be present in front of the constraint at all times in order to even out the fluctuations over time and to avoid the constraint from being forced to remain idle. As in line with Goldratt (1990), Breen et al. point out the importance of viewing the system as a whole and not just trying to improve some resources within the system randomly. All improvement efforts should be aimed at the constraint, and it *does* make sense to leave some other resources idle in order to keep the performance of the constraint intact. In addition, Breen et al. also emphasize the fact that, aside from the typical performance measures of the TOC such as T, I and OE, for-profit medical practices also should strive to meet other indicators of success, such as patient and staff satisfaction, compliance with accreditation boards or regulatory bodies, and operating within budget. The authors claim that without these conditions, any attempt to improve T and/or decrease I and OE would jeopardize the future of the medical enterprise, since these indicators are critical in determining the long term profitability of the system.

Aside from these healthcare applications, Reid (2007) presents a comprehensive application of the TOC to the banking industry, specifically, to the loan application and approval process of a full-service bank. The process begins when a customer arrives at the bank to apply for a loan. After the application, the loan officer firstly gathers information about the applicant's financial history. He then refers to credit agencies in order to establish the applicant's credit rating. The bank then decides whether to extend a loan or not, and if approved, determines a credit limit for the applicant. After the decision is made, the applicant is notified. Although Goldratt (1990) advocates against local-optimization and asserts that the system should be treated as a whole, Reid defends that this banking subsystem is still a valid candidate for applying the principles of the TOC, because the goal of the loan application department is in line with the overall goal of the bank, which is to make money now and in the future. In the loan application example, Reid assumes that the constraint is internal and is due to loan officers who cannot complete the necessary tasks within the process in a responsive and timely manner. In order to exploit this constraint, he

recommends prioritizing loan applications according to their profit potential and therefore spending time on applications that will bring the highest profit to the bank. As another option to exploit the constraint and create additional capacity, Reid proposes to off-load some of the work from the loan officers to less experienced yet competent employees. In doing so, requests that do not exceed some dollar amount or potential risk value may be chosen to transfer to these employees. Getting into contact with credit agencies and constructing a customer's credit rating may also be carried out by other underutilized bank employees. For the third step, Reid suggests having a non-fully occupied clerk make sure that each application is complete and eligible for further processing. This action assures that the loan officer does not waste time on applications that later turn out to be incomplete or ineligible according to the bank's policies. For the fourth step of the focusing process, Reid recommends to elevate the constraint by hiring an additional loan officer.

Aside from the previously mentioned conceptual applications of the TOC to the healthcare and banking industry, another application is presented by Siha (1999), where the author constructs a classified model for applying the TOC to service organizations. Instead of focusing on a single service environment, Siha borrows from Schmenner' (1986) service process matrix and identifies issues and problems related with each quadrant in the matrix, depicting solutions that the TOC can offer. The author also identifies constraints, and what Inventory and Throughput would correspond to for each service type, namely service factory, service shop, mass service and professional service.

### 3.2 Actual Applications of the Theory of Constraints to Service Environments

One of many actual applications of the TOC to the service industry is presented by Bramorski, Madan, and Motwani (1997), in which they handle the mortgage department of a bank. Bramorski et al. define Throughput as the rate at which a bank generates revenues for the services it provides. Inventory (or in its renamed form,

Investment) is the amount of money the bank spends in order to raise capital which in turn is used to generate Throughput. Included in Inventory are the principal amount and interest expenses. Operating Expense includes all direct and indirect expenses which the bank undertakes in order to generate Throughput. One way to reduce Operating Expense would be to engage in information technologies such as online and telephone banking. The bank that is studied by Bramorski et al. has identified its main constraint as the duration of the processing of individual home mortgage applications and aims to reduce this processing time to three weeks. For this purpose, the Five Steps of Focusing are applied to this bottleneck process. Within the mortgage application process, the bank identifies the main constraint as the time it takes to verify the employment of the applicant and conduct appraisal and survey of the property. The bank then searches for ways to exploit this constraint and manages to reduce this time by asking the applicant to submit documents, such as the applicant's pay stub of last month, in order to verify employment more quickly. The authors state that similar solutions are also developed for reducing time in the remaining operations, however the exact actions taken are not mentioned. For subordination purposes, the bank reorganizes its operations so that the constraint can perform at its best, and all three performance measures are thus improved. However, the specific recommendations for this step and how subordination was actually accomplished are not clearly defined. It is again ambiguous as to how the elevation step was realized and what specific steps were undertaken by the bank. Although the study of Bramorski et al. presents a detailed overview of the nature of the banking industry and how it relates to the Theory of Constraints, it does not give a full and comprehensive analysis of the actual changes that were devised and implemented by the bank.

A comprehensive application of the TOC to a service firm is carried out by Motwani and Vogelsang (1996). The authors are hired by a civil engineering and surveying firm named OMM Engineering, in order to solve the firm's problem of struggling to meet contract deadlines. OMM gives construction administration services such as

survey staking and inspection. The survey department consists of one professional surveyor and three field surveyors. Within the current setup, field surveyors usually have to wait for the instructions from the professional surveyor before leaving for a site in the morning. Sometimes they receive the necessary instructions early in the morning, sometimes they receive them the night before. When they cannot receive the instructions before the start of the day, this causes a delay in the return time of the field surveyors, and the necessary information cannot usually be downloaded at the end of the day for other engineers to process. Therefore, the survey department is identified as the major constraint, because all downstream processes depend on it and other workers cannot begin their duties unless the field surveyors complete their job.

In order to exploit this constraint, the authors suggest that the professional surveyor establish a system of giving the instructions to the field surveyors the night before, so that the surveyors can go out and start their jobs early in the morning and return to the office in time to download the information necessary for other engineers' tasks. However, the study does not mention whether there is sufficient capacity for the professional surveyor to always give the instructions the night before. For the subordination step, the authors suggest cross-training some of the junior engineers to help in with surveying. Upon investigation, it is also found that some activities can indeed begin before the surveyors complete their jobs. While waiting for the surveyors to arrive, engineers can complete numerous activities which would in turn shorten the overall project completion time. For this purpose, a checklist of pre-survey activities is constructed and introduced to the company. In order to elevate the constraint, hiring more surveyors is the obvious solution and this requires further expenditure. However, OMM has been having trouble recruiting surveyors for the past two years. Therefore the authors suggest recruiting directly from colleges and universities and advertising for surveyors. The authors also recommend making use of a global positioning system (GPS) which would reduce the number of people and time needed to carry out a survey. Motwani and Vogelsang do feasibility and net present value analyses in order to determine whether OMM should rent GPS

equipment or purchase it. The result favors purchasing the equipment. According to the authors, GPS would help OMM gain more revenue and increase its Throughput, while decreasing the backlog of survey-dependent activities. Consequently, OMM Engineering would perform better in terms of on-time project completions, resulting in a greater turnover of cash and customer satisfaction. The study of Motwani et al. indicates how the TOC can actually be applied to a service environment.

Another on-the-job implementation of the TOC to a service environment is put forward by Olson (1998) with an example from American Security & Alarm Co. The company's main area of operation is the sales and installation of burglar alarms. The three alarm technicians that the company employs are responsible for installations. In the current configuration, each technician works on his own and the three technicians altogether can complete approximately 26 installations in one month. However, average demand per month is about 32, therefore the technicians cannot catch up with the current demand and they are forced to work overtime. The installation process consists of 9 steps that may or may not overlap with each other. These steps are; setup, drilling holes, running wires, mounting components, connecting and programming the control panel, processing client's account data, product testing, user instruction and cleanup. Initially, it is thought that having the three technicians work individually on three separate installations was useful because three sales orders were being fulfilled simultaneously. After assessing the system, it was found that having all technicians work as a team on a single installation yielded higher productivity. Therefore, the installation process was redesigned accordingly. Compared to the previous configuration, the team structure shortened the duration of some of the steps by a direct 33%, since now the same task was being processed by three workers at the same time, such as drilling holes in different places of the house concurrently. Other steps which previously had to be done sequentially could now be done in an overlapping fashion. For example with the old setup, one worker had to drill all the holes, then setup all the wires himself after drilling the holes. Within the recommended setup, after a few number of holes have been drilled by one technician,

the other two can start working on the wiring of these holes, while the first technician keeps on drilling other holes. When all the holes are drilled and the wiring of these holes are being carried out by the remaining technicians, the one who has finished with holes can start mounting the components and others may join him when they are finished with the wiring. Therefore the total elapsed time of an alarm installation shrinks considerably under the recommended setup. In fact, under the team structure, the duration of the entire process is cut down to 249 minutes from the original 957 minutes, which is a major improvement. The throughput of the company increases from 26 installations a month to about 33.7 installations. According to Olson, the average gross margin of an alarm system of such a size would be $700, which shrinks to a net profit of about $525 after wages and overhead are excluded. With the current 33.7 installations, the gross margin mounts to $5110, instead of the previous $700. When overhead and wages are excluded, the net profit drops down to $5000, still a very high value compared to the previous net profit of $525, because now the management does not have to pay the workers for working overtime, since every sales order is now being completed well in time. With the example of American Security & Alarm Co, Olson has depicted the case of a real-world situation where the TOC can be used to enhance the profitability of a company operating in the service sector.

Another real world application comes from Lubitsh, Doyle, and Valentine (2005). The authors' study of the impact of the TOC in a National Health Service trust presents a quantitative and statistical approach towards the applicability and outcomes of the TOC in a healthcare environment. A pilot study of 40 months is conducted in order to investigate the impact of the TOC on waiting lines and throughput of patients of three different departments at the Radcliffe Infirmary (RI) at Oxford; the departments being neurosurgery, eyes and ear-nose-throat (ENT). A distinct feature of this research is that the researchers employ a control group at a different hospital that shows similar characteristics to RI and assess the success of the TOC before and after the intervention of solutions based on the principles of the

TOC. The outcome of the ARIMA (Autoregressive Integrated Moving Average) analysis proves that the TOC is useful in reducing waiting times and increasing the throughput of patients in the eyes and ENT departments, whereas it does not lead to a statistically significant level of improvement for the neurosurgery department. The authors claim this inefficacy in the neurosurgery department on the complex and less self-contained nature of neurosurgical operations, whereas procedures for both eyes and ENT departments are more routine and they do not depend as heavily on diagnostic services as neurosurgery. This dependent nature of neurosurgery makes it difficult to estimate the completion times of any procedure and implementing buffers for this department is fairly difficult. Lubitsh et al. conclude that as the work of a department becomes more similar to the relatively predictable nature of a manufacturing process, the application of the TOC will be more straightforward. Although this study pioneers a systematic and quantitative approach to measuring the actual effects of the TOC in a service setting, it fails to identify the specific problems and constraints and the exact remedial steps taken for each department. Lubitsh et al. mention that a two-day workshop related to the TOC intervention was given by a consulting company. However, the actual steps that this consulting company took to improve the waiting times and Throughput of the departments is not known to the reader.

A noteworthy application of the TOC to the healthcare sector is the research of Gupta and Kline (2008). The object of study is a Chemical Dependency (CD) unit within a Midwest Community Mental Health Centre (CMHC) agency, in which people with substance abuse disorders are treated. The CD Program is composed of psychiatrists, psychologists, clinical social workers and clinical support personnel. Gupta et al. state that the goal of a CHMC is twofold and is composed of a financial goal which is to make money now and in the future while providing satisfaction for both patients and employees, and a clinical goal which is to provide patients with high-quality care. Throughput of a CHMC comes from the reimbursements of third-party payers and patient co-payments. Inventory is all the money that is tied up

within the system such as computers, buildings and other sellable assets; the WIP being the patients waiting for service and patients currently receiving service. Operating Expense includes wages, salaries, rent and utility expenses. The patient flow in a CD unit is as follows: The patient first makes a phone call to the Access unit of a CHMC which is responsible for determining the most appropriate schedule for the patient. The Access unit gives the patient an Intake appointment, which marks the beginning of the evaluation and treatment process. During the Intake appointment, the therapist conducts a psychosocial evaluation and this appointment is followed by regular therapy sessions. Since most substance abusers are in need of medication treatment, the therapist refers the patients to the psychiatrist for formal psychiatric evaluation. If the psychiatrist decides that medication would prove beneficial for the patient, he or she begins the treatment and schedules follow up medication visits. Recurrent patients first check in with the receptionist of the CD unit, who notifies the clinician of the patient's arrival. The clinician then escorts the patient to his or her office. After the visit, the patient returns to the waiting room to proceed with the payment which is collected by the clinical support staff. According to the analysis of Gupta et al., the therapists and the psychiatrist are the most expensive resources of the unit. There is a waiting time of two to three weeks for Intake appointments and three to four weeks for psychiatric evaluations. Since the only source of Throughput for the CHMC is patient visits, any time spent on non-clinical activities is a waste of valuable professional time. Therefore, the load on the constraints must be transferred to the clinical support staff as much as possible and the waiting times of the patients should be reduced in order to generate more patient turnover. Gupta et al. mention that the clinic typically does not remind the patients of their upcoming appointments and patients cancel, late cancel or miss approximately 25% of scheduled appointments. Each missed appointment for psychiatric evaluation wastes 1.15 hours of valuable psychiatrist time. The authors estimate that each such occurrence costs the CHMC approximately $200, including the psychiatrist pay and lost revenue. If only three appointments are missed or cancelled each week, the yearly cost exceeds $10.000, which is quite significant. As a result, Gupta et al.

recommend that the psychiatrist should call new patients to schedule an appointment and to call those patients again to remind them of their upcoming appointment. This is thought to be useful since it forms the beginning of a relationship with the psychiatrist and the patient and it is likely that the patient will be less anxious on the first appointment, having talked to the psychiatrist at least twice before coming to the clinic. However, further reminder calls should be made by the clinical support staff, since it is a waste of professional time for the psychiatrist to be making reminder calls all the time. The other recommendation is to close the cases of patients who frequently miss or late-cancel their medication visits. Similarly, the therapist should also call and remind patients of their upcoming Intake appointments, but further responsibility of these calls should again be undertaken by the clinical support staff so as to create more available therapist time. It is noteworthy that this new procedure of clinicians calling their patients to introduce themselves and reminding them of their appointments actually reduced the no-show and cancellation rates for psychiatric evaluations from 43% to 20% during a four-month pilot study. Aside from missed and cancelled appointments, another waste of professional psychiatrist time occurs when the psychiatrist goes to the waiting room to bring back patients to his office and returns them to the waiting room at the end of the appointments. Gupta et al. state that each round-trip travel takes approximately 45 seconds per patient and this number amounts to 24 minutes of valuable psychiatrist time if the psychiatrist sees about 32 patients in a single week. The recommendation for this problem is the relocation of the office of the psychiatrist so as to be as close to the waiting room as possible, in order to minimize the travel time. However there are two issues that have not been addressed within this recommendation. Firstly, since no apparent reason is mentioned within the study as to why the psychiatrist should personally escort the patients back and forth, the clinical support staff may well be used to accompany the patients to and from the psychiatrist's office and this would result in a minimal loss of energy and professional time for the psychiatrist. The other issue is that relocating the office of the psychiatrist to be closest to the waiting room may prove to be distressing for both the patient and the doctor, since the waiting room is supposed to

be one of the noisiest places within the unit. The patient and psychiatrist alike may well prefer the quiet and peaceful atmosphere of an office located far away from the outside noise as much as possible.

