YAŞAR UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER THESIS

WAREHOUSE OPTIMIZATION AND ORGANIZATION: CASE STUDY AT A STEEL CASTING COMPANY

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INDUSTRIAL ENGINEERING

PRESENTATION DATE: 25.11.2019

BORNOVA / İZMİR

NOVEMBER 2019

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ABSTRACT

Warehouse Optimization and Organization: Case Study at a Steel Casting Company

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November 2019

Pickiness in the consumers' behaviors forces the enterprises to produce "customer oriented" products and services that meet global standards. In the developing global market, the importance of the customer orientation and satisfying the customers' demands within short time increased considerably. In the global market where the product qualities are very close to each other and they have nearly the same contents therefore timeframe has become the selective criterion in most cases. The purpose of this study is to organize the pattern warehouse of a steel casting company located in Izmir. Finding patterns, which are kind of molds, in the warehouse in a reasonable amount of time saves material, labor and time. Thus, the reduction in the time required to search for a pattern and transport it to the production area reduces production costs. While handling those problems the frequency of the orders by customers of the patterns and the physical conditions of the warehouse are considered. A well-organized warehouse layout and a quick transfer of the patterns are targeted throughout the study. Furthermore, in order to maintain well-functioning of the system an application of RFID technology is proposed.

Key Words: Warehouse, Shelf allocation, optimization, mathematical model, RFID, Warehouse organization, layout change

ÖZ

Depo Optimizasyonu ve Organizasyonu: Örnek Olay İncelemesi Çelik Döküm Şirketi

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Kasım 2019

Tüketici davranışlarındaki seçicilik işletmeleri dünya standartlarında "müşteri odaklı" üretim ve hizmet yapmaya zorunlu kılmaktadır. Gelişen küresel pazarda müşteri odaklı olmanın, müşteri talebinin kısa sürede cevaplanmasının önemi gittikçe artmıştır. Ürünlerin kalitelerinin birbirine yakın olduğu, içeriklerinin benzer olduğu sıfır hata düzeyi ile hizmet verebilen küresel pazarda seçim ölçütü süre olmuştur. Bu çalışmada daha önce üretilmiş üretim modelinin firma içinde bulunamamasından kaynaklı sipariş termin gecikmeleri, kaybolan üretim modelinin tekrar üretilmesindeki işçilik kaybının azalmasını amaçlayan blok raf atama probleminin çözülmesi ve depo düzenlemesi konuları ele alınmıştır. Bu çalışmanın amacı model ambarında bulunan modellerin kolonlara ait raflardan alınarak üretim alanına getirilmesi sürecinde müşteri sipariş sıklıklarını da göz önünde bulundurarak kat edilen yolun en aza indirilerek taşıma maliyetlerinin azaltılmasıdır. Bu problemi ele alırken müşteri siparişindeki modellerin sipariş sıklıkları göz önünde bulundurulmuştur. İyi düzenlenmiş depo yerleşimi ve modellerin hızlı bir şekilde aktarılması çalışma boyunca hedeflenmiştir. Ayrıca, sistemin iyi işleyişini sağlamak amacı ile model deposunda RFID teknolojisi uygulaması önerilmiştir.

Anahtar Kelimeler: Depo, raf yerleşimi, optimizasyon, matematiksel model, RFID, depo düzenlemesi, yerleşim yeri düzenlemesi

ACKNOWLEDGEMENTS

First and foremost, I offer my sincerest gratitude to my supervisors Asst. Prof. Dr. Önder BULUT and Assoc. Prof. Gökhan KILIÇ for their encouragement, guidance and support throughout my study. I attribute the level of my master's degree to her encouragement and effort and without her this thesis, too, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

I wish to thank my family, and my wife Gül ÇELİK her encouragement and ongoing morale support.

Sezgi ÇELİK
İzmir, 2019

TEXT OF OATH

I declare and honestly confirm that my study, titled "Warehouse Optimization and Organization: Case Study at a Steel Casting Company" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Sezgi ÇELİK

Signature

………………………………..

December 24, 2019

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SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

SKU Stock Keeping Unit

OPL Optimization Programming Language of CPLEX - IBM

ERP Enterprise Resource Planning

WMS Warehouse Management information systems

GABM Genetic algorithms based on batching method

RFID Radio Frequency Identification

TDOA Time Difference of Arrival

SYMBOLS:

i Product index

k Block number

l Shelf number

bw_{kl} Width of shelf l of block k

bs_{kl} Length of shelf l of block k

bh_{kl} Heigth of shelf l of block k

ba_{kl} Weight capacity of shelf l of block k

d_{kl} distance to entrance of shelf l of block k

pw_i width of product i

ps_i Length of product i

ph_i Height of product i

pa_i weight of product i

w_i Priority multiplier for Product i

CHAPTER 1
INTRODUCTION

Global competition forces the companies to use their storage systems more efficiently. Therefore, an optimal planning of the storage activities and warehouse layout scheme has primordial importance. Complexities should be simplified, and the unclearness should be eliminated. Especially the labor force should be efficiently planned and used with the desired flexibility. The employees should be trained in order to act in the most efficient way. The products should be placed in warehouses in an easily understandable order. Finding a required item should not be a difficult task and should not take much time.

In parallel with the recent competitive and rapidly changing market demands, making studies on the flexibility, quality and productivity of logistic process has become necessary. When the global competition conditions and trade volumes are considered the reduction of the storage costs and speeding up the production processes by using the warehouses effectively and ultimately reducing the delivery time of the products are the factors which help the firms to take a lead in their sectors. Management of transport and storage processes constitute the most important items in the logistic activities. In the warehouse planning; the enterprise policy, properties of products and raw materials should be taken into account.

Making surveys on the characteristics of the customers' orders, transport costs, delivery and stock profiles are important and necessary. The layout of the warehouse is of vital importance for profitability of the enterprise, increases the profit and ensures continuity of the profit margin. Time efficiency and efficient use of transport vehicles facilitates the minimization of the transport costs. Easy availability of the goods stored in the warehouse plays an active role in ensuring occupational safety and promoting motivations of the employees.

In order to obtain the desired results in the storage activities it is needed to handle the problem with an engineering approach considering the limits and restrictions of the field. With help of such an approach the transport distances of the items coming to or going from the warehouses can be minimized, so time required for transport will be reduced which in turn leads to minimization of costs. Efficient use of time and labor force in addition to the reduction of costs will contribute to the companies to be more competitive. Within that context, managers of the logistic departments of the companies are trying to find optimal solutions for storage problems. Different methods and models are developed for storage activities and warehouse layout schemes. In this study it is tried to develop a feasible method of storage of goods in the warehouse of the related company. Every aspect of the subject is carefully examined, and a quite suitable model is presented.

From the above-mentioned perspective, this thesis considers the pattern (a kind of mold) warehouse organization and optimization problem of a steel casting company, which is located in Izmir. The patterns used in production are stored in the pattern warehouse of casting company. A mathematical model is developed to minimize the distance of those patterns, placed on the shelves in the warehouse, to the production area by considering their order frequencies. That means the patterns of more frequently ordered products are tried to be placed at the shelves closer to the entrance of the warehouse. The number of the patterns and the blocks of the warehouse shelves is too high the mathematical model is verified by using a smaller data set. After the mathematical model is verified the data of the firm is processed with the mathematical model and the obtained results are compared with the values of the previous situation.

In order to avoid staying "on paper" and put into practice the placements of the patterns obtained by employing the mathematical model, it is necessary to organize the warehouse in which the patterns are stored. Places of the blocks in the warehouse are changed and a new warehouse layout is constituted. The distances of the blocks in the new layout arrangement to the entrance of the warehouse are measured and the obtained values are used in the mathematical model. The difference of the objective function between the actual and the proposed warehouse layout plans revealed that the proposed layout is more effective. The blocks on which the patterns placed are fixed onto the floor and ceiling in order to prevent the patterns from falling. Removal of those blocks and placing them on the proposed places is an expensive process. In order to determine location of the patterns of the products and to facilitate to find the pattern among the shelves of the blocks a work with the RFID system is proposed.

CHAPTER 2
LITERATURE REVIEW

In the article “A Literature Survey on Planning and Control of Warehousing System” [1] provided high quality solutions to the complex problems of storage decisions. Like the warehouse management systems, the modern information technologies also employ simple intuitive scanning methods. In most cases, the warehouse performance can be improved with at least 10 smart planning and control methods. When the relevant literature is reviewed, the number of published articles presenting optimal solutions is very few and there is a need for research. Most of the articles discuss intuitive procedures. In most of the articles in the relevant studies, there are models trying to minimize the travel time and increase productivity to the highest level. However, the increase of the productivity to the highest level is not a unique purpose in most cases. To observe the delivery deadlines of the customer orders is of vital importance. Therefore, some compromises are needed between the productivity and the urgency. Rendering flexible the workmanship is an important issue in the warehouse management. Flexibility provided in that way facilitates the transfer of the warehouse employees to the other areas when supplementary labor is needed. If the labor force is not sufficient it is needed to recruit temporary employees. To minimize the labor cost detailed capacity planning procedures are needed. A capacity plan defines the number of employees and sources needed by an activity. Similarly, it is needed to develop procedures in order to manage the complex storage activities under time limitations.

In logistics sector the shelf spaces are one of the main sources used for attracting more customers. [2] argued that effective shelf management strengthens the customer-sales the customer-seller relation and increases customer satisfaction by lowering the stock levels. Management of shelf spaces is one of the major factors affecting the business of retail trade. Therefore, management of shelf spaces is an important issue for management of retail operations. In the study a model proposed for optimization of the shelf spaces. The aim is to allocate the most suitable shelf spaces by taking into account the space flexibility factor.

