

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES FACULTY OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
INDUSTRIAL ENGINEERING STREAM



COMPUTER AIDED LAYOUT PLANNING FOR MANUFACTURING
INDUSTRIES OF ETHIOPIA

(Case in Kotebe Metal Tools Factory)

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A Thesis Submitted to Addis Ababa University, Faculty of Technology, Department
of Mechanical Engineering, in Partial Fulfillment for the Award of the Degree of
Master of Science in Mechanical Engineering (Industrial Engineering)

October, 2009

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POSTGRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitle “Computer Aided Layout Planning for Manufacturing Industries of Ethiopia: Case in Kotebe Metal Tools Factory” is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been duly acknowledged.

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This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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LIST OF ABBREVIATIONS

- KMTF : - Kotebe Metal Tools Factory
- CRAFT: - Computerized Relative Allocation of Facilities Technique
- CORELAP: - Computerized Relationship Layout Planning
- ALDEP: - Automated Layout Design
- PLANET: - Plant Layout Analysis and Evaluation Techniques
- COFAD: - Computerized Facilities Design
- TCR: - Total Closeness Rating

ACKNOWLEDGMENT

Prior to everything, glory to God who gives everything for nothing for making me start and finish my work. Then my family whose love and support never got offsite. And of all my family, to my Dad who wanted to see me be in bigger places. I would also like to pass my gratitude to Mesfin Mulugeta and Wondwosson Mulugeta, for supplying materials that I need and supporting me in editing my work.

Then comes my advisor Dr-Ing Daniel Kitaw and co-advisor Ato Birhanu Beshah for their unreserved support, encouragement and professional advice in my work and life. And to all my friends at AAU who supported me by giving supportive ideas in my work. My deepest appreciation also goes to all staff members of KMTF, specially Ato Bekele Bayisa, Ato Alem Kasa, Ato Haylegebriel Guta and Ato Teklu Tefera for their support by giving me the information that I need and encouragements. Thank you all very much.

Finally to my friends who are there whenever I need them and lend me their hand in my work. My dear friends Seniyet Tsgaye, Binyam Almaw, Ermias Kebede, and Misrake Arega, thank you very much.

Ameha Mulugeta

2009

ABSTRACT

Layout planning has been considered as one of the vital areas for improving performance of any business process. Its main concern is reducing cost by maximizing adjacency of high interaction components of a system or reducing material handling cost or distance between the components. Taking KMTF's layout as a case, this study considered three approaches of layout design.

The first approach utilized the improvement of the existing layout. Section wise exchange and machine wise exchanges are made to the current layout to arrive at a better layout than the currently being used layout. Making the exchange section wise and then using the machine arrangement obtained by this method to be further improved by machine wise exchange is observed to give better layout than improving the current machine arrangements. The exchange has been made according to CRAFT improvement routine.

The second approach has been done to construct a new layout for KTMF sections using CORELAP construction routine and then improving the constructed layout using CRAFT improvement routine. But the current layout is observed to be better starting point for improvement using improvement routine than the constructed layout. This shows the current layout is good but can further be improved by using improvement routines. To show the applicability of the approach another study published by Yugoslav Journal of Operations Research has been explained. This approach is suggested to be used in planning a new layout.

The third approach introduced is the roll forging machine into the improved layout. The approach assumes the Roll forging machine is used by four products and the dies for the four products are brought together with the machine. Accordingly location of the new Roll forging machine has been obtained using single facility layout problem.

Finally, it is concluded that the current layout is a good initial layout for improvement using CRAFT algorithm and a better layout is achieved by improving the current layout. Furthermore, construction routine followed by improvement routine is concluded to be good means of arriving at good layout in initial design of layouts. The improved layout and Roll forging are recommended for KMTF shop floor.

Key words: Computer Aided Layout Planning, Roll Forging, Layout design, CRAFT

1. CHAPTER ONE: INTRODUCTION

1.1. Background of the problem

Facilities planning and design is a complex and broad subject that is present in a variety of disciplines. Facilities planning and design determines how an activity's tangible fixed assets satisfy the activity's objective. Facility layout is the arrangement of work space which, in general terms smoothes the way to access facilities that have strong interaction. Its aims are similar regardless of whether the organizations are services or manufacturing. Facilities are of crucial importance to organizations because, they usually represent the largest and most expensive assets of the organization [1] [2] [5]. If facilities are arranged optimally, manufacturers can decrease work in process, material handling costs, total production costs and significantly enhance a system's efficiency [3]. In manufacturing plant, layout problem involves determining the location of machines, workstations, and other facilities to achieve minimized material-handling costs and facilitated traffic flow. This in turn brings safe workplace for employees and where necessary provide supervision and face-to-face communication and thereby increase employee morale, minimize the risk of injury to personnel and damage to property [4].

Computer's aid in plant layout design has its own advantage. Computer can perform the computations and generate several solutions much more rapidly than manual procedures [3]. The computerized layout methods are heuristics; they do not guarantee an optimal solution. Nevertheless, an efficient solution is realized. These methods are categorized as either construction or improvement-type routines: Construction-type layout generates a block layout based on the relationship between different departments. Among the most popular ones within this category are CORELAP (Computerized Relationship Layout Planning), ALDEP (Automated Layout Design) and PLANET (Plant Layout Analysis and Evaluation Techniques). Improvement-type layout requires an input of a feasible block layout and aim to reduce movement cost by attempting simultaneous pair-wise (or more) position exchanging among the departments. Among the most popular improvement-type methods are CRAFT (Computerized Relative Allocation of Facilities Technique) and COFAD (Computerized Facilities Design) [3] [5] [6].

When the factories design their layout in the initial erection of the machineries, they place the machineries with totally subjective conclusions. This subjective conclusion is very narrow in its scope to include the different factors that must be taken into consideration to come up with an efficient layout. The paper will consider the vital objectives of layout design and show efficient layout design procedure. Kotebe Metal Tools Factory will be taken as the case company to show efficient layout design for Ethiopian manufacturing industries. The paper will analyze the two approaches of computer aided layout planning approaches mentioned earlier (construction and improvement) and come up with better layout. Using the same procedures other Ethiopian manufacturing industries can plan their facility layout that takes in to consideration the different factors of facility layout design.

1.2.Statement of the problem

Globalization has made the world one big market place. In Ethiopia, most companies do not participate in other countries market. They couldn't even satisfy the local market demand. The major factor for this is low productivity of the industries. As outlined earlier, to improve one's productivity the layout efficiency should be given much priority. The problems that occur due to inefficient layout design are:

- If the layout being developed is new inclusion of products is made on the estimation or study conducted. Thus, the layout efficiency is dependent on the quality of study made and the market response to the product.
- The availability of information like product quantity, processing times, machines reallocation costs, etc affects the quality and analysis of the layout being made.
- Designing new layout or providing improvements in existing layout requires high investment and commitment of management
- When we consider KMTF layout in particular, it is unable to produce the products in the required quantity and quality and is thus less productive
- With the current arrangement of the factory equipment, profit is not attained as planned in the initial plans
- Long distance traveled by WIP from one processing to the next making the material handling expensive and more non value adding
- Workers fatigue and frequent accidents that are occurring in the shop floor with the long distances that are traveled

1.3.Objectives

Aim of any organization is being effective and efficient then other objectives like profit, satisfaction of stake holders, serving the customer, or other objective of the organization. Keeping the objective of any organization, the general and the specific objectives of the study are described below.

General objective

The main objective of the study is to design a layout for Kotebe Metal Tools Factory production floor which is better than the currently employed layout and apply roll forging in the layout using the different computerized layout algorithms.

Specific objectives

The specific objectives of the study are to:

- ✓ Analyze the current layout of KMTF production floor
- ✓ Assess the different layout planning techniques that a company can choose from to increase its productivity and minimize material handling movement and cost
- ✓ Use the capabilities of computer to arrive at efficient layout that is better than traditionally designed layout
- ✓ Include roll forging technology in the improved layout so that the benefits of roll forging technology are attained
- ✓ Facilitate the manufacturing process and flow of operation in the shop floor
- ✓ Assess the different approaches that can be followed to arrive at an efficient layout
- ✓ Different computerized algorithms of layout planning are analyzed by their different shortcomings and if possible propose a method to overcome them.

1.4.Significance of the study

It is evident that plant layout affects the efficiency of a facility. Building an optimal facility layout benefits mostly the company and its clients as well. Since the aim of any manufacturing industry is to increase its profit, sales volume, while creating convenience for its workers and satisfying the customer, facility layout problem should be given highest priority. This study prepares guidelines to effective layout design for manufacturing industries of Ethiopia. Upon implementation the industries would attain higher efficiency.

To show this, KMTF's improved layout efficiency is weighed against the previous layout of the factory.

In addition, this study can be taken as a benchmark and motivation for other factories in Ethiopia to follow scientifically proved and professionally designed layouts for material and service production. The recommendations forwarded at the end of the study will also put light on what approaches to follow, specifically for KMTF and other similar factories.

The study benefits the industries in attaining the mentioned advantages. Furthermore improved layout reduces production cost which reduces unit cost. This in turn decreases the product price for competitive advantage in the market place. Therefore an efficient layout will also benefit the customer by bringing less costly product while the quality is maintained as before or improved. Also the increased production volume will satisfy the unmet demand of the customer.

1.5.Scope and Delimitations of the study

As discussed in the introduction part of this study, there are numerous computerized layout planning algorithms to follow. Each of these algorithms possesses their distinguishing characters. Also, as discussed previously, the major divisions in layout planning are construction of new layout starting from blank and improving the current feasible layout. One algorithm from each of these divisions is selected and using that algorithm layout of KMTF production floor layout is designed. Thus, the study does not attempt to use all computerized algorithms for layout design of KMTF.

Furthermore, to show the aid of computers in the layout problems, the case taken is only in KMTF. Other companies can take the same procedure to arrive at their own effective layout.

1.6. Methodology

To attain the objectives of this study the following methods have been employed.

Primary data collection:

Direct data collection from the shop floor about the current dependency between sections will be major primary data collection method. The relation between departments is essential for placing the departments with both material handling distance minimization and adjacency objectives. Sections having high dependency with each other are placed close to one another so that high volume of material will not travel long distance or the adjacency objectives are met. Other formal and informal communications are used to reveal departmental inter dependency which is not clearly stated in documentations. The people actually doing the work know their section's relation with other sections. These data will be one means to construct the activity relationship diagram.

Contact with the managerial administration department has been done to obtain information like production capacity to construct the load matrix, average shop floor worker's salary to determine the transportation or material handling cost, building footprint and current layout of KMTF's shop floor.

Secondary data collection:

Previous data collected by other researchers and studies done on KMTF's manufacturing processes has been used as one of the secondary data source. Useful information from these studies has been filtered and used. Other secondary data source is literature review. Different books found in different libraries of Addis Ababa University and others libraries as well as electronic information source and the internet, to obtain articles and journals; has been assessed to obtain information on computer's aid in layout planning process. The focus area of the data collection and review was on the different computerized algorithms that are available and their logic. After analyzing the major algorithms and describing their drawbacks, selection will be made and the selected algorithm will be applied in KMTF's shop floor to arrive at better performing layout than the currently being employed one.

Data analysis

The data collected using both methods was organized so as to create the relationship diagram between different sections and costs associated. With the secondary data collected

computerized layout planning algorithms has been analyzed. The constructions as well as the improvement types of layout planning methods were well analyzed. The associated computer algorithms which are many in number, are also analyzed and selection has been made from these algorithms to apply them in KMTF's layout planning. Using the relationship diagram and cost obtained from primary data and selected computerized algorithms during the secondary data collection, better and improved layout for KMTF's production floor has been proposed. Finally the benefit obtained from the improved layout will be compared with the currently being used layout to draw conclusions and recommendations.

1.7. Organization of the Documentation

The document has four chapters. The first chapter will cover the problem statement, objectives of the study the methodology followed and the scope of the study. This will be the guiding outline followed by the study. The second chapter will cover the related literature review about layout problems, types of layout and different computerized layout algorithms available. The importance of layout planning and other important points will also be discussed in this chapter. On the third chapter data collected and analysis of the data will be discussed. In this chapter, the information gathered from the factory will be organized to form the necessary inputs for the layout planning such as relationship between different sections, cost matrix, etc... From the different computerized algorithms selection for use in the study will also be made in this chapter. On the fourth chapter the input data collected will be used by the selected computerized algorithms to generated different alternatives. Then selection of the optimal/suboptimal layout will be discussed. Roll forging will also be introduced into the selected near optimal layout. The selected layout with and without roll forging machine inclusion will be compared with the currently being used one and significance of the benefit obtained will be discussed on the same chapter. Finally, conclusions and recommendations will be forwarded.

2. CHAPTER TWO: LITERATURE REVIEW

2.1.Introduction

Industrial competitiveness depends on reductions in operating expenses such as those related directly to facilities and their design. Furthermore global competitiveness and advances in technology have given rise to the need for effective space utilization. For a manufacturing firm, the facilities planning function determines the effectiveness with which the manufacturing facility best supports the production activities [6].

The use of computers in layout design in our country has been at the final drawing stage. After the locations of departments are set subjectively, the final drawing of the layout is done using Auto CAD. The assistance of computers is only in drawing. In this paper, other helpful capabilities of computers will be discussed and furthermore apply them in the selected case company. Generation of different alternative layouts will be shown in the paper.

This paper tries to show the effectiveness of using computers to better plan and organize a facility. For this purpose different publications that discussed plant layout problems and different approaches proposed to solve them has been exploited. To this end more than 12 journals and publications and 4 books have been assessed to have a clear understanding about the basic problem that underlies. Though the proposed approaches vary, their basic objective i.e. enhancing productivity by either reducing material handling cost, increasing adjacency of highly related workstations or both has been clearly seen.

2.2.Layout planning

Facilities planning and design determines how an activity's tangible fixed assets satisfy the activity's objective. Plant layout or the best arrangement of facilities and machines within a plant is one of the key elements of the facilities design problem. Traditionally, layout planners usually employed string diagram and templates or replicas of facilities and equipments to design a plant. The methodology itself is very intrinsic that relies on subjective judgments and rules of thumb [3].

Plant layout design is the act of planning a good workable disposition of industrial facilities like operating equipment, storage space, material handling equipment and all other supporting services along with the design of the best structure to contain these facilities [2]. It is the arrangement of work space which, in general terms smoothes the way to access facilities that have strong interaction. Its aims are similar regardless of whether the organizations are services or manufacturing. The main concern with the plant facility layout planning is to reduce the cost of materials handling, as poor materials handling can generate business problems [8].

A plant layout can be defined as follows [17]:

Plant layout refers to the arrangement of physical facilities such as machinery, equipment, furniture etc. within the factory building in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of material to the shipment of the finished product.

Similarly according to Riggs,

“The overall objective of plant layout is to design a physical arrangement that most economically meets the required output – quantity and quality.”

According to J. L. Zundi,

“Plant layout ideally involves allocation of space and arrangement of equipment in such a manner that overall operating costs are minimized.”

Form all the above definitions given by different scholars; we can see that all have one common ground – reduced cost of operation.

Facility layout belongs to the class of spatial allocation problems that have been studied in various contexts, including architecture space planning, manufacturing layout and offices layout Plant layout is a part of facilities design, which includes more global issues such as building design, material handling, etc. In general, plant layout analysis includes a study of the production line process flow charts, material flow diagrams, product routings, processing times, development of from-to charts, relationship diagrams between different departments in the facility and the cost of material movement [7].

Manufacturing companies spend a significant amount of time and money designing or redesigning their facilities because the design of a facility layout has a tremendous effect on the operation of the system that it houses. A poor facility layout can be costly and may result in poor system performance as well as customer dissatisfaction. However, the design of an efficient manufacturing system must take into account a number of issues including the determination of the products to be manufactured, the manufacturing or service processes to be used, the quantity and type of equipment required, and the preliminary process plans. Additionally, the formation of the manufacturing departments and their layout, the determination of the material handling methods to be used, and the quantity and types of material handling devices needed to perform the required material handling are some of the more important issues to be addressed [11].

2.3.Importance of plant layout

In the business world, company managers are exposed to continuous challenges. One of these challenges is to equip their organizations with the ability to compete in a global marketplace [8]. The magnitude of the investment in new facilities each year renders the criticality to the plant layout generation function. As discussed previously, plant layouts can be of various types and can significantly impact the overall effectiveness of production systems. It is generally accepted that effective facilities planning can reduce material handling cost by at least 10 to 30 percent. The main objectives of the plant layout function are to enable the manufacture of the product economically in the required volume and variety [9].

Plant layout is an important decision as it represents long-term commitment. An ideal plant layout should provide the optimum relationship among output, floor area and manufacturing process. It facilitates the production process, minimizes material handling, time and cost, and allows flexibility of operations, easy production flow, makes economic use of the building, promotes effective utilization of manpower, and provides for employee's convenience, safety, comfort at work, maximum exposure to natural light and ventilation. It is also important because it affects the flow of material and processes, labor efficiency, supervision and control, use of space and expansion possibilities etc [17]. Facilities are of crucial importance to organizations because, usually, they represent the largest and most expensive assets of the organization. The

layout planning of facilities constitutes an important logistics management issue to be faced by an organization. If not tackled in the early phases it can generate logistics implications for the company involved [8].

The importance of the physical layout and design of a manufacturing process cannot be underestimated. The efficiency of an operation depends on the proper utilization of personnel and equipment, and the efficient movement and storage of materials. Traditionally, facility layout has been accomplished manually by employing a cut-and paste approach where permutations of a layout are explored by rearranging work stations and equipment. This approach is effective when the number of locations is small. However, the number of alternative arrangements is $n!$, where n = the number of available sites to locate a facility, department, workstation, or piece of equipment. For example, if $n = 17$, the number of potential layouts is in excess of 350 trillion. Clearly, the trial and error approach is not feasible for determining the best solution [12].

The trial and error approach generally cannot be used while the objective of any organization is to reduce cost and maximize profit. It is a critical long-term process and requires a high capital investment. Moreover, any modification or rearrangement of the existing layout represents a comparatively large expense and cannot be easily accomplished since most machinery and equipment do not have the flexibility of being easily moved whenever needed. Consequently, facilities layout design is an important industrial issue as it directly and indirectly minimizes the total cost of products. Subsequently, it lends a helping hand against competition and increases the factory's productivity (Sha and Chen, 2001), business performance (Canen and Williamson, 1998), the effective utilization of manpower, space and infrastructure, as well as the wellbeing and morale of the worker [10].

The importance of plant layout, as discussed previously from different experts has been argued. To summarize these points, an efficient plant layout is one that can be instrumental in achieving the following:

- a) Proper and efficient utilization of available floor space
- b) To ensure that work proceeds from one point to another point without any delay

- c) Provide enough production capacity.
- d) Reduce material handling costs
- e) Reduce hazards to personnel
- f) Utilize labor efficiently
- g) Increase employee morale
- h) Provide for volume and product flexibility
- i) Provide ease of supervision and control
- j) Provide for employee safety and health
- k) Allow ease of maintenance
- l) Allow high machine or equipment utilization
- m) Improve productivity

In addition, an efficient layout will also reduce inventory and associated costs. With emptier floor space released it creates opportunities for management to expand utilization in volume of the existing products, new management initiatives may bring new products to be manufactured in the plant. The business competition is enormous. The domestic market is under siege from overseas competition. The above results would provide advantages to the company over the competition – certainly a good solution of the facility layout and its continuous improvement, it would efficiently contribute to keeping the company on the competitive edge. Organizations with superior resources such as technology and management are usually the winners. Also an efficient plant layout will provide the overall wellbeing and morale of the worker and keep the company as the winner [8] [9]. Even though most machinery found in Ethiopian manufacturing industries are old-fashioned, the effective arrangement of these machines would help utilize their capacity efficiently. Proper layout planning would help these industries attain objectives which include [16]:

- To minimize the investment required in new equipment.
- To minimize the time required for production.
- To utilize existing space most efficiently.
- To provide for the convenience, safety, and comfort of the employees.
- To maintain a flexible arrangement.

- To minimize the materials handling cost.
- To facilitate the manufacturing process.

Furthermore, plant layout is a dynamic rather than a static concept meaning thereby if once done it is not permanent in nature rather improvement or revision in the existing plant layout must be made by keeping a track with development of new machines or equipment, improvements in manufacturing process, changes in materials handling devices etc. But, any revision in layout must be made only when the savings resulting from revision exceed the costs involved in such revision. Revision in plant layout may become necessary on account of the following reasons [17]:

- a) Increase in the output of the existing product
- b) Introduction of a new product and diversification
- c) Technological advancements in machinery, material, processes, product design, fuel etc.
- d) Deficiencies in the layout unnoticed by the layout engineer in the beginning.

The plant layout of most manufacturing industries found in Ethiopia is set at the initial erection of the plant. Only some of these industries try to rearrange their layout to attain better performance level or to introduce new technology. Up to now we have seen what we mean by plant layout and its importance for a company's objective. In the next section we will see what is meant by plant layout problem.

2.4. The Plant Layout Problem

Plant layout problem can arise in various numbers of ways and can have significant effect on the overall effectiveness of the production system. Therefore it is highly desirable that the optimum plant layout be designed. Unfortunately, the magnitude of plant layout problem in any factory is so great that true system optimization is beyond our current capabilities. The approach normally taken by many researchers to solve plant layout problem is to try to find a satisfactory solution. A layout problem might arise because of [16]:

- Bottlenecks in the production process
- A change in the design of a product,
- Replacement of one or more pieces of equipment
- Unexplainable delays and idle time
- The addition or deletion of a product from a company's product line,
- A significant increase or decrease in the demand of a product
- Change in the design of the process
- The adoption of new safety standards
- Organizational changes within the company or decision to build a new plant
- Crowded conditions
- Back tracking
- Poor house keeping
- Excessive temporary storage space
- Obstacles to materials flow
- Failure to meet schedules
- High ratio of material handling time to production time etc

It is clear that layout problem can be very complex system design problem requiring the most sophisticated system analysis and design tools in order to design satisfactory layout solutions. While designing a factory we should keep the following factors in mind [17]:

- a) *Factory building*: The nature and size of the building determines the floor space available for layout. While designing layout, the special requirements, e.g. air conditioning, dust control, humidity control etc. must be kept in mind.
- b) *Nature of product*: product layout is suitable for uniform products whereas process layout is more appropriate for custom-made products.
- c) *Production process*: In assembly line industries, product layout is better. In job order or intermittent manufacturing on the other hand, process layout is desirable.
- d) *Type of machinery*: General purpose machines are often arranged as per process layout while special purpose machines are arranged according to product layout

- e) *Repairs and maintenance:* machines should be arranged so that adequate space is available between them for movement of equipment and people required for repairing the machines.
- f) *Human needs:* Adequate arrangement should be made for cloakroom, washroom, lockers, drinking water, toilets and other employee facilities, proper provision should be made for disposal of effluents, if any.
- g) *Plant environment:* Heat, light, noise, ventilation and other aspects should be duly considered, e.g. paint shops and plating section should be located in another hall so that dangerous fumes can be removed through proper ventilation etc. Adequate safety arrangement should also be made. Thus, the layout should be conducive to health and safety of employees. It should ensure free and efficient flow of men and materials. Future expansion and diversification may also be considered while planning factory layout.

Once the main reason of a company to plan for changing or rethinking of its current layout is identified and the different factors of plant layout problem are considered, better layout of the plant will be attainable. Setting one company's main objectives and planning its resources so as to meet those resources is mandatory. One basic and common objective of manufacturing industries in Ethiopia and other countries is increasing one's productivity. In the next section we will see the relation between plant layout and productivity.

2.5. Layout and Productivity

Every industry aims for higher productivity rate because as the production increases it will soon follow the rate of increase in terms of profits. There are several ways on how to improve productivity. One of which that is being considered is having an efficient plant layout. Every infrastructure requires having a layout. A layout is consisted of the detailed plan of the structure being constructed or reconstructed. It emphasizes the arrangements and proper positions of the basic elements of the plan. A layout serves as a guideline for the builders as well as the owners of the establishments to visualize the physical appearance of the infrastructure. A layout also includes the proper allocations of space and equipments that will be used within the production of the plant. It is a very important aspect within the manufacturing cycle. Plants should have an ideal layout in order to improve their productivity means. A properly laid out plant ensures a

smooth rapid movement of materials and employees. However, plants layouts are dynamic in concept because it tends to adapt several changes regarding the need for improvement of the industry.

In this section we will examine the improvements that are attained by a good layout with respect to the productivity of a company. Now let us see what we mean by productivity

Productivity growth determines our living standards and the wealth of nations. This is because the amount a nation can consume is ultimately closely tied to what it produces. By the same token, the success of a business generally depends on its ability to deliver more real value for consumers without using more labor, capital or other inputs. A higher productivity means a greater opportunity for prosperity. It also leads to a lot of benefits such as it decreases the cost of production which results to a domino effect that also decreases the cost of the product therefore it would become more affordable and available to the public. It tends to lower the production cost and it increase production as it increase the profits of the company. It promotes social and economic progress. It alleviates poverty. It improves working conditions of the workers as it increases their wages. Lastly it advocates exporting companies to compete more in foreign markets [20].

Productivity is a simple concept. It is the amount of output produced per unit of input. While it is easy to define, it is notoriously difficult to measure, especially in the modern economy. In particular, there are two aspects of productivity that have increasingly defied precise measurement: output, and input. Properly measured, output should include not just the number of products coming out of a factory but rather the value created for consumers. Similarly, a proper measure of inputs includes not only labor hours, but also the quantity and quality of capital equipment used, materials and other resources consumed, worker training and education, even the amount of "organizational capital" required, such as supplier relationships cultivated and investments in new business processes [15].

One of the basic aspects that can affect the productivity of an industry is the plant layout. The plant layout involves the planning path each component part of the product is to be followed within the plant. It also includes the proper coordination of each parts so that the process of

manufacturing will be carried out in the most economical and practical manner. A plant layout is composed of a detailed plan of the infrastructure – the sketches, drawings that are carefully scaled on order to achieve the real visualization of the plan that is going to be implemented. Considering a plant layout involves a long-term strategic decision that once taken, it cannot be changed. Many have been occupied by the thought of having large profits but before entering such façade there are still many things to be considered to really find progress within manufacturing [20].

Where does productivity growth come from? By definition it doesn't come from working harder -- that may increase output, but it also increases labor input. Similarly, using more capital or other production factors does not necessarily increase productivity. Productivity growth comes from working smarter. This means adopting new technologies and new techniques for improving production [15].