While the previous suggestions served the purpose of exploiting the constraint and subordinating everything else according to it, the following recommendations by the authors serve the purpose of elevating the constraint should the previous improvement attempts fail to increase the capacity of the psychiatrist and the therapists. The clinical support staff should be used to the extent possible in order to relieve the doctors from chores and paperwork that do not require any special expertise. However, the CHMC has difficulty recruiting and retaining clinical support staff mainly due to the low entry pay of $8 per hour and pay delays of three to four weeks. Consequently, Gupta et al. advocate a steady rise and on time payment of wages for the clinical support personnel, and justify the related financial burden upon the by the gain from Throughput via enhanced available therapist and psychiatrist time. Secondly, the unit may consider employing a psychiatric nurse who is capable of fulfilling some of the duties presently carried out by the psychiatrist, such as logging in sample and patient assistance medications and preparing them to be dispensed to the upcoming week's patients. Gupta et al. believe that the implementation of all the earlier recommendations would spare the CHMC the need to pay for additional therapist and psychiatrist time. This study of Gupta and Kline represents a unique example in the literature due to its thorough analysis and constant emphasis on employee and patient satisfaction. The suggestions for raising wages of clinical support personnel may well be a source of satisfaction. However, this study would have been more complete if a patient and employee satisfaction survey was conducted before and after the period of the pilot study. It might be impossible to implement the wage raises for the clinical support personnel right away, but there were still many new proposals within the study that might have a strong influence on patient and therapist/psychiatrist satisfaction. The numbers show that the no-show or cancellation rates have significantly dropped due to the new configuration, but

management is unaware of its implicit effects on the satisfaction of the patient and the doctor.

Another comprehensive application of the TOC to the healthcare environment is described by Kershaw (2000) in which the author presents the case of an oncology clinic, where management is striving to increase patient volume and satisfaction. The author defines the output of the system as a human being and the Throughput as "reimbursement rate less the cost of drugs and medical supplies for the number of patients seen and treated". The treatment process at the oncology clinic consists of 6 steps that involve the patient checking in with the receptionist, going to the lab for blood tests, going to the exam room for pretreatment, seeing the doctor in an exam room, going to the treatment room to receive chemotherapy and going back to the receptionist to arrange a follow-up appointment. The main problem with the treatment process is the growing number of complaints from patients due to excessive waiting time, therefore the main purpose of Kershaw's study is directed at decreasing the average waiting time of a patient. This is linked to decreasing the average treatment time of patients, because the treatments of patients last longer than the time allocated for each appointment and upcoming patients are thus subject to waiting. The author identifies the bottleneck in the treatment process to be the unavailability of treatment chairs. This subsequently leads to a pile-up of work-in-process patients. The financial position of the clinic restrains the clinic from acquiring more treatment chairs. Therefore the TOC efforts are directed at streamlining the treatment process itself. The average time a patient spends in a treatment chair is about 2.5 hours and is composed of establishing intravenous (IV) access (15 minutes), administrating drugs (2 hours) and educating the patient (15 minutes). The clinic decides to shift the posttreatment education to the final 15 minutes of chemotherapy so that the patient can receive the treatment and the education simultaneously in the treatment chair. Establishing IV access on patients' arm or hand is also now relocated to be carried out at the lab instead of the treatment chair, because the patient is required to go to the lab for blood tests anyway. These

actions helped reduce the overall treatment time from 2.5 hours to about 2 hours. Since the administration time of chemotherapy depends on the volume and flow rate of the particular drug being used as well as the patient's physical condition, further time reduction during this stage is limited. The only possible reduction is extracted from emergency cases where some time was wasted while looking for equipment and supplies when nurses encountered unusual problems with patients due to the side effects of chemotherapy drugs. The clinic solves this problem by placing mobile supply caddies in treatment rooms that can easily be moved from chair to chair. In order to further relieve the constraint, the clinic schedules pretreatment education for patients that are to receive chemotherapy for the first time, at a different day than that of treatment, which also decreases that patient's waiting time the next time he or she comes to the clinic. Although it would mean an extra trip to the clinic for the patients, receiving education about their treatment process prior to the actual chemotherapy appointment may help to relieve their psychological stress and anxiety. However, this new configuration has no effect on the waiting time of returning patients. As a result of these efforts, the number of patients treated per day rises to an average of 30 per day instead of the usual 24, and the average treatment time decreases from 2.5 hours to 2 hours. The recommendation pertaining to shifting the posttreatment education to the final 15 minutes of the chemotherapy session may prove to be ineffective for both the clinic and the patient, since many chemotherapy drugs have a very strong adverse effect on the patient's physical condition and this effect climaxes towards the end of the session. To counter the side effects, some patients are also given strong antihistamines, which eventually put them in a state of lethargy. Thus, it would be better to give this education to the patient at the very beginning of the drug session, where the patient still feels strong and willing enough to listen. Additionally, the clinic can also give this posttreatment education to the patient in a written form and the patient would not worry about forgetting some of the details that were mentioned to him or her during the administration of chemotherapy. Having a written document that can be referred to at any time and place would benefit the patient and may even positively affect his or her satisfaction

of the clinic. All in all, Kershaw's study demonstrates the effect of the TOC in a healthcare environment and discusses how it can be used to improve customer satisfaction and Throughput in a service setting. However, it would have been better if a patient satisfaction survey was carried out as a result of these changes in order to measure more correctly the effects of newly implemented changes within the clinic's treatment process.

# CHAPTER 4

# THE ELECTIVE COURSE REGISTRATION SYSTEM

This chapter introduces the service to which the steps and principles of the Theory of Constraints are applied. This service is the elective course registration system used in the Department of Business Administration (BA) at Middle East Technical University (METU). This chapter elaborates on the specific components and steps of the interactive registration process of METU and the Elective Course Pre-Registration System (ECPRS) which is used by third and fourth year BA students. Firstly, the registration process employed in the university is described and the general rules and guidelines related to this system are presented. Following this, the principles of the ECPRS are explained and the current flow of processes within this system is analyzed. In the proceeding section, a crucial part of the registration process, which is the approval process, is described in detail. In the final section, the performance measures of the system, namely the Throughput, Inventory and Operating Expense of the registration process are defined.

## 4.1 The Registration Process

At the beginning of every academic semester, all METU students need to follow certain predefined steps in order to choose courses, construct a schedule and finalize their registration process. Aside from their must courses, depending on their year (freshman, sophomore, junior or senior) in the university, students also have to choose a number of elective courses from a wide selection of offerings. METU gives all students the opportunity to add or drop any course, be it a must or an elective course, in an interactive fashion over the Student Affairs Information System (SAIS). Each semester, this online interactive registration session lasts for three days and

students are expected to have added all their required courses for that specific semester by the end of this period. Since the SAIS is an online system, students do not have to come to school personally and physically join a queue to register to a certain course. While adding must courses, students rarely experience a capacity problem such as not being able to enroll to a must course, because the university is obliged to create additional capacity for a must course that a student has to take. However, adding elective courses is a more cumbersome process for students because the SAIS works on a first come first served basis, and the courses may become full before the student even has a chance to access the system. Therefore, students have to settle for other courses that do not interest or serve them as much. At the end of this three-day registration period, students are required to go and personally see their advisors, who are either faculty members or research assistants. The duty of an advisor is to check that students have added the required courses, and the total number of courses that they have added does not exceed the limits dictated by their cumulative grade point average (CGPA) and university rules, that there is no conflict between the timetables of added courses, and that the students have fulfilled the prerequisite conditions of a course that they have added, if any. When the advisor does not find any problem with the list of courses of the student, he/she gives approval to the student over a different interface of the SAIS, and the student's registration becomes officially valid. According to the university's academic rules and regulations, if students do not receive advisor approval by the end of the three registration days, the course portfolio that they have constructed over SAIS is not valid and their studentship for that particular semester will be forfeit.

### 4.2 The Elective Course Pre-Registration System

Over the course of years, the Department of Business Administration has found a way to give its students the opportunity to express their preferences and enroll to their favorite elective courses to the extent possible, without having to be subject to

the first come first served approach of the university's registration system. Within the Elective Course Pre-Registration System (ECPRS) that the department has developed, students bid for elective courses according to their interest in a subject. Following this bidding procedure, students earn the right to add the courses they have won onto the university's registration system, SAIS. With the help of the ECPRS, the places of students in a course are reserved and the students can add the courses they have won through bidding on the SAIS anytime they wish during the three-day interactive registration period, without having to worry about courses being full. However, the ECPRS is not integrated with the university's SAIS. It is a web based internal student placement program. Hence, winning a course through the bidding system does not mean that the course is automatically added to the student's registration profile in SAIS. If students wish to make any changes in their list of courses after bidding, these changes must be reflected to the SAIS as well, because in the end, the official record keeping and registration approval of a student is done through the SAIS. ECPRS simply indicates whether a student is entitled to add an elective course over the SAIS or not.

The ECPRS is used by third and fourth year Business Administration students. According to the department curriculum, the total number of elective courses that needs to be taken by BA students is 15. Third year students are required to take 7 elective courses, and the remaining 8 courses need to be taken during the students' fourth year. Each elective course has a predefined capacity of 35 students. Every student has an online ECPRS account on which they can see these courses and perform bidding. At the beginning of their third year, each student is given a total credit of 1500 bidding points to be allocated among the 15 courses they need to take. The student is expected to use this total credit over four semesters, and the decision of how many bid points to give to each course is entirely up to the student. Depending on the popularity of the course and how much the student wants to take it, higher bidding points may be required in order to secure a place in the course. If a student has already spent the 1500 points, the following semester(s), he/she cannot

participate in the bidding process and will have to enroll to courses which have unused capacity, regardless of his/her interest in the course.

The ECPRS consists of two steps. The first step is the Bidding Process, which becomes active at 9:30 am on the first day of the registration period and ends at 16:30 the same day. The second step is called Manual Pre-Registration and it starts at 9:30 on the second day of the registration period and lasts until 17:30 on the third day. During the Bidding Process, students log in to their ECPRS account with their student ID and password and place bids for courses they would like to take that semester. Below are the screenshots taken from the ECPRS website. Figure 4.1 and Figure 4.2 present the log in and main menu pages of the ECPRS respectively.

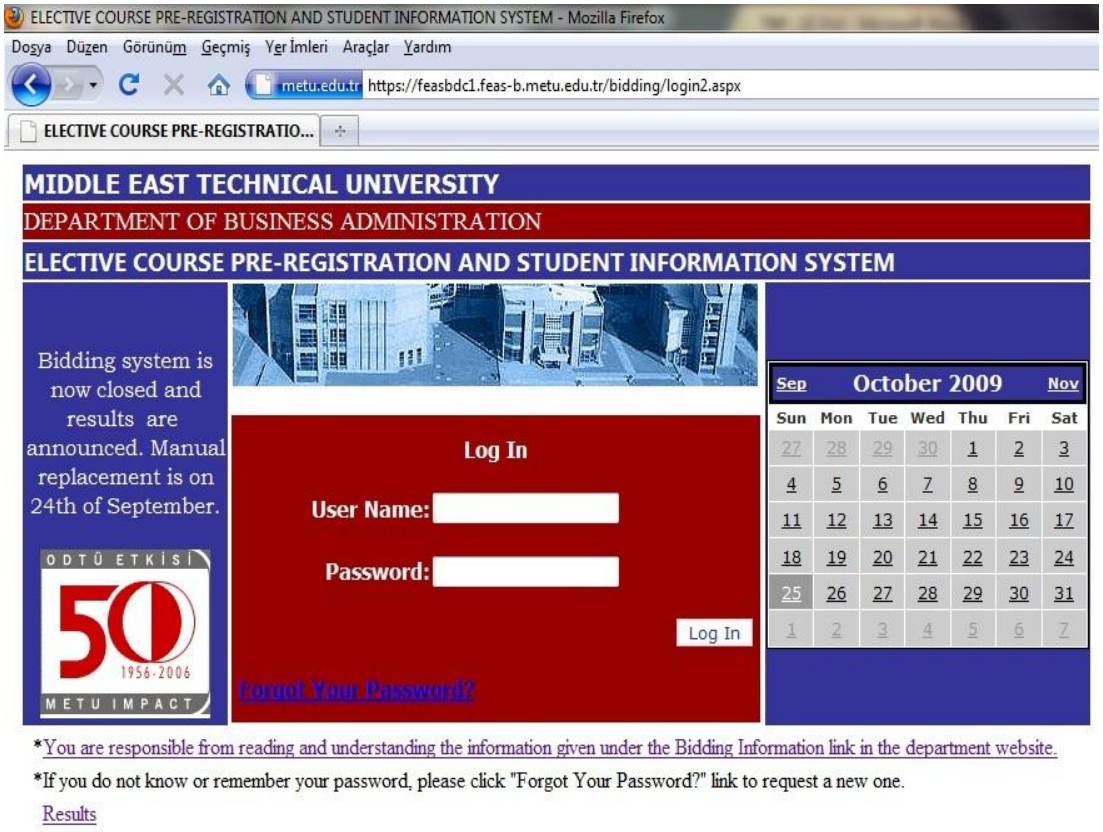


**Figure 4.1:** The Log In Page of the ECPRS
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/login2.aspx*

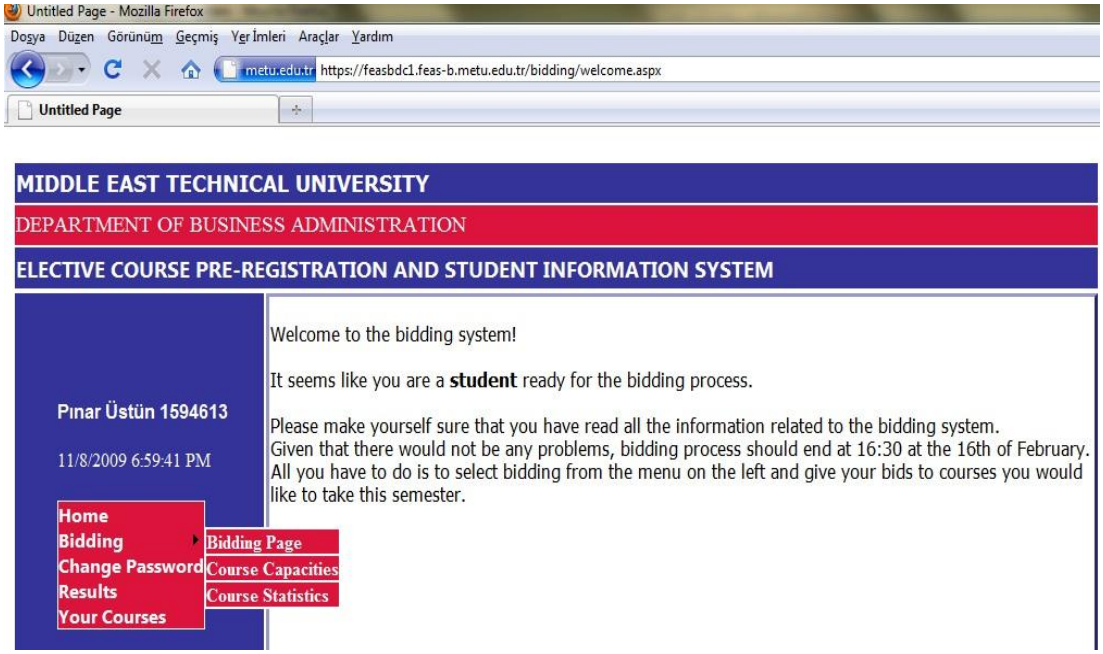


**Figure 4.2:** The Main Menu of the Student ECPRS Account
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/welcome.aspx*

In the Bidding Process, the only determinant is the amount of bids students decide to place for a course. Therefore the higher bidder has priority among the students who wish to take that course. If there are students who have placed the same bid for a specific course, then the time of bidding is checked and priority is given to the early bidder. Throughout the Bidding Process, students can see the bidding statistics which are updated every two hours by the system. These statistics consist of the minimum, maximum and average bids given that semester for a specific course and they can be viewed by students through their online ECPRS account. This information helps students to anchor their bids more correctly. A sample screenshot of the statistics is given in Figure 4.3.