In the research titled “Batching orders in warehouses by minimizing travel distance with genetic algorithms” [3] authors emphasized that accelerating the movement of products in warehouses is a critical issue for minimizing the distance to be covered and the time to be spent. The warehouse administrators. are trying to discover the most economical way to achieve it. By doing so it will be possible to prepare customer orders at optimally reduced costs. Developing a mathematical model for preparation of the orders batches is a very difficult task. Because the total distance to be covered is a function of the contents of the batch and the layout of the warehouse. In this study an optimization approach is suggested for preparation of orders in which the total distance of movement of the items is directly minimized. A Genetic Algorithm (GA) is proposed for batch processing method. The suitability of the algorithm is tested in several exemplary cases.

In their study titled “The adaptive approach for storage assignment by mining data of warehouse management system for distribution centers” [4] authors developed a new approach. No information about the product is used in assignments made by that approach. The biggest advantage of that method is the increase in usability of areas. But non-utilization of the product information affects the productivity of storage activities negatively.

In his article named “Design and control of warehouse order picking” [5] the warehouse from the viewpoint of order picking. The order collection activity is defined as a costly job and a work-labor activity for each warehouse. A literature review is conducted on the problems with the design and control of the manual order collection process. It is calculated that the cost of collecting orders may reach 55 % of the cost of managing the warehouse. In order to function productively, the design and optimality of the order collection system must be examined. Optimality of the layout design focuses on storage assignment methods, routing methods, integration and regionalization of the order.

In their articles entitled “optimization of warehouse storage capacity under a dedicated storage policy” [6]. Authors tried to optimize the warehouse storage capacity. The determination of area requirements was examined in a storage system operating with assigned storage capacity. When demand exceeds the storage capacity, the insufficiency of the space poses a problem. In order to meet the need of the area, some storage space is rented. In order to minimize the cost of the rented area, a non-linear programming model was formulated. A search procedure including repetitions that provides optimal solutions has been developed. It provided an approach that worked with the cost-effective order amount model.

In [7] authors compared the barcode and RFID Systems. In the article position determining by RFID on two- and three-dimensional planes is studied. Signals broadcasted by RFID antennas have not got a unique focus. Position determination is achieved more effectively in the systems containing more than one reader. In the study several position measuring systems are examined. RSSI (Received Signal Strength Indication) is a term used for computation of the signal quality received by the client device. According to IEEE.802.11 Standards every manufacturer defines its own “RSSI_MAX” Value. For example, while Atheros has been using the value 0-60 Cisco uses the value 0-100. Another position determination method is the TdoA Method (Time Difference of Arrival). That method uses the time difference between the signals received by the readers.

In [8] “Genetic Algorithms in Search and Machine Learning” a solution named “chromosome” is encoded in form of a string containing several components (genes). Premier population of chromosomes is created in accordance with some principles or selected randomly. The algorithm is used for evaluating the fitness of the potential solutions. Optimization made with help of GAs is based on (a) selection of the pairs of chromosomes with probabilities proportional to their fitness (b) match of pairs to obtain a new offspring. The unsatisfactory solutions are replaced by new developed solutions using some fixed strategies. It is continued to evaluate, optimize and replace the solutions up to the required criteria are met. The evaluation, optimization and replacement of solutions are repeated until the shutdown criteria are met.

In his article named “Research on warehouse operation: A comprehensive review” [9] authors examined the assignment approaches. The warehouse assignment approaches can be grouped in three categories. Those are; random placement, approach on class basis and approach of grouping in relation to the products families. Random placement approach is very simple. It is supported by the usability information of the available warehouse. The assignments are made randomly to the closest or the furthest places. With that research, it is aimed to summarize and classify the research results and to investigate the research possibilities. Thus, the latest developments related to the research about the planning of the warehouse operations are examined. Also, the studies are made on the planning of the warehouse operations. It is indicated that the published studies focus on a few points and do not cover the full scope of the issue. Number of SLAP - Storage Location Assignment Problems and Routing Problems-constitute 32% and 38% of the literature, respectively. On the other hand, regionalization calculations constitute 6% of the literature. It is stated that the problems indicated in the study are in the operational dimensions, the decisions are made quite frequently, and the effects of those decisions last for a short time and they are limited with local dimensions. In short, the need to studies about the management of the storage systems is still continuing. In those studies, the various procedures of warehouse activities should be examined as a whole. The faced problems should be handled from the viewpoint of practices. All the targets of the storage activities should be observed without neglecting any of them.

In the research titled “Optimal Storage and Order Picking for Warehousing” [11] researchers tried to develop optimization techniques related to storage and order picking processes. It is aimed to solve problems in the storage organization and the order collection by using optimization techniques. A dynamic planning system is developed for the storage organization and the order collection operations. This planning system takes into account the dynamic structure of the customer order, the configuration of the collection area and the machine - human interface. A generalized zero-one quadratic assignment model is developed on the bases of customer order characteristics and collection zone configuration. An intuitive way is followed to approach the optimal solution.

In the research titled “Efficient order batching methods in warehouses” [12] the way of processing the orders in warehouses is examined. Grouping and clustering orders reduces the travel time in a picking route. The competence of the warehouse personnel is important for well-functioning of the grouping and clustering process of the orders. A well-organized grouping and clustering may yield significant savings of time and cost. The aforesaid grouping and clustering method are something complex from the solution viewpoint. In practice simple methods such as “first-come first-served” are applied. That means the picking vehicle picks the required items in the received order. After the order groups are created the itinerant dealer problem should be solved – in a manner that it contains one in each route- for constituting the travel time. Two groups of algorithms are taken into evaluation: The Seed Algorithms and Time Saving Algorithms. They are compared from the viewpoints of travel time, number of the prepared batches and the size of volume of the processed items. Transparency, simplicity and CPU time is important parameters in problems related to warehouse management systems. The Seed Algorithms are compatible with S-Shape and the picking devices with large capacities whereas Time Saving Algorithms are compatible with large gaps and the picking devices with small capacities. If CPU time is important Seed Algorithms should be preferred.

In [13] “Increasing warehouse order picking performance by sequence optimization” authors tried to organize the picking lines. Because the movement time of the materials in the warehouses covers the larger part of the order picking process, the importance of the organization of the picking lines in the batches is emphasized from the viewpoint of obtaining high productivity. In a situation research made in an electronic device company a total improvement of 7.4 % is observed. Because of the employed method it is argued that the picking staff and illogical points in the arranged order must be discussed.

In the article titled “Organizing warehouse management” [14] the warehouse management is considered as a combination of planning and controlling. With that approach the way of organization and application of the process and procedures of warehouse activities are discussed by considering the complexity of the required tasks and dynamics of markets. A conceptual model with multi-variables is developed on the basis of the literature. Then that model is tested in 215 warehouses with help of questionnaires. In view of the results of the tests it is seen that the most important factor is the complexity of tasks in the warehouse management. Accordingly, the coverage of the task, rules of the related decision and control action should be planned in all their complexities. On the other hand, some differences occur in the warehouses when they are used for production or distribution purposes due to changes in the properties of the stored items and planning their scopes. Moreover, it seems that the complexity of tasks is the most important specifications in warehouse management information systems (WMS). In this study the "complexity of task" and "market dynamics" are connected in a model. Then that model is tested in several warehouses. After the tests it is found that the tax complexity is a more important factor than the market dynamics in warehouse management. It is concluded that when the warehouse task becomes more complex; a more complex planning, a more complex set of decision rules and a more detailed control system are required. If the demand is less predictable planning should be more comprehensive.

In the article titled "Reduction of walking time in the distribution center of de Bijenkorf" [15], authors tried to minimize the time spent in order picking. They emphasized that the walking time in a warehouse consists a considerable part of the time spent for order picking therefore it should be reduced as much as possible. From that viewpoint the layout, size of the warehouse floors, ways of picking materials and tools used for picking are the important factors to be considered. It seems possible to develop storage strategies by making some arrangements in the layout and routing methods. Thus, the time spent for finding, picking and transporting the items can be reduced considerably.

In the research named "Routing methods for warehouses with multiple cross aisles" [16] authors examined the way of routing in the warehouses including cross aisles. In short, they stated that there are four methods to decrease the path to be covered for picking orders. Those are: determination of the appropriate way of picking, change of the structure of the warehouse, placing the products at appropriate places and constituting orders according to the batches.

In the article titled "Near-optimal solution of generalized resource allocation problems with large capacities" [17] researchers the problem of allocating the limited resources to the activities are studied. The matter is to decide which resource is needed by an activity and the amount of the needed resource. In this study placement of stocks in a large distribution center is examined. The devices such as automated bands are accepted as resources and the stored products are accepted as activities. The products coming from external suppliers are received in a central stocking area which is not automated. The problem consists of deciding which items are to be picked from the automated area and to define the space to be occupied by those items. It is something difficult to choose hundreds of items from among tens of thousands of items. It is important to take into account the cost of internal transfer of stocks in addition to savings of time and labor. This problem has common applications with the well-known rucksack problem. In three practical ways the rucksack problem is modelled. First; the domain of each allocation variable is continuous. Each allocation unit is designed as multiples of the standard dimensions. Second one is a technical condition which is satisfied only in cases of a finite number of choices. Thirdly; more than one resource is modelled, and each activity is assigned to one resource at most. With that model the most efficient allocation is obtained when the enough resources are available. The performance is satisfactory, and it is seen that the model is suitable for the warehouse management purposes.