In working smarter, it is true that with proper plant layout, it will help enhance the productivity more. Thus, great planning and care are just a few hints that should be considered. A plant layout is said to be efficient if it aims to achieve various objectives that an industry needed especially in terms of productivity. The efficiency of production is greatly affected by rendering proper plant layout. As discuss, each industry has its own plant layout that will comply with their needs and functions. However, there are times that plant layouts are merely influences by several factors which every entrepreneur should learn to acknowledge first before directing to the plan. Layouts may differ from one plant to another but it is applicable to all types of plants. Special layouts are imposed to an industry that is more complicated and hazardous. Generally, plant layouts should be conducive to the health and safety of the employee and as well as it should provide satisfaction and convenience from time to time [20].

Changes should always be for the better of things. We should seek for changes to have some improvements in our life. Plant layouts will definitely help improve the productivity but each industry should learn to adapt within the changes they want to pursue. Manufacturing industries of Ethiopia should also explore the different approaches that are followed by other companies worldwide and adapt them to their own specific condition to be more productive. Up to now we

have seen how plant layout relates with improving productivity of a company and attain its objectives. In the next section we will see the different approaches or methodologies for layout development.

2.6. Layout development methodology

A number of plant layout development methodologies/procedures have been developed to facilitate the design of layouts. We will mention briefly some of the most significant contributions to the field. Specifically we will consider the ideal system approach by Nadler with the layout planning steps recommended by Immer, Apple and Reed [16].

Nadler's Ideal system approach: Although developed initially for designing work systems, his approach is also applicable for designing plant layouts. Although more a philosophy than a procedure, the ideal systems approach is based on the following hierarchical approach toward design: aim for the theoretical ideal system, conceptualize the ultimate ideal system, design the technologically workable ideal system and install the recommended system. The focus is the opposite of what is typically used in practice, where the layout designer concentrates initially on the present method rather than aiming for the theoretically ideal.

Immer's basic steps: Immer declared "analysis should be composed of three simple steps, which can be applied to any type of layout problem. These steps are: put the problem on paper, show lines of flow and convert flow lines to machine lines." He defined a good layout as a means of placing the right equipment coupled with the right method in the right place to permit the processing of a product unit in the most effective manner through the shortest possible distance and in the shortest time. The importance of good layout as a factor in insuring low cost production is thus well established and its need is well understood.

Apple's procedure: Apple recommended that twenty detailed sequence of steps be used in designing a plant layout. It starts with procuring basic data and analyzing it. Then designing the productive process with the material flow pattern plan will follow. It continues with the material handling plan, equipment requirement, individual workstation design, activity relationships, storage requirements, auxiliary activities and services plan and space requirements, building

types evaluation of the above and then install and follow up on the implementation of the layout are included in the twenty steps.

Reed's procedure: he proposed a ten step procedure for planning and preparing layouts. He recommended the steps to be taken in his systematic plan of attack. The steps include analyzing the process to be produced, process required to manufacture the product, prepare layout planning charts, determining work stations and storage areas, establishing aisle width and office requirement, considering personnel facilities, surveying plant services and providing future expansion ways.

The above layout planning approaches vary in their degree of specificity. However, they are alike in their emphasis on the design aspects of layout planning. Taken together a comprehensive layout planning approach would emerge [16].

The most popular approach used in designing plant layouts has been the systematic layout planning (SLP) approach developed by Muther (1976). Once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram, modifying considerations and practical limitations. A number of alternative layouts are designed and evaluated. The systematic manual procedures of SLP have provided a sound foundation for computer-aided approaches. Integration of the processes eliminates duplication of input and the possible exclusion of important information. A computer-aided system will generate alternative solutions to the planning problem [6].

Because the development process is iterative, judgments can be introduced into the graphics during the adjustment phase. Finally, the system provides the planner with reports, diagrams and charts to use when documenting the project. The facility layout process can be conceptualized as a process of design database development, where the final content of the database is the layout specification. The design database may contain data in a variety of formats, such as drawings, numerical specifications and text. The layout planner must integrate the current state of the layout database, the layout requirements and constraints and any necessary domain-specific knowledge such as standards and local regulations in making layout decisions [6] [5].

In SLP once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations, when combined with the relationship diagram, lead to the construction of the space relationship diagram. Based on the space relationship diagram, modifying considerations and practical limitations a number of alternative layouts are designed and evaluated. The first five steps of SLP (prior to developing the space relationship diagram) involve the analysis of the problem while up to developing alternative layouts constitute the search phase and the last step is selection phase [16]. Though all the layout planning methodologies generate different alternatives by considering different factors, one must select one method to generate layouts. In this paper we will use SLP as basic methodology because it considers qualitative as well as quantitative components of a facility. Flow of material (from to chart) and activity relationship diagram are examples.

2.7. Computer Aided Layout Planning

Several rigorous approaches have been applied in computer aided layout planning. These are [19]:

1. *Bubble diagramming*: this is not really a technique but rather a means of illustrating an intended arrangement of activities. It is popular among planners and interior designers.
2. *Graphical layout technique*: as defined by Richard Muther, this is a graphical means of resolving multiple objective and constraints. It is most popular among industrial engineers.
3. *Scoring techniques*: this calculates the relative worth of a completed block layout. These are popular among industrial engineers and office space planners
4. *Clustering techniques*: A numerical approach that focus on grouping of activities, often without reference to size, place, or layout.
5. *Layout algorithm*: Mathematical routines that automatically generate block plans from data on relationships and space.

All the techniques described above have their own advantages. But the last technique i.e. layout algorithm considers the size and relationship between different section and their interrelationships due to flow of materials and other qualitative relationships. Therefore from the

above approaches the one that will be followed in this paper will be the layout algorithms and it will be discussed as follows.

The field of computer aided layout planning began in the 1960's [19]. The search phase of SLP should try to generate as many candidate layouts as possible for evaluation. By generating more alternatives, the chance of getting a good one will be better. However, typical layouts usually consist of numerous activities and it will be time consuming to generate the layout without any aid [4]. The solution procedures for the process layout are usually based on a set of over-simplifying assumptions, and many practical considerations have to be incorporated in the development of a package of practical value in the layout planning process [3].

Several mathematical models are available in the literature to determine an optimal solution for the layout problem. They vary from a simple assignment model formulation to the more complex ones. However, when the number of facilities becomes large, the model becomes complex and difficult to handle analytically. Obtaining the necessary data to be fed into the model is another burden in the formulation. Thus the development of an efficient model to solve a large layout problem has been a challenge and an area of research interest. These reasons led researchers to have a special interest in the development of computer programs seeking a solution for the layout problem. The computerized layout methods are heuristics; they do not guarantee an optimal solution. Nevertheless, an efficient solution is expected [8].

Essentially there are two types of such heuristic routines: construction and improvement [7].

1. **Construction-type layout routines:** This type of routine generates a block layout based on the relationship between different departments. It involves a serial assignment of each facility to a location until a solution is built [12] [19]. It generates a layout straight from the activity relationship chart, space requirement and shape. However, it provides only one unique layout in the end, which could, sometimes, be far from what was expected [4] [8]. Among the most popular routines within this category are CORELAP (computerized relationship layout planning) (Lee ,and Moore 1967), ALDEP (Automated layout design) (Seehof ,and Evans 1967) and PLANET (Plant layout analysis and evaluation techniques) (Deisenroth ,and Apple 1972) [7].

2. **Improvement-type layout routines:** The improvement type on the other hand starts with a layout and tries to improve it by interchanging the locations of the activities. The criteria for such improvement are usually the transportation costs or material handling cost. This type of routine requires an input of a feasible block layout and aim to reduce movement cost by attempting simultaneous pair-wise (or more) position exchanging among the departments. It generates a solution that depends on the initial solution and the procedure may get caught in local optima which could be looked at as a disadvantage [8] [12]. Among the most popular improvement-type routines are CRAFT (computerized relative allocation of facilities technique) (Armour ,and Buffa 1963) and COFAD (Computerized facilities design) (Tompkins ,and Reed 1973) [4] [7].

2.7.1. CRAFT

CRAFT (Buffa et al., 1964) is representative of improvement type layout algorithm. It is more popular than the other computer based layout procedures. It is an improvement algorithm and starts with an initial layout and proceeds to improve the layout by interchanging the department's pair wise to reduce the total material transportation cost. It does not give the optimal layout; but the results are good and near optimal, which can be later corrected to suit the need of the layout planner [13].

This algorithm is characterized by efficiently allocating the departments in heuristic way. Under the criterion of minimizing the material handling costs for multiple product items, where this cost is expressed as a linear function of the transportation distance. Basically, CRAFT seeks an optimum design by sequentially improving the layout, based upon material flow analysis, as given in an initial layout specified as either an existing layout or a predetermined spatial array. CRAFT is an improvement procedure, but interchange of departments is restricted to those that are either equal in area or sharing a common boundary in order to retain the original shape of the factory site [3]. Input data required for CRAFT include [1] [13]:

1. The initial layout
2. Material flow data
3. Material handling cost data

4. The number and location of all fixed departments
5. Area of the departments

Material flow and material handling cost data, in the form of from to charts, are conveniently used to express the number of items transported per time period and the material handling cost required to move one unit of distance between any combinations of two departments [1].

CRAFT procedure

- 1) Determine department centroids
- 2) Calculate rectilinear distance between centroids
- 3) Calculate the total cost of material handling for the initial layout by utilizing the from-to charts
- 4) Consider exchange of locations for those departments which either require the same area or have a common border, by employing pair wise or three way interchange. The exchange producing the greatest anticipated improvement, i.e. reduction in total cost, is made.
- 5) The above procedure is repeated until no further improvement can be made to reduce the transportation cost [1] [13].

The transportation distance between pairs of departments in CRAFT is calculated as the rectilinear distance between centroids of departments; that is $|x_i - x_j| + |y_i - y_j|$ for departments i and j , where (x_i, y_i) and (x_j, y_j) are the coordinates of the two departments [1].

The CRAFT program does not guarantee to find the least cost layout, since not all possible exchanges are considered. It does, however, produce a suboptimal solution that cannot be easily improved upon. In CRAFT the final solution is dependent on the initial layout given. There is no mathematical certainty of attaining the desired optimal solution after a given number of iterations. If the starting solution is quite close to the optimal solution by chance, then the final solution is attained only after a few iterations. However, as there is no guarantee that the starting solution will be close to the global optimum, the expected number of iterations required to arrive at the final solution tend to be quite large thereby straining computing resources [14].

It is advised to obtain alternative solutions from several different starting layouts and then choose the best one. The final layout plan obtained through the CRAFT program is recommended to be modified into a realistic layout plan via some manual adjustments taking qualitative factors and practical limitations into account [1] [13]. The figure below shows an example of layout in an Excel Add in program by Paul A. Jensen. By this program each department is given its own designated numbering and color. Best switches are selected to improve the layout and come to lower cost of the layout. In this specific example the switched departments are department 9 and department 10 which are shown on the left upper corner of the figure.

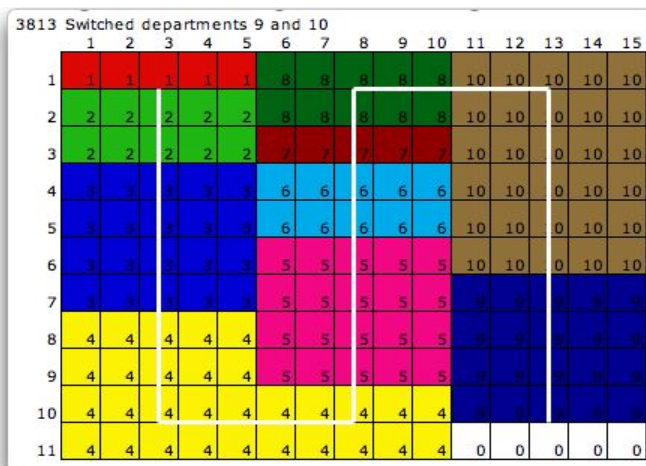


Figure 2.1: Example of CRAFT representation of departments in Excel add in software (Source: Operations Management-Industrial Engineering by Paul A. Jensen)

2.7.2. CORELAP

CORELAP is representative of the construction type of layout algorithm. It is concerned with generating a layout based upon closeness ratings determined from an activity relationship diagram [1]. CORELAP expresses the interdepartmental relationships in a closeness relationship matrix, which is then used to construct a layout [3]. It constructs layouts by locating rectangular shaped departments. The relationship chart provides the basis for the order in which different departments are placed [13]. The input data needed by CORELAP include:

1. The number of departments N,
2. The area of each department,

3. Activity relationship diagram for each departments, and
4. Weights for activity relationships (which will be decided by the layout planner e.g. A=6, E=5, I=4, O=3, U=2 and X=-1)

The closeness rating between departments i and j is based upon the weight assigned to the activity relationship between the two departments.

CORELAP procedures

COREPLAP follows the procedure below [1] [13]:

- 1) Choose the department having the largest Total Closeness Rating (TCR) and place it in the middle of the layout drawing
- 2) Scan the relationship diagram to find any department having an A rating with the previously chosen department from step 1 and place that department near to it. If no more exists, a check is successively made to find any department having an E rating, followed by an I rating, then followed by an O rating. In case of ties, the department having the largest TCR is chosen.
- 3) If no department has been found so far, choose an unassigned department with the largest TCR. Place this secondly selected department near the first selected department in the layout drawing.
- 4) Scan the relationship diagram again to find an unassigned department having an A rating with the first selected department; if not, try to find one with the secondly selected department. If none exists, search for any unassigned department having an E rating with the first selected department and then with the secondly selected department followed by a rating of I, O, and U. For the case that no department is found, choose an unassigned department with the largest TCR. Then place the department next to the first or second selected department. (Now three departments have been placed in the layout drawing)
- 5) Repeat the above search process until all departments under consideration are placed.

2.7.3. ALDAP

ALDAP is basically a construction algorithm but it can also be used to evaluate two layouts. The algorithm uses basic data on facilities and builds a layout by successively placing the layout using relationship information between the departments [13]. ALDEP employs a probabilistic approach in generating layouts [3]. The basic inputs to ALDAP are:

1. Length and width of facility
2. Area of each department
3. Minimum closeness preference (MCP) value
4. Sweep width
5. Relationship chart showing the closeness rating
6. Location and size of any restricted area

ALDAP procedure [13]

- 1) Input the previously outlined inputs
- 2) One department is selected randomly and placed in the layout
- 3) Next the algorithm uses minimum closeness required between departments for the selection of departments to be placed with an earlier placed department. Select the department having maximum closeness rating. If there is no department having minimum closeness preference than any department that remains to be placed is selected
- 4) If all the departments are placed in the layout, proceed to the next step otherwise go back to step 3
- 5) Compute the total score of the layout
- 6) If the total score obtained is acceptable score proceed otherwise return to step two and select other department randomly

2.8. Single-Facility Location Problems

Travel distance plays a very important role in evaluating facility layouts, since the cost of material handling is often directly proportional to travel distance, the longer a material handling transport, the more it can cost. Travel distance depends on locations, of course starting ending points of trips. Thus it is natural that we focus on the simplest type of location problems, single

facility location problems. Consider a new machine to be located in a manufacturing shop. The new machine receives parts from existing machines and supplies parts to existing machines. Thus, there is a total cost of moving part to and from the new machine. This total cost depends on the location of the new machine and we wish to locate the new machine so as to minimize the total cost.

Let m denote the number of existing machine, and for each existing machine i , denote its location by P_i . We assume that we know the number of trips per month, say t_i , between P_i and X , where X is the location of the new machine. Thus if $d(X, P_i)$ denote the distance between X and P_i , $t_i d(X, P_i)$ is the total distance items travel per month to and from the new machine and the existing machine. If we consider rectilinear in the figure below, we can have several different paths between a new facility location X and an existing facility location P_i for which the rectilinear distances are the same. With the understanding that $X = (x, y)$ and $P_i = (a, b)$ we have the following equation [17].

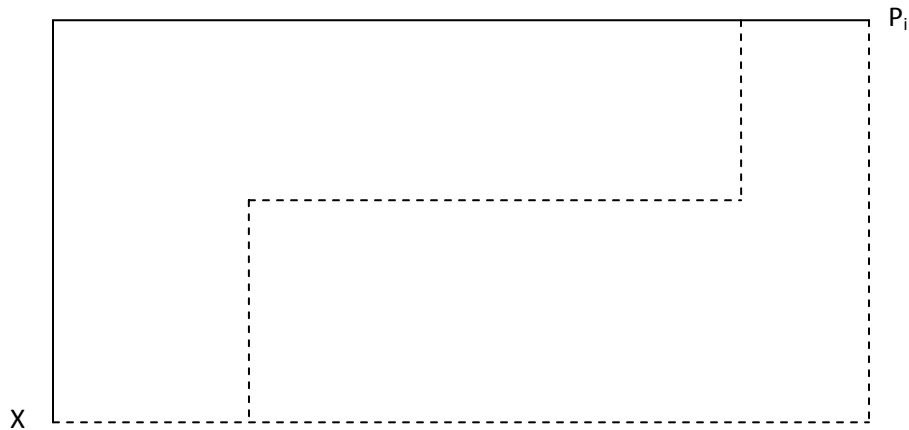


Figure 2.2: Different rectilinear paths between X and P_i having the same rectilinear distances

$$f(x, y) = \sum_{i=1}^m w_i (|x - a_i| + |y - b_i|)$$

Let us define $f_1(x)$ and $f_2(x)$ as:

$$f_1(x) = \sum_{i=1}^m w_i(|x - a_i|) \qquad f_2(y) = \sum_{i=1}^m w_i(|y - b_i|)$$

Now we can conclude that $f(x, y) = f_1(x) + f_2(y)$

That is, the total cost of movement is the sum of the cost of movement in the x direction and the cost of movement in the y direction. Thus an implementation of the equation is that we can minimize the total cost of movement by solving the two smaller- and independent- problems of minimizing the cost of movement in the x direction and minimizing the cost of movement in the y direction. The best choice of x has absolutely no effect on the best choice of y, and vice versa! Also, we observe that the two costs of movement functions have exactly the same form, so that every conclusion we draw about one cost function applies to the other. In particular, if we have a way to minimize one cost function, we can also apply it to minimize the other cost function. The point x and the points a_1, \dots, a_m are all points on the line, and $|x - a_i|$ is the distance on the line between x and a_i . Thus minimizing the two functions $f_1(x)$ and $f_2(y)$ will result the minimization of the whole function $f(x, y)$ [17].

2.9. Practical cases

B. Gopalakrishnan, R. Turuvekere and D.P. Gupta used CRAFT algorithm to improve layout of a medium-sized aluminum and steel fabrication company located in Pennsylvania. The primary product of the plant is truck bodies and trailers. The plant uses 130 different types of extrusion material and 25 different types of sheet material in the manufacturing processes. The plant receives orders for various types of sheet metal and extruded products requiring some fabrication to be undertaken. Layout rearrangement is an intrinsic part of this manufacturing scenario. The figure below shows a comparison between the existing and the layout suggested by CRAFT [6].

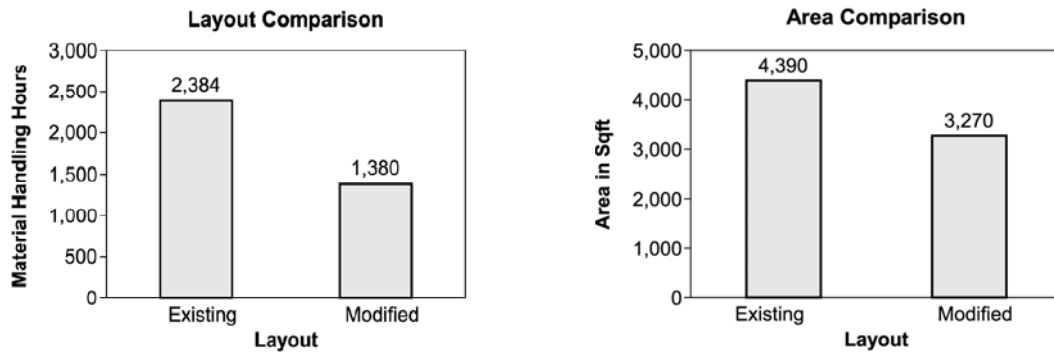


Figure 2.3: Improvements obtained by the plant

The materials handling time is reduced to 1,380 hours as compared to the 2,384 hours required previously, representing a 42 percent reduction in materials handling time per year. The materials handling volume reduction of 36 percent is also obtained from the CRAFT solution. Other benefits of better space utilization are also realized in the plant [6]. Dr. M Khoshnevisan and Sukanto Bhattacharya presented in their paper proposed a semi-heuristic optimization algorithm for designing optimal plant layouts in process-focused manufacturing/service facilities. The proposed algorithm marries the well-known CRAFT with the Hungarian assignment algorithm. Being a semi-heuristic search, the algorithm is more efficient in terms of computer CPU engagement time as it tends to converge on the global optimum faster than the traditional CRAFT algorithm - a pure heuristic [14].

2.10. Summary of Literature Review

Up to now definitions of plant layout, importance of facility layout, the plant layout problem, layout and productivity have been seen deeply. And in the previous section the aid of computer in layout planning has been discussed. The usefulness of the computerized algorithms like CRAFT in the improvement routines and CORELAP in the construction routines has also been seen to have general understanding and detailed procedure of the main routines. All the above literature is reviewed so as to have a better and elevated understanding of plant layout importance and benefits. Furthermore, computer's application other than for drawing purpose is also illustrated taking both construction and improvement routines. Algorithms like CRAFT, CORELAP and ALDAP are also discussed in detail.

One of the limitations observed in CRAFT final sub optimal layout is the dependency of the solution on the initial layout used. If the initial layout used is very far from the optimal layout the final solution will also be far from the optimal layout. On the other hand if the initial layout used is near to the optimal solution then the final solution will also be near to the optimal solution which is very good. Thus the question raised is “How can one know the initial layout used in CRAFT is good so as to give near to optimal solution?” This question is still wide area of research. In this paper we will see how layout constructed by CORELAP or other construction routine can be a better input for CRAFT routine.

2.11. Ethiopian Manufacturing Industries

Ethiopia's industrial sector is backward in its structure, employment, and technological content. The current contribution of the sector to the GNP is about 12%, about one third of which comes from handicrafts and small-scale industries. Although it is hard to obtain reliable statistical information, some estimates indicate that the sector as a whole employs no more than 3% of the total labor force, and nearly half of this is in handicrafts and small-scale industries. The magnitude of dependence on imported machinery and spare parts is high in the metal and chemical industries, exceeding, according to some estimates, 95%. By the same token, the imported industrial inputs for the metal and chemical industries are about 95 and 80%, respectively [21].

Basic industries, such as design, fabrication, and metallurgy, which are crucial for the development of the industrial sector, are hardly existent. For example, the value of metallic products and electrical manufacturing is about 5% of that of total industrial output. The metal and engineering firms, such as the Akaki Spare Parts and Hand Tools Factory, Truck and Bus Assembly, Kotebe Metal Tools Factory, Kaliti Steel Works, and Ethiopian Iron and Steel Industries, are important institutions but have low capacities for adapting, developing, and producing the technologies required by the economy.

To make these companies more competitive and serve the nation, companies need to make themselves more productive than ever. Introducing new and up-to-date technological equipment certainly need high investment which will not be easy for low to medium income country.

Utilizing the available technology effectively is wiser. Thus, this paper improves the performance/productivity of one of Ethiopian manufacturing industries, Kotebe Metal Tools Factory, by rearranging its current layout to a better one.

2.12. Kotebe Metal Tool Factory Background

History of the factory

Kotebe Metal Tools Factory (KMTF) was established in 1969 by private investors and up on the transition of government it was nationalized and has become the part of the National Metal works corporation in the late Derge regime. KMTF is established as an enterprise on 1992 and was made under the supervision of Basic Metals and Engineering Industry Agency from 1996 onwards. The factory was then privatized to Nigat Mechanical Engineering Share Company from March 2006 up to date. Its aim is to produce hand tools. Currently the factory's visions are:

- To design & manufacture various hand tools and implements.
- To sell its products in domestic & foreign markets directly or through agents
- To procure in domestic and foreign markets inputs and capital goods, necessary for its operation and development.
- To render generally in any other business activities that helps for the attainment of its products.

The workforce is directly in contact with the layout. Proper layout promises safe and convenient work environment. The education level of the current employees of KMTF the different sections are given in the table below.

Table 2.1: Distribution of labor in Organizational Sections

Job Description	Professional	Semi Professional	>12 Grade	9-12 Grade	1-8 Grade	Read/Write	Total
Production & Technical	7	12	20	19	34	14	106
Administration	6	4	15	9	5	6	45
Total	13	16	35	28	39	20	151
%	8.61	10.6	23.18	18.54	25.8	13.25	100

2.12.1. Product and Process in the Factory

Kotebe metal tools factory has been producing many types of hand tool for agriculture, construction and other purposes. The main manufacturing processes used are three. These are:

1. Hot Working Process
2. Cold Working Process
3. Machining Process

Many of the products produced by the factory are shown in table below. Other special order products that are given by the customer are also produced.

Table 2.2: Product type

No	Description	No	Description
1	Stone Hammer 10 kg flat	16	Craw bar 2.0 m Dia. 28mm
2	Stone Hammer 8 kg flat	17	Stamper Dia. 28x2m +3.25 kg pb)
3.1	Stone Hammer 6 kg flat	18	Garden hoe / 2 finger (plate)
3.2	Pointed Hammer 6 kg flat	19	Shovel No. 5
4.1	Stone Hammer 5 kg flat	20	Shovel no. 2
4.2	Pointed Hammer 5 kg flat	21.1	Spade harar (big) (spade) Local mat.
5.1	Stone Hammer 4 kg flat	21.2	Spade harar (big) (spade)50mn coil
5.2	Pointed Hammer 4 kg flat	22	Door bolt (140mm) (base plate)
6.1	Stone Hammer 3kg	23	Racke /10 finger/ (support)
6.2	Pointed Hammer 3kg	25	Sickle from newly imp. Mat
7.1	Stone Hammer 2kg	26	Buckle md10
7.2	Pointed Hammer 2kg	27	Buckle MD11
7.3	Cobble Hammer 2kg	28	End clip
8	Stone Hammer 1.5kg	29	D-ring
9	Special Hammer 1.25kg	30	Fastener Big No. 1
10	Pointed Hammer 1kg	31	Fastener Big No. 2

11	Pick Axe 2kg	32	Fastener small no.1
12	Axe Congo 3lb	33	Fastener Small No.2
13	Axe Congo 4lb	34	Stone Chisel
14	Craw Bar 1.5 m Dia. 28mm	35	Stone Chisel Dia. 12
15	Craw Bar 1.5 m Dia. 32mm	36	Stone Chisel Dia. 14

From the above mentioned products the company has selected 12 vital products that must be produced to stock because their demand over the past years has been tremendous and profitable. These products are:

1. Stone hammer 6kg flat
2. Hammer 3kg
3. Stone hammer 1.5kg
4. Pick axe 2kg
5. Axe Congo 4&3 lb
6. Craw bar 1.5m D 32
7. Garden hoe / 2 finger
8. Shovel No. 5&2
9. Spade Harar (Big)
10. Door bolt (140mm)
11. Racke 10 finger
12. Sickle

KTMF is aiming to manufacture these products to stock and accept other special orders that are placed by the customers. The current manufacturing process of the products uses more than 50 different machines.