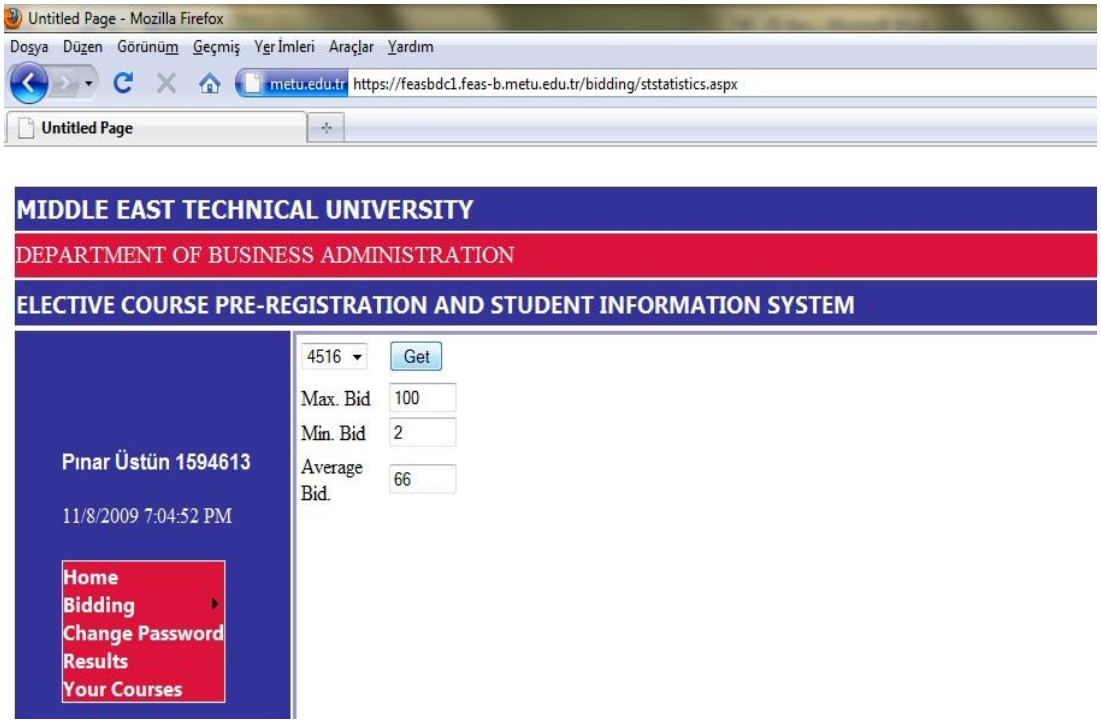


**Figure 4.3:** The Bidding Statistics of a Chosen Course
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/ststatistics.aspx*

At 16:30, the Bidding Process is closed and finalized, and students no longer have access to the bidding page on their ECPRS accounts, although they still have access to information about finalized course statistics and current course capacities for the rest of the registration period. After the results are announced, students can see on their ECPRS accounts whether or not they succeeded to win the courses they have bid for.

On the second day of the registration process, Manual Pre-Registration begins. This step is carried out by the advisors. If students decide to drop a course they have previously secured a place through the Bidding Process, or if they want to add courses because they did not succeed to win the required number of courses through the Bidding Process the previous day, they have to personally see their advisor. In cases where students have placed a bid but did not succeed to win the course, these unsuccessful bids are repaid to them by the advisor using the advisor interface of the

ECPRS during Manual Pre-Registration. On the other hand, if students are content with the results of the Bidding Process and have won all the courses that they wanted, they may skip the Manual Pre-Registration entirely and proceed with approval. During Manual Pre-Registration, the advisor logs in to the advisor interface of the ECPRS and can see the list of students for each course, as shown below in Figure 4.4.

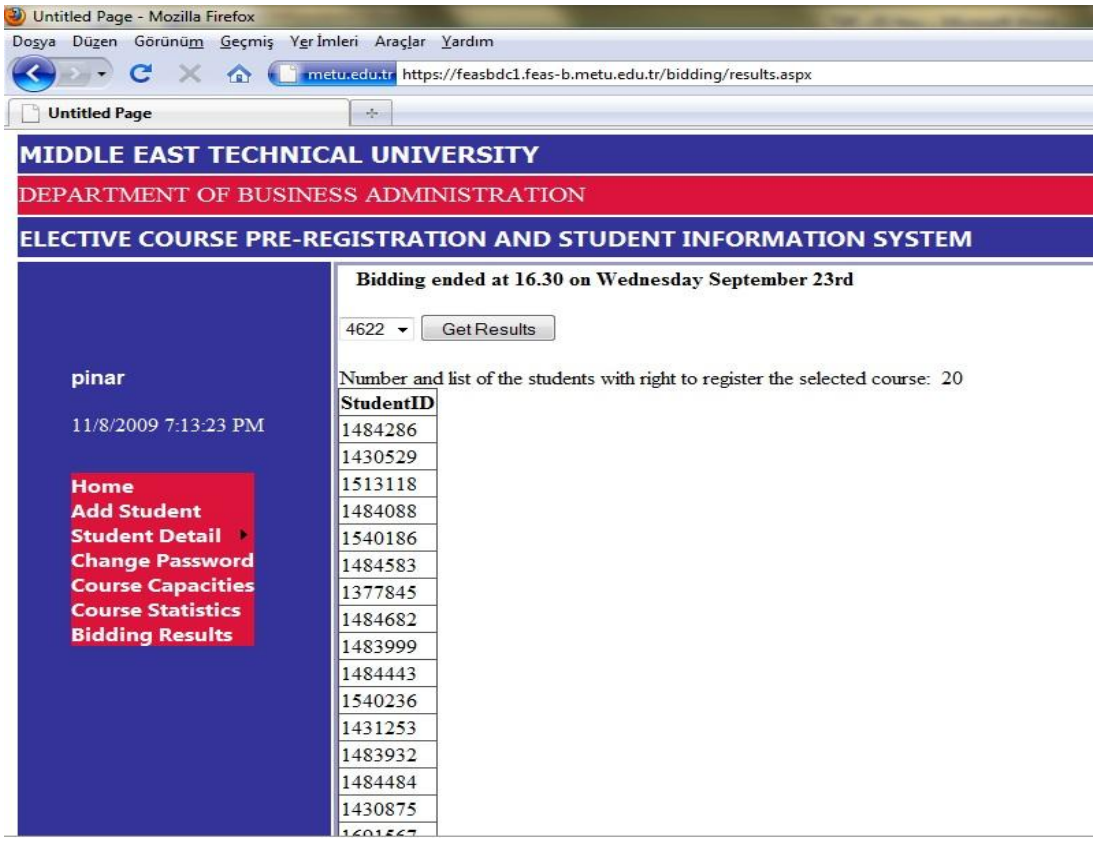


**Figure 4.4:** The Results of the Bidding Process According to Course Code
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/results.aspx*

If a student decides to drop a course that he/she previously secured a place in, the advisor selects that specific course from the student's list of courses and drops the course. Should the student wish to add a course which he/she may or may not have bid for during the first day, the advisor adds the course to the student's course list, provided that there is available capacity in the course and the student has sufficient

bidding points to take the course. Sample screenshots related to dropping and adding courses are given in Figure 4.5 and Figure 4.6 respectively.

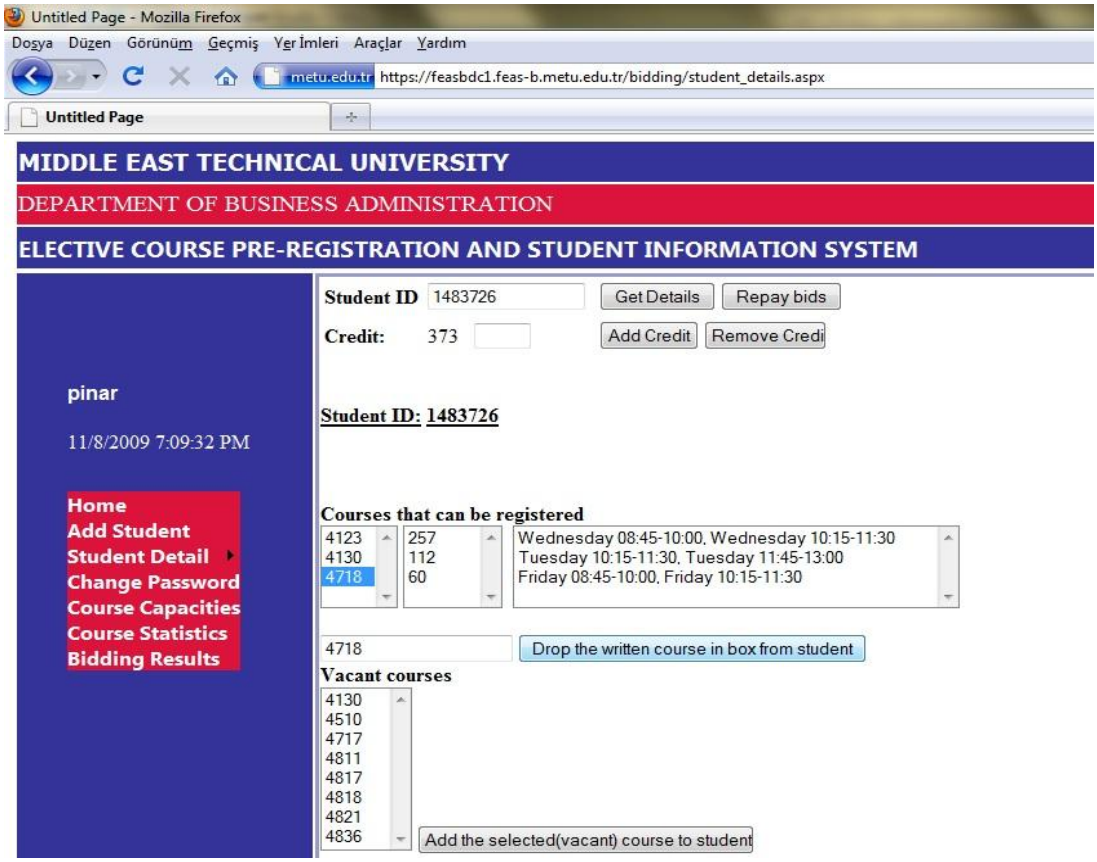


**Figure 4.5:** Dropping a Course from the Student's List of Courses
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/student_details.aspx*

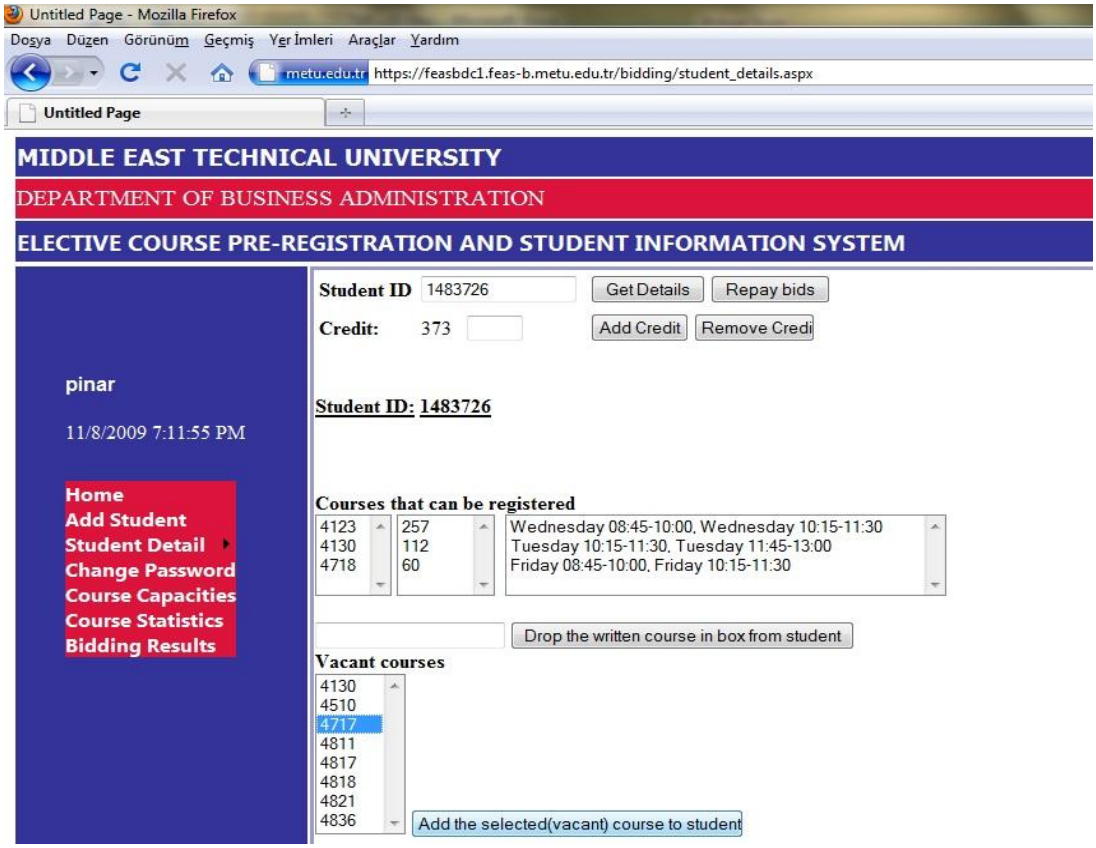


**Figure 4.6:** Adding a Course to the Student's List of Courses
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/student_details.aspx*

The Manual Pre-Registration lasts for two days and students can make any number of changes to their list of elective courses by coming to their advisor's office. During the Manual Pre-Registration period, students can see current information regarding course capacities on their ECPRS accounts. This information is continuously updated by the system whenever a capacity change occurs. A related screenshot from the ECPRS is given in Figure 4.7.