CHAPTER 3 OPTIMIZATION FOR THE WAREHOUSE SHELF ALLOCATION PROBLEM AT A STEEL CASTING COMPANY

3.1. A STEEL CASTING COMPANY

The firm started its activities in 1979 in the Pınarbaşı District of İzmir which a port on the Aegean Sea Coast is. It produces steel casting parts in the weight range of 5 – 5,000 kg resistant to wear, impact, high temperatures and corrosion for the mining, marine, machine industry, cement and construction sectors. It receives 85 % of the orders from abroad. Because it collaborates with various sectors it has got about 5,600 different products/patterns in different dimensions.

After examination and approval of the order received from the customer a study is performed for determining the way of production of the demanded part at the Simulation Stage and the details of the pattern production are specified at that stage. Figure 3.1. Technical drawing on Magmasoft. After technical drawing simulation phase begins. Appendix 2. Casting simulation on Magmasoft.

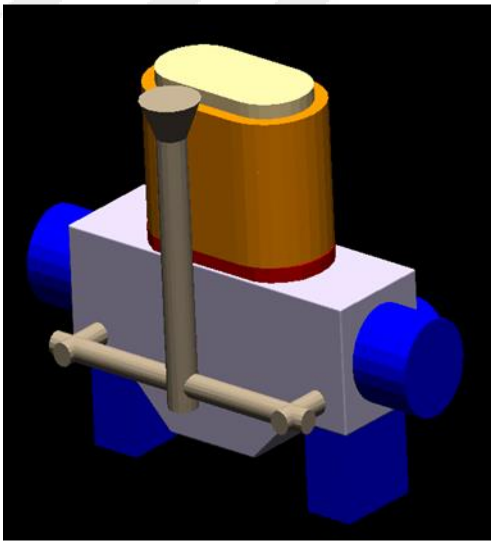

Figure 3.1. Tecnical drawing on Magmasoft *Photo is taken by Sezgi ÇELİK*

With help of SOLIDWORKS and IRONCAD 3D Design Software the technical drawing in 3 dimensions of the demanded product is made and the obtained technical drawing is adapted to the production purposes and 3D data needed by determination of the weight of the casting part and the casting simulation is prepared. Before starting the production, the risks which may harm the product quality are determined and the relevant protective measures are taken. If it is considered necessary for production of a part; a casting simulation is prepared by using MAGMASOFT Simulation Programs and the eventual risks which can occur during the casting process is minimized and the mold design and casting parameters are specified for production of the casting part of the highest quality at the lowest cost.

After the product to be cast is specified by the technical drawings the stage of pattern production begins. Development of the pattern is the first step of the steel casting process. Appendix-1 stage of pattern making.

A pattern is an approximate copy in one-to-one correspondence with the part to be cast and is used to obtain the cavity to be filled by the poured molten metal into the mold. While determining the shapes and dimensions of the patterns; the shrinkage of metals after solidification, machining allowances, and draft (taper) facilitating the removal of the pattern from the mold and the core prints must be considered. In the casting technology the appropriate design of the pattern and production of high quality has primordial importance. It is not possible to prepare a high-quality mold and to obtain a satisfactory casting if an inappropriate pattern is used. Appendix 3. Left wooden pattern (Valve 6')- Right wooden pattern (Valve 1').

Two sorts of patterns are made in the factory;

a) Wooden Patterns

b) Metallic Patterns

a- Wooden (plywood) Patternmaking: In wooden patternmaking pine wood is used, it is laminated composite material. It is cheap and widely used in the foundries. The, sprues, runners, vent holes and other cavities formed by hand in the sand molds can be considered together with the patterns or as separate parts of the patterns. In order to fit the small parts, which are treated with difficulty, into the larger parts some paste (polyester) is used. When it is desired that it does not stick at the next stage a glue (named “polivaks”) is laid on the surfaces with help of a brush. In order to make it have a long lifetime the wooden pattern is painted for providing protection against dust and moisture. Figure 3.2 Wooden pattern.

b- Metallic (Aluminum) Patterns: They are like the wooden patterns. They are used when the surfaces of high quality are required. They are preferred in accordance with the demand and desire of the customer. One of its disadvantages is its high cost. Their lifetimes are longer than other sorts of the patterns.

Figure 3.2. Wooden Pattern (Valve 16') *Photo is taken by Sezgi ÇELİK*

After completion of the patternmaking the molds are prepared at the production areas. In the mold making; various molding sands, and hardeners used for hardening sands and the channels called runners allowing the entry of the molten metal into the mold cavity are used.

In mold making; first the pattern is placed onto a flat plate and a flask is placed over it. Then sand is then packed tightly around the pattern. Appendix 5. Sand Mold after removal of the pattern. One half of the pattern is molded in the drag and the other half is molded in the drag. After the sand is dried the pattern is removed from the mold by wiggling gently. Then the cores, risers, runners and chills are placed. The mold is painted, and it is waited for drying of the paint. Aim of painting is to obtain smooth surfaces. Then the dried paint is heated. The upper part is placed onto the lower part of the mold, the molding flasks are fixed by using pins and the mold becomes ready for casting. Figure 3.3. View of the pattern in the sand mold

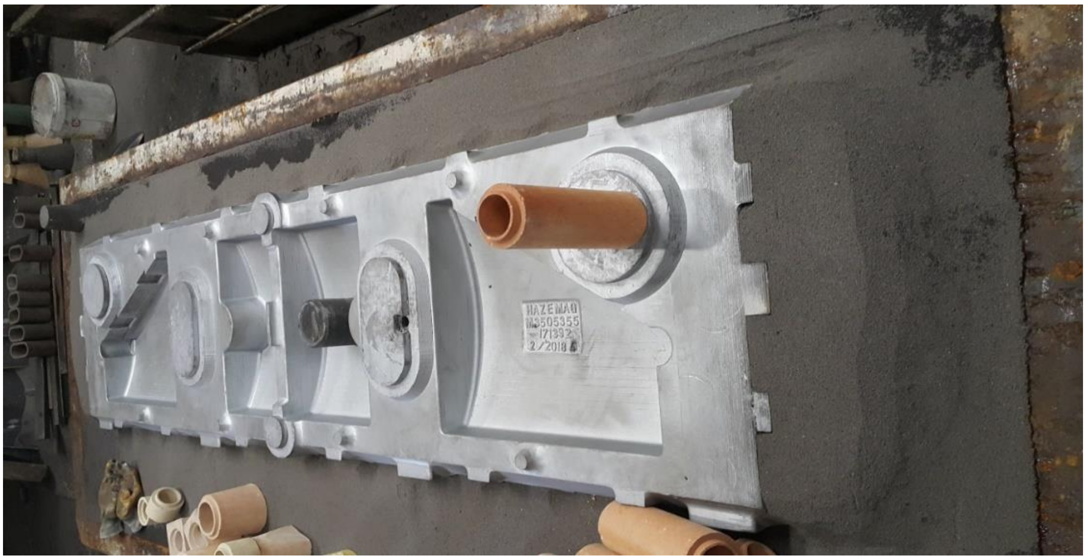

Figure 3.3. View of the pattern in the sand mold *Photo is taken by Sezgi ÇELİK*

After molding the stage of melting and casting starts. Appendix 6. Filling the mold with sand. The materials conforming to the standards/specifications requested by the customer are put in the induction furnaces in the factory. Samples are taken from the molten mixture and they are analyzed by spectrometer in the laboratory. If the results of the analysis are satisfactory the casting is started. Appendix 4 – Sectional view of a sand mold ready for casting.

The molten metal is taken out from the furnaces with ladles and transferred to the casting area by carrying the ladles and poured into the prepared sand molds. Appendix 7. Taking molten metal in to the ladles from the furnace. Compliance with the standards indicated in the order of the customer is very important. Composition of the metal melted in each furnace is regularly analyzed with spectrometers. Spectrometer is capable to analyze Iron-Nickel base alloys and 20 different elements including nitrogen included in the alloys. Amount of the elements included in the molten mixture can be determined. The basic logic can be defined as follows: passing lights of defined spectrums through the prepared solutions and determining the amount of the light absorbed by the solution.

There are two main types of induction furnaces: coreless and core (channel) type furnaces. In both types of furnaces, the metal is surrounded by an electric coil which can be considered as the primary coil of a transformer. The alternating current passing through that coil induces electric currents in the conductor metal which can be accepted as the secondary coil and creates large amounts of heat. Because the heat is emerged in the metal to be melted melting occurs very rapidly and in a very clean manner. The factory has 4 coreless induction furnaces. The linings of the furnaces number 3 and 4 are cleaned, renewed and repaired annually less than the larger furnaces number 1 and 2. Figure 3.4. Pouring molten metal in to the sand molds.

Figure 3.4. Pouring molten metal into the sand molds *Photo is taken by Sezgi ÇELİK*

In virtue of the quality standards each casting is numbered with a charge number. That charge number facilitates the traceability of the product.

After finishing the casting process, it is waited for some time defined by standards according to the weights and wall thicknesses of the casting parts then the shakeout of the mold is made, and they are freed from sand. Then the machining is applied.

Machining is a material removing process applied with help of hard, angled, abrasive grains or tools made of those grains. Machining is one of the basic metal processing steps. The cutting edges on the grains causes the formation of shavings. During the metal removal the abrasive stone turns around its axis at quite high speeds. Cutting process is realized by the friction between the abrasive stone and the work piece. The abrasive stone is obtained by binding the abrasive grains with help of various binders. After casting the parts are freed from sand and impurities by sand blasting apparatus installed in the factory and are machined by using various grinders and prepared for heat treatments.

Mechanical Cleaning

Purpose of surface cleaning is the complete removal of the dusts, oil, dirt and oxides on the surfaces of the metal parts. Various methods are employed for surface cleaning.