The main customers of KTMF are local organizations governmental or nongovernmental organizations like NGOs, road construction companies and others. These are governmental and non-governmental organizations, households, construction companies and others. Marketing of the products is executed in different ways, these are; the customer directly contact the factory at

the shop of the company that sales the items directly to the individual customers, orders that customers place of a specific product that is designed and produced by the company and special orders that are placed by the customer with design specifications.

The company used to import its products from other countries. The main raw materials are from Zequla Steel Rolling Mill Enterprise and some raw materials are imported from abroad. The raw materials are received as per the contractual agreement between them. The raw materials are inspected up on delivery.

Up to now, the company has been making some modifications to its layout due to different reasons like unavailability of spare parts of some machines. To continue operation some machine's components have been used as spare parts for other machines. Also minor changes due to product design change have been made. But total rearrangement or reconsideration of the layout has not yet been well thought-out. The arrangement of the machines would highly influence the productivity and performance of the factory. Thus the paper will use the aid of computers to arrive at near optimal layout of the production floor. The detailed layout problem of the factory is described in the next chapter.

3. CHAPTER THREE: DATA COLLECTION AND ANALYSIS

3.1.Data collection

To arrive at near optimal layout, one must first clearly identify and pinpoint the areas where problems are observed and make those problems visible to all concerned. The purpose of the layout design must be clearly understood and the proposed layout should provide a significant change according to a company's objective. There should also be a good understanding of the company not only about the layout but also the competitiveness as well as the productivity that is attained by the company.

As described in the previous chapter, KMTF produces many products to keep in stock and by customers order. Also in the previous chapter the 12 vital products that KMTF has selected are given. To produce these 12 products different machines and processes are used. In the next section the processes that followed are given. The work stations (machine codes) that each operation requires is also given.

Though many products have different process to follow, these are some products that have almost the same process. These products' processes are given in one table.

Table 3.1: Hammers process flow

1. Hammer 6kg, 3kg and 1.5kg

	Sledge hammers	Work stations
1	Cutting	Band saw
2	Heating	PRKSS
3	Pre-forging	MPM 500
4	Heating	PRKSS
5	Piercing	PMS 100
6	Correction	MPM 500
7	Hardening	PRK -40/60
8	Grinding	SZD - 400
9	Tempering	PEH - 2B
10	Polishing Edge	DDPM
11	Painting	FK - 60

Table 3.2: Pick axe process flow

2. Pick axe 2kg

	Pick axe	Work station
1	Cutting	PMS160A
2	Heating	PRKKS
3	Pre-forging	MS250B
4	Heating	PRKKS
5	Piercing I, piercing II, side trimming	PK300/100
6	Hole flash trimming	PMS100B
7	Heating	PRKKS
8	Tips forging & trimming	MS250B
9	Curve forming	T7R-X-7466
10	Grinding	Double Disc Grinder
11	Hardening	PRK-40/60
12	Tempering	PEH-2B
13	Polishing	DDPM
14	Painting	FK-60

Table 3.3: Axe Congo process flow

3. Axe Congo 3&4 lb

	Axe Congo 3 & 4 lb	Work station
1	Cutting	PMS 160A
2	Heating	PRKKS
3	Pre-forging	MPM/500
4	Piercing ,side trimming	PK 300/100
5	Trimming the flash of web at lower part of the hole	PMS100B
6	Heating	PRKKS
7	Hammering(Flattening)	MS100B
8	Tip trimming	PMS100B
9	Hardening	Water quenching Tank
10	Grinding	Double Disc Grinder
11	Tempering	Electrical Pit Furnace
12	Polishing	Double Disc Polishing M/c
13	Painting	Deep Painting Tank

Table 3.4: *Craw Bar process flow*

4. Craw bar 1.5m D 32

	Craw bar	Work stations
1	Cutting	PMS 160
2	Heating	PRKSS 0.8
3	Forging side 1 (Hexagonal making)	MPM 500
4	Heating	PRKSS 0.8
5	Forging side 2 (Hexagonal making)	MPM 500
6	Trimming side	PMS 160
7	Heating	PRKSS 0.8
8	Straightening side 1	MS 250
9	Heating	PRKSS 0.8
10	Straightening side 2	MS 250
11	Heat treatment	PRK-40/60
12	Grinding	SZD 400
13	Heat treatment	PEH-2B

Table 3.5: *Garden Hoe process flow*

5. Garden hoe / 2 finger

	Garden Hoe		Work stations
1	Hoe plate	Cutting to width	Gullitine shear
2		Trimming	PMS 63
3		Heating	PRKSS
4		Forming	PMS 63
5	Eye	Cutting the tube to length	AS 460
6		Piercing	WS 15
7	Finger	Cutting to length	PMS 63
8		Bending	PMS 40B
9	Assembly	Weld the plate to the eye	Welding Machine
10		Weld the finger to the eye	Welding Machine
11		Grinding	SZD 400

Table 3.6: Shovels process flow

6. Shovel No. 5&2

	Shovels	Work stations
1	Cutting Strip	Gullitine shear
2	Blanking	PMS 160
3	Piercing	PMS 40B
4	Heating	PRKSS
5	Shaping	Screw press F 1232
6	Curling	Drop belt hammer
7	Tumbling	Tumbling machine
8	Painting	Deep Painting Tank

Table 3.7: Spade Harar process flow

7. Spade Harar (Big)

	Spade Harer		Work stations
1	Spade	Cutting strip	Gullitine shear
2		Cutting to size	Gullitine shear
3		Piercing	PMS 40B
4		Shaping	F 1232
5	Sleeve	Cutting to strips	Gullitine shear
6		Cutting to size	PMS 63
7		Piercing	PMS 40B
8		Shaping	PMS 40B
9	Riveting	Rivet Forming	V 23
10	Assembly	Riveting sleeve with spade	PMS 100 EA

Table 3.8: Door Bolt process flow

8. Door bolt (140mm)

	Door bolt		Work stations
1	Base Plate	Cutting plate	Gullitine Shear
2		Piercing & Cutting	PMS-63
3		Forming Spring/Embossing	PMS-63
4	Bolt	Cutting and piercing	PMS-63
5		Bending	PMS-63
6		Upsetting	PMS-63
7		Rumbling	OB-750

8	Eye	Strip cutting	Gullitine Shear
9		Cutting And Piercing	PMS-40
10		Rumbling	OB-750
11	Guide	Slitting Raw Material	Gullitine Shear
12		Blanking	PMS-63
13		Bending	PMS-63
14		Tumbling	OB-750
15	Lock	Cutting to strips	Gullitine Shear
16		Cutting in to pieces	PMS 63
17		Bending	PMS 40 B
18	Assembly	Guide In To Plate	Riveting Machine
19		Eye And Bolt	Riveting Machine

Table 3.9: Racke process flow

9. Racke 10 finger

	Racke 10 finger	Work stations	
1	Support Strip	Cutting	PMS 63
2		Piercing	PMS 63
3		Trimming	PMS 63
4		Bending	PMS 63
5	Handle Neck	Cutting sheet metal	NU-13
6		Blanking	PMS 100
7		Piercing-1	PMS 100
8		Piercing-2	PMS 100
9		Heating	PRKSS
10		Curling	Drop belt hammer
11	Riveting	Rivet forming	V-23
12	Assembly	Welding	Welding Machine
13		Bending into form	PMS 63

Table 3.10: Sickle process flow

10. Sickle

	Sickle	Work stations
1	Sickle Blade	Cutting
2		Helve trimming
3		Notching
4		Straightening
5		Bending the bow
6		Blade tip trimming
7		Hardening
8		Tempering
9		Finish Grinding
10		Brush notching
11		Polishing
12		Grinding the helve
14	Handle	Cutting
15		Center Forming
16		Turning
17		Drill center
18		Drill to diameter
19		Drilling die & Grooving
20	Ferrule	Cut to strip
21		Drawing
22		Piercing

All products, except for sickle, are produced in the tools manufacturing factory of KTMF. In this factory, including the raw material store, there are seven main sections that participate in the production process. These are the forging section, heat treatment section, machining section, grinding section, painting section, welding section and the raw material store. The current layout of these sections with their machines arrangement is shown on the current layout of the tool manufacturing factory. The other factory i.e. the sickle manufacturing factory is dedicated for the production of sickles. It has been in operation for more than 24 years now. The arrangement of its machines and rooms is also shown below. The machine list for both tools and sickle manufacturing factories is also given.

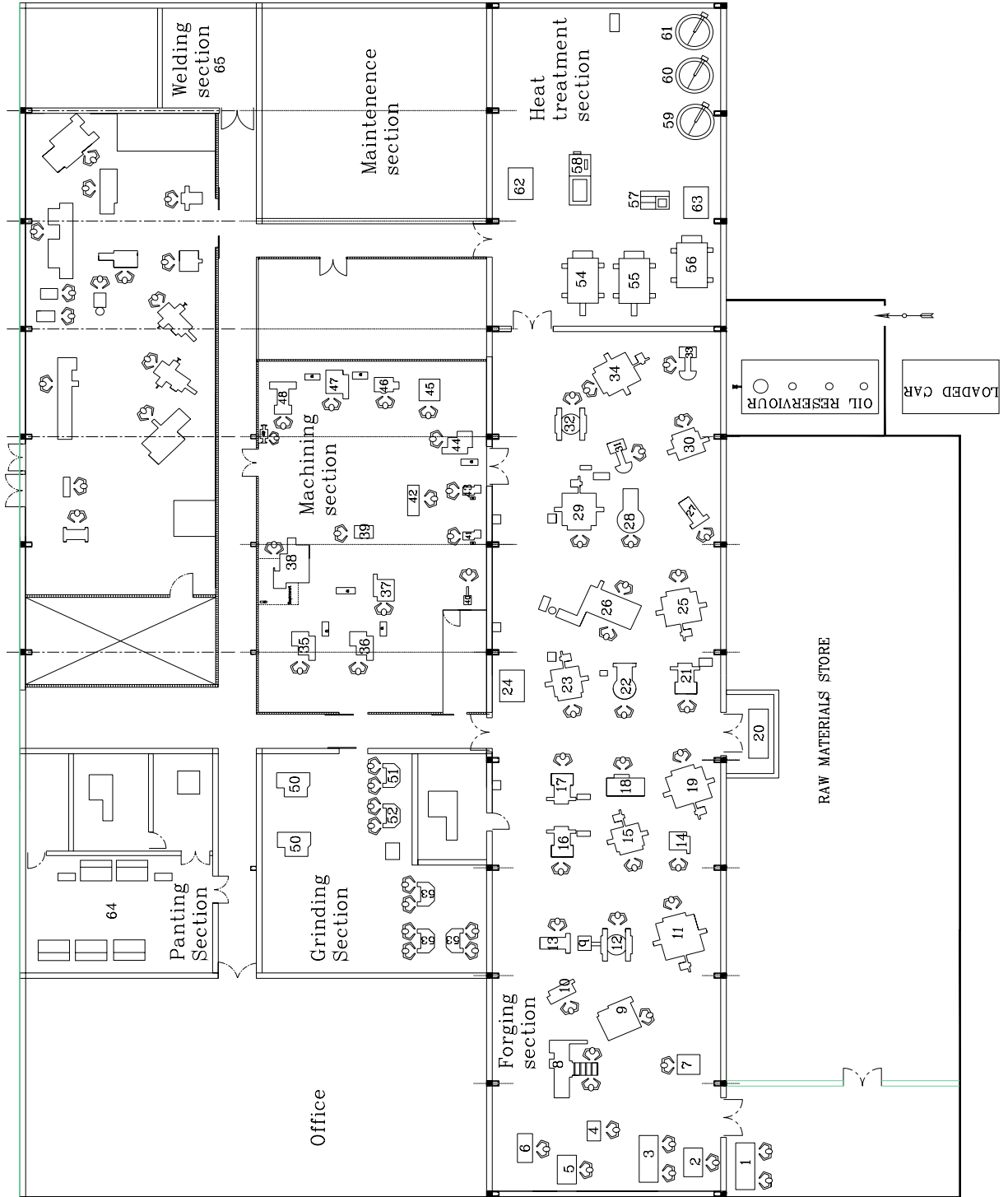


Figure 3.1: Actual layout of tools manufacturing factory of KMTF

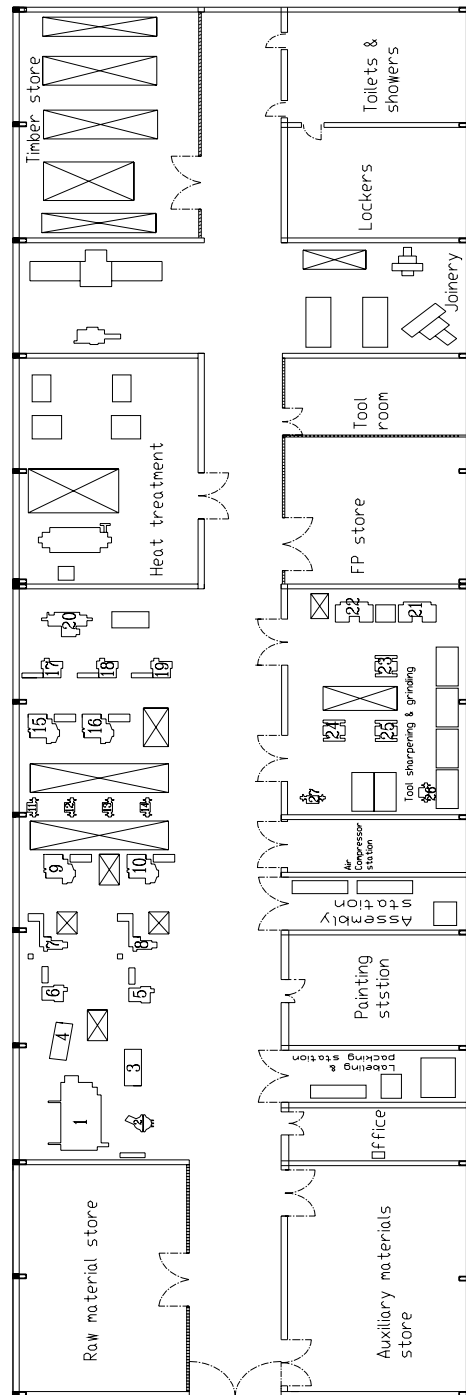


Figure 3.2: Actual layout of Sickle manufacturing factory of KMTF

3.2. Analysis of Sections Interrelationship

The 12 products selected are produced using the processes given in the previous tables and utilizing the different machines found in the seven sections. The flow of products through the different machines is given in the annex part of this paper. The quantity of these 12 products produced in the years 1999EC, 2000 E.C (of 12 months) and 2001 E.C. (of 9 months) is given below. This data is the actual performance of the factory in the mentioned years.

Table 3.11: Production performance of three years and average monthly production

No	Products	Production of 2001 E.C. (for 9 months)	Production of 2000 E.C. (for 12 months)	Production of 1999 E.C. (for 12 months)	Average Production per month
1	Hammer 6kg	171	257	3983	1106
2	Hammer 3kg	123	158	26	319
3	Stone hammer 1.5 kg	141	182	150	275
4	pick axe 2 kg	1726	2589	26955	3532
5	Axe Congo 4&3 lb	4384	13521	16906	3036
6	crow bar 1.5mtØ 32	205	230	-	551
7	Garden Hoe 2 finger	623	935	3433	725
8	Shovel No. 2 & 5	51370	77055	37592	10460
9	Spade Harrar	22806	34209	65950	8131
10	Door Bolt 140 mm	58147	87221	96822	29893
11	Rake 10 Finger	5784	8676	6744	1367
12	Sickle No.3	34513	51770	101490	20695

According to the process flow of the products the seven sections have various interactions between them. Different products make different travels to the sections. Based on the

production of the products, from-to chart showing flow of parts for the current layout is drawn. In doing so the flow of the material is seen from movement between sections point of view and not movement between each machine. The back and forth movement of parts between departments is analyzed and then the quantity of material that flows between the sections is noted to make from-to chart of the sections. This chart is shown below.

Table 3.12: From-To chart between different sections

	RM store	Forging	Machining	Grinding	Heat treatment	Painting	Welding
RM store		157,205	10,948				
Forging			235,094	3,036	5,783	10,460	
Machining		98,535				10,223	2,175
Grinding					551	4,736	
H. treatment				5,783			
Painting							
welding			725				

The figures in the above table show the number of parts of all products together that are transported between the sections. Based on the quantity of transported material between sections taken from-to chart, the activity relationship analysis is made. It is built by considering the quantity of material transported between any two sections. For the analysis the closeness ratings (A, E, I, O, U and X) are assigned for the relation between the seven sections. The activity relationship chart is then drawn by giving A rating for high material flow and U for least or no material flow between sections. For example forging and machining sections are known to have high volume of products being transported between them (sum of 333,629). Thus the highest ranking (A) is given for their relation. Other interdepartmental relationships having less material flow between them are given U rating signifying there is undesirable closeness necessity. The range of material flow intensity and the assigned rating given to the range is described in the table below. Following the same procedure for all sections the activity relationship chart is drawn and is shown below.

Table 3.13: Rating range considered for activity relationship diagram

	Range of Rating	Given Rating
1	>300,000	A
2	300,000-150,000	E
3	150,000-10,000	I
4	10,000-500	O
5	<500	U

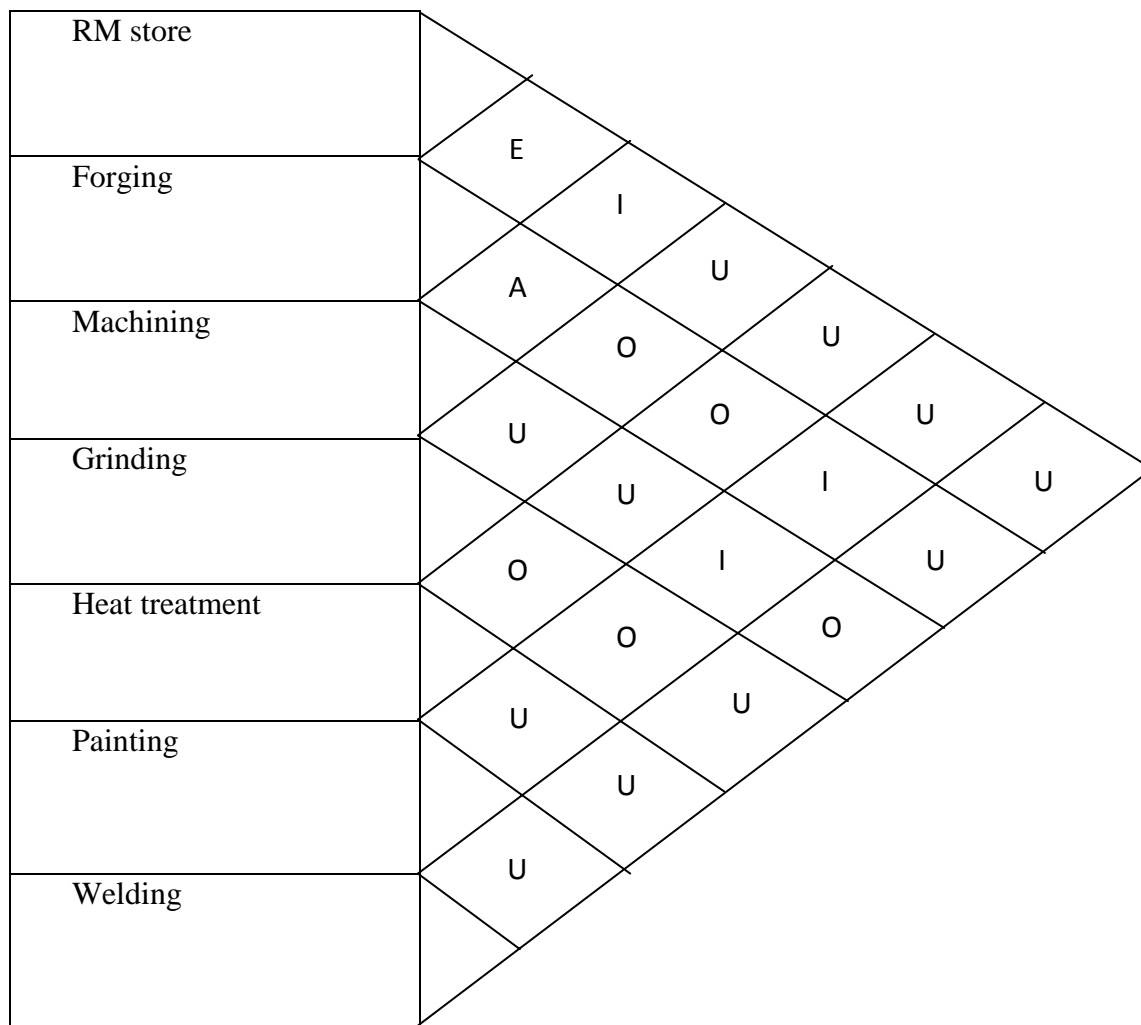


Figure 3.3: Activity relationship chart

All ratings have been included in the activity relationship chart to have a fair distribution of the ratings. One rule of thumb to follow in assigning the ratings is to have all the values in the chart. A and E ratings should have low percentage than the others (around 5%) and U rating should have more than 50% of the rating given. The percentage of each rating in the activity relationship chart is given with the table below.

Table 3.14: Rating percentage in activity relationship chart

Rating	Available number in chart	Percentage
A	1	5%
E	1	5%
I	3	14%
O	5	24%
U	11	52%
Total	21	100%

Based on the activity relationship chart shown above activity relationship diagram has been drawn. This diagram clearly shows the closeness necessity between different sections. From the above information and diagram below we can see that forging section and machining section has high closeness rating. They are given A rating and are close to one another in the current layout. High volume of material that is transported between these sections will not be required to travel long distance. The same is true for raw material and forging sections. They are placed near to each other while having an E rating.

On the other hand the high volume of material transported between forging and painting department is required to travel long distance. The same is true for material transported between heat treatment sections and grinding section. Materials transported between grinding and painting as well as between forging and heat treatment, on the other hand, are small in quantity but these departments are placed close to each other. One of the problems stated at the beginning of this study is long distance travelled by parts to be processed after finishing one operation. In the current layout of KMTF sections having high quantity of material being transported between them are placed far from each other and sections with less closeness

necessity are close to each other. This becomes one initiator for layout rearrangement in KMTF.

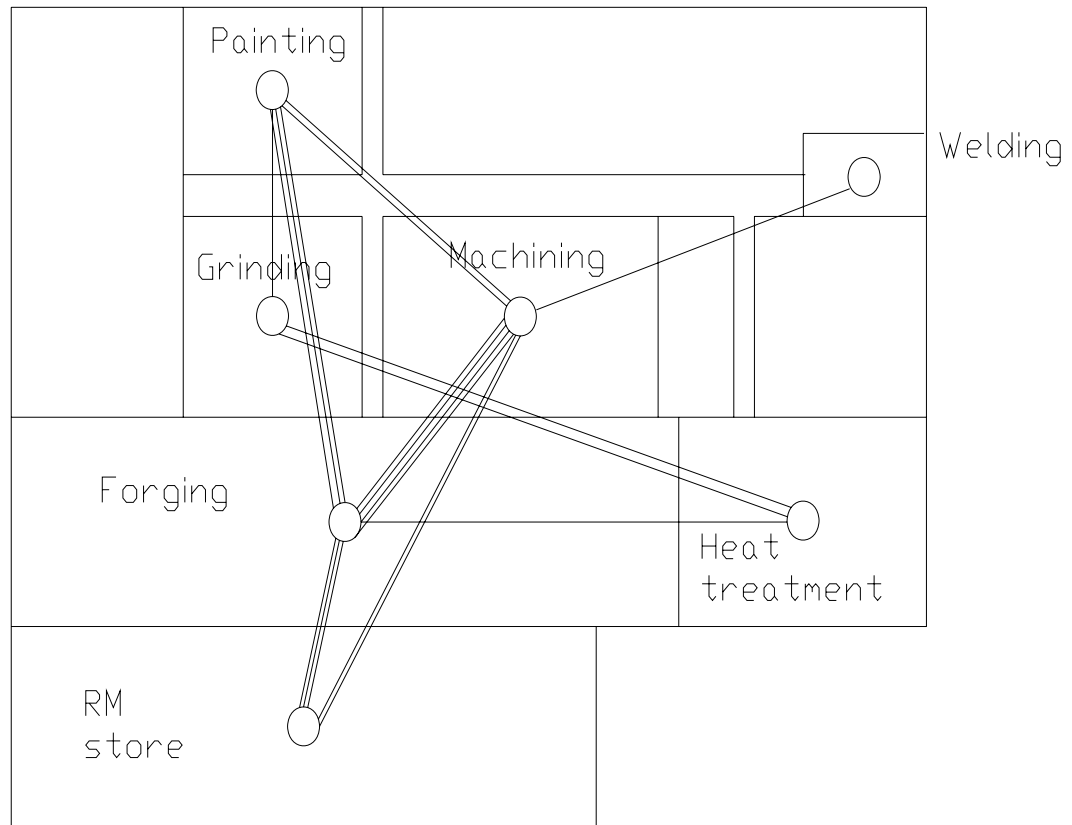


Figure 3.4: Activity Relationship Diagram

Furthermore wasting the factory's time and resource in transporting high volume of materials through long distances, the planned production volume as well as profit could not be attained. Designing a better layout for KMTF manufacturing shop floor is thus reasonable and mandatory. The flow intensity of the seven sections is shown in the figure 3.5 below.