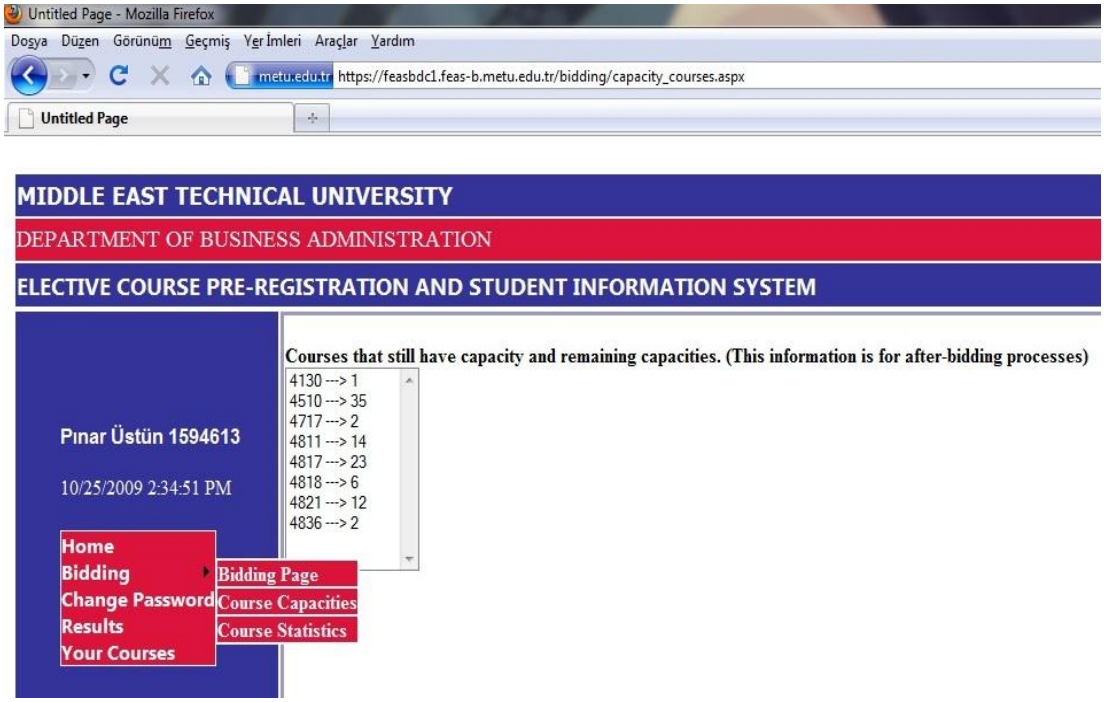


**Figure 4.7:** Up-to-date Course Capacities During Manual Pre-Registration
***Source:*** *https://feasbdc1.feas-b.metu.edu.tr/bidding/capacity_courses.aspx*

It is important to note that the Manual Pre-Registration works on a first come first served basis, therefore large queues in front of the advisors' offices are inevitable and early comers have the priority in choosing courses. However, as students come and go and make changes on their list of courses, a place which was not previously available may become available for a course later in the day. In such a situation, the first student to come to his/her advisor's office gets the course, regardless of whether or not some other student had previously wanted to take the course.

The Department of Business Administration currently has about 300 students enrolled in their junior and senior year. Two advisors are appointed to each class, so advisors each serve about 75 students. During the Manual Pre-Registration process, aside from adding and dropping courses to and from the students' lists of bid courses, advisors are also required to check whether there is a time conflict in the students' schedules. If there are any conflicts, the student is urged to find another course to

add, since the university rules dictate that an advisor shall not give approval to students whose courses have overlapping schedules. Except for the approval process, the advisor does not use any judgmental capabilities during Manual Pre-Registration, because the rules of the registration system are predefined and students do not need their advisors to add or drop courses for them.

### 4.3 The Approval Process

As stated before, every METU student is obliged to receive advisor approval by the end of the three-day registration period. The approval process consists of students coming to their advisor's office, entering their student password on the advisor's interface of the SAIS, and the advisor clicking the "approve" box on the students' registration profile, after checking that the list of courses constructed by the students is appropriate. The list of courses that the student constructs is not officially valid until the advisor approves it. Since the Department of Business Administration employs the ECPRS, the advisors also have to check whether the list of elective courses that a student adds using the university's SAIS is the same as the list of courses that the student has won using the ECPRS or the Manual Pre-Registration. Since the two systems are not integrated, one of the most commonly faced problems is that students add courses using the SAIS, regardless of whether they have won the course through bidding or not. In such cases, advisor approval is not granted and the student is required to drop the course from the SAIS, because some other student may be entitled to add the course, since he/she has won the course through the ECPRS. Similarly, it also happens that students decide to drop a course from their registration profile over the SAIS, but forget or ignore to visit their advisor to drop the course from the ECPRS during Manual Pre-Registration. In such cases, other students complain that there is not available capacity for a specific course over the ECPRS, despite the fact that there is sufficient capacity for that course over the SAIS. Consequently, advisor approval is also not granted to such students unless

they have the course dropped from the ECPRS as well. Usually, advisors become aware of such problems when another student complains about the situation, or when they are giving approval to such students. Since a student may choose to come for advisor approval on the last day, and as the registration process of other students is affected by the problematic student, the advisors are required to track such cases and identify the names of students who cause discrepancies within the system, so that the registration process of remaining students continues to proceed smoothly.

Based on their registration and approval processes, students can be categorized into four groups. This categorization will later prove to be useful while identifying the Throughput, Inventory and Operating Expense of the system. In the first group, there are students who have managed to win all their desired courses through the Bidding Process on the first day and do not need to make any change in their course portfolio. Since these students do not make any changes to their list of courses, they do not need Manual Pre-Registration and directly go to their advisor to receive approval in a single transaction. The students belonging to this category generally finalize their registration process by the end of the second day. However, the number of such students is relatively small. Figure 4.8 presents the flowchart pertaining to this category of students.

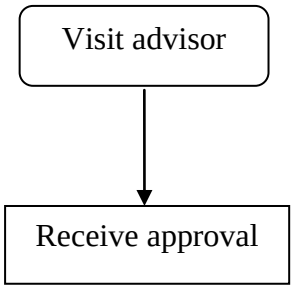


**Figure 4.8:** The Flowchart of the First Group of Students

In the second group, the students are those who have not succeeded to win the necessary number of elective courses or who wish to make a change in their list of courses. These students go to their advisors to perform Manual Pre-Registration. After Manual Pre-Registration, the students decide to finalize their registration and

proceed with approval right away, since they are now content with their course portfolio. Therefore, the registration process of this group of students ends in two transactions, one for Manual Pre-Registration and the other for approval. Students belonging to this group usually finish their registration by the end of the second day. Figure 4.9 shows the flowchart pertaining to this category of students.

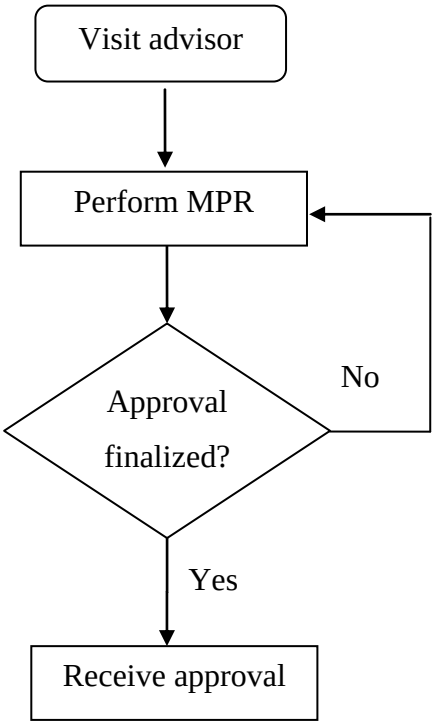


**Figure 4.9:** The Flowchart of the Second Group of Students

The third group of students consists of those who wish to make a change in their list of courses, or who might be willing to wait for a place to become available in a course. These students come to see their advisor more than once for Manual Pre-Registration, and even after having constructed a valid course portfolio, they may prefer to wait before approval because they are not totally content with their list of courses. Therefore, it is highly possible that this group of students will not have received their approval by the end of the second day. The total number of transactions needed for such students to finalize their registration process is not known. This group increases the workload of the advisors significantly. Figure 4.10 presents the flowchart pertaining to this category of students.

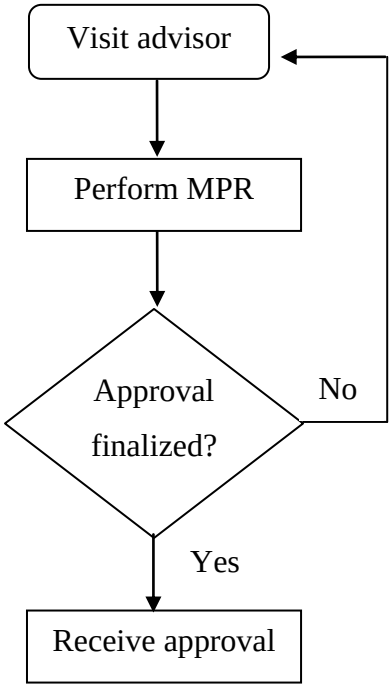


**Figure 4.10:** The Flowchart of the Third Group of Students

The fourth group of students within the registration system consists of those who visit their advisors in order to receive *un-approval*. Once students receive advisor approval, it is still possible for them to make a change in their list of courses until the end of the three-day registration period. However, these students must first see their advisor, because in order for them to be able to access their registration profile over the SAIS and make a change in their list of enrolled courses, their advisor must first *un-approve* their list of courses using the advisor interface of the SAIS. As was the case with the approval process, students have to go to their advisor's office to enter their student password on the advisor's interface of the SAIS. After the advisor gives *un-approval*, the students might make a change in their list of courses or they may decide to leave their course portfolio as it was. In either case, as university rules dictate, such students need to re-visit their advisor in order to receive approval once again, otherwise their previous schedule will be valid. When a student receives *un-approval*, it is very difficult to estimate his/her return time and the number of transactions he/she will require until receiving *re-approval*. However, the number of

such students is very small compared to the rest of the student population. Figure 4.11 presents the flowchart pertaining to this category of students.

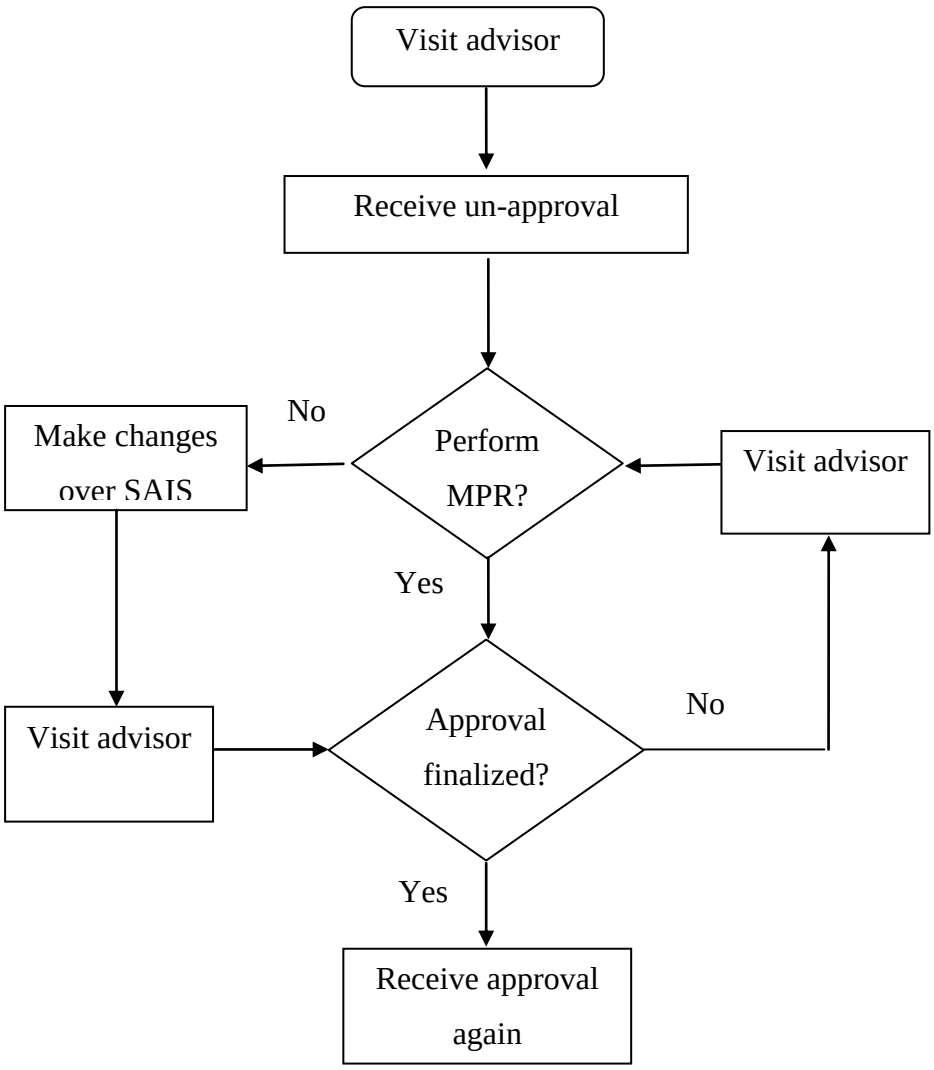


**Figure 4.11:** The Flowchart of the Fourth Group of Students

### 4.4 Performance Measures of the Registration System

This section defines the Theory of Constraints performance measures for the registration system, which are Throughput (T), Inventory (T) and Operating Expense

(OE). The discussion presented here will later be used in Chapter 5 to identify the factors that affect the performance measures of the registration system and to diagnose the areas where improvement efforts should be focused.

As discussed in Chapter 2, Throughput is defined as system outputs such as products or services that have left the system in the form of sales. To define Throughput for the registration system of the Department of Business Administration, it is necessary to first identify what the server, the service and the system output are. Within this system, the server is the advisor. The main service is *giving advisor approval to students,* which will be referred to as the *productive transaction* in the remainder of the study. Advisors also perform supplementary services like the Manual Pre-Registration and providing information to students about courses and instructors. These services will be referred to as *intermediary transactions,* since eventually such transactions lead to advisor approval. Besides these, advisors also perform transactions in order to resolve the conflict between the two registration systems (SAIS and ECPRS) stemming from student errors. These transactions are named as *counter-productive transactions*, because they adversely affect other students' registrations, and the Manual Pre-Registrations and advisor approvals of students are delayed due to this situation. The system output consists of students who have received approval from their advisors and finalized their registration process.

As mentioned before, each student goes through a different number and type of transactions in order to finalize their registration. The ideal situation is to have a single transaction per student where the student receives approval and leaves, so that the number of total transactions carried out within the system becomes equal to the number of students assigned to an advisor, which is fixed and known. Hence, 100% of all transactions carried out would be productive. However, in this system, although the number of students is fixed, the number of transactions that each student requires is unknown. For the first group of students mentioned in the previous section, the number of transactions is one, where students immediately receive approval and leave in a single visit. The second group of students requires two or

more transactions in a single visit, which consist of one or more intermediary MPR transactions and the advisor approval transaction. Even if a student requires a total of two transactions consisting of one MPR and one approval transaction, which is the minimum possible for this group, only 50% of the transactions carried out for this student is productive. In the third group, this percentage decreases even more, since the number of intermediary and counter-productive transactions that these students require and the number of visits they make to their advisor's office is not known. The fourth group of students has a registration pattern similar to those in the third group, since after receiving *un-approval*, which is an intermediary transaction, the number and type of transactions and the number of visits such students require until receiving approval again is not known. The occurrence of such type of students decreases the overall productivity and causes statistical fluctuations throughout the system.