Sandblasting Apparatus

The best surface cleaning is made by blasting method. Recently a lot of hard and abrasive solid particles are used. In this method the grains having in the defined granulometry (or some other hard grains) are blasted by a gun onto the metal surfaces at high speeds (300-600 km/h). Thus, the rust and other impurities on the surface can be completely removed. This method consists of abrading and roughening the surfaces to be painted by bombardment of hard materials blasted with high pressure. Steel balls (shot) are used as abrading material. Cleaning by blasting provides highly clean surface suitable for painting.

In the grinding department of the factory there are two sandblasting apparatus with the shot code 460 and 660. The process lasts for 30 minutes at maximum and 10 minutes at minimum depending on the dimensions of the part and demand of the customer. The desired roughness value of the surface depends on the type, largeness, shape of the abrading material and the application pressure. Appendix 8. Balls used as abrading material in sand blasting machine and the sandblasting apparatus.

3.2. PROBLEM DEFINITION

There are 5,600 patterns used by the firm in the production. When customers give orders, the related patterns are searched by the employees of the firm in the pattern warehouse located outside the factory and the found patterns are transferred from there to the factory. When the work order for production is issued the employees of the pattern workshop go to the pattern warehouse, which is a building having 3 floors, to find the required pattern and take it to the pattern workshop for making necessary measurements. No arrangement is implemented for discovering the place of the required pattern, the usual applied way is to go to the pattern warehouse and to search it unmethodically. It takes 8-10 hours averagely to find a pattern and take it to the pattern workshop from the pattern warehouse. If a pattern produced before for a previous order is not found in the pattern warehouse when a new order is received; it is needed to be produced again. That is a waste of time, materials and labor. In order to avoid that loss and to find and transport the available patterns to the production area it is necessary to place them in a regularly organized way.

Because of the considerable size of the pattern warehouse and irregular placement it becomes impossible to find some patterns present on the shelves. If a needed pattern is not found in the pattern warehouse an urgent work order is issued to the pattern workshop for production of that pattern in order to avoid the delay in delivery of the ordered product. Therefore, delivery time of the orders is an important factor to be considered in warehouse management. Reproduction of the unfound patterns charges the pattern workshop with an extra workload and in order to prevent the deadline of delivery from being adjourned some overwork is required, so extra costs are created for the company. In the last 10 years about 166,600 TL was spent for reproduction of the unfound patterns. The part equal to 101,000 TL of the aforesaid amount is the pay for overwork hours and the remainder 50,600 TL is the cost of the used materials.

The required patterns are searched by two employees in the pattern warehouse having 3 floors and occupying a volume of 7,560 m^3 and the found patterns are transferred to the factory with help of a forklift. According to the results of the time studies the operation of finding the pattern in the warehouse consists 83 % of all the time needed for submitting it to the staff employed in production.

The cost of reproduction of the unfound patterns and the cost of transfer of the patterns from the warehouse to the factory reach about 1,086,000 TL in the last ten years. 15 % of the aforesaid amount is the cost caused by the reproduction of the unfound patterns.

The placements of the patterns on the shelves of the pattern warehouse were examined twice in the last year and the transfer costs were calculated as 80,000 TL and 110,000 TL respectively. But they did not take account the products data. Whereas placing the patterns on the shelves according to their dimensions and the utilization frequencies has become a very important activity. Accordingly, the actual shelves of the warehouse and warehouse system were examined. The widths, lengths, heights, weights and frequencies of orders were documented. The current warehouse arrangement was examined, the widths, lengths, heights of the shelves and their distances to the entry of the warehouse were determined.

The purpose of this thesis is to organize the pattern warehouse from the most ordered pattern toward the least ordered one in a suitable way to use the forklift effectively and to minimize the time required to take the desired model from the warehouse.

3.3. Current Warehouse System

The patterns used in production of the ordered goods by the customers are stored in a pattern warehouse having 3 floors outside the factory. In that building used as pattern warehouse there are shelf columns in different dimensions on each floor. On those columns there are shelves at different heights and in different numbers. In order to save the structural integrity of the shelves each shelf has its own specific and measured weight carrying capacity. In Table 3.1 Distribution of the shelf columns according to pattern warehouse floors is shown. In Figure 3.5 Drawings of the current layout of the warehouse is given.

Table 3.1. Distribution of the shelf columns according to pattern warehouse floors

	Number of Blocks
1st Floor	10
2nd Floor	47
3rd Floor	75

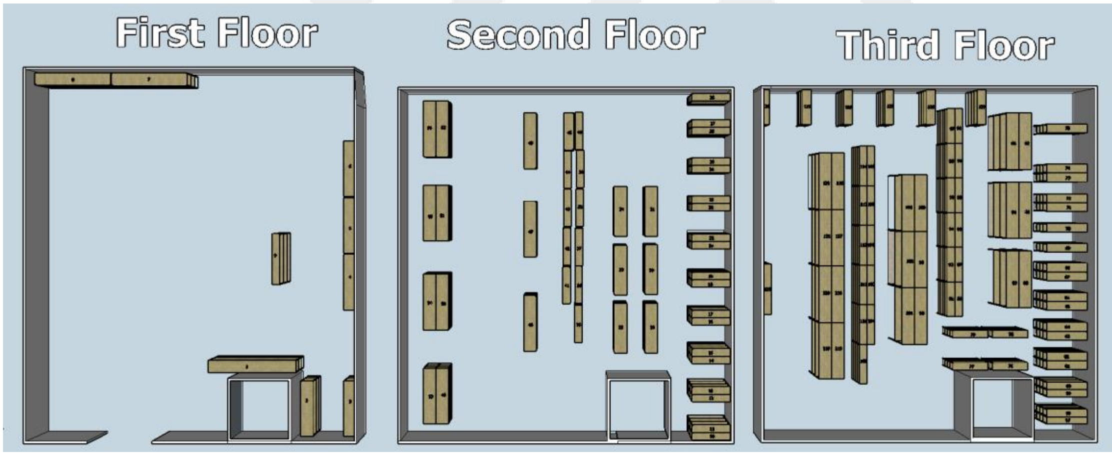

Figure 3.5. *Current* layout of the warehouse *Figure is drawn by Sezgi ÇELİK*

- The shelf columns in the warehouse are not used in their full capacities.
- Searching patterns required for production takes considerable time.
- The used patterns are not placed onto the controllable determined shelves.
- Because the patterns are not placed in an organized way onto the shelves in the columns effectively/in full capacity some patterns are put onto the unoccupied areas randomly on the floors of the warehouse. As a result, finding and taking patterns becomes more difficult in the warehouse.

3.4. MATHEMATICAL MODEL

Purpose of the model is to ensure the assignment of the patterns to the shelves in a way enabling us to minimize the distance of transport by fork-lifts by taking into account the frequencies of the customer orders.

Parameters

i: Product index i= 1, 2, …, I

k: Blok number k=1, 2, …, K

l: Shelf number l=1, 2, …, L

bw_{kl}: Width of shelf l of block k

bs_{kl}: Length of shelf l of block k

bh_{kl}: Height of shelf l of block k

ba_{kl}: Weight capacity of shelf l of block k

d_{kl}: distance to entrance of shelf l of block k

pw_i: width of product i

ps_i: Length of product i

ph_i: Height of product i

pa_i: weight of product i

w_i: Priority multiplier for Product i

Decision Variables

For i=1,2,3,…, I

$$X_{ikl} = \begin{cases} 1 \text{ if the product i is assigned to the shelf l of block k} \\ 0 \text{ , otherwise} \end{cases}$$

Minimize Z:

$$\sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} X_{ikl}\, d_{kl} w_i$$

Constraints:

$$\sum_{k=1}^{K} \sum_{l=1}^{L} X_{ikl} = 1, \qquad \forall\, i \in I \qquad (1)$$

$$\sum_{i=1}^{I} X_{ikl} pa_i \leq ba_{kl} \qquad \forall\, k \in K, \in L \qquad (2)$$

$$\sum_{i=1}^{I} X_{ikl} ps_i \leq bs_{kl} \qquad \forall\, k \in K, l \in L \qquad (3)$$

$$X_{ikl} ph_i \leq bh_{kl} \qquad \forall\, i \in I, k \in K, l \in L \qquad (4)$$

$$X_{ikl} pw_i \leq bw_{kl} \qquad \forall\, i \in I, k \in K, l \in L \qquad (5)$$

The above is a general model in the sense that our multiplier w_i can have different meanings in different environments (firms). In our application it will be the order frequency (of_i) of item-i. of_i is calculated by dividing the number of customer orders of product item-i to the total number of orders for all items within a given time interval. However, in other applications w_i might be a function of travel time, cost or any other kind of a priority major of the product. Furthermore, we develop the model by allowing different width, height and length for different shelves of different blocks. In some real-life cases these values might be independent of shelf index, and this is the case for our application.

In our real-life application, the number of the products are I= 5,590; the number of blocks are K=129 and these blocks have different number of shelves changing from 1 to 3 depending on the block index, which is l in the model.

In order to function the mathematical model efficiently five constraints are defined. In the first constraint it is demanded to place all the patterns onto the shelves (1). The second constraint requires that the total weight of the patterns assigned to one of the shelves columns should be equal or less than the total load capacity of the column. If the weight of the assigned patterns exceeds the capacity of the shelves column then the column will be distorted (2). The third constraint states that the total length of the assigned patterns must be equal or shorter than the length of the relevant shelf's column (3). The fourth constraint imposes the requirement that the height of any assigned pattern must not exceed the height of the relevant shelf in the column (4). The fifth constraint requires the width of any assigned pattern must not exceed the width of the relevant shelf in the column (5).

3.5. VERIFICATION OF THE MODEL

It is aimed to test the mathematical model by using a relatively small scale for providing easiness before employing colossal data. The following scenario has been developed for the desired control.