The analysis made up to now is in the macro level (sections interrelationships). In the next section we will see the analysis in the micro level (machine interrelationship). Using the flow between different machines by the 12 products given in the annex B, the flow intensity and other parameters are analyzed.

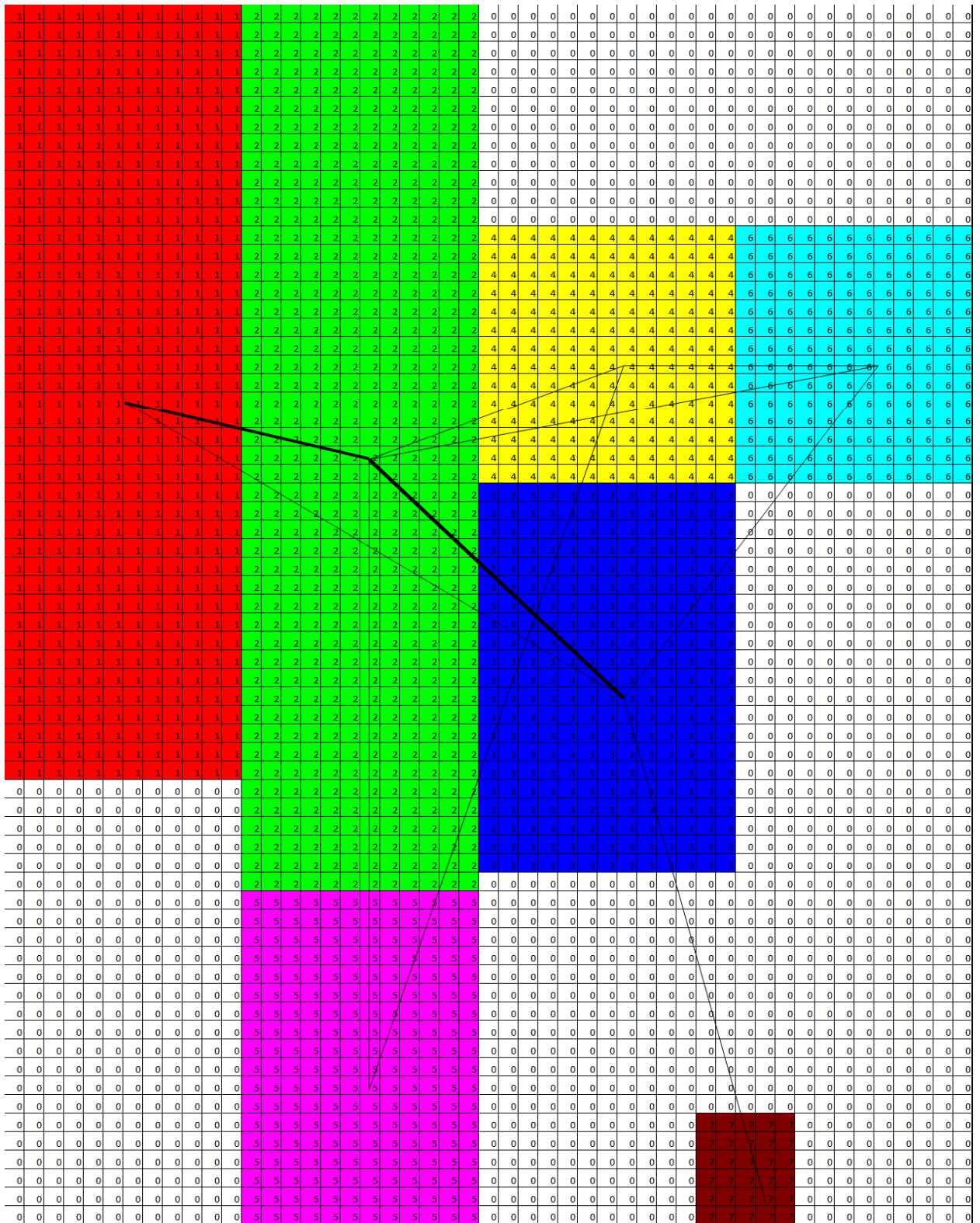


Figure 3.5: Flow intensity between sections in tools manufacturing factory

3.3. Analysis of Machines interrelationship

After analyzing the different sections relationship and the flow of the products between the sections, the individual machines interrelationship is analyzed. For this purpose flow of parts through each machine (given in the annex section) is analyzed to obtain from-to chart of the machines.

To analyze the flow between the machines the factory floor is divided into cells of 1m^2 each. The tools factory is 37meters wide and 66meters long. Therefore the factory has 2442 m^2 area. The relative location of each machines on the cells divided is assigned. This is done using an Excel Add-in which uses as input the facility dimension, number of departments (machines in our case), name and size of each department, location or centroid of each department, flow matrix and cost matrix of the departments.

After inputting these parameters the flow intensity between the machines is obtained. This flow intensity diagram shows the flow magnitude of parts between the different machines. It includes both the forward as well as the backward flow of parts. The thick line identifies high flow intensity and thin line shows lower intensity of flow. This flow diagram is shown below.

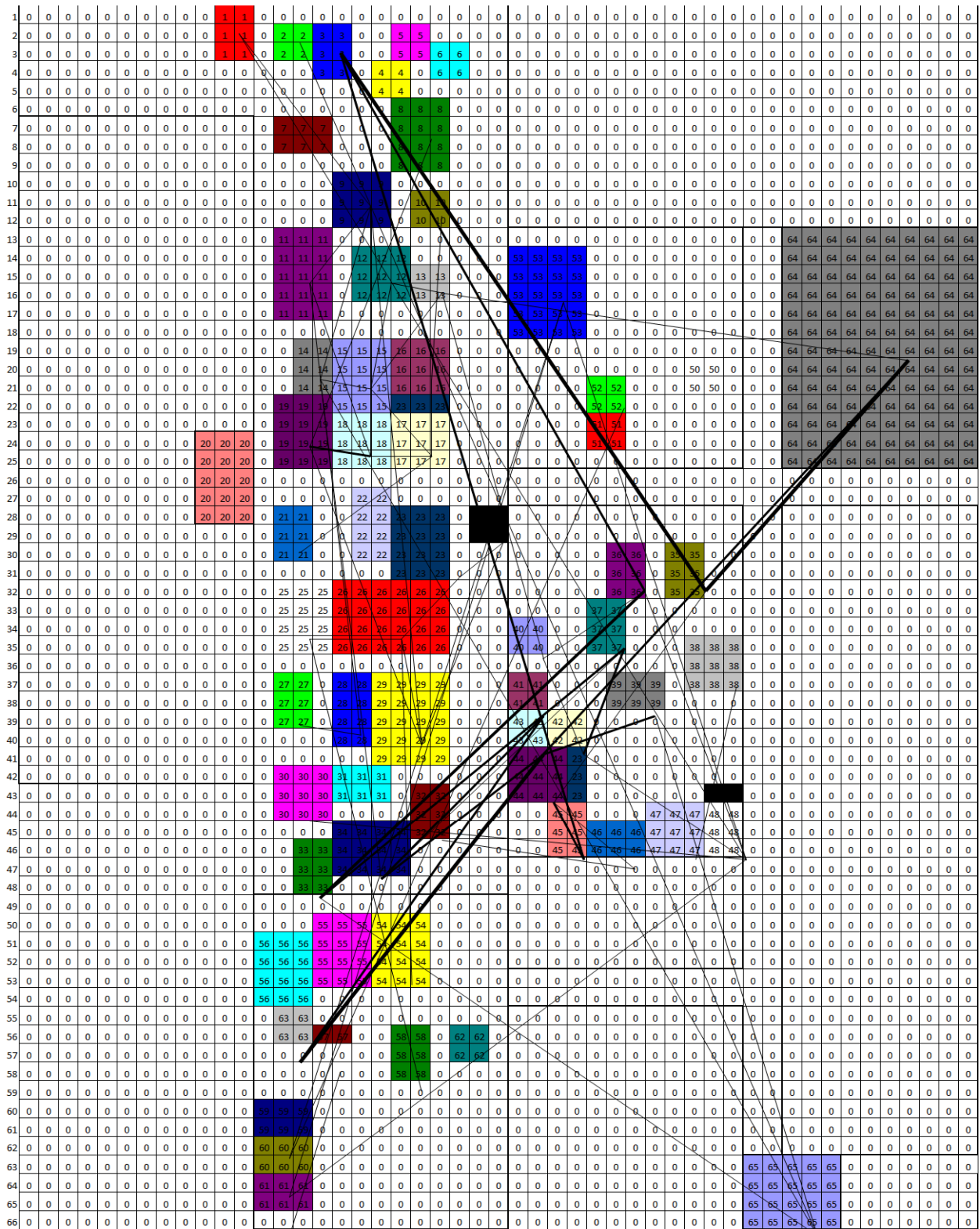


Figure 3.6: Flow intensity between machines of tools manufacturing factory

In the above layout of the tools manufacturing factory, we can see that there is high intensity of material flow between different sections. For example:

Between machine 3 and 35 the amount of material flow is 14654 parts per month

Between machine 35 and 64 (painting) the amount of material flow is 14654 parts per month and

Between machine 63 and 43 the amount of material flow is 14654 parts per month

Even though these machines have high intensity of material flow, they are located far from one another as shown in the figure. There is also high movement of material with lower intensity than the previously mentioned machines but which are significant enough to be improved.

When we see flow intensity diagram of the sickle factory, there exists a back-and-forth movement of the parts frequently between different machines of the factory. The factory is dedicated to production of sickles. The handle of the sickle use to be produced in the factory. But due to lack of quality of the wood the sickle produced in KMTF could not compete with imported sickles. The management then decided to import the handle and ferrule from foreign countries. This has increases the competitiveness of the product significantly.

For a factory that produces only one type of product, like the sickle factory, the layout should permit the smooth and straight flow of parts. In the flow intensity diagram shown below one can clearly observe that there is returning back of products to get processed. Example of such flow include flow from machine no 15 (bow bending process) to 4 (straightened). This back and forth movement is a waste of energy and time while being more exhaustive for the workers involved.

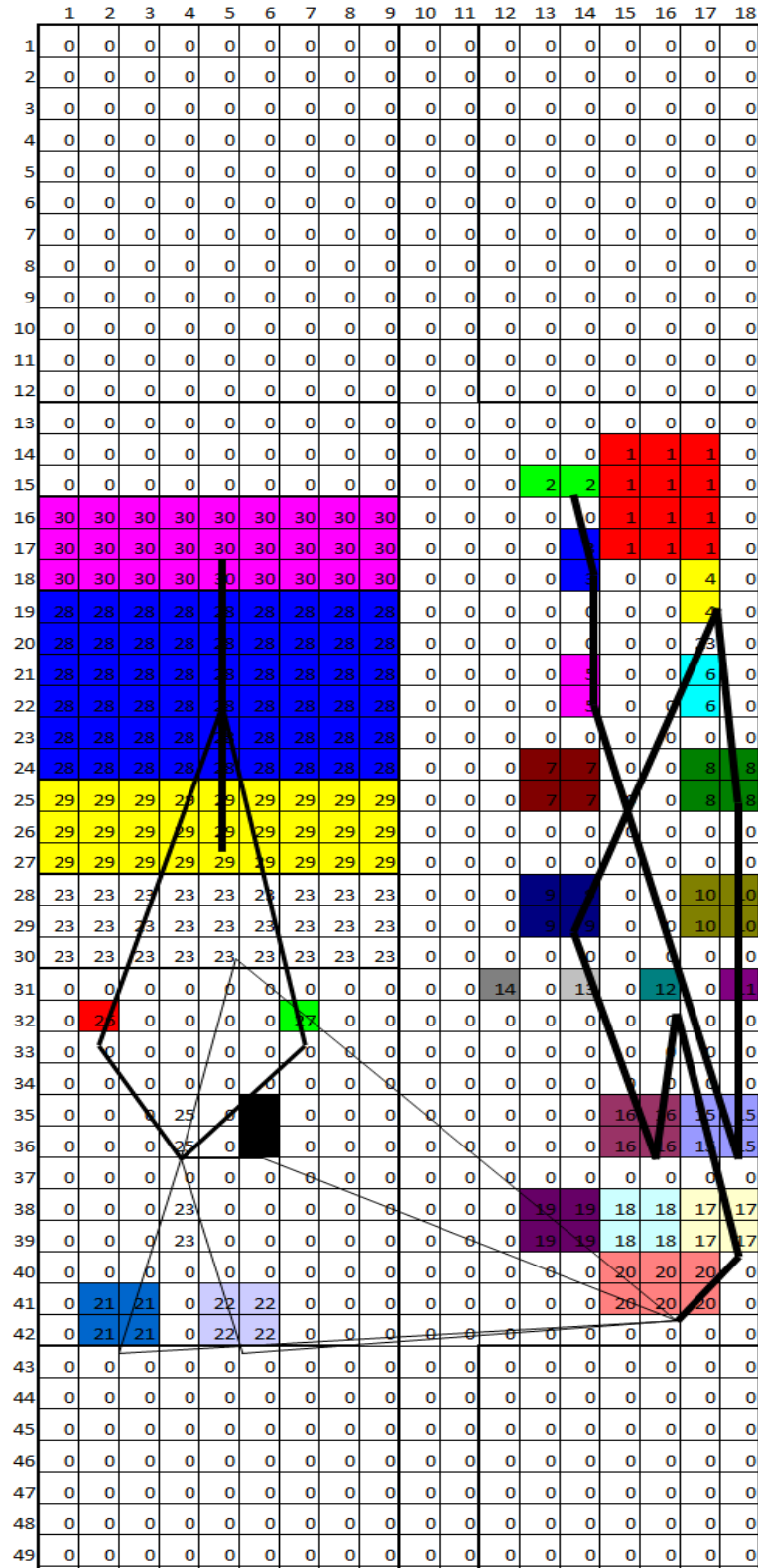


Figure 3.7: Flow intensity between machines of sickle manufacturing factory

To summarize the problems observed

- ✓ Long distanced traveled by high volume of material in the tools manufacturing factory
- ✓ Back and forth movement of sickle parts while the factory is producing only one type of product i.e. sickle
- ✓ Workers fatigue in transporting the parts through the long distances in the tools manufacturing factory and back and forth in the sickle factory.
- ✓ The factory's resources are being utilized for unnecessary material handling of these parts which is making it less profitable

4. CHAPTER FOUR: COMPUTERIZED ALGORITHM APPLICATION

In the previous chapter, to understand the problem areas of the factory, data has been collected and analyzed from different departments. The current actual layout is drawn for both tools and sickle factory. The production process of 12 selected products of the company is also tabulated to analyze the flow of parts in the factory. The performance of the current layout in quantity of product for the last three years produced has been collected from planning department. The sections interrelationship due to material flow has been analyzed and problem areas are clearly stated. The relationship between different machines is also analyzed.

In general, long distance of material travel and unnecessary back and forth movements of parts are some of the major problems identified in the previous chapter. Other inefficiencies like fatigue for workers and reduced profitability of the company are some of the problems that are also observed. In this chapter we will apply improvement routine type of computerized algorithms i.e. Computerized Relative Allocation of Facilities Technique (CRAFT) to improve the current layout.

As mentioned in the literature review summary section, the solution obtained by CRAFT depends on the starting (initial) layout used. Construction routines provide layout that is built from blank. This layout is sub optimal and does not grantee its optimality but is still a good layout. In this chapter, thus construction routine followed by improvement routine will be used to show that use of the two routines together can be more productive than pure construction or pure improvement routines.

To show this, the solution obtained by applying CRAFT using the current actual layout of KTMF as initial layout will be compared with a layout that is constructed by construction algorithms and then by improvement routine (CRAFT). The effectiveness of the two routines when used together will be shown.

4.1.Improvement routine (CRAFT) in KMTF layout

4.1.1. Section wise exchange

Section wise flow intensity of the tools manufacturing has been shown previously in chapter three. By exchanging sections that are either equal sized or adjacent to one another, the total material handling cost will be evaluated. And if improvement is attained, then the exchange is kept and this process continues until no further exchange, that will decrease the cost, is available. For this purpose a Microsoft Excel Add-in that is provided by Paul A. Jensen, which utilizes CRAFT algorithm is used. The program accepts different inputs from the user like facility length and width, number of departments available, area of each department, from-to matrix and cost matrix. We will discuss each step in detail.

The first page that displays when new layout from the add-in is selected is shown below. This dialog box requires the user to input the facility name and number of departments that are available. In our case the name of the facility for the tools manufacturing factory is set as “Toolsfactory”. The number of departments is set at 7 and the distance measure is made in meters.

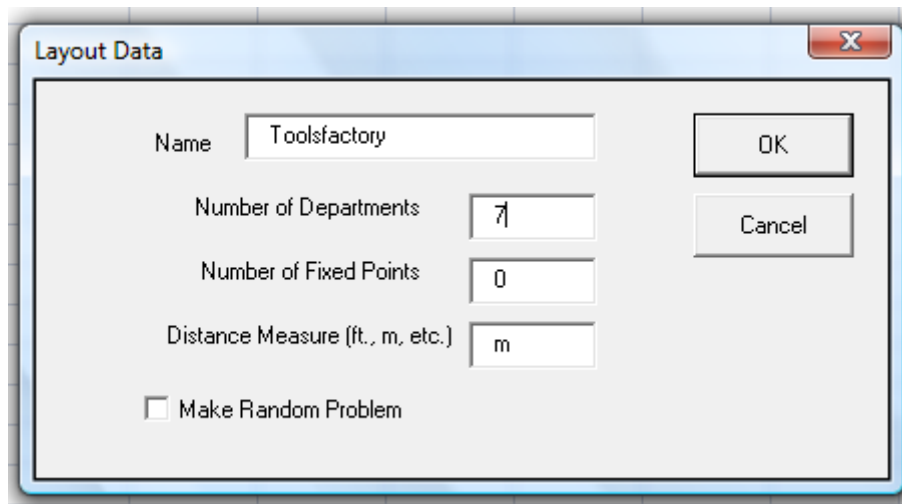


Figure 4.1: Layout Data Entering Dialogue

Pressing OK button results in a spreadsheet that allows the user to fill further information. The window that requests the facility information (width and length of facility) is shown below.

Scale-m/unit	1	Cells
Length-m	66	66
Width-m	49	49
Area-sq.m	3234	3234

Figure 4.2: Facility Information Entering Box

In the above table the facility length and width in the specified distance measuring scale would be fed. For the tools manufacturing factory the length of the facility is 66 meters and its width 49 meters. Here the area next to the raw material store where oil reservoir is placed and an open area for truck maneuvering area are also included in the facility area. This area will not be used to place facilities but is included for convenience because the program accepts a facility that is rectangular shape.

When putting the data in to the table the program automatically calculates cells with the scale-meter per unit as specified by the user. In this case it is set to indicate one unit cell represents one meter by one meter area (1 meter square). The program also calculates the total area of the facility and in this case it has been calculated as 3234 m². Following the facility information table departmental information table is filled with the required data.

	Name	F/V	Area	Cells
Dept. 1	RM	V	504	504
Dept. 2	Forging	V	624	624
Dept. 3	Machining	V	273	273
Dept. 4	Grinding	V	162	162
Dept. 5	H. treatment	V	234	234
Dept. 6	Painting	V	143	143
Dept. 7	Welding	V	24	24

Figure 4.3: Department Information Entering Box

This table is used to insert the name of the departments with their respective area requirements. There is also a column where the departments being fixed or variable in location option provided. If the variable option is selected the program will change the location of that section in the optimization process. If the fixed option is selected the location of that section will not be changed in the optimization process. Below this table the flow matrix is available.

FROM	TO						
	RM	Forging	Machining	Grinding	H. treatment	Painting	Welding
RM		793	56				
Forging			1,181	16	31	53	
Machining		495				52	12
Grinding					3	26	
H. treatment				31			
Painting							
Welding			4				

Figure 4.4: Flow Matrix Entering Table

This table describes the amount of material that has been transported from one station to the other using containers. Using the production process given in chapter three and in the annex part of this paper the flow of each product between different sections is summed up to give the total material flow between any two sections. Materials are transported in bar from raw material and using containers in other sections. Transported material varies in number. An average of 200 parts per container is being transported per container. The backward movement of parts is shown at the lower part of the table (from machining to forging, from heat treatment to grinding and from welding to machining). Next to the flow matrix the last part of this spreadsheet displays the cost matrix. In this table the cost matrix is needed to be filled.

The material transported from the raw material store to forging section and within forging section utilizes an overhead crane. The operation cost of this overhead crane as estimated by the engineering department of KMTF is obtained from the department and is 0.00008birr/sec and also the worker who operates the overhead Crain is level one. To obtain the transportation cost between the seven sections by the use of the two means of transportation are used. Distance from one section to another is assumed to follow the actual travel path and the speed of transportation is also assumed to be two meter per second. The cost matrix is thus filled using the combination of the two transportation means.

In the upper portion of the spreadsheet the data that has been filled (name of the facility, number of departments and measuring scale) are displayed. Now that all the data required is filled the button next to the layout data “Define facility” should be pressed.

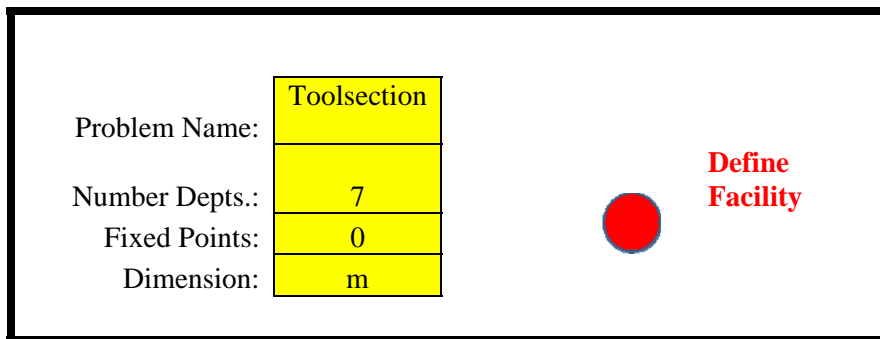


Figure 4.6: Layout Data Display

Pressing this button initiates the program to display the next dialog box that provides different processing options. The first option provided is the solution method having two options: opt. sequence and traditional CRAFT methods. The first, i.e. opt. sequence, will place the departments in the layout automatically. The second option uses the CRAFT method of improving an initial layout. For our tools factory, since there is no specific sequence of inter departmental flow exists, we will use the traditional CRAFT method and is thus selected for the solution method option. As discussed in earlier chapters CRAFT utilized pair wise departmental exchange of sections. For the exchange to be made the departments must have either same area requirement or must have common boundary.

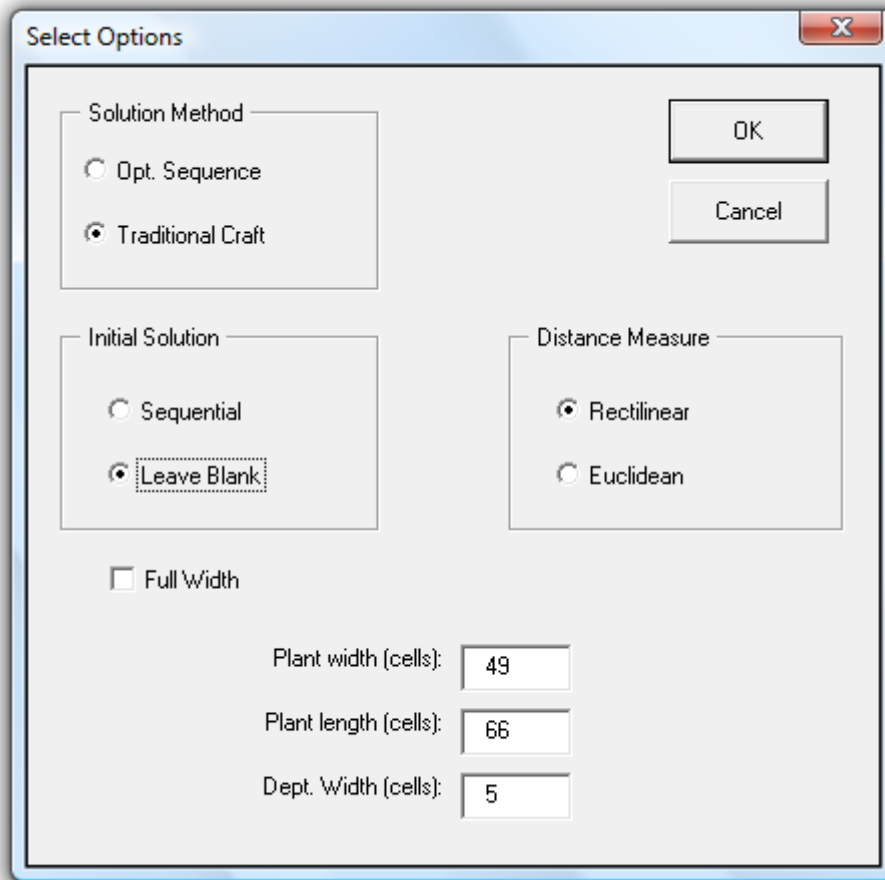


Figure 4.7: Analysis Type and Means of Analysis Entering Dialogue Box

The next option provided is the initial solution that will be input to the program. Here there are two options: sequential and leave blank options. The sequential option places the departments according to the sequence of departments provided by the user or set by default in the program. The leave blank option crates empty or blank cells on which the user can define the position of each department. An initial layout is constructed by placing numbers or colors on the blank layout. For this case we will place the departments by giving the designated number for each cell. This will allow areas that are not accessible for placing the sections to be restricted. The trucks maneuvering area and office area of the tools manufacturing factory will be restricted. Thus, the leave blank option for initial solution is selected.

The distance measure option has two options: Rectilinear and Euclidean methods. The Rectilinear measure takes the horizontal and vertical distance between centroid of two sections while the Euclidean measure calculates the straight distance between the two section centroids. In the last portion of the dialog box the user is prompted to verify the plant's dimensions (width and length) and department width. This is used while the opt. sequential solution method is selected. When the opt. sequential method is selected the departments are placed with the sequence provided and with the width set in this option. Since the case taken is traditional CRAFT, this option will not be used. Thus, it is left as the default value 5.

Once all the required data is filled, the 'OK' button is pressed prompting to define the department locations by numbering or coloring the cells with the assigned number or color. At the top of this spreadsheet the facility layout information filled so far is summarized. The information include the problem name (Toolsfactory in this case), number, dimension and area of the facility, the cost associated with the initial layout (which will have value at later stage) the method used etc. Below the summary data the departmental information is displayed.