In Goldratt's definition of Throughput, it is the sales event that marks a certain system output as Throughput. For this environment, it is the event of "receiving advisor approval" that creates Throughput. Therefore, Throughput is affected by the number of transactions carried out in the system. The Throughput of the system can be defined as the *ratio of total productive transactions to all the transactions including productive, intermediary and counter-productive transactions carried out in entire the system.* In other words, Throughput is *the total number of productive transactions divided by the total number of transactions in the system*. The formula representation of Throughput is given below, in Equation 1.

$$T = \frac{\sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} P_i + \sum_{i=1}^{n} I_i + \sum_{i=1}^{n} C_i} \quad (1)$$

In this representation, P stands for *productive transaction*, I stands for *intermediary transaction* and C stands for *counter-productive transaction*.

Therefore, increasing the Throughput is synonymous to decreasing the number of intermediary and counter-productive transactions in the entire system towards a minimum so that all transactions become productive, and each student leaves the system in a single transaction by receiving approval, as in the ideal situation. Consequently, the number of transactions in the entire system is subject to a lower boundary which is equal to the number of students in the system; that is, the number of students receiving approval in one transaction.

In this system, Inventory is determined by the number of students whose registrations are not yet complete. When students have not finalized their registration and received advisor approval, they are considered to be Work-In-Process (WIP) entities in the system. However, knowing the current number of students who have not yet received approval is not sufficient to determine the level of inventory within the system, because the number of transactions a WIP student will request until receiving advisor approval cannot be determined. Therefore, at any time, Inventory is *the total number of intermediary and counter-productive transactions carried out in the entire system for all WIP students.* Since the total number of such transactions a WIP student requires can only be known at the time the student leaves the system after receiving advisor approval, the level of Inventory in this system is unknown. The formula representation for Inventory is given below in Equation 2.

$$I = \sum_{i=1}^{n} I_i + \sum_{i=1}^{n} C_i \qquad (2)$$

On the advisor interface of the SAIS, an advisor can see how many and which students have already received approval. Since the number of students assigned to an advisor is predefined, the number and identities of students who have not yet received approval are also known. Therefore, at any given time, the current WIP level in the system can easily be determined. What an advisor does not know is when and how many times the WIP students will come, how long those students will remain as WIP, and how many and what type of transactions they will require before

finally receiving approval. Will the students require only intermediary transactions like asking for information on a specific course or a teacher, performing Manual Pre-Registration or simply visiting the advisor to learn about course capacities? Or will the advisors have to perform counter-productive transactions for students who have caused a disruption in the system? Therefore, although the number of WIP students is known, the level of inventory students will create in the system is not known. In addition to this, there is the fourth group of students who return to being a WIP in the system, after having previously left the system in the form of Throughput. These are the students who choose to receive *un-approval* in order to make a change in their course portfolios. These students represent *rework* for the advisor, since in this case a previously *sold* service is returned to the service provider for further processing. Therefore the presence of such students increases the WIP level in the system unexpectedly, causing fluctuations in overall Inventory and Throughput.

Goldratt (1990) identifies the Operating Expense of a system to be the money that is spent while transforming Inventory into Throughput. In the registration system, this *cost* is determined by the type and number of transactions and time spent per all types of transactions carried out for WIP students. Productive transactions take relatively shorter and more predictable time compared to other types of transactions. Therefore, Operating Expense *is composed of the number of productive, intermediary and counter-productive transactions in the entire system multiplied by the time incurred for each such transaction*. The formula representation of Operating Expense is given below in Equation 3.

$$OE = \sum_{i=1}^{n} (P_i \times pt_i) + \sum_{i=1}^{n} (I_i \times it_i) + \sum_{i=1}^{n} (C_i \times ct_i) \quad (3)$$

In this representation, pt*i* stands for *the time taken per productive transaction,* it*i* stands for *the time taken per intermediary transaction* and ct*i* stands for *the time taken per counter-productive transaction*. Since students require different transactions with different times, the *cost* of one student may differ from another. If

there is a student who has caused a disruption within the SAIS and ECPRS systems, trying to fix this occurrence may cost the advisor a long time, trying to find the student who has caused the disruption and identify other students who might have been negatively affected due to this disruption. Although this is a single transaction, the time, hence the Operating Expense that is brought to the system by this single transaction is significant. On the other hand, some students may wish to perform many intermediary transactions such as adding or dropping a course over MPR, and in this case each such a single transaction may last only seconds. Besides these, even if the transactions are the same, the time it takes for each student may again differ; as in the case of giving approval where the advisor has to spend more time checking the courses for an irregular student compared to a regular student. Therefore, to decrease the overall Operating Expense, the new system should be constructed by streamlining the existing operations, aiming to reduce the time it takes for each transaction, as well as reducing the total number of intermediary and counter-productive transactions within the system.

An improvement in any of these three performance measurements will have a simultaneous effect on the others. For Throughput, since the number of productive transactions has a lower boundary equal to the number of students in the system, the way to increase Throughput is to decrease the denominator in Equation 1 by reducing the number of intermediary and counter-productive transactions. Since the SAIS and the ECPRS are not integrated, recommendations for Throughput mainly focus on intermediary transactions, as there is no way to prevent students from adding inconsistent courses over the two systems, thus causing counter-productive transactions.

It can be seen from Equations 1, 2 and 3 that the decrease in the number of intermediary and counter-productive transactions improves the Throughput and decreases the Inventory and Operating Expense simultaneously. In the ideal situation, all students receive advisor approval in a single transaction and leave the system. Therefore, there are no intermediary or counter-productive transactions and

the Throughput is equal to one, which is the maximum possible. In this ideal case, as there are no students performing intermediary or counter-productive transactions, WIP is zero and Inventory at any time is equal to the number of students left in the system. In this case, since there will only be productive transactions in the system, and if a fixed amount of time is assumed for approval transactions, Operating Expense should equal the number of students in the system times the fixed time required to give approval. Consequently, in order to reduce Operating Expense, the number of intermediary and counter-productive transactions and the time spent for each such transaction should be minimized.

# CHAPTER 5

# FACTORS AFFECTING THE PERFORMANCE MEASURES OF THE REGISTRATION SYSTEM AND RECOMMENDED SOLUTIONS

This chapter discusses the steps and problematic issues of the interactive registration process, identifies the factors that pull the Throughput of the system down and cause the Inventory and Operating Expense of the system to elevate. The transactions carried out by students and advisors are analyzed in the order of events during registration. The constraints and bottlenecks in the system are identified and resolved using the principles of the Theory of Constraints. Factors affecting the performance measures of the system are discussed below.

## 5.1 Password Generation and Log In

First time users of the ECPRS enter their student ID and hit the "Forgot My Password" (FMP) link found at the bottom of the log in page of the ECPRS website, as shown in Figure 4.1, to obtain a password. Their passwords are automatically generated by the ECPRS and sent to their university e-mail accounts. Returning users can log in to the system using their student ID and existing password. The time it takes for the passwords to reach students' mailboxes greatly depends on the server speed and the number of people using the same service at that time.

Under the current setup, there are many factors affecting the efficiency and user friendliness of the password generation process. These factors are listed below.

First time users click the FMP button and wait for their password to arrive to their mailboxes. When the password does not arrive immediately, students repeatedly hit the FMP link. Each time the FMP link is clicked the ECPRS automatically creates

and sends a new password to the e-mail account of the student. However, since many people concurrently use the department's server capacity, and students hit the FMP link repeatedly, the time it takes for password mails to arrive to student e-mail accounts increases and the passwords are delayed. There is a warning message on the log in page of the ECPRS, indicating that it might take 2 to 10 minutes for passwords to appear in students' mailboxes. However, many students ignore this information and visit their advisors in order to ask them what to do, since their password has not arrived yet and the advisor explains the system once again. This extra step counts as an intermediary transaction within the system, and students' trips to their advisors' office regarding password-related issues cause an increase in the Operating Expense and Inventory of the system, as well as decreasing the Throughput.

In some cases, the password e-mail arrives but for some reason drops in to the student's junk mail folder. In these cases, students visit their advisors to ask them what they should do. Since the password generation process is controlled by the ECRPS, the only answer that an advisor can provide to a student is to check his/her inbox and the junk mail folder again, because the password generation process always succeeds in sending passwords. As can be seen, these extra intermediary transactions increase the level of Inventory and Operating Expense of the system, while decreasing Throughput.

One other commonly faced problem is when students complain to advisors that the password sent to their e-mails does not work. The reason is that multiple passwords are generated when a student clicks the FMP link more than once, and the previous password generated and sent by the ECPRS becomes obsolete. Therefore, students have to wait and use the *last* password generated and sent by the system. In such cases, all the advisors can do is to tell the students to wait and use the password in the last e-mail sent by the system. These intermediary transactions are in fact redundant, and they significantly cause an increase in the Operating Expense and Inventory of the system, while pulling Throughput down. The delay in the password generation system caused by students' multiple password requests in turn causes a

delay in the completion of the registration process of students. This creates a constraint in the system, since all other downstream processes are affected negatively due to this delay. Thus, students stay as WIP entities in the system for longer periods of time and the Throughput of the system consequently decreases.

Another problem that occurs is that some students simply do not know what to do when they forget their passwords, and they visit their advisors to ask what to do about this situation. Currently, the FMP link can be directly accessed from the homepage (log in page) of the ECPRS, but some students do not realize this. When advisors tell students to click the FMP link on the website of the ECPRS, this intermediary yet redundant transaction escalates Inventory and Operating Expense, simultaneously pulling the Throughput down.

As can be seen, in all these instances, the common factor increasing the number of intermediary transactions is the students' unfamiliarity and with the system, and the fact that they do not pay attention to the warning and instructions provided on the ECPRS, which could partly be due to the lack of "user-friendliness" of the system.

In order to improve the current situation, some basic but important changes may be implemented, as listed below.

1. The fact that first time users also click the FMP link to obtain passwords is not logically correct. There should be a separate link for first time users to obtain their passwords and a separate link for returning users. This would help to eliminate the confusion that results when students do not know what to do when they first need or forget their passwords. Consequently, the Throughput of the system would increase and the Inventory and Operating Expense of the system would decrease since students would no longer need to visit their advisors and cause intermediary transactions.

2. Secondly, students should clearly see the information related to the time it may take for the password generation process to send a password e-mail to their accounts.

Although, under the current setup, there exists such an informatory message, it is located at the very bottom of the log in page and can be missed. A snapshot of this screen can be found in Figure 4.1. With a simple change in the design of the webpage, the visibility of this message could be greatly improved. The message could be written in bigger fonts and a different color could be used to catch the attention of students. The message should clearly that the advisors should not be visited to ask for help since they do not have any control over the password generation process. The warning should also remind students to check their junk mail folders. This would help to decrease Inventory and Operating Expense of the system, due to the decrease in the number of intermediary transactions. This causes a simultaneous increase in the system's Throughput.

3. Modifications to the ECPRS could make sure that only one password is generated for a certain student ID and sent to the e-mail assigned to that ID. This would eliminate the confusion that arises when students request a password more than once and elevate the constraint arising from the delay. This in turn would improve Throughput, since the number of intermediary transactions caused by student visits for such problems would be decreased. The Operating Expense of the system would fall down, as well as the level of Inventory.

4. One other recommendation that would significantly improve the password generation step is to let students know that they can obtain passwords *anytime* they wish, and that it does not necessarily have to happen on the day the registration begins. Therefore, on the webpage of the Department of Business Administration, there should be an announcement for third and fourth year students, informing them that the password generation process of the ECPRS works 24/7 and it would be for their benefit to obtain their passwords *before* registration begins. It should also be emphasized that obtaining their password earlier would give them an advantage since earlier bidders have priority in the system. This could ensure that a lower number of students rush to their advisors on the first day of registration for password-related

problems, and the Inventory and Operating Expense of the system would consequently decrease, elevating Throughput at the same time.

### 5.2 Rules and Guidelines of the Elective Course Pre-Registration System

After students log in to ECPRS the first time, they are directed to a page that shows the guidelines and rules of the ECPRS. After reading these guidelines, students have to click a button at the bottom of the page indicating that they have read and understood the rules and regulations about the system, in order to be able to proceed with bidding. These guidelines are also available as a separate link on the Department's website.

This step where students are introduced to the rules and guidelines of the ECPRS plays a crucial role on the effectiveness of the rest of the transactions. When students do not clearly understand how the system works, this results in an increase on the Operating Expense of the system, since advisors have to explain to students what they have to do when they do not understand or ignore a certain step or rule within the system, which increases the number of intermediary transactions. As the information that advisors provide is the same as that can be found in the system guidelines, the time advisors spend explaining the system to students is a preventable Operating Expense. Similarly, Throughput and Inventory of the system are affected adversely due to these redundant intermediary transactions. As can be seen, when students overlook or miss critical information found in the ECPRS guidelines, it creates a constraint in the system. Therefore, improvement efforts should focus on providing crucial information to students in a clear and concise manner and exactly when they need it, so that students do not skip reading the information just because they think it is long and complicated. Improving the user interface of the ECPRS in such a way would have positive effects on all the performance measures of the system, since they will smooth the downstream processes and students will have the

knowledge and opportunity to finish their registration process more quickly than before. Possible remedies are presented below.

1. A suggested change in the design of the ECPRS is that, instead of providing instructions to students at the very beginning of the process, students should be able to see the instructions, rules or warnings of specific steps when they have arrived to that step. For example, the information of how many bid points students will lose if they decide to drop a course later on when the course is fully occupied or when there is excess capacity, should be provided on the page where students pick courses to bid for.

2. Another recommendation is to construct a Frequently Asked Questions (FAQ) page, where students could seek answers to their ECPRS-related problems without visiting their advisors. This would decrease the Inventory and Operating Expense of the system, while simultaneously elevating Throughput. For example, for the password generation process, there might be a link on the introduction page of the ECPRS, directing the students to the FAQ page in case they are experiencing any problems related with this process. If a student is worried that his/her password has not arrived yet, he/she might consult the related section under the FAQ page and learn that this case is normal and might be because of the current overload on the system capacity and that the password *will* arrive. The FAQ page may also remind students to check their junk mail folders for passwords. Constructing such a page may help to decrease the number of intermediary and counter-productive transactions in the entire system. This has a direct effect on decreasing Operating Expense and Inventory in the system, due to the decrease in the number of intermediary transactions, which in turn leads to an increase in the Throughput of the system.

3. In order to familiarize the student with the system and reduce the occurrence of mistakes and students asking their advisors questions about how the system works, it might also help to put a link of a quick demo of the system on the main menu. This demo would briefly introduce the menu elements to students; such as where they can

follow current course capacities, change their passwords, or bid for courses and construct their list of courses. These basic additions to the design of the ECPRS would lead to a more user-friendly system, decreasing the probability of student related mistakes and guiding the students through each step of the registration process so that they experience a smooth and problem-free registration period. When students feel at ease and can easily navigate through the system, the unnecessary Operating Expense incurred through advisors explaining the system to students would decrease, while simultaneously decreasing Inventory and boosting Throughput.

### 5.3 Student Profile

After reading the guidelines, students are directed to a page where they are required to fill in certain information such as home address, telephone number and current GPA. Creating a profile is not mandatory and the information thus gathered is not used anywhere else within the Elective Course Pre-Registration System.