Scenario: The pattern warehouse is a one floor building and there are six shelf columns with equal number of shelves on the floor of the warehouse. The load capacities and distances to the building entrance of the columns are known. The number of patterns is thirty-nine and their weights, dimensions and order frequencies are determined. In Table 3.2 columns data of the scenario given. Appendix 9 Product dimensions of the scenario.

Table 3.2. The columns data of the scenario

Shelf no	Width (cm)	Length (cm)	Height (cm)	Shelf number	Weight capacity (kg)	Distance to entrance (m)
1	100	500	90	1	200	15
2	100	500	90	1	150	13
3	100	500	90	1	200	12
4	70	500	100	1	250	20
5	70	500	100	1	300	19
6	70	500	100	1	150	18
7	200	1,000	3,200	1	6,000	45

Because all the shelf columns are not equipped with weigh-bridges the total weight of the patterns assigned to those shelves cannot be calculated by the relevant employees. When excessive load is placed onto a shelf its structural integrity is lost and the patterns are damaged because of fall. As a result, the work process can be hindered by such undesired events. In order to avoid such undesirable setbacks, the employees do not place the heavy patterns onto the shelves instead they put them on the unoccupied space on the floor of the warehouse. That unoccupied space is at a distance of 45 meters to the entrance of the warehouse. The staff dealing with the taking the required patterns to the production area and returning the used patterns to their shelves assess the patterns according to their quantitative measures before placing them onto the shelves. Because of employing such a method, the shelves are not filled with the patterns that means the optimal use of the shelves is not reached.

While the mathematical model is developed the unoccupied zone in the pattern warehouse is described as 7th column.

If the organization of the exemplary model is reviewed it is seen that total volume of the placement on the shelves is equal to 24 m^3. Total weight capacity of the shelves is 1.250 kilograms. Total distance of the patterns on the shelves to the entrance of the warehouse is 979 meters.

The placements of the products on the shelves are as follows:

1st Shelf: Products 30,31,11 and 7.
2nd Shelf: Products 9,10,22 and 15.
3rd Shelf: Products 17,18,20,21 and 8.
4th Shelf: Products 27,5,26,14 and 6.
5th Shelf: Products 19,29,4,25 and 16.
6th Shelf: Products 35,32,37 and 39.
7th Shelf: Products 1,2,3,23,24,12,13,33,34,38,28 and 36.

Table 3.3. Placement Data of the Scenario

	Shelf 1	Shelf 2	Shelf 3	Shelf 4	Shelf 5	Shelf 6	Shelf 7
Shelf length (cm)	500	500	500	500	500	500	1,000
Total length of the assigned products (cm)	320	325	310	250	440	365	950
Ratio of unused length (%)	36%	35%	38%	50%	12%	27%	5%
Weight capacity of the shelf (kg)	200	150	200	250	300	150	6,000
Total weight of the assigned products (kg)	84	150	133	150	182	166	334
Total distance to entrance(m)	60	65	60	100	95	90	540

In the above table 3.3 placement data of the scenario the utilization way of the shelves when the patterns are placed without using any optimization technique can be seen. It is clear that the shelves are not used in their full capacities. The lengths of the shelves are not used optimally. Similarly, some load capacity is out of use. Because the unoccupied zone is preferred while placing the patterns total distance of the patterns to the entrance is increased. When the distance of the patterns on the shelves to the entrance of the warehouse is calculated the distance value of 979 meters is obtained.

Increase of the distance of the patterns to the entrance signify the increase the work path of the forklift and also the increase the work load of the forklift. It is assumed that the forklifts consume about an amount of diesel oil at a unit price of 2 TL/MT. In the exemplary case the distance equal to 979 meters creates a cost of 1,977.58 TL.

By examining the relevant data and taking into account the unused capacities a solution is proposed for the optimal utilization of the unused capacities through a mathematical model. The patterns assigned in the first case are analyzed with help of CPLEX and it is found that the mathematical model yields optimal results. Appendix 10. CPLEX Syntax of The Mathematical Model.

Placement of the products onto the shelves in the final case is as follows:

1st shelf: products 7,9,10,15,17,18,20 and 22.
2nd shelf: products numbered 8,23,24,29,36 and 39.
3rd shelf: products numbered 1,2,3,11,12,13 and 37.
4th shelf: products numbered 30,31,32,33 and 34.
5th shelf: products numbered 14,16,19,21,28,35 and 38.
6th shelf: products numbered 4,5,6,25,26 and 27.
7th shelf: no product.

Table 3.4. CPLEX solution of the verification problem

	Shelf 1	Shelf 2	Shelf 3	Shelf 4	Shelf 5	Shelf 6	Shelf 7
Shelf length (Cm)	500	500	500	500	500	500	1,000
Total length of the assigned products (Cm)	475	480	485	425	475	480	0
Ratio of unused length (%)	5%	4%	3%	15%	5%	4%	100%
Weight capacity of the shelf	200	150	200	250	300	150	6,000
Total weight of the assigned products (Kg)	200	150	200	183	282	150	0
Total distance to entrance(M)	120	78	84	100	133	108	0

Table 3.4 shows the CPLEX solution of the verification problem. When the first case is compared with the CPLEX Solution it can be seen that no pattern is placed into the 7th column. When the shelf length and the assigned patterns length are reviewed it is seen that the unused length capacity is decreased. Similarly, the unused load capacity of the shelves is decreased when it is compared with the used load capacity in the first case. The distance of the patterns on the shelves to the entrance of the warehouse is decreased from 979 meter to 623 meter in the proposed model. It is seen that an improvement equal to 36.3 % has been achieved in the performance related to the distance parameter.

As a result of the mathematical model verification explained in this section it is concluded that the model is feasible for solutions by using the data of very large scales.

3.6. SOLUTION

After verifying the mathematical model by using the exemplary data set the solution stage is started. There are columns with different number of shelves in the 3-storey pattern warehouse. Distances of those columns to the entrance of the warehouse are known quantities. On the other hand, their load capacities without losing their structural integrities are also known. The widths, lengths and heights of the shelves in those columns are measured and indicated in the Appendix 13. Measurements of Warehouse shelves.

Accordingly, frequencies of the orders received in the last ten years are researched in connection with the places of the patterns of the ordered products on the shelves of the columns and the results are recorded. Those order frequencies are used for assignment of the patterns to the shelves in a way that pattern of the more frequently ordered products is to be located closer to the entrance of the warehouse. The weights, heights, lengths and widths of the patterns are to be used for assignments of the patterns to the shelves. That information is given in Appendix 14. Measurements of patterns

The placements of the patterns in the columns in the warehouse are analyzed according to the ABC Analysis revealing the order frequencies of the company. The distances of the places of the patterns in the pattern warehouse to the production's areas are calculated in relation to their order frequencies.

The placements of the patterns of the products ordered by 255 companies are examined; the initial distance between the shelves and the entrance of the warehouse was 145,632 meters which was decreased to 115,791 meters after solution of CPLEX with help of the mathematical model. That method provides an improvement equal about 20.4 % to the company.

When the results of the mathematical model considering the order frequencies of the firms are examined it is seen that an improvement equal to 29,841 meters is obtained in comparison with the initial distances of the patterns to the production areas.

Furthermore, it is seen that unused and unusable volume capacities are decreased on the shelves of the pattern warehouses.

CHAPTER 4
ORGANISING THE WAREHOUSE

4.1. PROPOSED LAYOUT CHANGE

It is requested to put into practice the new model of the layout plan obtained as a result of the solution of the mathematical model. In order to reduce the total length of the models assigned to the shelves of the blocks according to the current situation, it is proposed to move the shelves.