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
RM	1	504	504	6	21	1
Forging	2	624	634	26.7523651	22.7381706	2
Machining	3	273	273	18.0274734	27.2106228	3
Grinding	4	162	162	17.8580246	45.3271599	4
H. treatment	5	234	234	29.9743595	55.9188042	5
Painting	6	143	143	18.0384617	60.0384598	6
Welding	7	24	24	18	53.0833321	7

Figure 4.8: Department Color Assignment and Area Definition

Here, the sections, in the sequence they have been filled earlier are displayed. Each section has been given a distinct number and color that would represent the section. The area requirement of each section is also given in the 'area required' column. In the next four columns the program itself will calculate the area defined for each section in the initial

layout, the x and y-centroid of each section and the sequence of the sections for operation. The sequence column is used if the opt. sequential methods is selected and thus will not be used in this case.

The user is required to fill the blank cell layout generated by the program to suit the available area. Thus the number of each section is placed on the blank layout to represent the actual tools manufacturing factory layout of KMTF. Areas for trucks maneuvering, office and other unused areas are kept blank.

After filling the layout with the section numbers, the 'evaluate' button on the top of the spreadsheet is pressed. This initiates the program to give the designated coloring for each number (or the designated number for each color depending on the one used initially) and evaluate the cost of the initial layout. The program uses the load moved between each section (from the from-to chart) and the material handling cost matrix given previously to calculate the cost of the layout. The spreadsheet that results from the above sequence of operations is shown in the figure below.

The cost of this initial layout as calculated as:

$$Z = \sum_{i=1}^m \sum_{j=1}^m x_{ij} c_{ij} d_{ij}$$

Where m - is the number of departments in the layout

d_{ij} - is the distance from section i to section j

c_{ij} - is the cost of transporting load one distance unit from section i to section j

x_{ij} - the amount of load moved from section i to section j

Z - Total movement cost per time period (the objective function value)

One limitation of this approach is that the distance traveled is calculated by the rectilinear distance calculation method. This means material transported is assumed to follow the X and Y coordinate distances between the centroids of the two sections under consideration. The actual distance traveled is more than the rectilinear distance between the sections.

Using this formula the cost of the initial layout is automatically calculated by the program which is 4,886 birr per month. If there are sections that are given lower number of cells than the area requirement in number of cell given in the previous tables, the program notifies the user to correct the mistake. If all the area requirement and area given are acceptable, the program is ready to optimize the layout. Pressing the ‘solve’ button initiates the program to start optimizing and the dialog box shown below comes.

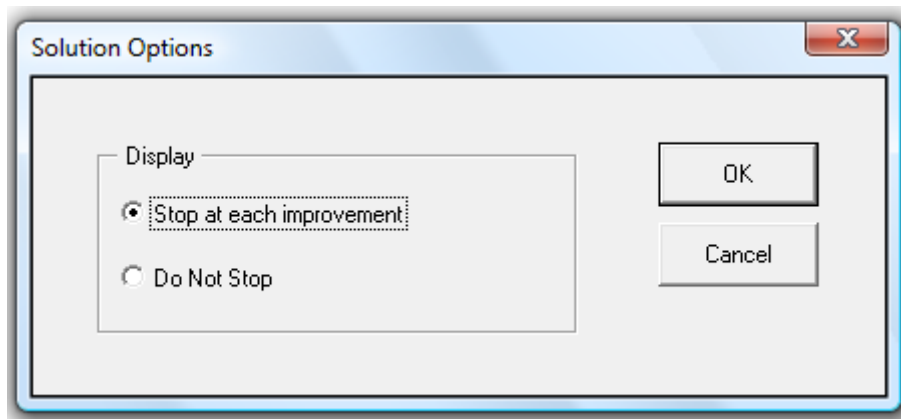


Figure 4.10: Solution Display Options

The program, while performing the optimization, can stop at each exchange of sections or continue the optimization until the final exchange is made where no exchange from that point on can bring any change. If the ‘Stop at each improvement’ option is selected, then the program asks the user to make the change prior to making the exchange. For this time the stop at each improvement is selected.

The program starts the optimization process and selects the best switch between departments that can bring highest saving in the layout cost. Prior to making the exchange the program asks the user if the change should be made by the dialog box shown below.

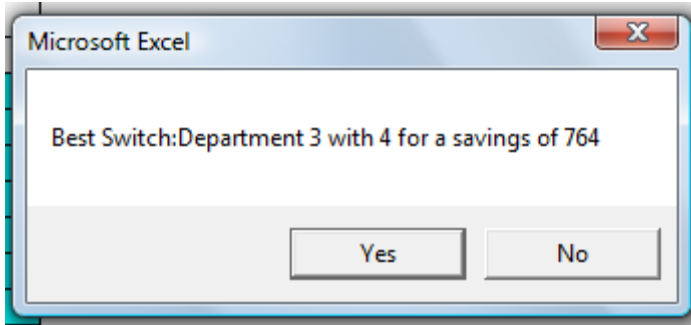


Figure 4.11: Best Switch Display

Here the program has selected to switch departments 3 (Machining) and 4 (grinding) because they have the same boundary. The saving that comes if the exchange is made is 764 birr. Pressing the yes button exchanges the two departments. The program automatically calculates the cost of the layout after exchanging the two sections. Now there is no more exchange that would result in material handling cost reduction. Thus the program displays the initial layout cost (4,886 birr per month) and the final layout cost as shown below.

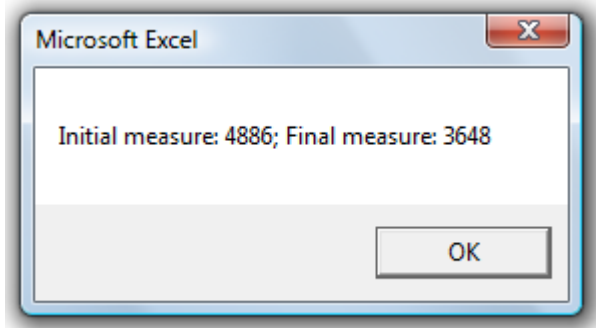


Figure 4.12: Layout Score Display

The program terminates after displaying the above dialog box. In case if the last exchange made increases the layout cost, the program notifies the user the exchange has increased the cost of the layout and stops prior to the exchange of these sections. In “Toolsfactory” case the number of iteration made by the program to arrive at the final solution is one. No further exchange would decrease the total cost. The number of iteration made and the final layout cost obtained is displayed by the program.

Init. Cost		2442			
			Iterations:	1	
Index	Init. Seq.	Iter.	Type	Action	Cost
1	1	1	Switch:	3 and 4	3648

Figure 4.13: Number of Iteration and Associated Cost Display

The solution obtained by the CRAFT method has improved the total material handling cost of tools factory by 1,238 birr per month. The final solution given produced irregular shape for the machining section. Thus, the planner needs to make some changes to have regular shapes for the section. Making those changes, again the layout is evaluated and the cost of the calculated to be 3,721 birr. It is clear that an improvement from the current layout has been achieved. The final improved layout is shown in the figure below.

4.1.2. Machines pair wise exchange

The solution obtained by interchanging the different section in tools manufacturing factory of KMTF is better than the current situation. Now let us improve it further by using detailed machine layout in the factory. The machines arrangement in the factory has been shown in the previous chapter. Using the same procedure we have employed for the sections pair wise exchange, we can improve the arrangement of the machines. All the machines found in tools manufacturing factory are 65 in number. This includes all the machines within the factory which are found in the sections mentioned earlier. The areas occupied by the machines in meter square and the number of cells given by the program are shown in the table below. Other information required like from-to chart and transportation cost matrix is also filled in their designated tables.

Table 4.1: Machines Area and Number of Cells Assigned

Name	Area	Cells	Name	Area	Cells	Name	Area	Cells
1	6	6	24	4	4	47	9	9
2	4	4	25	12	12	48	6	6
3	6	6	26	22	22	49	2	2
4	4	4	27	6	6	50	4	4
5	4	4	28	8	8	51	4	4
6	4	4	29	20	20	52	4	4
7	6	6	30	9	9	53	12	12
8	12	12	31	6	6	54	12	12
9	9	9	32	4	4	55	12	12
10	4	4	33	6	6	56	12	12
11	15	15	34	12	12	57	2	2
12	9	9	35	6	6	58	6	6
13	4	4	36	6	6	59	6	6
14	6	6	37	6	6	60	6	6
15	12	12	38	9	9	61	6	6
16	9	9	39	6	6	62	4	4
17	9	9	40	4	4	63	4	4
18	9	9	41	4	4	64	24	24
19	12	12	42	4	4	65	20	20
20	15	15	43	4	4			
21	6	6	44	9	9			
22	8	8	45	6	6			
23	12	12	46	6	6			

First the current arrangement of machines is evaluated. The actual arrangement of the machines is inserted into the program according to the number of cells given to each machine by the program and the designated location of each machine in the manufacturing floor. Here the raw material store is not included. Since the location of the raw material store has proven to be appropriate in section wise improvement, the location of the raw material store is kept as it is. The cost of the layout is evaluated and is found as 11,385birr per month. This layout will be used as an initial layout and improve it by CRAFT algorithm. After making 31 pair wise machines exchange a final solution has been obtained. The final solution reduced the layout cost to 6,405birr per month. The iterations made and the final attained layout of the machines is shown below.

Table 4.2: Iterations Performed for Machine Pair Wise Exchange

Iterations: 31

Iter.	Type	Action	Cost	Iter.	Type	Action	Cost
1	Switch:	33 and 39	10418	17	Switch:	29 and 65	6755
2	Switch:	7 and 35	9574	18	Switch:	14 and 46	6700
3	Switch:	14 and 45	8755	19	Switch:	39 and 46	6671
4	Switch:	41 and 63	8213	20	Switch:	12 and 39	6618
5	Switch:	12 and 44	7803	21	Switch:	21 and 46	6585
6	Switch:	39 and 48	7653	22	Switch:	12 and 38	6553
7	Switch:	13 and 24	7561	23	Switch:	42 and 63	6527
8	Switch:	15 and 23	7363	24	Switch:	39 and 63	6489
9	Switch:	52 and 62	7278	25	Switch:	38 and 21	6467
10	Switch:	41 and 52	7183	26	Switch:	19 and 23	6457
11	Switch:	34 and 32	7083	27	Switch:	19 and 18	6422
12	Switch:	33 and 37	7002	28	Switch:	24 and 51	6415
13	Switch:	53 and 56	6924	29	Switch:	46 and 48	6409
14	Switch:	25 and 54	6853	30	Switch:	53 and 52	6408
15	Switch:	31 and 46	6816	31	Switch:	7 and 21	6405
16	Switch:	31 and 39	6783				

The next step is to improve the layout obtained by exchanging the sections. The program is given the improved machine layout of section wise exchange as an initial layout of the problem. The currently being used one machine layout has total cost of 11,385 birr per month. When the layout improved by section wise exchange is evaluated, the cost reduced to 10,923 birr per month. Now we can start solving the problem to further improve it. The solving process is initiated and no stop is made between the exchanges.

After 22 switches are made the program has arrived at a final and improved solution. The cost 10,923 has been decreased to 6,293 birr per month. The switches made are shown below.

Table 4.3: Iterations Performed for Machine Pair Wise Exchange After Section Wise Improvement

Iterations: 22

Iter.	Type	Action	Cost	Iter.	Type	Action	Cost
1	Switch:	7 and 35	9861	12	Switch:	25 and 54	6739
2	Switch:	7 and 33	8709	13	Switch:	13 and 24	6679
3	Switch:	50 and 63	8002	14	Switch:	15 and 23	6507
4	Switch:	14 and 32	7754	15	Switch:	12 and 38	6443
5	Switch:	32 and 45	7466	16	Switch:	53 and 56	6403
6	Switch:	34 and 14	7330	17	Switch:	42 and 51	6371
7	Switch:	41 and 51	7192	18	Switch:	14 and 31	6346
8	Switch:	12 and 44	7062	19	Switch:	19 and 23	6336
9	Switch:	50 and 52	6970	20	Switch:	19 and 18	6301
10	Switch:	29 and 65	6887	21	Switch:	32 and 46	6294
11	Switch:	21 and 48	6809	22	Switch:	53 and 52	6293

It is clear that the solution obtained by solving the problem using section wise exchange then further improving the detailed machine layout rather than improving the current detailed layout directly by utilizing CRAFT algorithm is a preferred approach. The best detailed solution obtained so far is shown below.

4.1.3. Machines exchange in Sickle factory

When we look at the sickle factory, there is only one type of product being produced. The machines should be arranged so as to fit the products' process flow. The from-to chart for the machines in sickle factory is shown below. There are around 30 machines being used for the sickle production.

	TO																													
FROM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Painting	assembl	Packing
1																														
2			20695																											
3				20695																										
4								20695																						
5															20695															
6																														
7																														
8			20695																											
9																20695														
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19																														
20																						5174	5147	5174	5274					
21																										5174				
22																										5147				
23																										5174				
24																										5274				
25																											10348	10348		
26																												10348		
27																												10348		
Painting																														20695
assembly																														20695
Packing																														

Figure 4.17: From to Chart of Sickle Factory

With the current layout being used in the sickle factory, the cost is calculated and found to be 3,326 birr per month. Following the procedure used in the tools factory again for the sickle factory the layout has been improved as shown in the table below.

Table 4.4: Iterations Performed for Machines in Sickle Factory

Iterations:	11		
Iter.	Type	Action	Cost
1	Switch:	7 and 15	2802
2	Switch:	28 and 29	2716
3	Switch:	4 and 6	2566
4	Switch:	10 and 16	2416
5	Switch:	9 and 16	2366
6	Switch:	10 and 17	2316
7	Switch:	20 and 18	2258
8	Switch:	19 and 21	2210
9	Switch:	12 and 13	2185
10	Switch:	24 and 25	2167
11	Switch:	10 and 22	2158

The final improved layout is obtained on the eleventh iteration. The exchanges made and their savings are shown in the table above. The final layout has a cost of 2,158 birr with an improvement of 1,168 birr from the previous cost. Making the necessary adjustments the cost is further decreased to 2,084 birr. The actual arrangement of the machines is shown in drawings next to the program excel layout.

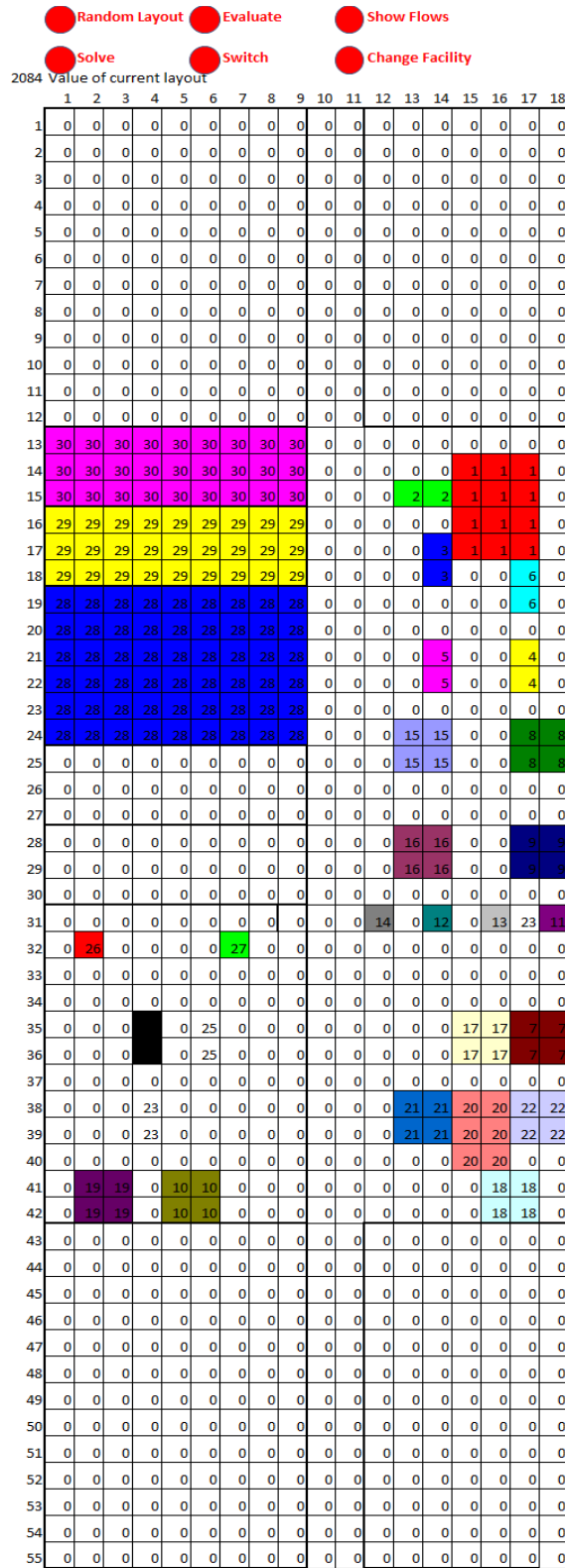


Figure 4.18: Improved Layout of Sickie Factory

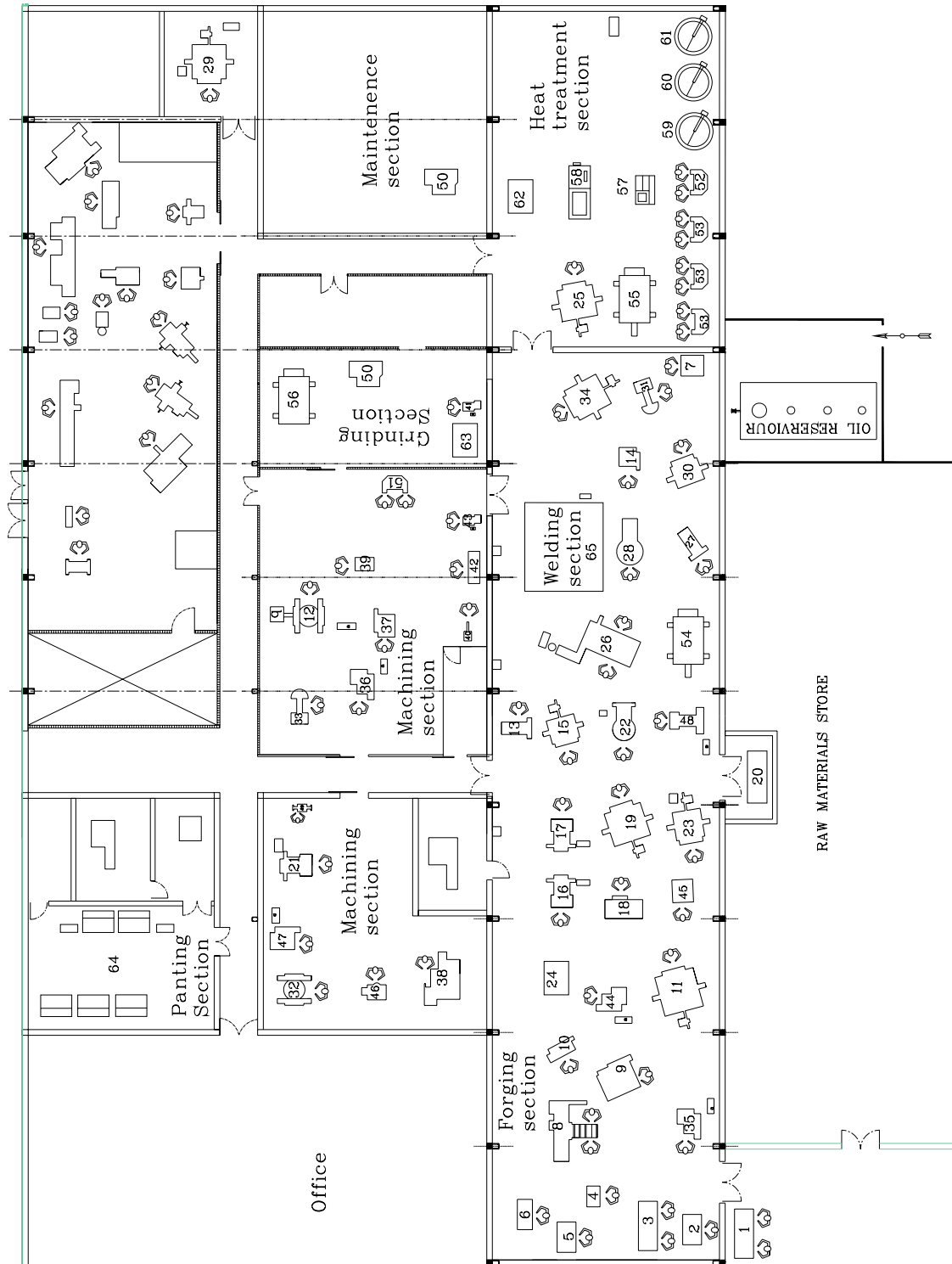


Figure 4.19: Improved Layout for Tools Manufacturing Factory

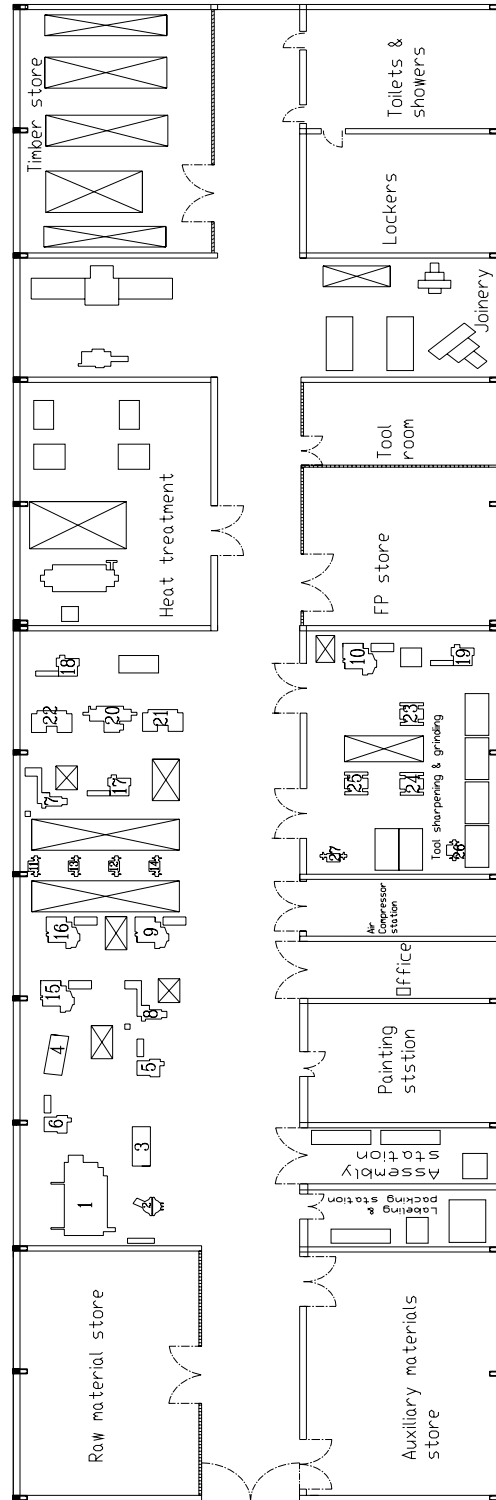


Figure 4.20: Improved Layout for Sickles Manufacturing Factory

4.2. Construction routine followed by Improvement routine in KMTF layout

In the previous section existing layout of KMTF has been improved using CRAFT algorithm. The improvements done were using section wise and individual machine. The improvement obtained has been progressing. First, section wise improvement brought some improvement then this layout has been improved by machine wise exchange. But all this improvement is dependent on the initial layout. Both initial layouts used i.e. section layout and machine layout, in the improvement procedure is the existing layout of KMTF. The question “Is the existing layout of KMTF good enough to bring about a near optimal final solution?” remains unanswered.

The layout obtained by the improvement routine is sub optimal, meaning it is not the final and optimal of all solutions. The same is true for the construction routine. If we construct the layout according to the construction routines or algorithm and then improve the constructed layout by improvement routines, the solution will be much closer to the optimal solution if not final itself.

For this purpose the construction routine is performed on the sections of tools manufacturing factory of KMTF. Here, the same data used for improvement purpose of the tools section is used again. CORELAP algorithm procedure, which has been described in the literature review section, has been followed to formulate the problem. The closeness ratings are given different numerical values. These values are 64 for A, 16 for E, 8 for I, 2 for O and 0 for U. By summing these values for the relationship diagram drawn previously for the seven section, the total closeness rating (TCR) for each section has been calculated. Each section has six relationships corresponding to the six other sections excluding it from the seven sections. The TCR of the sections and the rank for placing the sections in the new layout according to their TCR value is shown in the table below.

Table 4.5: TCR of Different Sections

Name	TCR	RANK
RM	24	3
Forging	92	1
Machining	82	2
Grinding	6	5
H. treatment	4	6
Painting	18	4
Welding	2	7

The section placed first on the layout is chosen by its TCR value and then it is placed at the center of the layout. The other sections are placed according to their relation rating given to them with the section already placed section. The section having the highest TCR value is the forging section. Therefore it is placed first and at the center of the layout. Next the section having A relation with forging section is machining section. Thus it is placed secondly adjacent to forging. Since there is only one A rating in the chart, we go for E rating. The one having rating E is between forging and raw material store, thus raw material store is third to be placed on the layout adjacent to forging. Similar procedure is followed to put the sections in the order required by the algorithm. Accordingly painting followed by grinding followed by heat treatment and lastly welding section is placed on to the layout.

The cost of the constructed layout depends on the location where the sections starting from the second department (machining) are placed. To avoid superficial judgments, different combinations of placements have been tried. The layout constructed is again improved using CRAFT algorithm as done previously on the existing layout. This also has been done on the same Excel Add-in used previously. The layout which comes to the lowest possible cost (4,817 birr) has been taken. Showing all the trials made would be pointless, thus the layout which brought the lowest cost (3,806 birr) is shown below.