1. Since the information students provide on the profile page is not used anywhere else in the system, and since filling in this profile is not mandatory, the profile step should be eliminated entirely. The only information that advisors need to perform Manual Pre-Registration is the ID number of the student. Also, as advisors already have access to the students' CGPA over their interface of the SAIS, there is no need for students to provide this information in their profiles. If this step is removed from the ECPRS, students would finalize their registration sooner and fewer students would stay in the system as WIP entities.

### 5.4 Courses with Overlapping Timetables

Once a profile is created, students are redirected to the main menu where they can change their passwords, see the list of courses offered for that semester, view course statistics announced every two hours and bid for courses. On the bidding page, students pick a course from a drop down list, and enter the bid points they would like to give for that course. On this page, the syllabi of courses (if provided by teachers) are available to students but students cannot see the timetable of courses. The timetable of all courses that are offered is available on a separate link on the Department's website. Additionally, the system does not display a warning message to students when they try to bid for courses that have overlapping timetables. Although advisors do not give approval to students with such time conflicts, the system does not prevent students from bidding for overlapping courses. When students bid for and win two courses that have clashing timetables, they have to perform extra intermediary transactions to drop one of those courses during MPR, because advisors do not give approval to such course portfolios. This causes an increase in the Inventory and Operating Expense of the system and decreases Throughput. To improve this situation, several changes might be implemented.

1. In order to eliminate the root cause of the problem arising from overlapping schedules, the ECPRS should be redesigned to automatically prevent the students from bidding for courses that have overlapping timetables. Students must be informed on the homepage of the ECPRS that advisor approval is not given to schedules that have timetable conflicts and therefore the addition of any courses that have timetable clashes will not be permitted. When students are not allowed to add such courses, they will not have to perform Manual Pre-Registration to have these courses dropped, and this is a major improvement in terms of the number of intermediary transactions in the system. When the number of intermediary transactions in the system thus decreases, the Throughput of the system increases, and the Operating Expense and Inventory in the system decrease.

2. Currently, the list of courses offered and their schedules can be found on the Department's website. The courses offered can also be found on the ECPRS but they are not displayed in a list format and students see the courses only in a drop down box. Therefore, in order to make the system more user-friendly and to decrease the time students spend on trying to put together information from different sources to decide on courses, the schedules of courses offered for that semester should be placed on the main menu of the ECPRS as well as the list of courses offered. These two should open in separate windows in a pop-up form so that students can easily switch between these windows while they are bidding or carrying out other registration-related processes in another window. In addition to the list of courses, students must also be able to access previous years' bidding statistics for courses. This information must be placed on the main menu of the ECPRS for all students to see. This would help students place more accurate bids for courses, increasing their chances of success. When students place their bids more correctly, the number of intermediary transactions needed to change their list of courses during the Manual Pre-Registration decreases. When the occurrence of such transactions decreases, Operating Expense and Inventory of the system consequently fall down, simultaneously increasing the Throughput.

3. In addition to providing the schedules for all courses offered that semester and previous years' bidding statistics, there must be a separate feature in the system for students to construct their personal timetable for the courses they must take and the electives they are bidding for, and see possible schedules. Within this function, students can pick courses from a drop down list and a trial timetable will be constructed for the student. From the drop down list, students should also pick their must courses so that they see whether there is any overlap between the timetables of elective and must courses. On this timetable, students should be able to see the final exam dates and the link for the syllabi of the courses they have chosen. With the help of this visible representation, students would make more wholesome decisions with regards to the courses they would like to bid for, and they would need fewer

transactions during the MPR to make changes or additions to their original list of courses. Most of the time, even if students win all the courses they initially placed bids for, they may decide to make a change to their courses because they have just realized that the exam dates of some courses are very close to each other, or the workload of a certain course is very demanding. Therefore, when students make choices while bearing in mind all this information beforehand, they would not need to change their list of courses later on, and this means fewer intermediary transactions throughout the system, that is, increased Throughput and decreased Operating Expense and Inventory.

All of the above mentioned improvements affect the registration system performance and effectiveness, since the ECPRS now provides many useful information to students which they previously asked from their advisors or tried to put together from different sources over the Department's website. Therefore, improvement efforts must focus on re-designing the ECPRS in a way that students have at their disposal the information and resources needed to make faster and more consistent decisions the first time, without having to frequently change them afterwards. Tackling the system from such a perspective would help students leave the system sooner and consequently decrease the Operating Expense in the system. It would also decrease the occurrence of students needing to receive *un-approval*, thus causing the number of intermediary transactions and the Inventory level in the system to decrease, while improving the Throughput.

With these recommendations, the ECPRS also becomes more user-friendly, since students have the opportunity to easily create visible trial timetables and the new system automatically prevents them from adding courses that have conflicting timetables. Although currently the advisor interface of the ECPRS displays a warning in case of conflicting timetables and advisors frequently remind students not to add conflicting courses, students still keep on adding such courses and this increases the number of intermediary and counter-productive transactions in the

entire system, since those courses have to be dropped later on during the Manual Pre-Registration.

### 5.5 Inconsistency between the Student Affairs Information System and the Elective Course Pre-Registration System

After the Bidding Process is finalized and the results are announced, students can see on their ECPRS accounts the list of courses they have succeeded to win through bidding. The advisor interface of the ECPRS warns advisors automatically when there is a time conflict between elective courses a student has won through bidding and approval is not given.

One very important problem that manifests itself later on in the registration process is when students add courses over the SAIS without having won them first via the bidding process; or when they drop courses over the SAIS but forget or ignore to have them dropped over the ECPRS via Manual Pre-Registration. This causes a disruption in the registration processes of other students and therefore is a major bottleneck in the MPR process, since such students have to wait as WIP students within the system because they cannot complete their registration due to a capacity mismatch that has been caused by such faulty students. This increases the level of Inventory and Operating Expense in the system, and at the same time pulls the Throughput down.

The cause of this problem is that the ECRPS and SAIS are not integrated and therefore there is currently no way of checking for discrepancies between the list of courses that students add over the SAIS and the list of courses that a student succeeds to win over the ECPRS. Therefore, the constraint resulting from this inconsistency cannot be removed entirely. The only way an advisor currently becomes aware of the situation is when students visit their advisor and complain that although they have won a course over the ECPRS, they cannot add it over the SAIS due to insufficient

capacity. The reverse situation also happens, and students sometimes complain that although the SAIS indicates available capacity for a specific course, there is not any available capacity seen on the ECPRS, therefore they cannot perform MPR and add the course. Each such visit is an extra counter-productive transaction for the system, elevating the Operating Expense and the level of Inventory in the system unnecessarily. As can be seen, this situation is a bottleneck for the entire system since it delays the registration of other students.

In all these instances, the main challenge is to identify the faulty student, and the first thing that advisors do is to let other advisors know so that the student causing the disruption is identified. The second action is to put warning notes around the Department to urge the faulty students to comply with the rules of the ECPRS or else advisor approval will not be given. If even after these actions the faulty student has not yet visited his/her advisor and remedied the problem, the advisor obtains the current SAIS class-roster for the specific course from the Department Secretary, and cross-checks the student ID numbers with those on the list of students who have succeeded to win that specific course over the ECPRS. The fact that the class-rosters of SAIS are not open to advisors represents additional time and effort on behalf of the advisors because they have to request these rosters from the Department Secretary. In addition to this, the list of students that advisors access over the ECPRS is not sorted according to student ID number, therefore it is harder to cross-check the ID numbers of students between the two lists and this adds to the transaction time. All these above transactions are counter-productive and they significantly increase the OE of the system. After the faulty student is identified through cross-checking, the advisor tries to contact the student. Although advisors are entitled to make any necessary changes on the list of courses of a student over the ECPRS, they do not have authorization to alter the list of courses a student adds over the SAIS and therefore cannot solve the conflicting situation without the student personally showing up. However, in order to decrease the occurrence of such situations, remedial actions should be taken, as presented below.

1. On the bidding page there should be a visible warning to remind students that they ought to add a course using the SAIS if and only if they have succeeded to win it through the bidding process, or they ought to have a course dropped from the ECPRS by performing Manual Pre-Registration if they decide to drop it over the SAIS. The new design should make sure that students fully understand that not complying with the rules of ECPRS adversely affects other students. Since the SAIS and the ECPRS are not integrated, giving students such warnings is the only way to minimize counter-productive transactions from occurring, and to decrease the Operating Expense and Inventory caused by such transactions, increasing the Throughput at the same time.

2. To make the identification of faulty students easier, the list of students that are enrolled in each course over the ECPRS should be sorted according to student ID number. This would decrease the time required to identify these students, and would help to decrease the Operating Expense resulting from this transaction.

3. Since students learn the result of their bidding process online on the Results section of their ECPRS accounts, every student sees the Result page at least once. Therefore, on this Results page, students should again be reminded that in order to qualify for advisor approval, the list of added courses over the SAIS should strictly match the list of won courses through bidding, or the list of courses added after performing MPR with advisors. Furthermore, punitive measures can be introduced such as deducting a certain number of bid points from the total bidding credits of such faulty students in order to discourage such behavior. Such measures are expected to decrease the occurrence of counter-productive transactions and help to alleviate the constraint resulting from the inconsistencies. These recommendations would in turn improve the Throughput of the system while simultaneously decreasing Inventory and Operating Expense.

4. A recommendation that pertains to the general procedures of the university's SAIS is to make the class-rosters accessible to advisors, so that they can track the identity

of the problematic student(s) easily, without having to visit the Department Secretary. Since this decreases the time incurred for counter-productive transactions, the Operating Expense of the system consequently decreases.

### 5.6 Manual Pre-Registration and Approval

The Manual Pre-Registration process begins at 9:30 on the second day of registration for students who wish to make any change in the results of their bidding process. Students who have won all their desired courses through bidding may immediately proceed with approval, skipping the Manual Pre-Registration step. Whatever their motive might be (either receiving approval or performing MPR), students have to form a queue in front of their advisors' door since the process works on a first come first served basis. During the three-day registration period, the remaining services of the ECPRS are open to students except for bidding, and students can see the current capacities of courses in their ECPRS accounts. If a spot opens up in a course that they wish to take, students can visit their advisors and perform Manual Pre-Registration. During MPR, as mentioned before, advisors repay the students' unsuccessful bidding credits back to them by clicking on a "repay bids" button. The students may proceed with approval after performing MPR once, or may choose to postpone receiving approval to the last day in order to add more courses or make further unknown number of MPR transactions and changes in their list of courses.

1. During MPR, one of the things that significantly boost the Operating Expense of the system is when students frequently come and ask their advisors about current capacities of courses, although they already have access to this information on their ECPRS accounts. Under the current setup, just to remind students that they have access to this information, advisors put papers around the Department, informing students that they can view the current course capacities from their ECPRS accounts anytime they wish. Advisors also sometimes print the current course capacities and announce them on their office doors, updating them as time progresses. As can be

seen, repeating a piece of information which is already available to students brings a considerable burden on the Operating Expense of the system, due to the increased number of intermediary transactions carried out to answer such questions. Therefore, although it would not totally eliminate the occurrence of students asking, reminding students once again on the Results page of the ECPRS that the current capacities of courses can be viewed anytime on the "Course Capacities" link that appears on the sidebar, should decrease the number of students occupying their advisors for this purpose.

2. One other action performed by advisors is repaying the unsuccessful bids of students by clicking the "repay bids" button. This step can easily be automated. The unsuccessful bids may automatically be repaid to students when the results of the bidding process are announced. Additionally, the Results page should be redesigned so as to give students a brief summary regarding the amount of bids they gave to each course, names of courses they did not succeed to win and the amount of unsuccessful bids repaid to students. The elimination of this step would decrease the number of intermediary transactions in the system, which would in turn improve all of the three performance measures simultaneously.

### 5.7 Cancellation of Approval

If students wish to make a change in their course portfolio *after* receiving approval, as in the fourth group of students, they have to come to their advisors and receive *un-approval* for their list of courses. This is an additional intermediary transaction that increases the Operating Expense. The level of Inventory in the system is also increased because the student who had previously left the system becomes a WIP entity once more, and the Throughput of the system decreases. Although this condition entirely depends on the university's rules and regulations, a possible recommendation related to this inconvenience is given below.

1. When students wish to make changes in their approved schedules, they will be able to access their registration portfolio over the SAIS without any authorization from their advisor. Therefore, they will not have to go to their advisor just to receive *un-approval.* However, when students access their course portfolio over the SAIS after it has been approved, the system will warn such students that after making a change in their approved schedules, they need to see their advisor to receive approval once again, otherwise their previous schedule will be valid. This would decrease the number of intermediary transactions in the system since the un-approval transaction is eliminated. Consequently, the Throughput, Inventory and Operating Expense of the system would be improved.

### 5.8 Late Announcement of Course Schedules

Under the current system, the schedule and syllabi of courses offered is announced about one week prior to the beginning of registration. This late announcement of course schedules and syllabi does not leave time for students to fully make up their minds about which courses to take. When they bid for courses they are not certain about, students may prefer to drop these courses later during MPR, increasing the number of intermediary transactions, hence the Operating Expense and the level of Inventory in the system. The Throughput of the system is also affected adversely because of this situation. Therefore, the schedule and syllabi of courses offered for the semester must be available to students well before the beginning of the registration period, so that students can compare courses thoroughly and choose courses that best fit their needs and expectations. This would reduce the likelihood of changing their minds afterwards.

### 5.9 Computer Laboratories

Another problem that advisors commonly face is the complaint from students about the crowded computer laboratories. During MPR, when an advisor urges the students to change their list of added courses over the SAIS, the students may request to use the computer of the advisor for this purpose, claiming that the computer laboratories are full. Normally, this is not consented. However, when there are long queues in front of advisors' offices and the advisor sends away students to the computer lab to make a small change in their registration profile over the SAIS, these students have to start back from the end of the queue. To remedy this inconvenience, an extra computer could be placed in the advisor's office for the use of the student who is currently performing MPR with his/her advisor. Therefore, when an advisor asks a student to make a change in his/her SAIS profile, the student could perform the change on the spot, using the parallel computer in the advisor's room, and finalize his/her registration process within the same transaction. This would decrease the time students spend in the system as WIP entities and therefore would be helpful to generate Throughput. When students perform the changes in a single visit, the number of transactions arising from such situations decreases. This causes an improvement on all the three performance measures of the system.

In order to determine whether the main problems presented here accurately represent issues faced by other end-users of the system, questionnaires were designed and distributed to advisors and students of the Department of Business Administration who use the ECPRS (see Appendix A, Appendix B, and Appendix C). The student survey was translated and distributed in Turkish in order to have a higher response rate and understanding from students. The Turkish version of the student survey can be found in Appendix D. In these surveys, students and advisors are asked to rate the importance of the problems identified in this chapter on a scale of one to five, one representing the least critical and five representing the most critical. Included in these problems are; Password Generation and Log In, Rules and Guidelines of the ECPRS,

Courses with Overlapping Timetables, Inconsistency between the SAIS and the ECPRS, Manual Pre-Registration, Cancellation of Approval, and Computer Laboratories. An additional survey designed for advisors rates how effective and applicable they find the recommendations presented in this thesis for each of these problems. In each survey, there is a section where students and advisors can discuss possible solutions and other difficulties they face during the registration period.