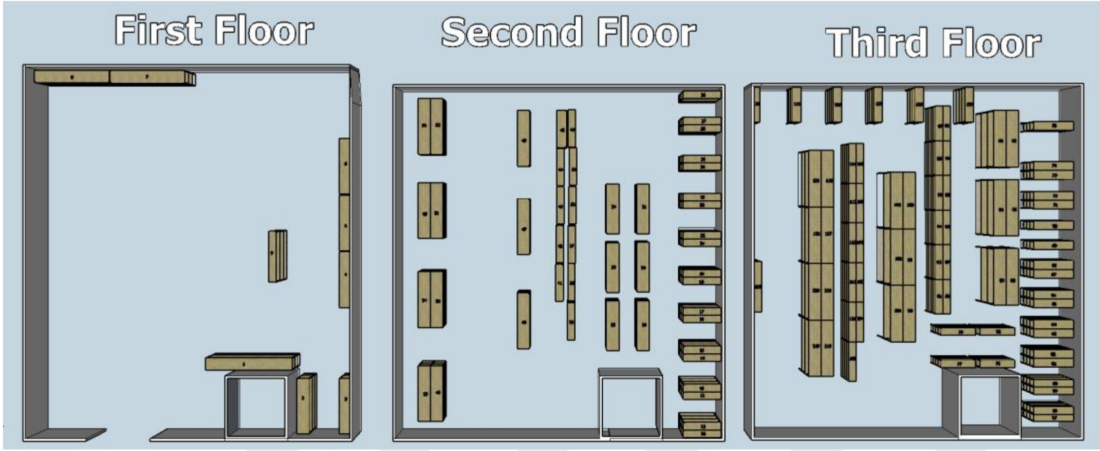

Figure 4.1.a. Initial warehouse layout *Figure is drawn by Sezgi ÇELİK*

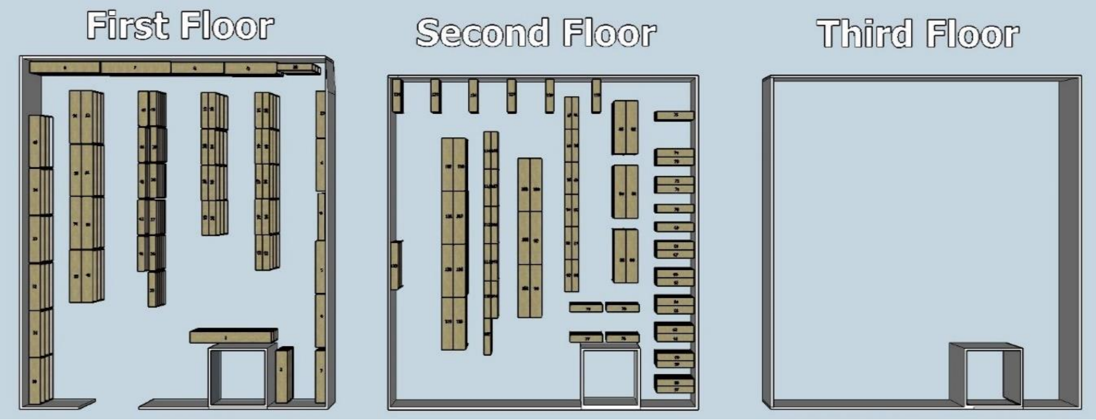

Figure 4.1.b. Proposed Warehouse layout *Figure is drawn by Sezgi ÇELİK*

After examining the CPLEX solution, development of a certain layout plan is proposed. Initially, there are ten blocks on the first floor, forty-seven blocks on the second floor and seventy-five blocks on the third floor. All calculations in the mathematical model are based on the distance of the shelves to the entrance. The blocks with the longest distance in the solution are the blocks on the third floor farthest from the entrance door. When we move some of the blocks from the third floor to the entrance floor and increase the number of blocks on the first floor from ten to fifty-seven and second floor has seventy-two blocks. In the figure 4.1.a. shows us the initial warehouse layout. figure 4.1.b. shows us proposed warehouse layout. Difference between those two layouts is the block number of the floors.

We re-run the mathematical model mentioned in the previous chapters. According to the proposed layout distance data; objective function value is better than initial warehouse layout.
In the last 10 years the travelled distance for transporting the patterns from the warehouse to the production area is 145,632 meters. That distance is decreased to 115,791 by initial layout of the warehouse. If the layout is changed and mathematical model is re-run the obtained result shall be 99,429 meters. Objective function value 14.1% decrease.

All blocks in the pattern warehouse are fixed onto the floors to prevent them from toppling over. There are different numbers of blocks on each floor of the three-floor pattern warehouse. Moving the blocks in the pattern warehouse is physically possible. But cost of the re organizing the warehouse by removal of the blocks requires a high cost.

4.2. TRACKING WAREHOUSE OPERATIONS VIA RFID TECHNOLOGY

There is a need for an extra arrangement in order to easily identify the pattern locations on the shelves of the blocks in the warehouse. It is important to realize the warehouse layout resulting from the resolution of the mathematical model.

4.2.1. WHAT IS RFID?

RFID consists of the initials of the words Radio Frequency Identification. As can be understood from the name, it is based on the identification of the information of objects by transmitting through radio frequencies. RFID; tag (Label) is the general name given to the technology that operates with radio frequencies which allows the movement of an object carrying a tag. With RFID, products can be recognized and tracked throughout their entire life cycle, from production to distribution. Not only products or objects, but also people can be identified with this technology. With this new technological infrastructure, data collection and service distribution take place without human intervention, error rate decreases and service speed and quality increases. The labels can be mounted directly on the product or mounted on containers, pallets or packages and used for different applications.

RFID tags can store large amounts of information, read and write quickly and collectively without errors, can be used in different environmental conditions and enable data communication from long distances thanks to readers.

4.2.2. RFID SOFTWARE AND HARDWARE

RFID technology has four basic components;

- RFID Tag
- Antenna
- Reader
- Software

Communication takes place between the reader and the antenna on the label. When the tag enters the communication area of a reader, it is detected by the reader. The detected label can be sent to the reader with their own identification code and other recorded data. transmit via radio frequency signals via product code (EPC)

4.2.2.1. RFID TAG

One RFID tag; consists of an integrated circuit and antenna. A microchip is attached to an antenna that receives the signal from the reader and sends it back to the reader. There are many kinds of labels according to their shapes, sizes, memory capacities and frequencies. There are generally three types of RFID tags. (Kamoun, 2009).

- Active tags: Tags with energy (batteries) on them. Active tags cost more when compared with the passive tags. On the other hand, active tags have more reading capacity. Passive tags read the distances 5 to 10 meters whereas active tags read that distances up to 300 meters.
- Semi-Active tags: Have power supply, when reader sends signal the semi active tags become activated. Reading capacity of the semi active tags are larger than passive tags. The batteries of Semi active tags have limited lifetimes as the active tags. (Kamoun, 2009).
- Passive tags: They do not have their own power supply. A Current is formed in the antennas of passive tags because of the magnetic field created by RFID readers. The passive tags are activated by that current. In brief passive tags has longer lifetimes but their reading distances are shorter. (Kamoun, 2009).

4.2.2.2. RFID ANTENNA

Their purpose is to provide communication between the tag and the reader / interrogator. A label communicates with an antenna via a wireless interface protocol. Antennas also differ considerably in their technical characteristics and shapes. They are used in both readers and labels. Its dimensions can range from 1 cm to 1 square meters. RFID antennas do not read the tags data only, but they write data on tags, they provide energy to passive tags and they verify the tags identity. (Kamoun, 2009)

4.2.2.3. RFID READER

The reader / interrogators enable the tags to be questioned and reacted via antennas. Readers read tags or in other words query them. During reading, the signal is continuously sent by the label (active). In the working principle of the passive tag, the interrogator sends the radio signals. These signals provide the energy of the passive label, causing it to start operating and broadcasting. The interrogator instantly detects signals from all tags in its domain. This automatically reduces the reading time.

If there are multiple tags in the interrogator's domain, there are different techniques to read them in order. These techniques are grouped under the name 'unification' and only labels of the specified serial number can react. The structure in which the interrogator controls the timing of the tags' response is known as the 'interrogator first speaks' method. The opposite is that the tags start to propagate their own information with the radio waves they receive from the interrogator. The first method is more reliable but slower than the second method.

Some interrogators also can write to tags at the same time. The result of the information to be read / write labels carrying the information. It can be updated. This capability enables us to meet customer needs, business processes and standards. It will be very useful if it changes at any time. Read / write Labels can be reused and provide cost advantages in the long run.

4.2.2.4. SOFTWARE

The software controls RFID equipment, manages information, and interface functions. The software is a glue that integrates the RFID system. In which industry front side, while managing readers and antennas, the interface section (middleware) directs this information to the server, where Database applications in the backbone run. For example, RFID is applied in a production environment. The software of the enterprise in question; information from different levels of RFID and it will need to know what phase of the supply chain information is.

4.2.3. WORKING PRINCIPLE

The first factor when using RFID technology is how to label containers, pallets, boxes and parts. The labeling shapes may change due to the properties of the products such as shape or content. The way of packaging of the products also affects the way of labeling. Designs that determine features such as readers' position in the process determine how the label will be attached to the product.

First, the tags are created by an encoder. The system assigns an EPC to each unit so that the RFID chip becomes a coded and intelligent tag. Encoders can print labels as well as enter information on existing labels. After creation, labels are attached to the parts either manually or automatically. A reading verification is performed before and after the application. Containers, pallets, boxes or parts can communicate with readers with the addition of labels.

4.2.4. TRACKING AND PICKING THE MODELS FROM THE WAREHOUSE

Labels of the required information should be created, and the labels should be affixed on the models. This information is the name of the customer to whom the Model belongs, the Dimension of the Model and the Weight of the Model. According to this information, firstly the label will be created, these labels will be printed and stuck on the model. Figure 4.1 shows RFID Antenna and RFID-Tag application in the pattern warehouse. In appendix 14 RFID Antenna and RFID tag application in the production area shown.

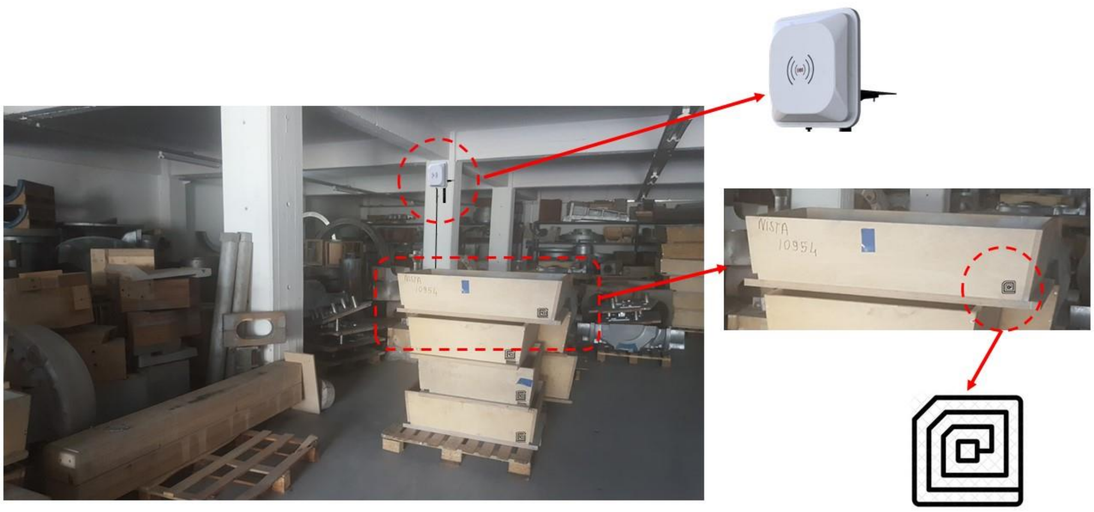

Figure 4.1 RFID Antenna and RFID-Tag Application in the Pattern Warehouse
Photo is taken by Sezgi ÇELİK

Even the process of removing the labels from the shelves of approximately 5590 models in the company constitutes a considerable cost by itself. Considering the process of entering the model information and printing the label on average two minutes, downloading the model from the shelf 2.3 minutes, and placing the label on the shelf after 3.2 minutes, the work load will be approximately 41,925 minutes. Assuming that there are 20 working days in a month and 8 hours in a day, this process will end in about 4 months.