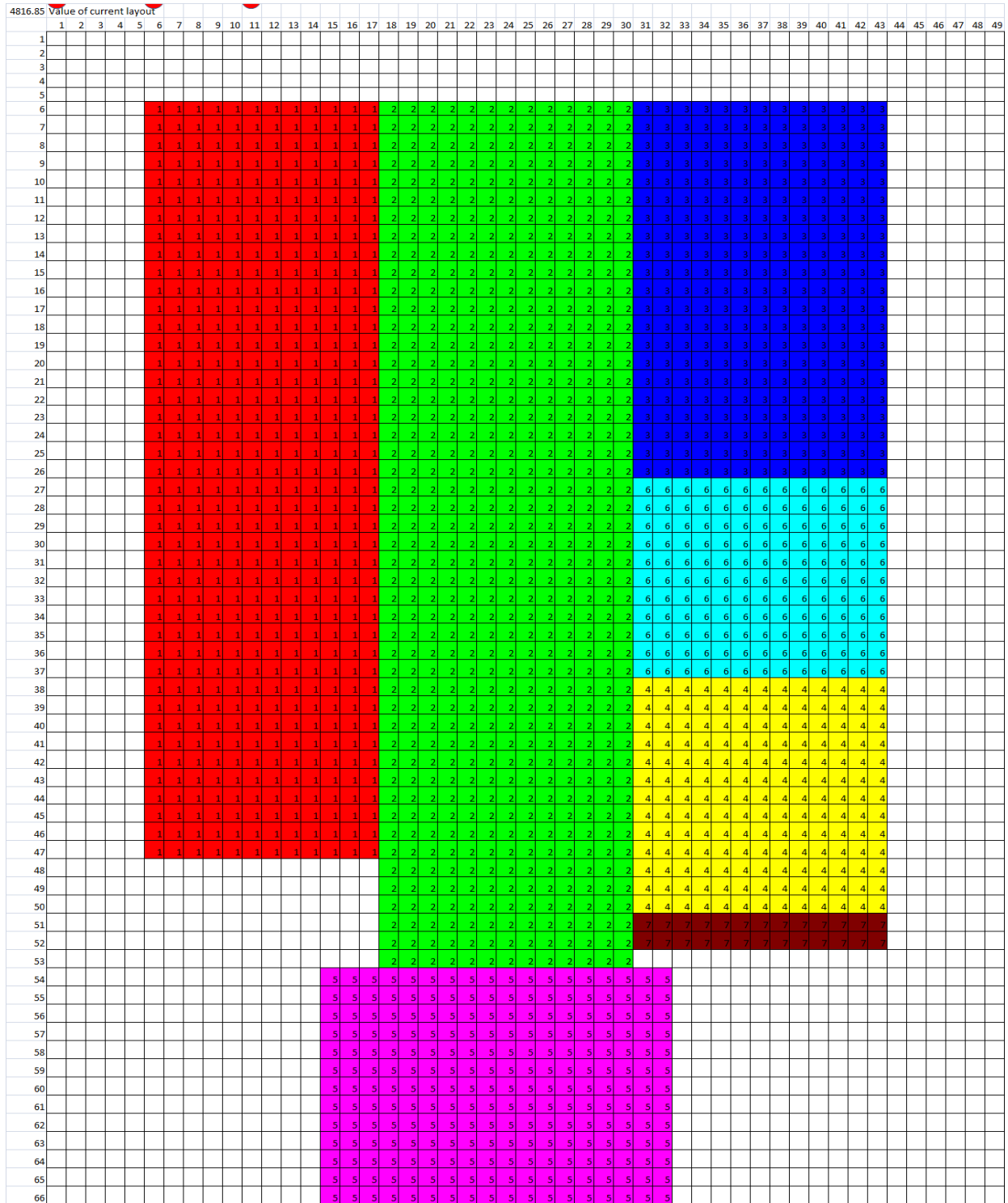


Figure 4.21: Constructed Layout of Tools Manufacturing Factory

The final solution is obtained after two iterations. But it is clear that the layout obtained by using only improvement routine (3,721 birr) is better than constructed one (3,806 birr). From this we can see that the current layout being used at KMTF is near to optimal itself than constructed ones. The construction routine followed by the improvement routine still brings good layout but since the current layout is a better layout than the constructed, it is chosen as the best initial layout for CRAFT improvement. The construction followed by the improvement routines is much useful when planning a new facility layout.

To show the benefit of utilizing construction algorithm followed by improvement routine, it is worth mentioning a study conducted by S. K. Peer, Dinesh K. Sharma, K. Ravindranath and M. M. Naidu at Yugoslav Journal of Operations Research. In this paper the researchers proposed two ways of planning the layout of a computer interface. The computer interface and the facility locations problems have common similarities. The optimal location of each component in both determines the effectiveness of the planned or built layout. The user interface components layout problem has the goal of locating the different components in order to achieve the greatest efficiency in exchanging the inputs and outputs between the user and the system. End-user productivity is tied directly to functionality and eases of learning and use [24].

The study proposes two approaches for designing the computer interface layout. The quadratic assignment model, which handles the distance weighted sum of one qualitative factor and one quantitative factor assigned with relative weights in the objective function is presented as first approach. Since, the range of the qualitative relationship ratings may be different from that of the quantitative interactions, and hence the effect of one factor may be dominated by the other factor in the final layout. The second approach presents an alternate quadratic assignment model, in which the distances between the locations weigh the sum of weighted normalized qualitative factor and weighted normalized quantitative factor in the objective function, so that the final layout reflects the relative importance of each factor. It is observed from the results of the second approach that the solution is improved using the improvement procedure over the construction procedure [24].

First the study determined the composite factor for factors being considered. Once, the composite factor has been obtained, the problem is solved as a single factor problem by either construction or improvement procedures.

The layout generated, using construction procedure, is taken as an initial layout for the improvement procedures. A pair-wise exchange process is followed to determine the best exchange of facilities at their locations exchange is incorporated. The exchanged layout will now become the initial layout. The pair-wise exchange process is followed after each new solution till there is no better solution possible. The better solution means that the value of predetermined objective function is better than the previous solution. When no improvement is possible in the latest solution, the search process is terminated [24].

Since, there exists one-to-one relationship between the manufacturing facilities layout problem in a plant and the textual and graphical user interface components layout problem in the human-computer interactive systems, the proposed methodology by the study is used for the layout design of the textual and graphical user interface components. The results of the first approach and the second approach of the proposed model are compared for the user interface components layout problem with the help of an example task.

The results from the study show first layout obtained using the existing single objective model for an intermittent user. The layout is constructed with layout score of 247. This layout is then improved by using improvement routine to score of 245. Then first using approach 1 by constructing the layout and then improving it and then approach 2 the scores improved are from 212.8 to 204.2 and from 211 to 196.1 respectively. It is observed from the results that the solution obtained using the construction procedure in the approach 2 is improved by an average of 3.614 % over approach 1. Further, it is observed that the solution obtained with the improvement procedure in the approach 2 is improved by an average of 4.20 % over approach 1 [24].

In conclusion, it is motioned that the effects of the issues related to perceptual, cognitive and motor actions such as familiarity, fatigue, monotony, boredom, etc. tend to overlap (Gray et al., 1993, John, 1990) in the layout design of the textual and graphical user interface components,

and hence all these factors are treated as a single qualitative factor. The quantitative factors, such as, frequency of use, interaction style, pace of interaction, step-by-step work, all-at- once work concerned with a user are expected to have similar effect on the layout of graphical and textual user interface components, and hence these factors are combined into a single quantitative factor [24].

It is observed from the results that the solutions of the first approach are improved over an existing single-objective model with the construction and the improvement procedures. *Similarly, the solution of the first approach is improved, using the improvement procedure over the construction procedure.*

From the above summary of the paper presented by S. K. Peer, Dinesh K. Sharma, K. Ravindranath and M. M. Naidu on Yugoslav Journal of Operations Research, it is clear that the construction routine of layout planning followed by the improvement routine brings a layout of better score.

4.3. Roll Forging in KMTF

A large number of items used in daily life require metal parts, which are forged by the manufacturer. Traditional metal forging was a labor intensive process in which the piece was formed by hand to meet the needs of the project. Modern metalworking facilities have a variety of types of equipment to use in the forging process. Open forging is what comes to mind when most people think of forging. It involves heating metal to a workable temperature and working with it directly on the anvil, hammering it into shape using various tools. This requires a high degree of technical skill and strength [22].

Forging is preferred to simply cutting metal to shape it for a number of reasons. The first is that forging improves the strength of the metal by aligning the grain along the lines of potential stress. In other words, a forged hammer is better equipped to handle pressure and pounding than one simply carved out of a base metal. The second is that forging is high economical: no part of the metal is wasted during the process, and unused portions can be re-melted for use in other pieces [23].

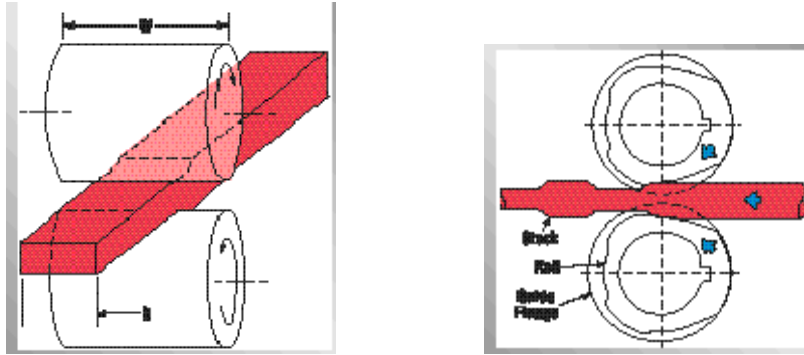


Figure 4.22: (a) Flat Roll Forging, (b) Roll Forging Using Special Shaped Rolls

Roll forging is accomplished by compressing a piece of metal between two rollers. The rollers have a die embedded in them, and as they compress the metal, they will force it to conform to the die. Roll forging is a popular forging technique because it can be made continuous with the use of multiple rollers and dies. This is a type of draw forging, because the piece is slowly drawn out into the needed shape.

4.3.1. Roll-Forging Machines for KMTF

KMTF sent crew of two people to China and they visited one company that produces metal hand tools and especially saw the production of pick axe in the company. Ato Aseged Mamo, who is one member of the crew, recommended the machine as follows.

- The machine for converting rail to sheet metals is a must, if local rails can be availed in quantity. Two flat rolls are used in this machine.
- Roll-forging of hexagonal and other sections as well as large scale pick axe and hoe production will also require this machine. Here, the upper roll will be flat and lower roll will fit the hexagonal or pick axe sections.
- The machine is versatile. Bulk manufacture of new products such as traditional tools “maresha”, “gesso” etc., is greatly simplified when employing this machine and is basically accomplished by changing / modifying the lower rolls.



Figure 4.23: Roll Forging for (left) Tools (right) Sheet Metals

It is possible to fit the two roll types into one frame until such time that demand is high enough and individual rolling machines are required for both products. The employment of a roll-forging machine at KMTF (at least one of units shown above) is mandatory.

Roll forging technology has proven to be worth importing for its ability to provide high quality of the forged products and the reduced cycle time of a product while forging. The quality of the current forging technique, press and hammer forging, depends highly on experience of the worker. And since the product is reheated again and again to attain the desired shape and dimension, the hardness of products may vary causing another quality problem. The hammer forging technique also requires the product to be placed on the anvil and hammered over and over until it attains the shape and dimension required, and is inserted in to furnace again to be reheated so that it can easily be deformed. This makes the operation cycle time at that point of production long.

4.3.2. Single facility layout problem for roll forging machine in KMTF

As to the recommendations given by the crew member and the process capabilities, the products which can utilize roll forging technology are four and the point of usage is described below. The machine that is to be imported by KMTF is assumed to have dies for the four products listed below.

Table 4.6: Machines and Processes Replaced by Roll Forging Machine

Product	Operation	Previous machine performing the operation	No of machines reduced from process
Pick Axe	Tips forging & trimming	PRKSS 0.8 [23], MS250B [28]	1
Axe Congo	Heating, Hammering(Flattening)	PRKSS 0.8 [23], MS100B [22]	2
Sledge Hammer	Shaping	MPM 500	1
Craw Bar	Heating, Forging side 1 (Hexagonal making), heating and Forging side 2 (Hexagonal making)	PRKSS 0.8, MPM 500, PRKSS 0.8	3

The point of roll forging machine usage for [machine number on drawing]:

Pick Axe: Between Holes flash trimming [26] and T7R-X-7466 [27]

Axe Congo: Between Trimming the flash of web at lower part hole [26], and Tip trimming [17]

Sledge Hammer: Between Piercing [18] and correction [17]

Craw Bar: Between Cutting [9] and Trimming side [9]

Table 4.7: Processes of Pick Axe with Roll Forging

Operations of Pick Axe		
	Pick axe	Work station
1	Cutting	PMS160A
2	Heating	PRKKS
3	Pre-forging	MS250B
4	Heating	PRKKS
5	Piercing I, piercing II, side trimming	PK300/100
6	Hole flash trimming	PMS100B
7	Heating	Roll forging
8	Tips forging & trimming	
9	Curve forming	T7R-X-7466
10	Grinding	
11	Hardening	PRK-40/60
12	Tempering	PEH-2B
13	Polishing	DDPM
14	Painting	FK-60

Table 4.8: Processes of Hammers with Roll Forging

Operations of Sludge Hammer(6kg,3kg & 1.5kg)		
	Sledge hammers	Work stations
1	Cutting	Bandsaw
2	Heating	PRKSS
3	Pre-forging	MPM 500
4	Heating	PRKSS
5	Piercing	PMS 100
6	Shaping	Roll forging
7	Correction	
8	Hardening	PRK -40/60
9	Grinding	SZD - 400
10	Tempering	PEH - 2B
11	Polishing Edge	DDPM
12	Painting	FK – 60

Table 4.9: Processes of Axe Congo with Roll Forging

Operations of Axe Congo 3 & 4 lb

	Axe congo 3 & 4 lb	Work station
1	Cutting	PMS 160A
2	Heating	PRKKS
3	Pre-forging	MPM/500
4	Piercing ,side trimming	PK 300/100
5	Trimming the flash of web at lower part of the hole	PMS100B
6	Heating	Roll forging
7	Hammering(Flattening)	
8	Tip trimming	PMS100B
9	Hardening	Water quenching Tank
10	Grinding	Double Disc Grinder
11	Tempering	Electrical Pit Furnace
12	Polishing	Double Disc Polishing M/c
13	Painting	Deep Painting Tank

Table 4.10: Processes of Craw Bar with Roll Forging

Operations of Craw Bar 1.5m 32 D

	Craw bar	Work stations
1	Cutting	PMS 160
2	Heating	Roll forging
3	Forging side 1 (Hexagonal making)	
4	Heating	
5	Forging side 2 (Hexagonal making)	
6	Trimming side	PMS 160
7	Heating	PRKSS 0.8
8	Straightening side 1	MS 250
9	Heating	PRKSS 0.8
10	Straightening side 2	MS 250
11	Heat treatment	
12	Grinding	SZD 400
13	Heat treatment	

Now, roll forging machine interaction with other machines of the existing facility machines is clear. The amount of product moved between the existing machines and the roll forge can be calculated as the feeding to roll forge and receiving from roll forge. Let us use the numbers of the machines and calculate the amount of product moved from one machine to the next per month.

Table 4.11: Quantity of Product Transported to or from Machines

Machine No.	Machine Code	Amount of material transported in product type	Quantity transported
9	PMS 160	2* quantity of craw bar	1102 pcs.
17	PMS 100	Quantity of Axe Congo + Sledge hammer	4736 pcs.
18	MPM 500	Quantity of Sledge hammers	1700 pcs.
26	PK 300	Quantity of Axe Congo + Pick Axe	6568 pcs.
27	TR 7	Quantity of Pick Axe	3532 pcs.

The material transported between the machines is assumed to be rectilinear. Thus the total material handling cost will be cost of handling the material in the X direction and cost of handling the material in the Y direction. To get the minimum cost we have to find the minimum of the two costs i.e. minimum cost of X direction movement and minimum cost of Y direction movement. Now we will write cost of the material handling in these directions. In doing so, the material handling cost per meter will be labor cost (level one operator) per second per meter which is 0.009birr.

Table 4.12: Machines having Interaction with Roll Forging and Quantity Moved

Machine	Quantity moved	Cost (app.)	X-coordinate	Y-coordinate
9	1102	10	15	3
17	4736	43	23	2
18	1700	15	29	3
26	6568	59	42	3
27	3532	32	42	6

The other information needed for single facility location problem is the location of the existing machines within the floor of the factory. The location of the machines is represented by a circle using its centroid of the machine location. These locations of machineries are represented in the figure below. This figure shows the whole layout of the forging section, where the roll forging would be utilized, excluding other machines which would not have any interaction with the roll forging machine soon to come.

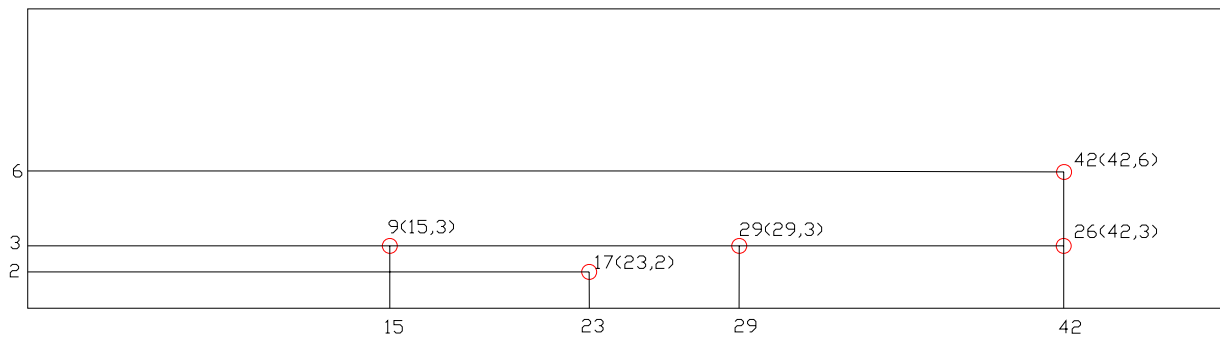


Figure 4.24: Existing Machines Locations in the Previously Improved Layout

Now we have the cost for transporting the materials form one machine to the other, the location of each machine and the actual arrangement of the machines in the layout. We can write the equation of the cost of material handling between the roll forge and existing machineries of the factory. we represent the location of the roll forging as (X,Y). Therefore, the equation of material handling cost between the roll forge and existing machines can be written as:

$$f(X, Y) = \sum_{i=1}^m w_i (|X - a_i| + |Y - b_i|)$$

Where m is number of existing machines

w_i is cost of transportation to the i^{th} machine

a_i and b_i X and Y coordinate of i^{th} machine

X and Y X and Y coordinate of the new roll forging machine

Let us define $f_1(x)$ and $f_2(x)$ as:

$$f_1(x) = \sum_{i=1}^m w_i(|x - a_i|)$$

$$f_2(y) = \sum_{i=1}^m w_i(|y - b_i|)$$

Now we draw the very useful conclusion that

$$f(X, Y) = f_1(x) + f_2(y)$$

That is, the total cost of movement is the sum of the cost of movement in the x direction and the cost of movement in the y direction. Thus an implementation of the equation is that we can minimize the total cost of movement by solving the two smaller- and independent- problems of minimizing the cost of movement in the x direction and minimizing the cost of movement in the y direction. The best choice of x has absolutely no effect on the best choice of y, and vice versa. It is also observed that the two costs of movement functions have exactly the same form, so that every conclusion we draw about one cost function applies to the other.

Now let us insert the values of each variable in to the equation.

$$f_1(x) = 10|x - 15| + 43|x - 23| + 15|x - 29| + 59|x - 42| + 32|x - 42|$$

Grouping $59|x - 42|$ and $32|x - 42|$ by summing them up:

$$f_1(x) = 10|x - 15| + 43|x - 23| + 15|x - 29| + 91|x - 42|$$

$$f_2(y) = 10|y - 3| + 43|y - 2| + 15|y - 3| + 59|y - 3| + 32|y - 6|$$

Grouping the similar ones together:

$$f_2(y) = 43|y - 2| + 84|y - 3| + 32|y - 6|$$

Finding the minimum of the above two equations and then their corresponding coordinates allows us to find the location of the new forging machine, (X, Y). So let's find the minimum of the two equations by drawing the above two equations.

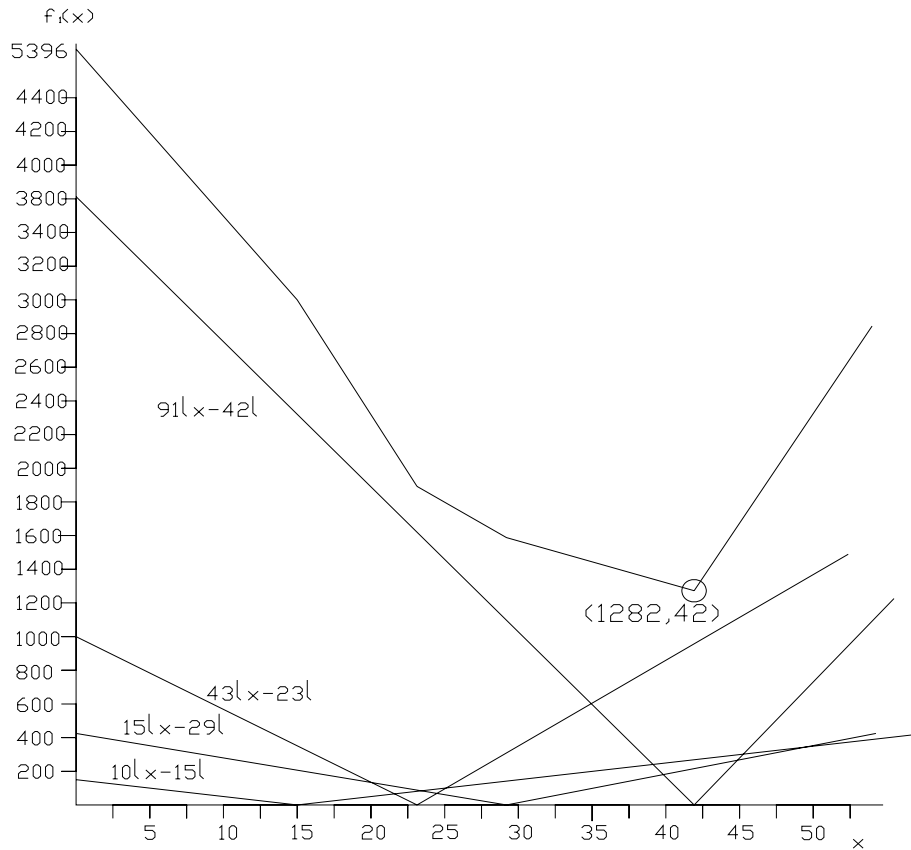


Figure 4.25: Minimization of $f_1(x)$

The graph above shows the first function i.e. $f_1(x)$. In the graph, the graphs of each components of the equation are drawn independently and then the cumulative $f_1(x)$ graph is drawn. All the graphs have one common characteristic i.e. the slope of the graphs changes from negative to positive at certain values of x . These points are at 15, 23, 29 and 42 values of x . On the cumulative graph the graph slope increases bit by bit until it changes from negative slope to positive slope. At the point where the graph increases its slope from negative to positive gives the minimum value of $f_1(x)$. At this point the value of the function is obtained to be 1282 (in the y direction) and the corresponding x coordinate is 42. Thus the x coordinate of the forging machine should be placed 42 meters from the left bottom corner of the forging section floor.

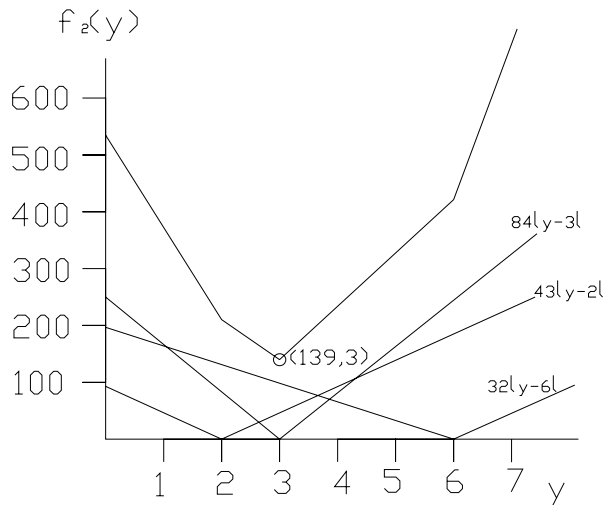


Figure 4.26: Minimization of $f_2(y)$

The same procedure is followed for the function $f_2(x)$ and the minimum value of the function is obtained as 139 in the y direction and 3 in the x direction. This implies that the x coordinate of the forging machine should be placed 3 meters from the left bottom corner of the forging section floor.

Thus the final location of the forging machine that minimizes the total material handling cost is given to be (42, 3) from the left bottom corner of the forging section floor. Placing the machine in this location will minimize the material handling cost that comes when the roll forging machine is used according to the assumptions made at the beginning of this section.

The forging machine location is incorporated in to the layout proposed earlier by improving the current layout by the use of the CRAFT algorithm. The drawing of the roll forging machine in the improved layout is shown below.