All advisors and 50 students selected via convenience sampling who were consulted generally agreed with the problems identified in the system. The advisors also found the related recommendations to be appropriate and effective. According to students, the inconsistency between the SAIS and the ECPRS, and the crowded computer laboratories were the most critical issues they faced during registration, followed closely by Manual Pre-Registration, un-approval, and courses with overlapping timetables. The least critical issue was about the rules and guidelines of the ECPRS. However, the advisors' prioritization of the problems were different than that of students. According to the advisors, the most critical problem was the Manual Pre-Registration, followed closely by the inconsistency between the SAIS and the ECPRS. The un-approval step was the least critical problem for advisors. The percentage distribution of the answers given by students and advisors are presented in Appendix E and Appendix F. The average and standard deviation of the values assigned by students and advisors are provided in Appendix G and Appendix H.

When asked about further problems or difficulties experienced with the ECPRS, students mostly complained about the performance of the system server, and mentioned that the bidding statistics could be updated more frequently. According to advisors, all problems and difficulties were correctly diagnosed by the thesis, and while they found the recommendations applicable and effective, they suggested scheduling a short meeting with students who would use the ECPRS for the first time explaining the rules and guidelines of the system, the calculation of bidding points to be deducted or added, and the potential penalties incurred in case of inconsistencies.

# CHAPTER 6

## THE PROPOSED SYSTEM

As presented in Chapter 2, Goldratt's (1990) cycle of ongoing improvement consists of five steps. Steps 1 and 2 of this focusing process involve identifying the system's constraints and exploiting them. In Chapter 5, the factors affecting the performance measures of the registration system have been identified and several solutions have been put forward in order to exploit and elevate those constraints. Steps 3 and 4 of the focusing process require the subordination of the rest of the system in order to work synchronously with the constraints, and finding ways to eliminate the constraints entirely. Using the details of the analysis in Chapter 5, this chapter presents a new design for the registration process of third and fourth year Business Administration students, and demonstrates how the system is subordinated and how some of the constraints can be elevated. Additionally, the chapter discusses how the Throughput, Inventory and Operating Expense of the system are affected as a result of the new flow of process. The chapter closes with a discussion of the fifth step in the focusing process, which is about preventing inertia from becoming a system constraint. The flow of the proposed system is given below.

Students visit the ECPRS homepage. Existing users enter their student ID and password to log in to the system. First time users click a new link called "Obtain Password" on the homepage to receive their passwords. Their passwords are automatically sent to their e-mail accounts. First time users are reminded that depending on the number of users in the system, it may take up to 10 minutes for the passwords to reach the students' e-mail accounts. Moreover, the system automatically makes sure that a student does not request a password more than once. Students are also informed that the advisors do not have any control over the password generation process and therefore should not be disturbed due to password

related problems. On this page, students will also find a link to a "Frequently Asked Questions" page, where they can search for answers to commonly encountered problems. When the number of students that visit their advisors due to password-related problems decreases, the number of intermediary transactions in the system also decreases. This leads to a decrease in Inventory and Operating Expense, since these are partly determined by the number of intermediary transactions within the system. The Throughput of the system increases in a similar fashion.

Students who forget their passwords retrieve them by clicking the "Forgot My Password" link on the homepage. Since the system will generate new passwords for such students, such students are again reminded about the general guidelines of the password generation process, just like first time users.

Under the new design, students are reminded on the department's homepage and other announcement boards that the password generation process of the ECPRS is accessible 24/7 and they are specifically urged to receive their passwords before the beginning of the registration period so that they will not lose time on the first day of the registration. They will also be reminded that early bidders will have priority throughout the bidding process, therefore they would benefit from finalizing their bidding process as soon as possible. This is expected to reduce the number of password-related complications encountered during the registration process. Consequently, the level of Inventory and Operating Expense of the system would fall, while simultaneously increasing Throughput.

Instead of giving all the rules and guidelines to students once and expecting them to remember all of this information throughout the whole registration period as in the current system, the newly designed ECRPS will provide warnings and information related to the use of the system whenever and wherever they are needed. In other words, password related rules will be given on pages where students retrieve their passwords; specific rules about the bidding procedure will be provided on the page where students place bids for courses. This design is expected to decrease the

number of students frequently visiting their advisors for guidance about the use of the system. This decreases the occurrence of intermediary transactions, hence the Operating Expense and the level of Inventory in the system. The Throughput is also affected positively.

The previously mentioned FAQ page is another very useful tool in order to decrease the intermediary and counter-productive transactions in the system, aiming to prevent such situations before they even occur. Under the new design, there is a link to the FAQ on every page within the ECPRS, urging the students to consult to the FAQ whenever they experience a problem, or are unsure about the use of the system. Since the problems and situations encountered by students are usually very similar, the answers provided on this page should help the students find out what to do in most instances. This would have an indirect impact on the occurrence of counter-productive situations, and also the number of intermediary transactions, since students would be more familiar with the system and they would not ask their advisors about specific steps in the registration process. This in turn would lead to an indirect decrease in Operating Expense and Inventory, and have an improving effect on Throughput.

Under the new design, students are not asked to fill a profile page before proceeding with bidding. Therefore students do not spend extra time for this step and occupy the computer lab for longer than necessary. This increases the capacity of computer laboratories.

After log in, students are reminded and encouraged to take a look at the quick demo link placed on the main menu. Students are also reminded that they can access the demo anytime and that for further questions they can also consult the FAQ page, given as a link.

After the introduction page, students access the bidding page and see the list of elective courses offered that semester. They are reminded once again that they cannot add courses that have overlapping schedules (the system automatically prevents it),

that they cannot add a course over the SAIS unless they have won it via bidding; and that if they decide to drop a course, and they have to drop it from both the SAIS and the ECPRS. When students are not allowed to add elective courses with overlapping schedules, advisors will not have to check for this situation during the approval transaction, and they will only check that a student's elective courses do not overlap with his/her must courses. This decreases the time incurred for productive transactions and consequently decreases the Operating Expense in the system as well. When students are frequently reminded about the rule for the SAIS-ECPRS consistency, it is also expected that the number of counter-productive transactions will decrease. These minor changes will lead to a simultaneous improvement in all the three performance measures of the system.

Under the proposed system, students have access to previous years' bidding statistics, which may help them to place more realistic bids. Consequently, the number of students who need to perform MPR to add or drop courses would decrease. This would lead to a decrease in the number of WIP students in the system, pulling Inventory and Operating Expense down, as well as increasing the Throughput.

The trial schedule feature also helps to improve the performance measures of the system in a similar fashion, as students are able to see conflicts in their schedule and reach course syllabi. This enables them to make more wholesome decisions about which courses to bid for. When students make correct choices the first time, their need for MPR transactions will decrease. Although the new system does not allow students to bid for elective courses with overlapping timetables, the trial schedule also enables them to place their must courses on their schedule and check for the presence of overlaps between their elective and must courses as well. When students bid for elective courses over their finalized schedule, advisors will only check whether the list of courses added over the ECPRS and SAIS are identical with each other, and there will be no further need for checking whether there are overlaps

between must and elective course schedules. This reduces the time spent during giving approval and therefore decreases the Operating Expense of the system.

Another feature of the new system is that it repays students' unsuccessful bids automatically at log in; therefore there is no need for the intermediary transaction that is currently carried out by advisors.

Under the new design, the MPR transactions that advisors perform are removed entirely. This is achieved by allowing student access to the existing MPR interface of the ECPRS so that they are able to make the changes in their list of courses themselves. This is very convenient for both the students and advisors, because students do not have to visit their advisors each time they wish to make a change in their course portfolio. This reduces the number of intermediary transactions significantly and elevates the constraint arising from MPR transactions. The proposed setup is given below.

On their ECPRS accounts, just as it is in the existing setup, students can see the up-to-date list of courses with available capacities and the number of available places in each course. In the new design, if they wish to drop a course, they select it from their list of courses and click the "drop" button. The system automatically calculates the number of bidding credits that will be deducted from the student according to the occupancy rate of the course and display a warning message in a dialogue box that reads "Since the course is (not) fully occupied, you will lose *x* bidding points. Do you want to proceed?" Students either click "OK" or "Cancel". If the course is dropped, a warning message is displayed, reminding students to drop the course from the SAIS as well. Similarly, when students wish to add a course, they select it from the list of available courses and click the "add" button. The system automatically calculates the number of bidding credits needed to take the course. If students have sufficient amount of bidding points, the system will display a message in a dialogue box that reads "In order to add this course, *x* bidding points will be deducted from your total bidding credit. Do you want to proceed?" to which students either click

"OK" or "Cancel". After a course is added, a warning message reminds students that they have to add this course to the SAIS as well. If a student does not have the required amount of bidding points, the message reads "This course requires *x* bidding points. You do not have enough bidding points to add this course." In this manner, students are able to perform Manual Pre-Registration on their own. Throughout the three-day registration period, students will be able to access their course portfolios over the ECPRS and make any number of changes to their list of elective courses. Since the new system does not allow placing bids for courses with overlapping timetables, and it automatically calculates the required number of bidding points to be deducted when adding a course, or to be returned when dropping a course, there is no room for student errors or abuses relating to these steps.

However, since the ECPRS and the SAIS are not integrated, there is no way to prevent the inconsistencies that occur between the students' lists of courses over these two systems. To minimize the occurrence of such instances and reduce the number of counter-productive transactions, penalty points are deducted from the students' overall bidding credit. The penalty points would act as a deterrent and force students to ensure consistency between the two systems. Additionally, there will be a constant reminder message that warns the students to make sure that their lists of elective courses taken over the SAIS should match the list of courses taken over the ECPRS, otherwise advisor approval will not be given.

As can be seen, the removal of the MPR transactions will be a major improvement over the existing system. Since the portion related to MPR transactions is totally eliminated and transferred to students, the number of intermediary transactions in the system will decrease significantly and advisors will mainly deal with giving approval. This is a significant step towards the ideal situation mentioned in Chapter 4.4, in which all transactions carried out by advisors are productive. Aside from this major increase in Throughput, this new design also causes a noteworthy reduction in Inventory and Operating Expense of the system. This recommendation is a clear

demonstration of how a system constraint can be elevated without requiring significant investment.

Under the new setup, advisors have access to class rosters from the SAIS in order to track students who knowingly or unknowingly violate the consistency rule between the two systems. Therefore, even if counter-productive instances occur, it will take less time for advisors to solve the problems, decreasing the Operating Expense of the system.

After receiving advisor approval, students will be able to make changes in their course portfolio over the SAIS without having to receive *un-approval* from their advisors. When students access their list of courses over the SAIS, they will see a warning message, reminding them that if they make a change in their list of courses and do not receive advisor approval again, their previous approved schedules will be valid. After this warning message, students will make the desired changes and visit their advisor for *re-approval*. When advisors no longer have to give *un-approval* to students, the number of intermediary transactions in the system will decrease further, improving the performance measures of the system simultaneously. However, the recommendations presented in this step would require a change in the rules and operation of the SAIS.

The design changes that the proposed system offers for the ECPRS are briefly summarized below:

1. Allow student access to the Manual Pre-Registration process of the ECPRS without visiting the advisor
2. Develop a more user-friendly interface
    a. Insert warnings and reminders where appropriate
    b. Construct a Frequently Asked Questions page accessible from the main menu and all other pages in the ECPRS

c. Construct a Quick Demo accessible from the main menu

d. Put course schedules and syllabi on the main menu

3. Avoid bidding for overlapping courses
4. Provide past years' bidding results on the main menu
5. Implement a Trial Schedule Generation feature on the main menu
6. Introduce a penalty point system to reduce inconsistencies

There are also some changes that are recommended for the SAIS which are given below:

1. Allow students to perform un-approval without their advisor's intervention and warn students on the next SAIS log-in to receive advisor approval after making any changes to the previously approved schedule
2. Allow advisor access to the class-rosters of courses over the SAIS

Lastly, it is important to discuss the fifth step in Goldratt's cycle of ongoing improvement, which dictates that even after the exploitation and elevation of constraints, the system should be monitored constantly in order to detect other constraints which may eventually arise in the system. Goldratt (1990) calls it preventing inertia from causing a system constraint.

Under the proposed system, various constraints have been elevated and the registration process has been streamlined. However, because the SAIS and the ECPRS are not integrated, preventing students entirely from causing inconsistencies between the two systems is not possible. Additionally, students now carry out MPR transactions without any supervision. This might lead students to think that they can cause violations in the system since they are without supervision. Such students would again be identified during approval, but the registration process of many other students would be adversely affected. Consequently, while decreasing the number of

intermediary transactions in the system significantly by removing MPR, the new design could possibly cause the number of counter-productive transactions in the system to increase. Therefore, the system must be monitored closely just in case this new situation creates another constraint in the system.

Other constraints or bottlenecks may also arise in the system after the recommendations are implemented, since a system is always bound to be subject to at least one constraint, as Goldratt (1990) mentions. Thus, the system must again be subject to the Five Steps of Focusing of Goldratt to identify new constraints and work on solutions to exploit and elevate them, and the cycle of ongoing improvement is thus continued.

# CHAPTER 7

# CONCLUSION

In this study, the principles and steps of the Theory of Constraints are applied to the elective course registration system used by third and fourth year Business Administration students at Middle East Technical University. The goal in this system is to ensure that all transactions carried out in the system are productive, which necessitates the elimination of intermediary and counter-productive transactions. Since this is neither realistic nor possible, the focus of this thesis is to reduce the number of intermediary and counter-productive transactions to the extent possible.

Unlike the applications of the TOC to manufacturing and profit-oriented service environments, it is not possible to define the performance measures of the elective course registration system, which are Throughput, Inventory and Operating Expense, in monetary terms. Therefore, the performance measures of the system are defined as would be appropriate for a system that does not have the goal of making money. The fundamental unit that replaces monetary units for the performance measures of the system is the transaction. In the elective course registration system, since the Throughput is determined by the number and type of transactions that lead to approval, the unit that defines Throughput is the transaction. Likewise, the level of Inventory is dependent on the number of intermediary and counter-productive transactions carried out for WIP students; therefore, the unit used for defining Inventory is also the transaction. Operating Expense represents the cost of turning Inventory into Throughput, and in this system, cost is represented by the time spent by the advisor to perform the productive, intermediary and counter-productive transactions until all students receive approval. In other words, the Operating Expense in this system is the time it takes to turn WIP students into Throughput. The

fundamental unit for Operating Expense is again the transaction, since the cost is determined by the time spent for each type of transaction.

The elective course registration process is analyzed in order to identify the constraints in the current system. These constraints have been verified through the questionnaires distributed to advisors and students, and the results show that the correct constraints have been identified. Using the principles and tools of the TOC, recommendations are put forward in order to elevate or exploit these constraints to the extent possible. The solutions that are presented under the proposed system have also been found appropriate and effective by other advisors using the system.

A major constraint in the system, which is the Manual Pre-Registration process, is removed entirely in the proposed system, and all MPR transactions are transferred to students. Students are enabled to add and drop elective courses throughout the registration period using the ECPRS without the assistance of advisors. The transfer of MPR to students causes a significant reduction in the number of intermediary transactions carried out by the advisor, and improves all three performance measures simultaneously.