Each passive tag has 5meters reading range. RFID readers placed on the center of the circle which is shown Figure 4.1.a. is current warehouse layout. First floor needs 4 reader. Second floor 9 reader. Third floor needs 9 reader. Current layout needs 22 readers to cover all the tags. Figure 4.1.b. is proposed layout. First floor needs 11 readers to cover all passive tags. Second floor need 8 readers. Proposed layout needs 19 readers. Cost of each RFID HF Reader 500$. Total Reader cost of the current warehouse is 11,000$. Cost of the RFID Reader of proposed layout is 8,500$.

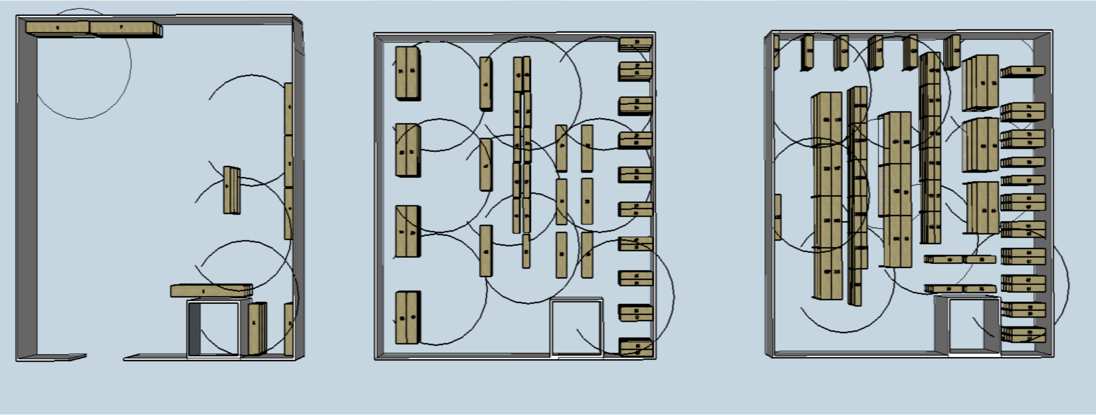

Figure4.2.a Current Layout proposed RFID Reader Locations *Figure is drawn by Sezgi ÇELİK*

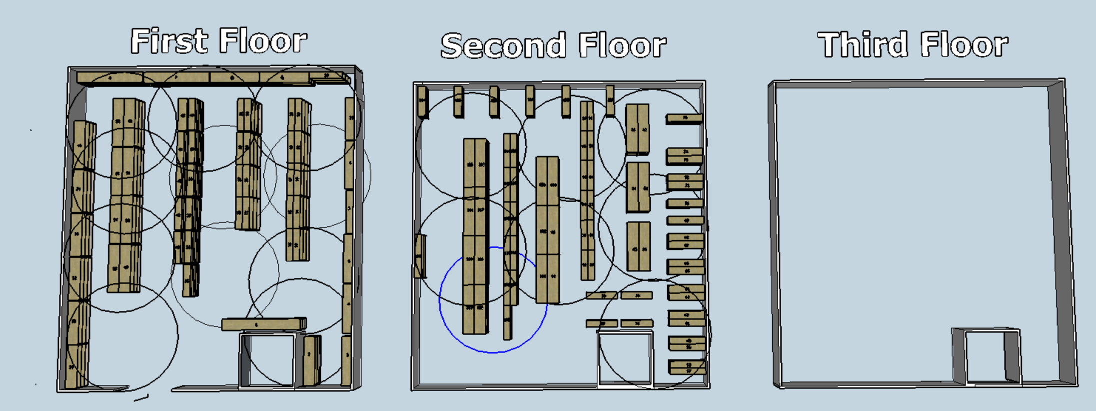

Figure4.2.b Proposed Layout RFID Reader Locations *Figure is drawn by Sezgi ÇELİK*

CHAPTER 5
CONCLUSION

In this study the follow up of the semi-products and products are analyzed in a firm dealing with steel castings production and the possible improvements in the warehouse layout are researched. The orders of the last ten year have been analyzed on the customer basis and their frequencies are examined. When a customer order is received first the availability of the related pattern is checked and if it is produced previously and is not given to the customer it is assumed that the pattern is available within the company. In order to produce the ordered casting, the related pattern must be found in the pattern warehouse and must be taken to the production area. There are two employees in charge of: finding the required patterns in the warehouse, taking them to the production area and placing them on the relevant shelves again after the production process. Time needed for finding patterns and taking them to the production area causes some cost and reproduction of an unfound pattern means an extra cost and time and material loss for the company.

In the analysis of the actual situation it is found that no algorithm is employed for assignment of the patterns to the shelves and they are placed onto the shelves at haphazard. Therefore, some confusion is caused by the existing irregularity while a required model is researched.

It is aimed to determine the optimal places of the patterns on the shelves by assigning them according to their order frequencies with help of a mathematical model. After the mathematical model is developed it is found that the assignments of the patterns according to the order frequencies are more efficient than the assignment in function of the placement volumes. The former transport distance of 145,632 meters in the actual layout is reduced to 115,791 meters in the proposed layout which signifies an improvement equal to 20.4 %.

When we run the mathematical model according to the new lengths after the proposed layout arrangement, the objective function value has decreased to 99,429 Meters. Compared to the initial situation, it improved by 31.7%. It is physically possible to implement the proposed settlement plan. It is a costly process to place the blocks fixed to the floor and ceiling and to re-fix them in the suggested places.

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APPENDIX 1 – STAGE OF PATTERN MAKING

Photo is taken by Sezgi ÇELİK

APPENDIX 2 – CASTING SIMULATION ON MAGMASOFT

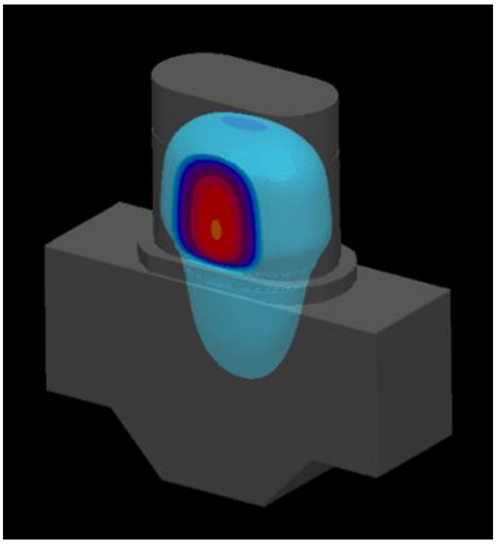
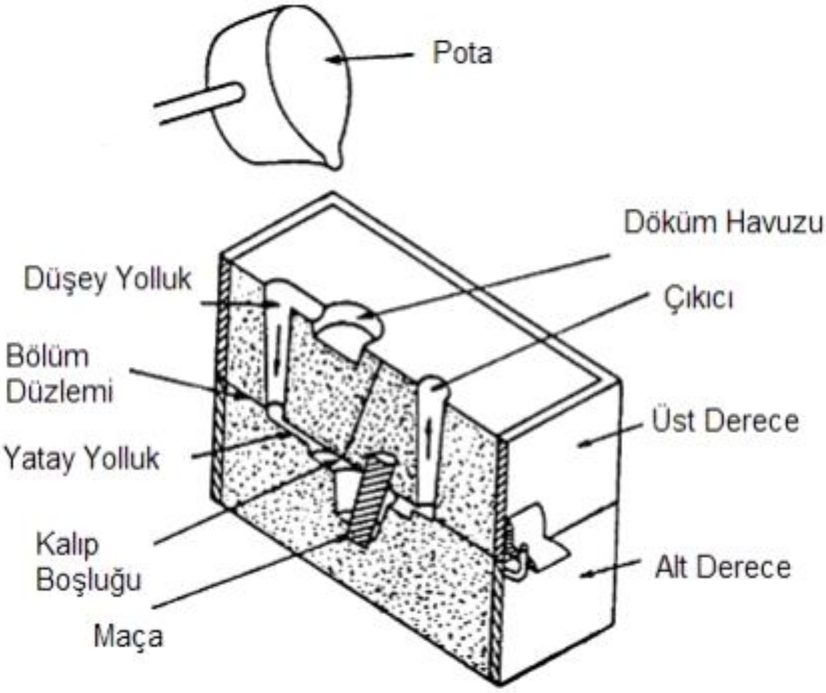


Photo is taken by Sezgi ÇELİK

APPENDIX 3 – LEFT WOODEN PATTERN (VALVE 6’) - RIGHT WOODEN PATTERN (VALVE 1’)

Photos are taken by Sezgi ÇELİK

APPENDIX 4 –SECTIONAL VIEW OF A SAND MOULD READY FOR CASTING



Pota: Ladle, Düşey Yolluk: Vertical Runner, Döküm Havuzu: Pouring Basin,
Bölüm Düzlemi: Parting Surface (Line), Yatay Yolluk: Horizontal Runner,
Çıkıcı: Vent (Vent Hole), Kalıp Boşluğu: Mould Cavity, Maça: Core, Üst Derece: Cope Alt Derece: Drag