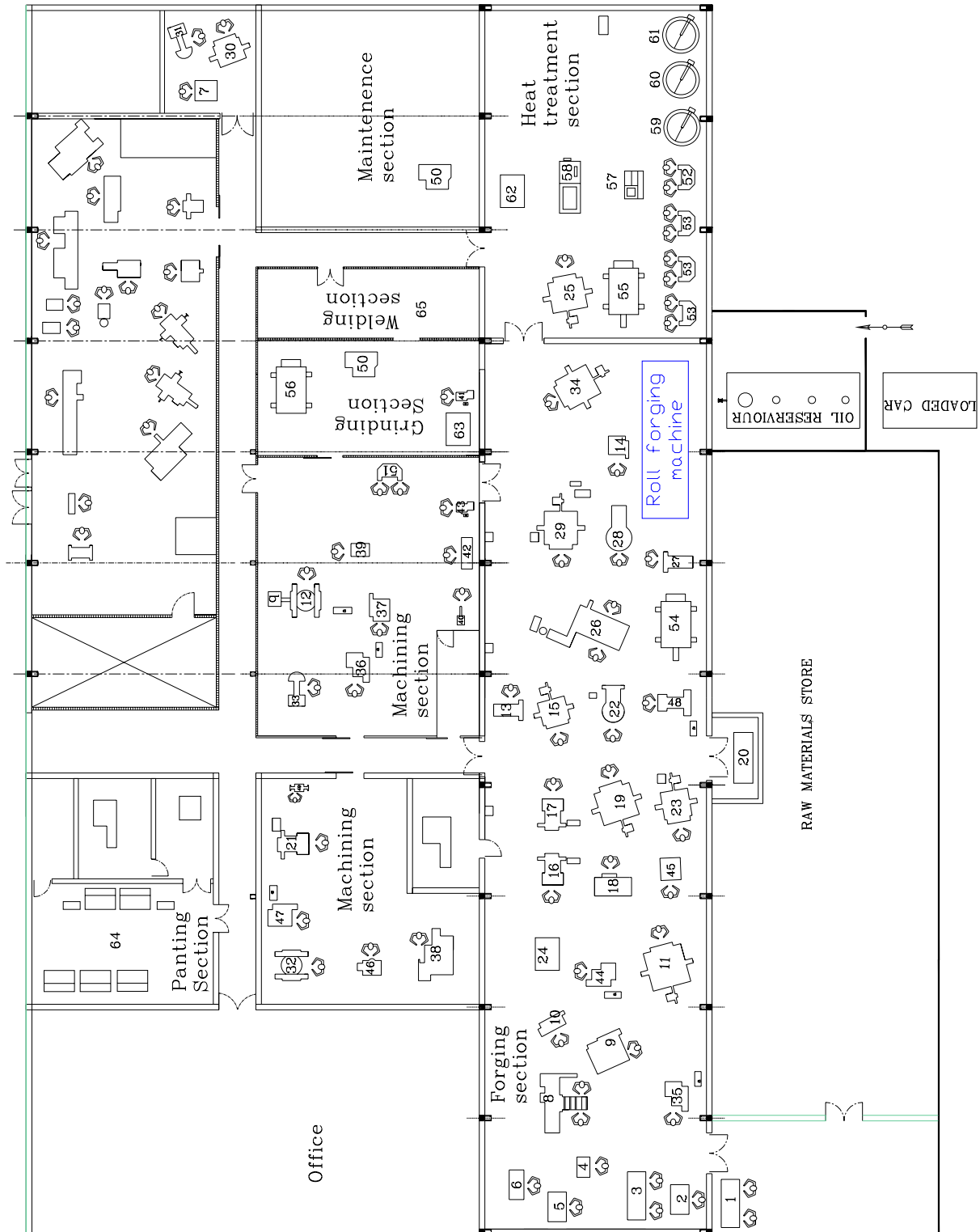


Figure 4.27: Improved Layout of Tools Factory Including Roll Forging

4.4. Comparison of Proposed Layouts

To see the improvements achieved by the computerized layout planning heuristics and roll forging inclusion in the layout, it is worth analyzing the distance traveled by the parts within the machines. This would signify the layout improvement achieved. For this purpose the three layouts, the existing or currently being used layout, the improved layout without the roll forging machine and the layout where the roll forging is included, are compared by the distance of the material moved.

Table 4.13: Comparison of the three layouts

No	Products	Approximate Distance traveled by products in meters		
		Existing layout	Improved layout	Roll forge layout
1	Hammers	196	214	214
2	Pick axe 2 kg	228	223	205
3	Axe Congo 4&3 lb	166	239	254
4	Craw bar 1.5mtØ 32	256	153	190
5	Garden Hoe 2 finger	485	388	388
6	Shovel No. 2 & 5	139	193	193
7	Spade Harrar	404	344	344
8	Door Bolt 140 mm	545	540	540
9	Rake 10 Finger	365	360	360
10	Sickle No.3	202	135	-
Total Distance traveled		2986	2789	2688

The 12 products that are considered as the vital products of the company are grouped in ten (the three hammers are grouped as one because they have the same process). The distance traveled by the parts for sickles does not consider the layout incorporating roll forging because the sickle factory doesn't use the roll forging. The roll forging is inserted in the forging section of the existing layout. The products that do not use the product are traveling the same distance in the roll forging layout as in the improved layout without roll forging. Four products, hammers, pick axe, axe Congo and craw bar distance traveled varies because the roll forging eliminates some

machines form the process of these products and changes the length to be traveled to reach and depart from the roll forging machine.

The above table summarizes the distance traveled by the products within the machines of the tools manufacturing factory. Here we can see that the existing layout incorporates high distance of travel (2,986 meters). The next improved layout results in a less distance being traveled (2,789 meters). Still the layout which incorporated the roll forging has reduced the distance traveled further to 2,688 meters. Here the first two layouts can be compared without any problem because both are considering tools as well as sickle manufacturing factories while the third layout is concerned only on the tools factory and not on the sickle factory. To make the comparison fair to all three layouts, the distance traveled in the sickle factory should be subtracted from both of the first two layouts. Thus, the distance traveled in the two layouts excluding sickle factory is 2,784 meters and 2,654 respectively.

Form the above observations and the score of the layouts, it is appropriate to say that cost reduction and distance reduction can be obtained by implementing the layout rearrangement suggested. The layout incorporating the roll forging will be even better. But for the roll forging layout to be practical, certain limitations mentioned earlier must be fulfilled. These limitations are first, the roll forging must come with the appropriate dies to manufacture the products assumed to be workable on the roll forging machine. Secondly, the products must be produced in mass. If the products are being produced in the quantity they are now being produced, the roll forging will not be economical to import. To see this let us analyze percentage of the four products selected with respect to the other products of the factory. The analysis will be between the four products and the other products from the 12 vital products.

The quality of product produced in the last three years (33 months with 9 months of current year) is shown in the table below. Here, the summation of the four products which could utilize roll forging is 71,707 parts (Hammers, Pick axe, Axe Congo and Craw bar) while the summation of parts produced is 186,847 parts. Now the percentage of these four parts to the produced quantity of product is:

$$\frac{71,707}{186,847} * 100\% = 8.78\% \text{ of the 12 products}$$

Table 4.14: Production quantity of 33 months

No	Products	Production quantity of 33 months
1	Hammer 6kg	4411
2	Hammer 3kg	307
3	Stone Hammer 1.5 kg	473
4	Pick Axe 2 kg	31270
5	Axe Congo 4&3 lb	34811
6	Crow Bar 1.5mtØ 32	435
7	Garden Hoe 2 finger	4991
8	Shovel No. 2 & 5	166017
9	Spade Harrar	122965
10	Door Bolt 140 mm	242190
11	Rake 10 Finger	21204
12	Sickle No.3	187773

This is a small quality as the products are six in number, half of the vital products. Furthermore, if we take a look at the sales value of the vital products of the year 2001, the total sales value of the 12 vital products is 2,959.37 birr while the total sales value of the four products is 1,219.36 birr, which is 41.2% of the total sales value of the vital products. The sales data of the products is shown below. Both the above figures, the quantity manufactured and the sales value of these four products, further decrease as we consider the other products which are manufactured as per customer orders. Since these products are manufactured for stock, their number remains constant while other products may be manufactured in the quantity the customer requires them to be produced.

Table 4.15: Sales of products in birr

Product	Selling price	Sales in value
Hammer 6 kg	104.35	206.73
Hammer 3. kgs	68.05	24.47
Hammer 1.5 kgs	33.2	24.7
Pick Axe 2 kgs	30.39	686.45
Axe Congo 4 lbs	40	146.64
Axe Congo 3 lbs	30	127.33
Crow bar 1.5mtØ 32	146	3.04
Garden Hoe 2 fingers	17.56	19.52
Shovel No. 2	27.98	18.77
Shovel No.5	33.61	481.77
Spade Harrer	25.45	219.49
Door Bolt 140 mm	4.5	380.77
Rake 10 fingers	15	82.39
sickle No.2	15	152.79
sickle No.3	18.7	384.51
Total		2959.37

Therefore it is arguable that roll forging should be introduced into the factory's manufacturing floor if the company decides to produce these products in larger quantities. To quote the words of Ato Aseged Mamo, one of the member on the team that has been sent to China by KMTF and observed the machine operate, "Roll-forging of hexagonal and other sections as well as *large scale* pick axe production will also require this machine". Ato Aseged has also emphasized the large scale production requirement. If the large scale production is approved, the quality of the product will be outperforming than that of the current product. The current manufacturing practice is dependent on the skill of the operators. The operators hammer the heated product over and over by the hammer press machine till required dimension is achieved. For example, the dimension of work in process of stone hammer need to be 60 by 30 centimeters. The workers observe and perform the process only by eye observation. Thus, roll forging machine will produce products having higher quality and higher gain structure for the products being produced.

4.5.Rearrangement Cost Estimation

The improved will bring the advantages mentioned in chapter two only after implementation. Thus in this section cost estimation will be computed by making some assumptions. The first assumption is that the rearrangements of the layout will be taken as a project and subcontracted to a consulting firm having the skill, experience and capability to take on the challenges. The selection of the consultant to undertake the project will be KMTF's management responsibility. Auction can be posted to invite competitive consultants or if the company has consultant that is capable of undertaking the rearrangement in a qualified manner then the project can be given that consultant.

After the consultant has been selected then cost of the project need to be estimated. There are 31 machines in tools factory and 15 machines in sickle factory that need to be relocated in the new and improved layout suggested. On average one machine is estimated to take three days to be dismantled and reinstalled in the new location. Thus 91 days will be needed for tools factory and 45 days for sickle factory. Assuming 22 working days total relocation dates required will be 136 which are approximately 6 months. This is considering one machine at a time and single crew performing the task. The consultant can perform this task in multiple crews. Let's assume the project is performed in two crews. Thus the project will require three months. One crew should have at least one expert of machines or a mechanic and two laborers. Then again on average one mechanic is paid 90 birr per day and laborers 30 birr per day. Thus one crew cost per day will be 150 birr. There might be a need to hire supervisors for each crew. One supervisor would cost 120 birr per day increasing the cost per day to 270 birr per day.

Table 4.16: Rearrangement Manpower Cost Estimation

No.	Reason for cost	Quantity	Cost per quantity per day	Total cost per day
1	Supervisors	2	120	240
2	Mechanics	2	90	180
3	Laborers	4	30	120
Total cost per day			270	540
Total cost in project duration				73,440

There are other costs to consider like administrative costs, miscellaneous cost and contingency costs. For our case administrative cost is considered to be 20%, miscellaneous cost 10% and contingency cost 5% of the total cost of project.

Administrative costs = 14,688 birr

Miscellaneous cost = 7,344 birr

Contingency costs = 3,672 birr

The total estimated cost of the project would thus be the summation of all the above costs. Therefore total cost of the project will be:

$73,440 \text{ birr} + 14,688 \text{ birr} + 7,344 \text{ birr} + 3,672 \text{ birr} = 99,144 \text{ birr}$

Thus the total cost of the project is estimated to be approximately 100,000 birr. This KMTF should give the project to the consultant with these considerations.

When we see the saving that improvement of the current layout brought, the initial cost of tools factory layout was 11,385 birr per month which is then improved to 6,293 birr per month with saving of 5,092 birr per month. Again, current cost of sickle factory layout is 3,326 birr per month while the improved cost is 2,084 birr per month with 1,242 birr savings per month. Adding these two savings, the total saving per month of the improved layout will be 6,334 birr per month. If we divide the total cost of layout rearrangement, the number of month that will be required to compensate the cost incurred while implementation of the project will be 15.8 months or approximately 16 months.

Therefore in general, upon implementation of the rearrangements suggested, KMTF will incur total cost of 100,000 birr in three months. The rearrangement would bring a saving of 6,334 per month. After one year and four month the cost would reach its breakeven point and would start to bring its actual benefits.

5. CONCLUSIONS

Layout planning problem is one of the factors that play significant role in the effectiveness of a manufacturing, any type of layout aspect for that matter. After careful analysis of the current layout of KMTF and computerized layout planning algorithms, the following conclusions are made.

- The current layout at both tools and sickle manufacturing factory is less efficient in that it incorporates many back and forth movements of the parts to be produced. These are further amplified by the location of sections as well as machines having high interaction far apart from one another. For example machines 3 and 35 and 63 and 43 are some of the machines having high volume of product being transported between them but are placed far from one another in tools factory. In the sickle factory, flow from machine no 15 (bow bending process) to 4 (straightened) could be raised as an example.
- Furthermore, wasting the factory's time and resource in transporting high volume of materials through long distances, the planned production volume as well as profit could not be attained. Designing a better layout for KMTF manufacturing shop floor is thus reasonable and mandatory.
- After the current layout has been analyzed, two different alternative new layouts have been developed. First the current layout of sections in the tools factory has been improved by using an excel add-in program utilizing CRAFT improvement routine. Then the machines arrangement with the improved sections layout is evaluated and then improved by the same CRAFT routine. The existing machine arrangement has also been improved but better layout score has been attained with the improved section then improved machine arrangement.
- Another approach followed was to construct a new layout using construction routine and then improve it by CRAFT algorithm. But the layout constructed incurred higher cost than the existing layout. Thus it has been accepted that the current layout is good enough to be that initial layout for improvement by CRAFT algorithm. But the proposed layout has been found to be good for planning new layout. This has been supported by a study

published on Yugoslav Journal of Operations Research journal number 2, pages 171-192, in year 2004.

- The other conclusion made concerns the inclusion of roll forging machine by importing the machine from abroad. To find a location for the machine a single facility layout problem has been analyzed. Here, the machine is assumed to come with dies that would make it perform its operations on four products. These products are Pick axe, Axe Congo, Crow bar and hammers. To this end, the machine's point of use has been made by the author. With this assumption made, the location of the machine has been found to be at 42 meters to the right and 3 meters up from left corner of the forging machine.
- The roll forging machines addition into the improved layout has also been challenged by the author. If the products that would utilize the forging machine are the four products assumed (Hammers, Pick axe, Axe Congo and Crow bar) and the volume of the four products is the same as the current volume being produced, the machine would not be economical to import. But if the company is planning to manufacture the four products in large scale, then roll forging technology introduction would be mandatory. It would allow more volume to be produced, since it reduces the cycle time of products that the current operational and is fast at performing the operations, and the quality of the product will be outperforming than the current product quality.
- The new proposed layout would have a payback period of one year and four months. The total rearrangement cost of 100,000 birr will be compensated fully by the saving of 6,334 birr per month within 16 months. Thus, the proposed layout is economical and would bring sustainable improvement.

6. RECOMMENDATIONS

Based on the analysis made, result obtained and conclusions drawn, the following recommendations are forwarded to KMTF.

- KMTF should realize that the current layout is less efficient and act fast. The company has the awareness that the layout is performing less than expected but slowed to act on it. This study thus has forwarded a layout which is better than the existing one. No layout can be called the optimal since there might be a slightly better one than the one on hand. Thus, it won't be morally and scientifically genuine to declare the layout proposed is the one and the only optimal one. But the company should apply the proposed layout since there is no other better layout in place.
- Roll forging is a good technology to introduce to bring a better market share and produce high volume and better quality. It is known for its excellent product quality and strength due to the grain structure of the metal while it is roll forged. The optimal location of the roll forging machine has been calculated using single facility layout problem. If the product comes with the assumed four products, then the location calculated is optimal and should be used. If the machine capability or dies brought are different, then the same procedure should be followed and the location be obtained. But this all is restricted if the volume of product to be manufactured by roll forging is not justifiable.
- Construction routine of new layout and then improving it by improvement routines is effective in planning a new layout. In case of KMTF the existing layout has outperformed the constructed layout, thus it is used as an initial layout for CRAFT improvement routine. But still the approach is effective to be used for new layout design. Thus, if KMTF planes to construct a new facility or plan to build another facility within the existing compound, it should use the approach to arrive at a near optimal layout.

7. FUTURE RESEARCH AREAS

After conducting the research and analyzing the different aspects of layout design, the following research areas are recommended to be undertaken in the future.

- ✓ Different computerized layout algorithms are available. These algorithms come with their own disadvantages. Some of the disadvantages encountered in CRAFT include being restricted to rectangular shape, being unable to use open spaces which are left empty by the user to notify the space is not occupied, and again the testing method of the initial starting layout. Thus future studies should focus on providing ways to minimize or overcome these disadvantages.
- ✓ In this study, the layout obtained by construction routine followed by improvement routine gave more cost than the improvement of the initial layout. This is resulted from the current layout being good layout. But from the study published by Yugoslav Journal of Operations Research, construction routine followed by improvement routine is shown to be effective. Thus further independent studies should be conducted to show the effectiveness of this approach.
- ✓ The sickle factory at KMTF is producing much less than the market demand in Ethiopia. Dominant brands at the market place are brought from foreign countries like China. Thus the reason for KMTF's sickles being incompetent in the market should be studied independently and actions to overcome those inefficiencies of the product should be put into action to ascertain the competitiveness of the company.
- ✓ Studies on other products of KMTF should also be conducted continuously to get grip on the dynamic market. The studies should focus mainly on quality and appearance of the products as compared with other company products.

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ANNEX A: LIST OF MACHINES AND THEIR NUMBER

I. List of machines found in Tools manufacturing factory

No	Name of machine	Code	Remark
1	Guletine machine		
2	Sheraing machine	NG 3	
3	Disk saw	Taeber	
4	Power hack saw		
5	Shearing machine		
6	Power hack saw		
7	Press machine	PMS 40B	
8	Band saw	AS 460	
9	Rigid Eccentric press	PMS 160A	
10	Universal shearing machine	NU 13	
11	Oil fired chamber furnace	PRKKS 1	
12	Friction screw press	F-1232	
13	Drop belt hammer	TR 7	
14	Eccentric press	PMS 40B	
15	Oil fired furnace	PRKKS 0.4	
16	Rigid eccentric press	PMS 100B	
17	Rigid eccentric press	PMS 100B	
18	Double acting hammer	MPM 500	
19	Oil fired chamber furnace	PRKKS 0.8	
20	Rubling machine		
21	Eccentirc press	PMS 40B	
22	Pneumatic hammer	MS 100B	
23	Oil fired chamber furnace	PRKKS 0.8	

24	Water tank		
25	Oil fired chamber furnace	PRKKS 0.8	
26	Triple crank press	PK 300	
27	Drop belt hammer	TR 7	
28	Pneumatic hammer	MS 250B	
29	Oil fired chamber furnace	PRKKS 0.8	
30	Oil fired chamber furnace	PRKKS 0.4	
31	Spring hammer	MR 80A	
32	Friction screw press	PC 150	
33	Spring hammer	MR 80A	
34	Oil fired chamber furnace	PRKKS 0.8	
35	Eccentric press	PMS 63	
36	Eccentric press	PMS 63	
37	Eccentric press	PMS 63	
38	Rivet making machine		
39	Column drilling machine	WKA-25	
40	Spot welding machine	Zpb 12	
41	Riveting machine		
42	Turret lathe machine	RV 40	
43	Riveting machine		
44	Eccentric press	PMS 63	
45	Eccentric press	PMS 40B	
46	Friction screw press	PC 40	
47	Eccentric press	PMS 63	
48	Eccentric press	PMS 100	
49	Double disk grinding machine	SZ 750	

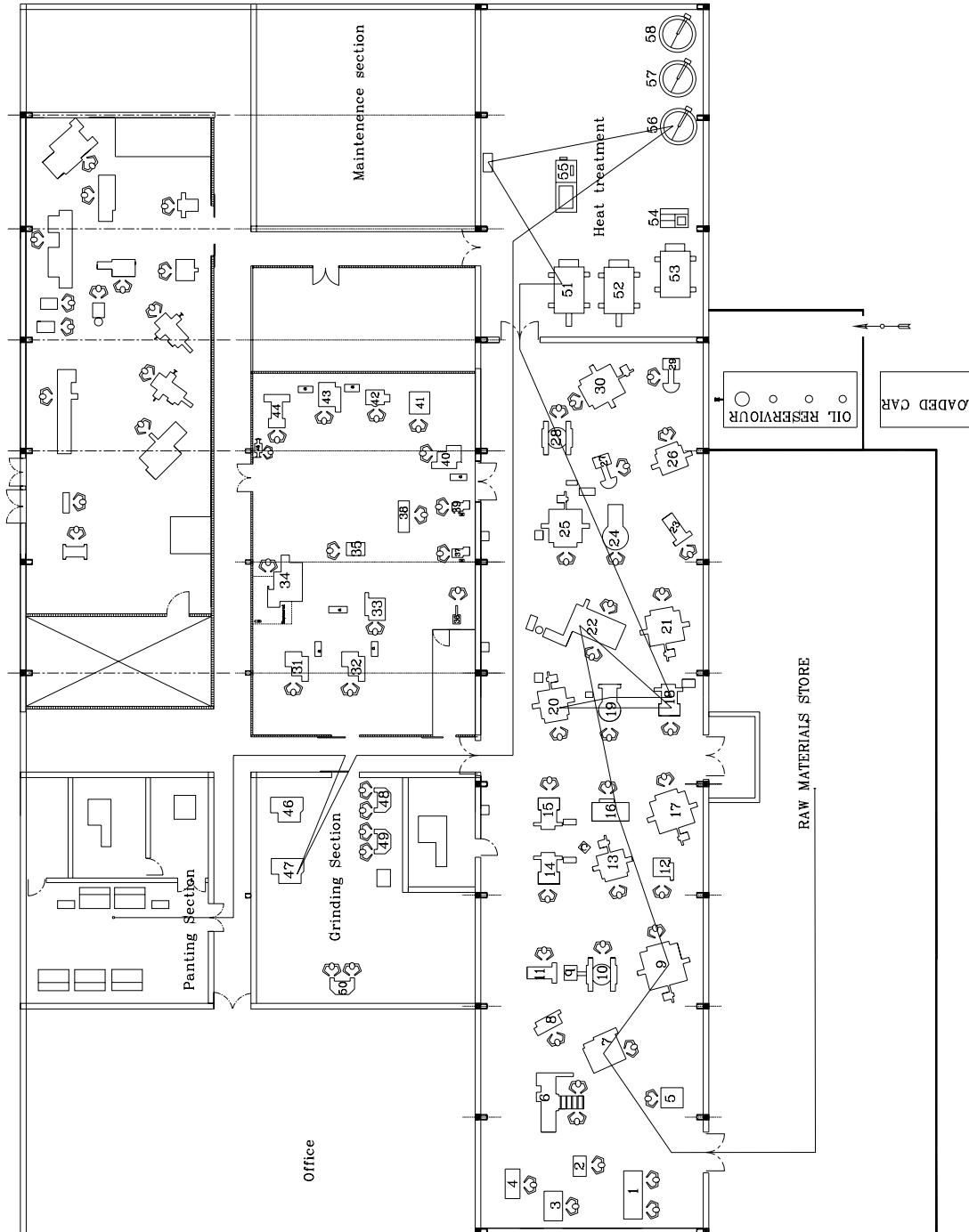
50	Wet grinder	WD 250	
51	Double disk polishing		
52	Double disk polishing		
53	Double disk grinder	SZD 400	
54	Chamber oven- oil fired	PRK 40/60	
55	Chamber oven- oil fired	PRK 40/60	
56	Electrical furnace	SK 15-5	
57	Oil quenching tank	CO-10950	
58	Oil/water quenching tank	CO-10950	
59	Tempering furnace		
60	Tempering furnace		
61	Tempering furnace		
62	Three way oil furnace		
63	Electrical pit furnace		
64	Deep painting tank		
65	Welding machine		

II. List of machines found in sickle manufacturing factory

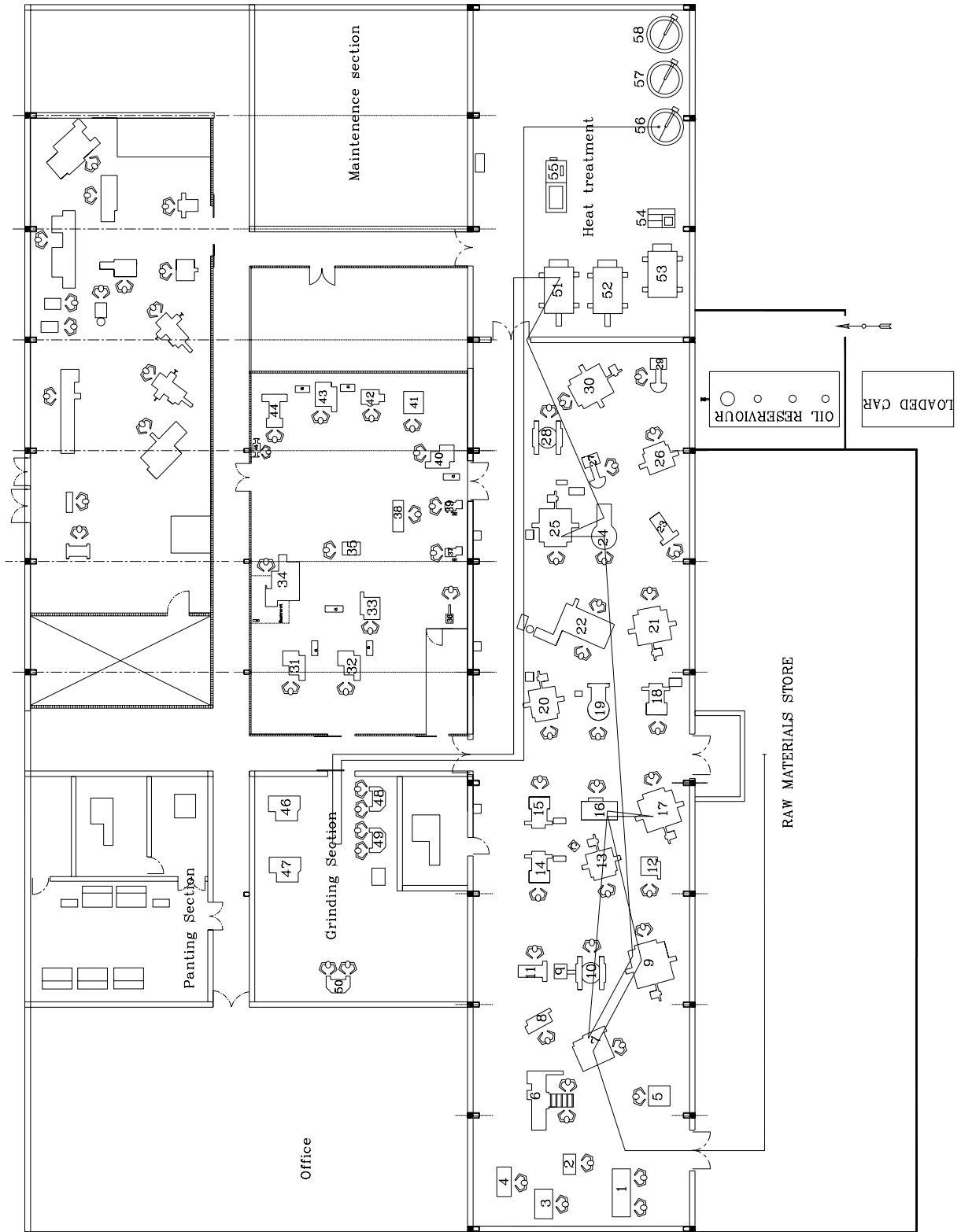
No	Name of machine	Code	Remark
1	Guillotine shear	NG 88	
2	Uncoiler		
3	Strengtheners	CUPK-250	
4	Strengtheners	CUPK-250	
5	Eccentric press	PMS 16cp	
6	Eccentric press	PMS 16cp	
7	Notching machine	UBS-02	