In the new design of the ECPRS, the intermediary transactions carried out for the deduction of bidding points for dropped or added courses, as well as returning unsuccessful bidding points are automated. This further decreases the number of intermediary transactions in the system and improves the system's performance measures.

Constraints rooting from student-related mistakes are alleviated by redesigning the ECPRS. Firstly, the interface is designed to be more user-friendly through the quick demo and FAQ links in the menu. Secondly, the system is modified to provide warning information to students just when it is needed at each step of the bidding process, rather than providing overall guidelines at the beginning. Thirdly, the system provides past years' bidding statistics to help students allocate their bidding points more accurately. The password generation process is rationalized and the

student profile entry is removed to reduce the capacity problem in the computer laboratories. A trial schedule feature is embedded in the system to help students check timetable overlaps among their selected elective courses, as well as between elective and must courses. The students' selection of appropriate courses is also facilitated by the provision of pertinent information such as final exam dates and course syllabi during the generation of the trial schedule. Moreover, the system automatically prevents bidding for elective courses that have overlapping schedules. This is a significant improvement over the existing design in terms of the number of intermediary transactions carried out in the system.

Penalty points are introduced to deter students from causing inconsistencies between the SAIS and the ECPRS, in order to reduce the time spent by advisors on counter-productive transactions trying to alleviate the bottleneck caused by inconsistencies. Moreover, the new system proposes access to the class rosters of the SAIS by advisors to further reduce the time spent by advisors to identify the students that cause the inconsistencies.

The cancellation of the approval process is streamlined such that students are able to reconstruct their course portfolio without having to go to the advisor, thus removing another intermediate process. The proposed system thus helps to improve the Throughput, Inventory and Operating Expense simultaneously and brings the system closer to its goal.

By collecting and comparing data on the number of productive, intermediary and counter-productive transactions and the time taken for each transaction in the current and proposed systems, the actual impact of the proposed system on the current Throughput, Inventory and Operating Expense can be measured. However, since a number of recommendations in the proposed system require changes in the rules and operation of the SAIS, and the remaining recommendations necessitate modifications to the ECPRS, the quantitative evaluation of the new system's impact on the performance measures is beyond the scope of this thesis.

Additionally, a survey can be carried out to assess the satisfaction levels of advisors and students after the recommended changes in the proposed system are implemented. This qualitative assessment would provide further ideas to improve the system performance.

This study has shown that the main challenge in the application of the TOC to a service system is the correct adaptation and interpretation of the Throughput, Inventory and Operating Expense. It has also shown that the principles of the Theory of Constraints and the Five Steps of Focusing can be applied to service systems which are not-profit oriented. The approach taken in this thesis in the identification of the performance measures could serve as an example for future applications of the TOC to non-profit service environments.

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# APPENDICES

## APPENDIX A: STUDENT SURVEY

Dear Student,

Given below are problems and difficulties students experience during the Elective Course Pre-Registration (ECPRS) process. According to you, how critical are these situations? Please mark your answer for each question, as 1: *Not critical at all*, 2: *Not very critical*, 3: *Slightly critical*, 4: *Critical*, 5: *Very critical*. Approximately how many times do you visit your advisor for these problems during the registration period? Please write in the place indicated with ____.

**A. Passwords and Log-In** **1 2 3 4 5 ___**

Students consult advisor when they forget their passwords, when their passwords are not sent to their email inboxes or the passwords do not work.

**B. ECPRS Rules and Guidelines** **1 2 3 4 5 ___**

Students consult advisor about the rules and operation of the ECPRS, like how many bid points will be lost when dropping a course, or the current number of available places in courses.

**C. Conflicting Courses** **1 2 3 4 5 ___**

Students win the right to add two courses with conflicting timetables, but later they have to drop one of them because advisor approval is not given under these circumstances.

**D. SAIS-ECPRS Inconsistency** **1 2 3 4 5 ___**

A student adds a course over the SAIS without having won it through bidding, or a student drops a course from the SAIS but does not drop it over the ECPRS as

well. Other students' registration are adversely affected, and they inform their advisor about this situation and wait for the problem to be resolved.

**E. Manual Pre-Registration** **1 2 3 4 5 ___**

Students have to visit advisor to make changes in their list of courses because they cannot make these changes on their own.

**F. Un-approval** **1 2 3 4 5 ___**

Students have to personally visit advisor to receive un-approval.

**G. Computer Laboratories** **1 2 3 4 5 ___**

During Manual Pre-Registration, students have to leave advisor's office and go to the computer lab to make changes. Then they have to start back from the end of the queue in front of the advisor's office. Knowing this, students sometimes ask to use the computer of the advisor to make these changes.

Are there any other problems or difficulties that you experience?

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Thank you for your time.

## APPENDIX B: ADVISOR SURVEY PART 1

Dear Advisor,

Given below are problems and difficulties advisors experience during the Elective Course Pre-Registration (ECPRS) process. According to you, how critical are these situations? Please mark your answer for each question, as 1: *Not critical at all*, 2: *Not very critical*, 3: *Slightly critical*, 4: *Critical*, 5: *Very critical*.

**A. Passwords and Log-In** **1 2 3 4 5**

Students consult their advisor when they forget their passwords, when their passwords are not sent to their email inboxes or the passwords do not work.

**B. ECPRS Rules and Guidelines** **1 2 3 4 5**

Students consult advisor about the rules and operation of the ECPRS, like how many bid points will be lost when dropping a course, or the current number of available places in courses.

**C. Conflicting Courses** **1 2 3 4 5**

Students win the right to add two courses with conflicting timetables, but later they have to drop one of them because advisor approval is not given under these circumstances.

**D. SAIS-ECPRS Inconsistency** **1 2 3 4 5**

A student adds a course over the SAIS without having won it through bidding, or a student drops a course from the SAIS but does not drop it over the ECPRS as well. Other students' registration are adversely affected, advisors are informed about this situation and they try to identify the faulty student and fix the problem.

**E. Manual Pre-Registration (MPR)** **1 2 3 4 5**

Students have to visit advisor to make changes in their list of courses because they cannot make these changes on their own. It is not known how many students will visit their advisor for MPR until receiving approval.

**F. Un-approval** **1 2 3 4 5**

Students have to personally visit advisor to receive un-approval.

**G. Computer Laboratories** **1 2 3 4 5**

During Manual Pre-Registration, students have to leave advisor's office and go to the computer lab to make changes. Then they have to start back from the end of the queue in front of the advisor's office. Knowing this, students sometimes ask to use the computer of the advisor to make these changes.

Are there any other problems or difficulties that you experience?

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Thank you for your time.

## APPENDIX C: ADVISOR SURVEY PART 2

Dear Advisor,

Given below are certain recommendations designed to solve or improve the problems and difficulties experienced by advisors during the Elective Course Pre-Registration (ECPRS) process. According to you, how realistic and applicable are these solutions? Please mark your answer for each question, as 1*: I do not find them realistic or applicable at all,* 2: *I find them not very realistic or applicable*, 3: *I find them slightly realistic and applicable,* 4: *I find them realistic and applicable*, 5: *I find them very realistic and very applicable.*

**A. Passwords and Log-In** **1 2 3 4 5**

First time users obtain their passwords from a separate link; only one password is generated per student; students are reminded not to visit advisors for password-related issues; they are urged to receive their passwords beforehand and the system provides clear information about the generation process and arrival time of passwords.

**B. ECPRS Rules and Guidelines** **1 2 3 4 5**

The system provides warning and reminders about the operation principles of the ECPRS where they are needed; students are reminded about where they can access current course capacities; a Frequently Asked Question page is constructed and made accessible from the main menu; a Quick Demo feature which familiarizes students with the system is constructed and made accessible from the main menu; previous year's bidding results, course syllabi and schedules are provided on the main menu,

**C. Conflicting Courses** **1 2 3 4 5**

System does not allow for bidding for courses which have overlapping timetables; a Trial Schedule Generation feature is constructed to help students

detect any possible conflictions among their must and elective courses beforehand.

**D. SAIS-ECPRS Inconsistency** **1 2 3 4 5**

A penalty system is introduced to deter students from causing inconsistencies; the system reminds and warns students about the rules and guidelines of the ECPRS to reduce such occurrences.

**E. Manual Pre-Registration (MPR)** **1 2 3 4 5**

Students are able to make any changes to their course portfolio without visiting their advisor; the calculation of bids necessary to add a course and the calculation of bids that will be lost when dropping a course are automatically calculated and deducted; unsuccessful bids of students are automatically repaid at log-in.

**F. Un-approval** **1 2 3 4 5**

Students do not need to visit advisor to receive approval; they are able to access their student profile over the SAIS without un-approval; the system automatically warns students that if they do not receive approval after making any changes to their schedule, their previously approved schedule will be valid.

**G. Computer Laboratories** **1 2 3 4 5**

An extra computer is placed in advisors' offices to be used by students during Manual Pre-Registration; students are able to make any changes to their course portfolio immediately.

Do you have any other recommendations?

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Thank you for your time.

## APPENDIX D: TURKISH VERSION OF THE STUDENT SURVEY

Sayın Öğrenci,

Aşağıda Seçmeli Ders Ön Kayıt Sistemi (ECPRS) süresince öğrencilerin yaşadığı düşünülen birtakım sorunlar verilmiştir. Bu sorunlar size göre ne kadar önemlidir? 1: Hiç önemli değil, 2: Çok az önemli, 3: Biraz önemli, 4: Önemli, 5: Çok önemli olacak şekilde verdiğiniz notu lütfen aşağıda her soru için işaretleyiniz. Bu sorunlardan herhangi biri için kayıt süresi boyunca danışmanınızı yaklaşık olarak kaç defa ziyaret ettiniz? Lütfen ___ ile belirtilen yere yazınız.

**A. Şifre Edinme ve Sisteme Giriş** **1 2 3 4 5 ___**

Öğrenci şifresini unuttuğunda, şifresi gelmediğinde veya mevcut şifresi çalışmadığında danışmanına soruyor.

**B. ECPRS Kuralları ve İşleyişi** **1 2 3 4 5 ___**

Öğrenci sistemin kuralları ve işleyişiyle ilgili problem yaşadığında danışmanına soruyor. Örneğin bir dersi bıraktığı zaman kaç puanı gideceğini veya güncel ders kapasitelerini nereden göreceğini öğrenmek için danışmanını ziyaret ediyor.

**C. Çakışan Dersler** **1 2 3 4 5 ___**

Öğrenci ders programları çakışan iki dersi birden ekliyor, ancak buna izin verilmediği için öğrenci derslerden birini düşürmek zorunda kalıyor.

**D. OIBS-ECPRS Uyuşmazlığı** **1 2 3 4 5 ___**

Bir öğrenci ihale yoluyla dersi kazanmamış olmasına rağmen OIBS üzerinden gekliyor, veya OIBS üzerinden düşürdüğü bir dersi Manual Pre-Registration yaparak bırakmıyor. Bu durumda diğer öğrencilerin kaydı sekteye uğruyor, öğrenci danışmanını bu durumdam haberdar ediyor ve sorunun çözülmesini bekliyor.

**E. Manual Pre-Registration** **1 2 3 4 5 ___**

Öğrenci ders programında değişiklik yapmak için danışmanını ziyaret etmek zorunda kalıyor, bu değişiklikleri kendisi yapamıyor.

**F. Danışman Onayının Kaldırılması** **1 2 3 4 5 ___**

Öğrenci onay aldıktan sonra derslerinde değişiklik yapmak isterse verilmiş olan onayın kaldırılması gerekiyor. Bu iş için öğrencinin tekrar danışmanını ziyaret etmesi gerekiyor.

**G. Bilgisayar Laboratuvarları** **1 2 3 4 5 ___**

Manual Pre-Registration sırasında öğrenci derslerinde değişiklik yapmak zorunda kaldığı zaman danışmanın yanından ayrılıp bilgisayar laboratuvarlarına gidiyor ve dönüşte danışmanın ofisinin önünde tekrar sıraya giriyor. Bu nedenle zaman zaman değişiklikleri yapmak için danışmanının bilgisayarını kullanmayı rica ediyor.

Yukarıda verilen sorunlardan başka sizin sıkça karşılaştığınız problemler nelerdir?

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Zaman ayırdığınız için teşekkürler.

## APPENDIX E: PERCENTAGE DISTRIBUTION OF ANSWERS GIVEN TO STUDENT SURVEY

| | Password and Log In | ECPRS Rules and Guidelines | Conflicting Courses | SAIS-ECPRS Inconsistency | Manual Pre-Registration | Un-approval | Computer Labs | Password & Log In |
|---|---|---|---|---|---|---|---|---|
| **Very Critical (%)** | 30 | 16 | 36 | 38 | 30 | 30 | 46 | 30 |
| **Critical (%)** | 32 | 32 | 30 | 28 | 36 | 32 | 18 | 32 |
| **Slightly Critical (%)** | 18 | 18 | 14 | 16 | 18 | 20 | 18 | 18 |
| **Not Very Critical (%)** | 10 | 18 | 8 | 10 | 4 | 10 | 10 | 10 |
| **Not Critical At All (%)** | 10 | 16 | 12 | 8 | 12 | 8 | 8 | 10 |

## APPENDIX F: PERCENTAGE DISTRIBUTION OF ANSWERS GIVEN TO ADVISOR SURVEY PART 1

| | Password and Log In | ECPRS Rules and Guidelines | Conflicting Courses | SAIS-ECPRS Inconsistency | Manual Pre-Registration | Un-approval | Computer Labs | Password & Log In |
|---|---|---|---|---|---|---|---|---|
| **Very Critical (%)** | 33 | 33 | 33 | 50 | 50 | 17 | 17 | 33 |
| **Critical (%)** | 50 | 50 | 50 | 33 | 50 | 17 | 33 | 50 |
| **Slightly Critical (%)** | 0 | 17 | 17 | 17 | 0 | 33 | 17 | 0 |
| **Not Very Critical (%)** | 0 | 0 | 0 | 0 | 0 | 33 | 33 | 0 |
| **Not Critical At All (%)** | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |

## APPENDIX G: THE AVERAGE AND STANDARD DEVIATION OF VALUES ASSIGNED BY STUDENTS

| | Password & Log In | ECPRS Rules and Guidelines | Conflicting Courses | SAIS-ECPRS Inconsistency | Manual Pre-Registration | Un-approval | Computer Labs |
|---|---|---|---|---|---|---|---|
| **Average** | 3,7 | 3,1 | 3,7 | 3,8 | 3,7 | 3,7 | 3,8 |
| **Standard Deviation** | 1,3 | 1,3 | 1,4 | 1,3 | 1,3 | 1,2 | 1,3 |

## APPENDIX H: THE AVERAGE AND STANDARD DEVIATION OF VALUES ASSIGNED BY ADVISORS

| | Password and Log In | ECPRS Rules and Guidelines | Conflicting Courses | SAIS-ECPRS Inconsistency | Manual Pre-Registration | Un-approval | Computer Labs |
|---|---|---|---|---|---|---|---|
| **Average** | 3,8 | 4,2 | 4,2 | 4,3 | 4,5 | 3,2 | 3,3 |
| **Standard Deviation** | 1,5 | 0,8 | 0,8 | 0,8 | 0,5 | 1,2 | 1,2 |