APPENDIX 5 – SAND MOULD AFTER REMOVAL OF THE PATTERN

Photo is taken by Sezgi ÇELİK

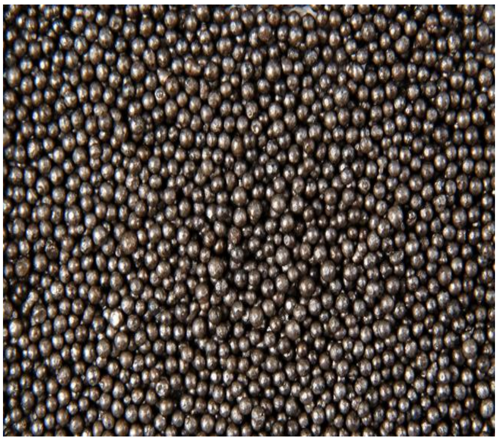
APPENDIX 6 –FILLING THE MOULD WITH SAND

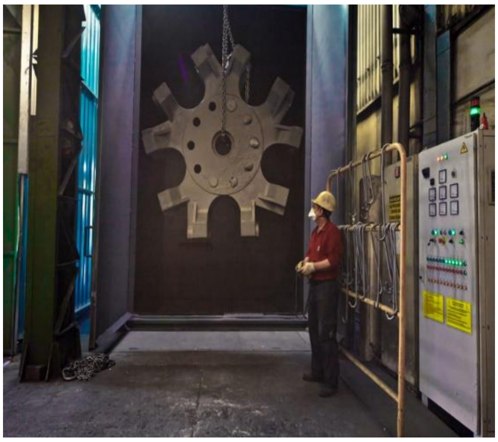
Photo is taken by Sezgi ÇELİK

APPENDIX 7 –TAKING MOLTEN METAL INTO THE LADLES FROM THE FURNACE

Photo is taken by Sezgi ÇELİK

APPENDIX 8 – BALLS USED AS ABRADING MATERIAL IN SANDBLASTING MACHINE AND THE SANDBLASTING APPARATUS





Photos are taken by Sezgi ÇELİK

APPENDIX 9 –PRODUCT DIMENSIONS OF THE SCENARIO

Number of Product	Width of Product	Length of Product	Height of Product	Weight of Product	Order Frequency of product
1	100	60	85	17	0.03306
2	100	70	85	33	0.03857
3	100	80	85	50	0.04408
4	70	90	100	17	0.04084
5	70	75	100	17	0.03403
6	70	75	100	17	0.03403
7	65	80	70	33	0.02360
8	65	80	70	17	0.02360
9	65	80	70	33	0.02360
10	65	80	70	33	0.02360
11	90	65	90	17	0.03413
12	90	65	80	33	0.03034
13	90	90	80	17	0.04201
14	70	50	80	50	0.01815
15	70	50	80	17	0.01815
16	70	50	80	33	0.01815
17	70	50	80	17	0.01815
18	70	50	80	33	0.01815
19	70	50	80	50	0.01815
20	70	50	80	17	0.01815
21	70	50	80	33	0.01815
22	70	50	80	17	0.01815
23	90	75	85	33	0.03719
24	90	75	60	17	0.02626
25	60	80	100	33	0.03112
26	60	65	100	33	0.02528
27	60	65	100	33	0.02528
28	60	100	60	50	0.02334
29	60	100	65	33	0.02528
30	60	80	50	33	0.01556
31	60	95	30	33	0.01109
32	55	150	40	17	0.02139
33	55	65	60	33	0.01391
34	55	65	70	50	0.01622
35	55	80	80	33	0.02282
36	70	65	90	17	0.02655
37	70	65	90	33	0.02655
38	70	65	90	50	0.02655
39	70	90	90	33	0.03676

APPENDIX 10 – CPLEX SYNTAX OF THE MATEMATICAL MODEL

```
int nbproduct=...; //Number Of product
range product=1..nbproduct;

int pw[product]=...; // width of product
int ps[product]=...; // Length of product
int ph[product]=...; // Height of product
int pa[product]=...; // weight of product
float ofi[product]=...; // order Frequency of Product

int nbblock =...; //Number of block
range block =1..nbblock;
int bw[block]=...; //Width of blok
int bs[block]=...; // Length of blok
int bh[block]=...; // Heigth of blok
int ba[block]=...; //weight capacity of blok
int distance[block]=...; //block distance to enterance
dvar int X[product][block]in 0..1;
minimize
  sum(g in product, s in block)
  X[g][s]*ofi[g]*distance[s]; //objective function
    subject to {
// all models must be assign/
  forall(g in product)
            sum(s in block) X[g][s]==1;
// width constraint//
            forall(g in product,s in block)
  X[g][s]*pw[g]<=bw[s];
// Length constraint //
forall(s in block)
 sum(g in product) X[g][s]*ps[g]<=bs[s];
  // Height constraint//
  forall(g in product,s in block)
  X[g][s]*ph[g]<=bh[s];
// weight constraint
              forall(s in block)
  sum(g in product) X[g][s]*pa[g]<=ba[s]; };
```

APPENDIX 11 – THE INPUT DATA FOR MODEL VERFICATION

```
nbproduct=39;
nbblock=7;
pw=[ 100, 100, 100, 70, 70, 70, 65, 65, 65, 65, 90, 90, 90, 70, 70, 70, 70, 70, 7,0 70, 70, 70, 90, 90,
60, 60, 60, 60, 6,0 60, 60, 55, 55, 55, 55, 70, 70, 70, 70];
ps=[ 60, 70, 80, 90, 75, 75, 80, 80, 80, 80, 65, 65, 90, 50, 50, 50, 50, 50, 50, 50, 50, 50, 75, 75, 80, 65,
65, 100, 100, 80, 95, 150, 65, 65, 80, 65, 65, 65, 90];
ph=[ 85, 85, 85, 100, 100, 100, 70, 70, 70, 70, 90, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 85, 60,
100, 100, 100, 60, 65, 50, 30, 40, 60, 70, 80, 90, 90, 90, 90];
pa=[ 17, 33, 50, 17, 17, 17, 33, 17, 33, 33, 17, 33, 17, 50, 17, 33, 17, 33, 50, 17, 33, 17, 33, 17, 33, 33,
33, 50, 33, 33, 33, 17, 33, 50, 33, 17, 33, 50, 33];
distance=[15,13,12,20,19,18,45];
ofi=[ 0.033062137, 0.038572494, 0.04408285, 0.040841464, 0.034034553, 0.034034553,
0.02359729, 0.02359729, 0.02359729, 0.02359729, 0.034131795, 0.030339373, 0.042008363,
0.018151762, 0.018151762, 0.018151762, 0.018151762, 0.018151762, 0.018151762, 0.018151762,
0.018151762, 0.018151762, 0.037194905, 0.026255227, 0.031117306, 0.025282811, 0.025282811,
0.023337979, 0.025282811, 0.015558653, 0.01108554, 0.021393148, 0.013905546, 0.016223137,
0.022819358, 0.026546951, 0.026546951, 0.026546951, 0.036757317];
bw=[100,100,100,70,70,70,200];
bs=[500,500,500,500,500,500,1000];
bh=[90,90,90,100,100,100,3200];
ba=[200,150,200,250,300,150,6000];
```

APPENDIX 12 – SOLUTION OF THE MATHEMATICAL MODEL

Number Of products	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
1	0	0	1	0	0	0	0
2	0	0	1	0	0	0	0
3	0	0	1	0	0	0	0
4	0	0	0	0	0	1	0
5	0	0	0	0	0	1	0
6	0	0	0	0	0	1	0
7	1	0	0	0	0	0	0
8	0	1	0	0	0	0	0
9	1	0	0	0	0	0	0
10	1	0	0	0	0	0	0
11	0	0	1	0	0	0	0
12	0	0	1	0	0	0	0
13	0	0	1	0	0	0	0
14	0	0	0	0	1	0	0
15	1	0	0	0	0	0	0
16	0	0	0	0	1	0	0
17	1	0	0	0	0	0	0
18	1	0	0	0	0	0	0
19	0	0	0	0	1	0	0
20	1	0	0	0	0	0	0
21	0	0	0	0	1	0	0
22	1	0	0	0	0	0	0
23	0	1	0	0	0	0	0
24	0	1	0	0	0	0	0
25	0	0	0	0	0	1	0
26	0	0	0	0	0	1	0
27	0	0	0	0	0	1	0
28	0	0	0	0	1	0	0
29	0	1	0	0	0	0	0
30	0	0	0	1	0	0	0
31	0	0	0	1	0	0	0
32	0	0	0	1	0	0	0
33	0	0	0	1	0	0	0
34	0	0	0	1	0	0	0
35	0	0	0	0	1	0	0
36	0	1	0	0	0	0	0
37	0	0	1	0	0	0	0
38	0	0	0	0	1	0	0
39	0	1	0	0	0	0	0

APPENDIX 13 – MEASUREMENTS OF WAREHOUSE SHELFS

Location	Block No	Width (Meter)	Length (Meter)	Height (Meter)	Number of Shelfs	Distance to the Enterance (Meter)
First Floor	1	1	7	2	3	16.82
First Floor	2	0.9	4.5	2	3	27.55
First Floor	3	0.9	4.5	2	3	34.55
First Floor	4	1	4.5	1.6	3	31
First Floor	5	1	4.5	1.6	3	30
First Floor	6	1	4.5	1.6	3	31
First Floor	7	1	6	2	3	27
First Floor	8	1	6	2	3	28
First Floor	9	0.6	4	2.5	3	19

Total Number of shelves is 129. Only 9 blocks of the first floor given.

APPENDIX 14 – RFID ANTENNA AND RIFD TAG APPLICATION IN THE PRODUCTION AREA