8	Notching machine	UBS-02	
9	Eccentric press	PMS 63cp	
10	Eccentric press	PMS 63cp	
11	Grinding machine	SUW50-300	
12	Grinding machine	SUW50-300	
13	Grinding machine	SUW50-300	
14	Grinding machine	SUW50-300	
15	Eccentric press	PMS 63cp	
16	Eccentric press	PMS 63cp	
17	Eccentric press	PMS 16cp	
18	Eccentric press	PMS 16cp	
19	Eccentric press	PMS 16cp	
20	Oil furnace (0.4m ²)	PRK 25/40	
21	Finish grinding m/c	OND 3500	
22	Finish grinding m/c	OND 3500	
23	Finish grinding m/c	OND 3500	
24	Finish grinding m/c	OND 3500	
25	Wire brush machine		
26	Polishing machine		
27	Polishing machine		

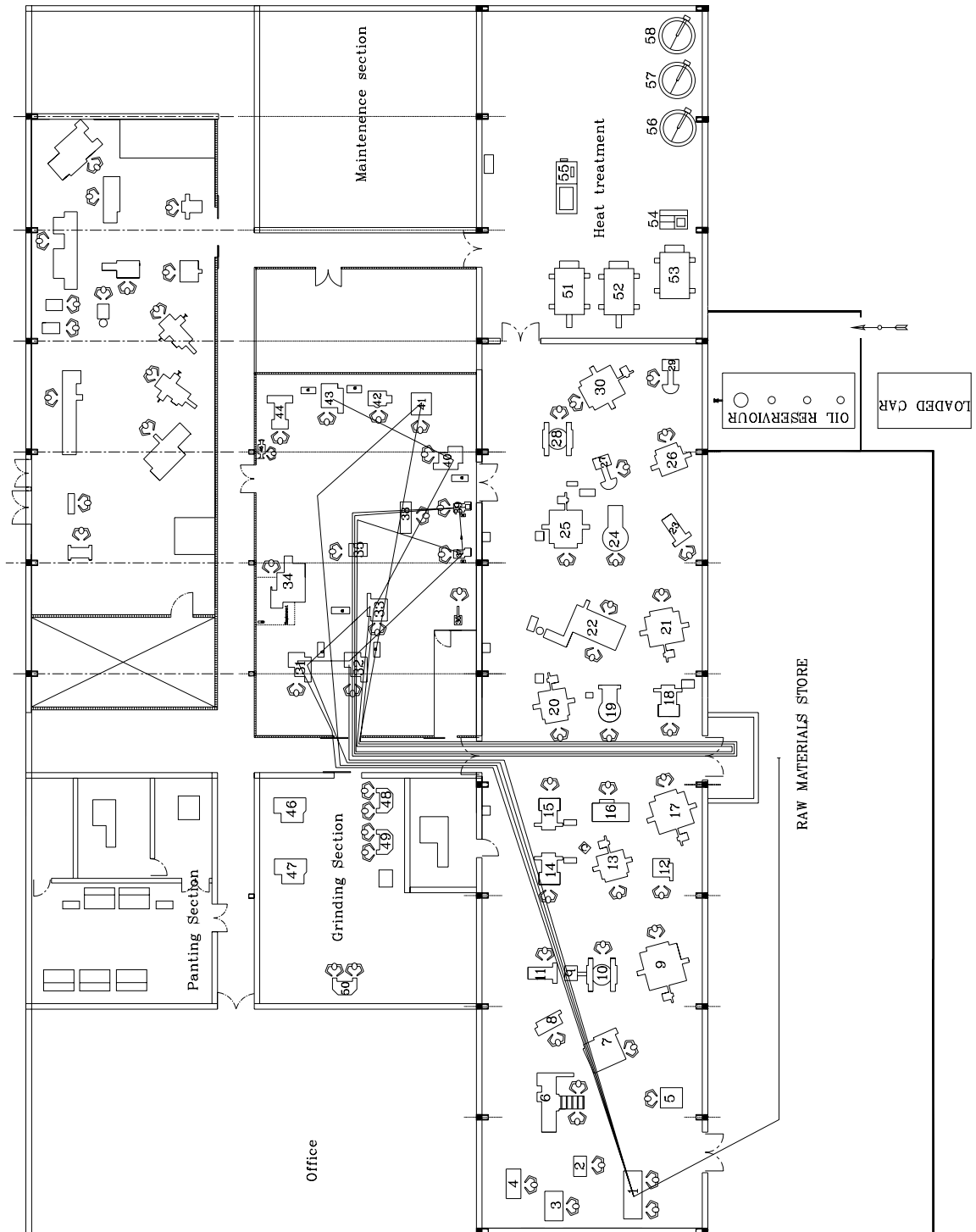
ANNEX B: FLOW OF EACH PRODUCT IN THE FACTORY FLOOR



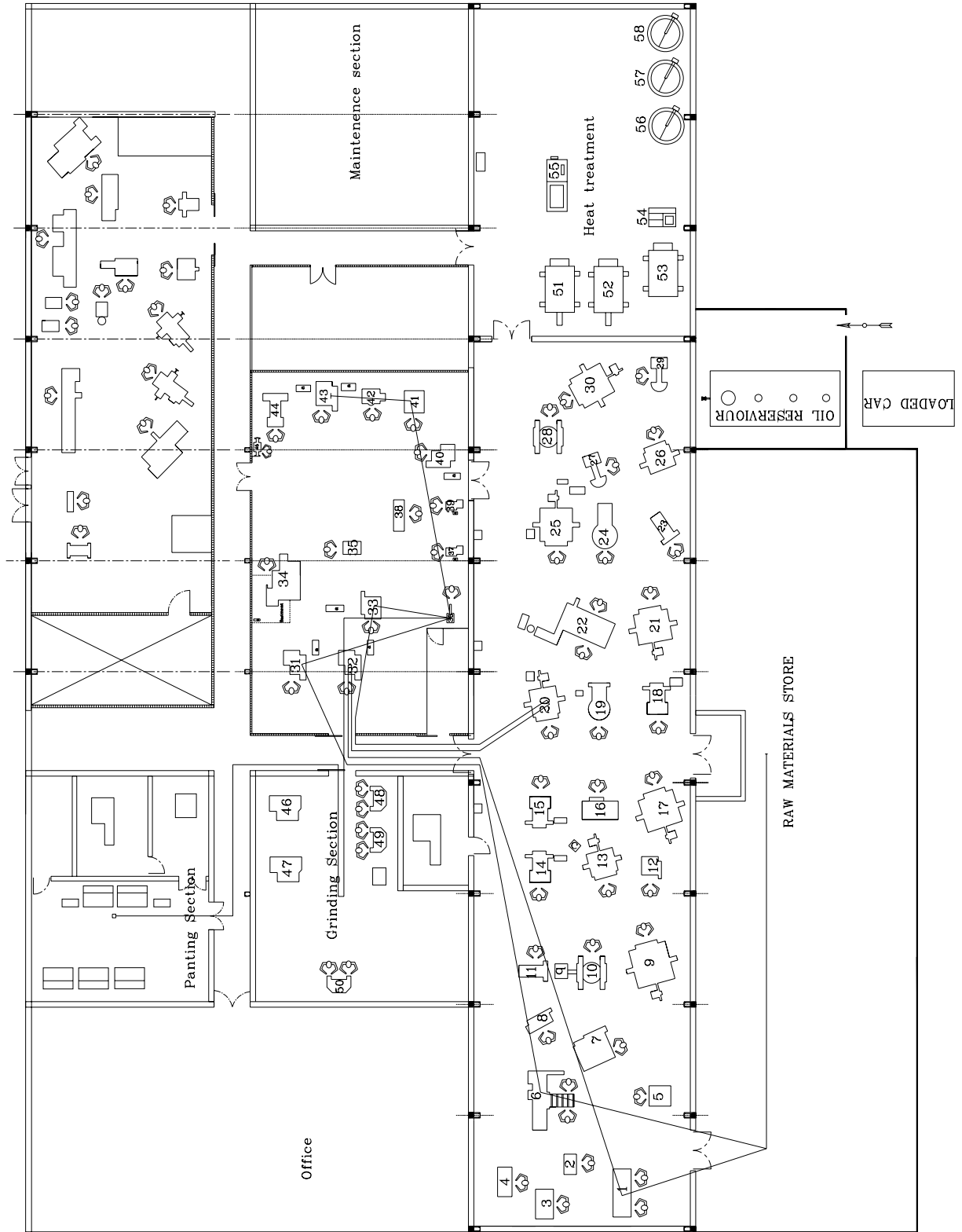
Flow of Axe Congo



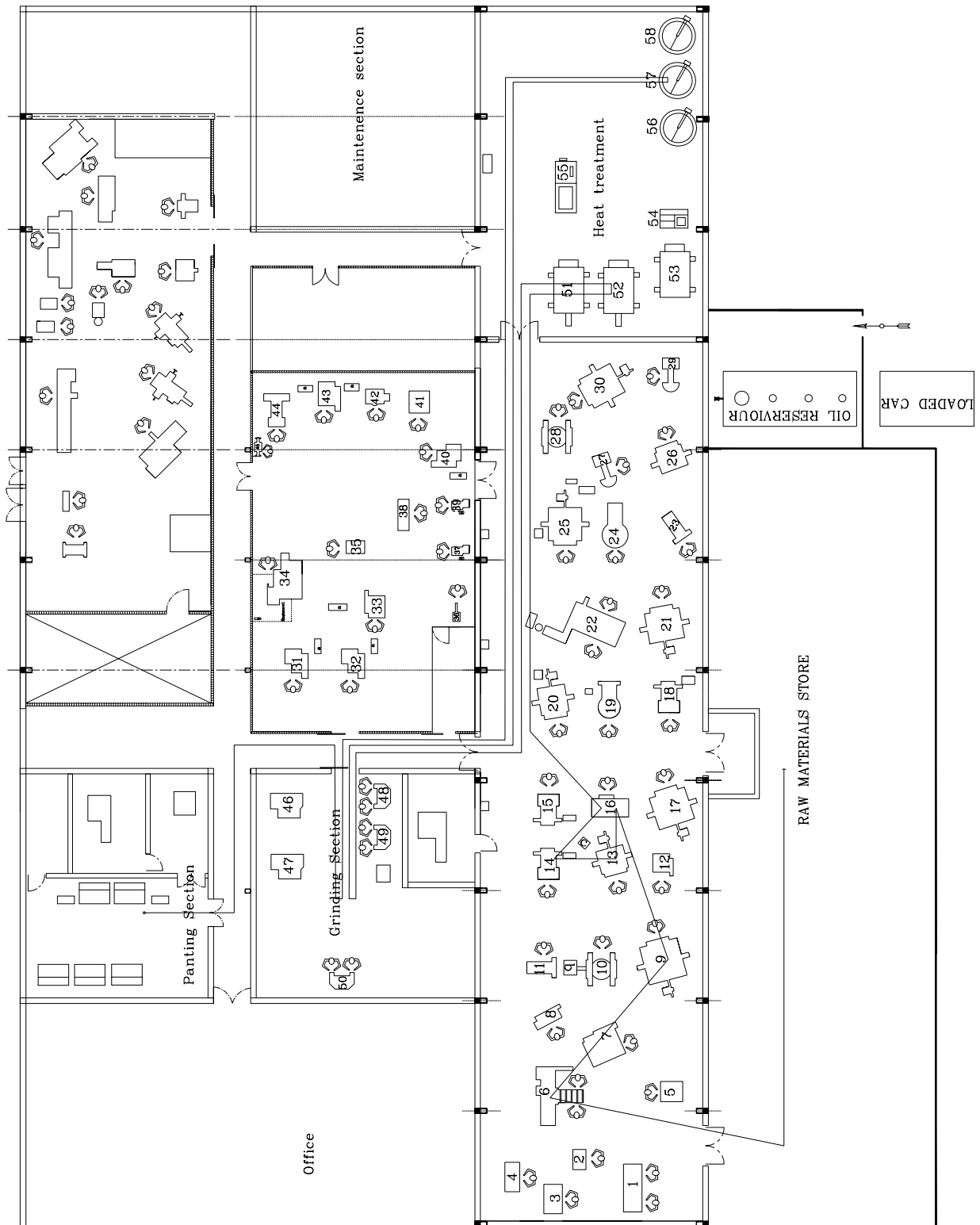
Flow of Craw bars



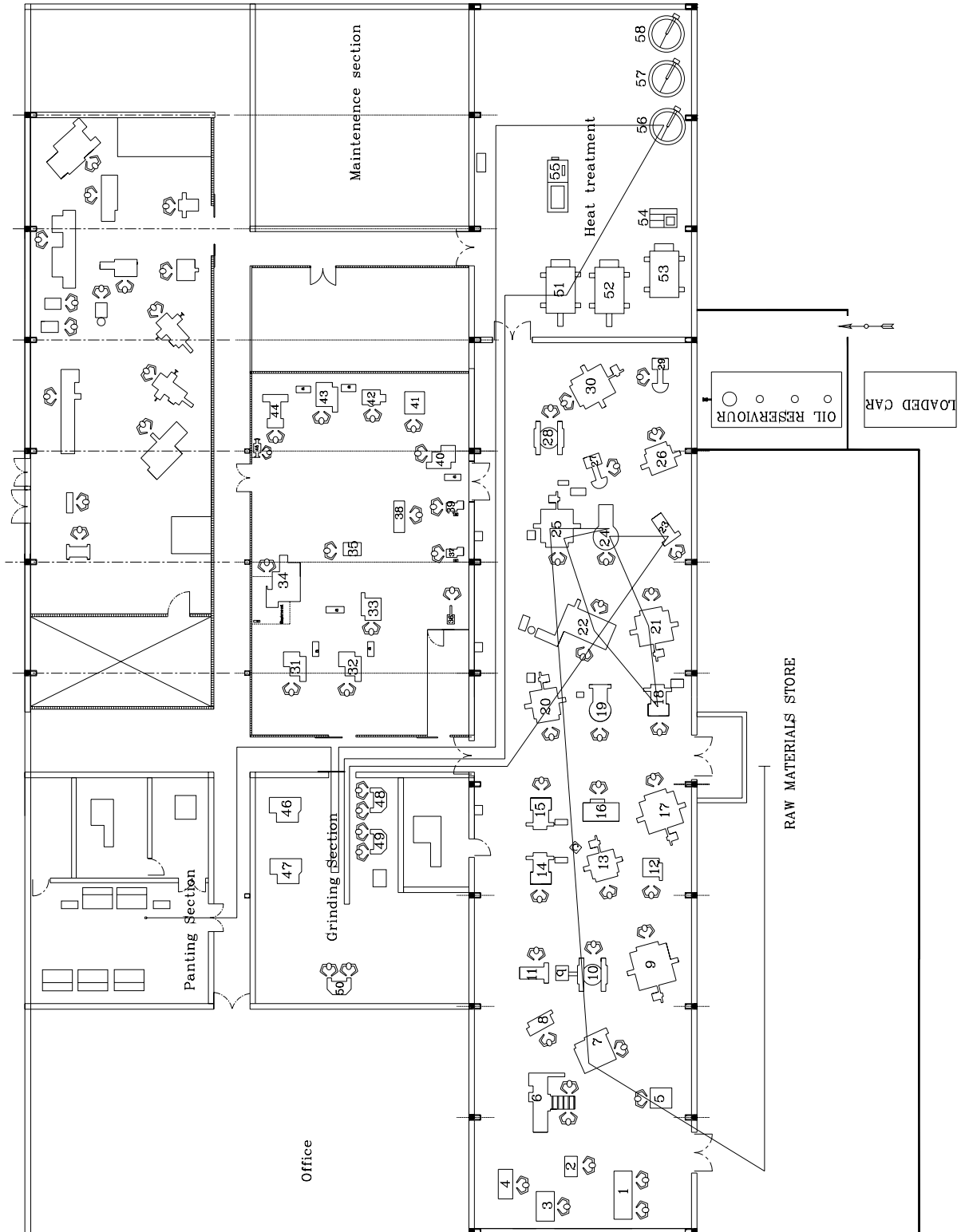
Flow of door bolt



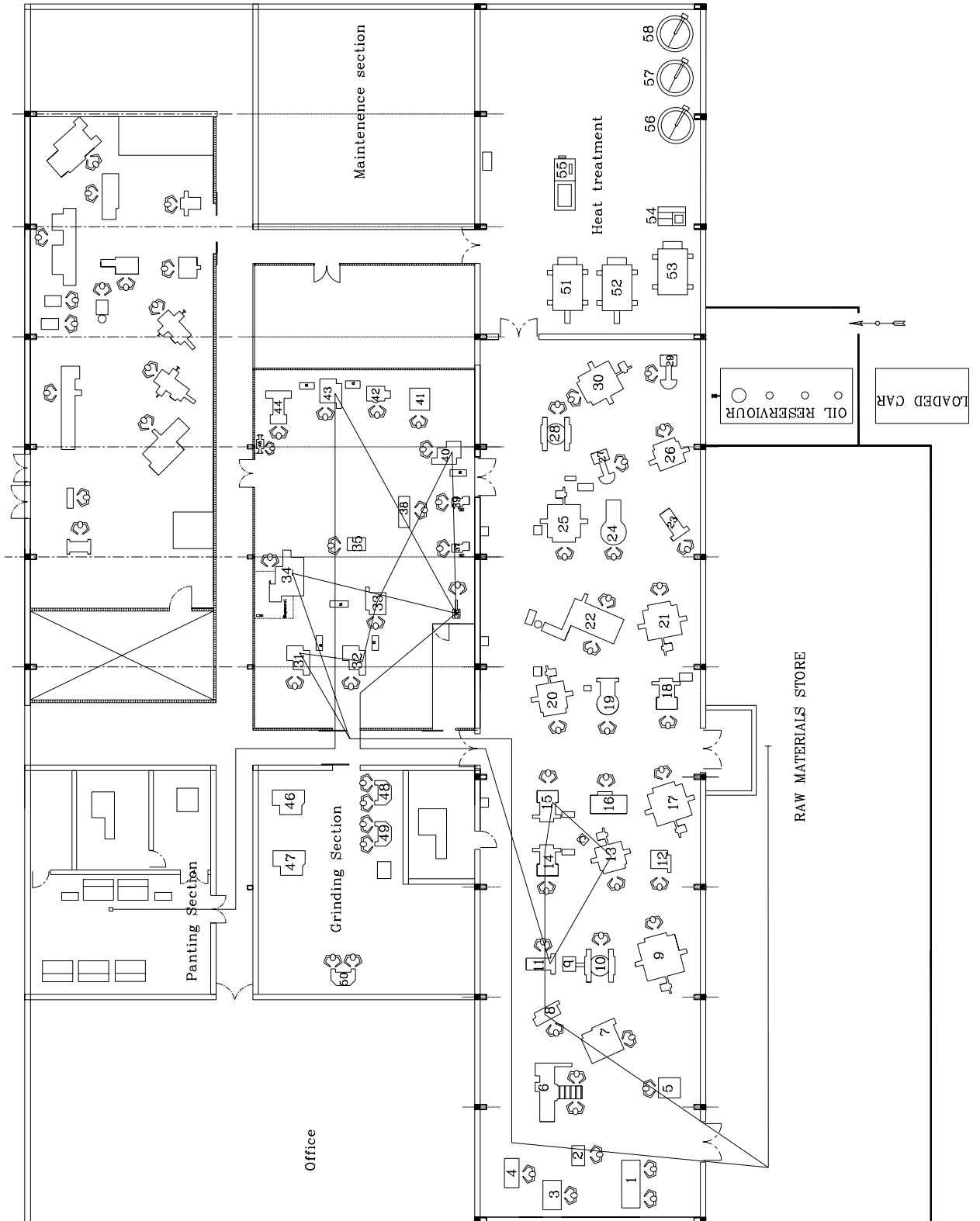
Flow of Garden hoe



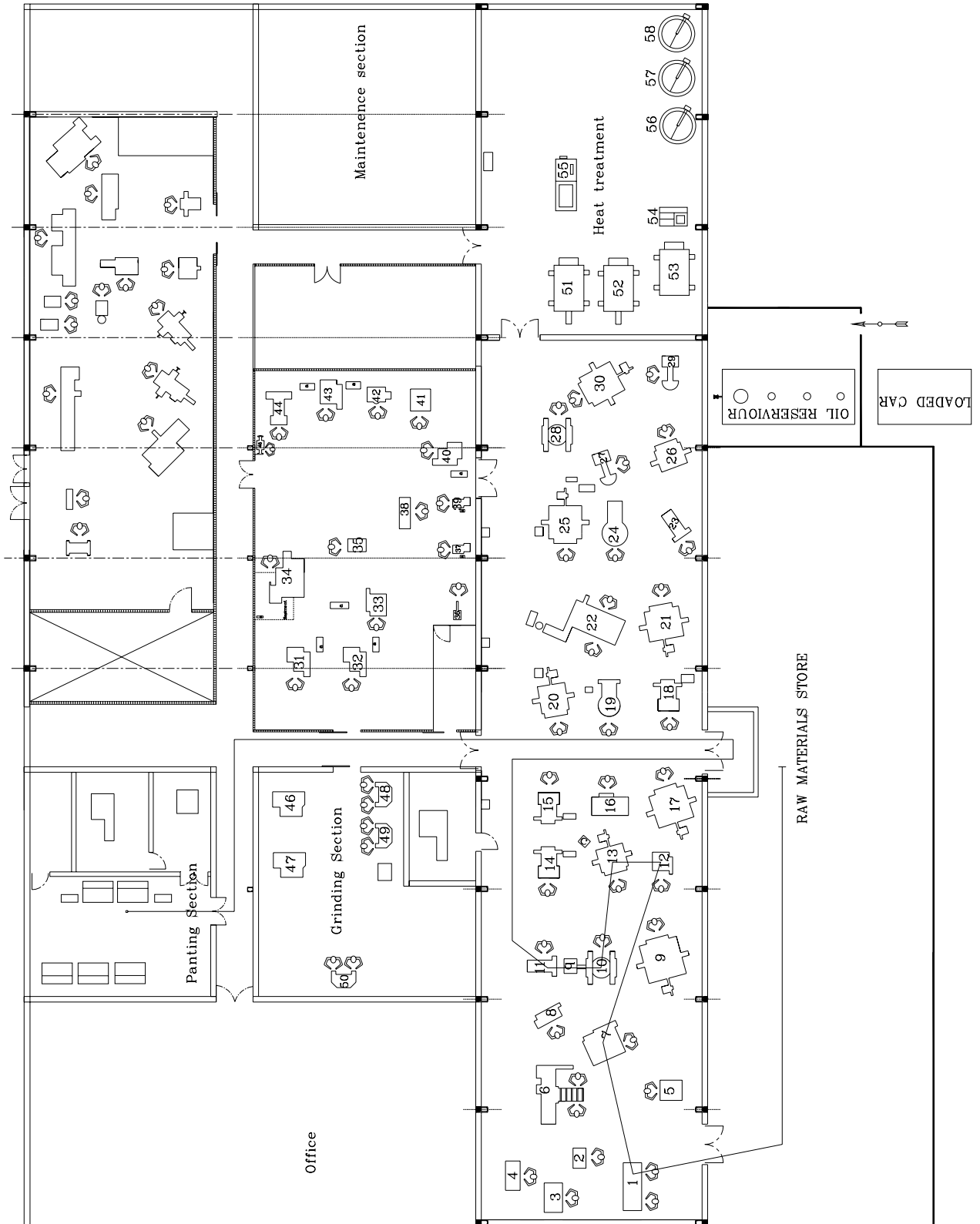
Flow of hammer



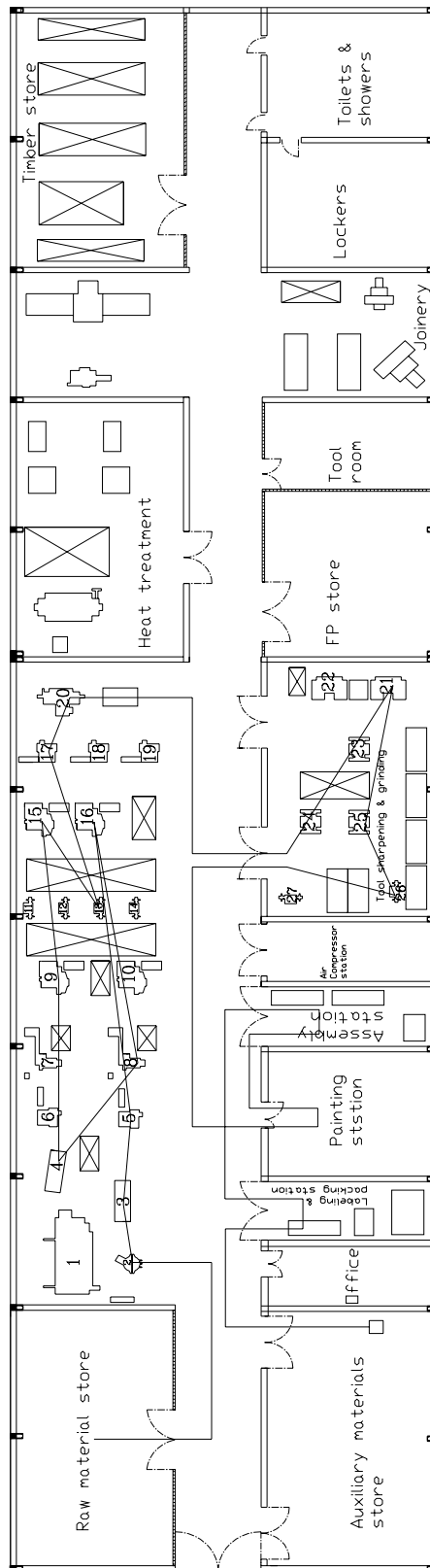
Flow of pick axe



Flow of Racke



Flow of shovel No. 2 and 5



Flow of sickle