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School of Mechanical and Industrial Engineering

MSc. in Industrial Engineering

Productivity improvement through Scrap reduction in rebar manufacturing by using Taguchi loss function

(case company Steely RMI –Rolling -2)

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Declaration

This is to witness that this thesis entitled ― Productivity improvement through scrap reduction in rebar manufacturing industries by using Taguchi loss function method (case company Steely RMI –Rolling -2) submitted in partial fulfillment of the requirements for the award of the degree of M.Sc. School of Mechanical and Industrial Engineering, Addis Ababa University done by Asfaw Alemu under my guidance. The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institutions to the best of my knowledge and belief.

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Acronyms

GDP	Growth Domestic Products
GNP	Growth National Products
EPRDF	Ethiopian People's Revolutionary Democratic Front
ADLI	Agricultural Development Led-Industrialization
EISF	Ethiopian Iron and Steel Factory
RMI	Rolling Mill Industry
BOP	Basic Oxygen Process
BOF	Basic Oxygen Furnace
Q-BOP	Quelled Basic Oxygen process
EAF	Electric Arc Furnaces
OHF	The Open Hearth Heater
HM	Hot Metal
NaF	Sodium Fluoride
EU-10	Ten Candidate Europe Country
EU-15	Fifteen Candidate Europe Country
AGC	Automatic Gauge Control
AWC	Automatic Width Control
ASC	Automatic Shape Control
APC	Automatic Profile Control
TMCP	Thermo-Mechanical Control Processing
HSLA	High Strength Low Alloy
USD	United States Dollar
PLC	Programmable Logic Controllers
MW	Mega Watt
CCM	Continuous Casting Machine
CSR	Corporate Social Responsibilities
Hr	Hour
L	Length
Kwh	kilo watt hour
M bars	Milibars
Atm	standard atmosphere
Pascal’s or kilopascals.	Measuring unit of pressure
Gcal/t	Giga calories per ton
ϕ	Diameter
$\prod$	Pie

Abstract

There are approximately ten active rebar manufacturing industries in Ethiopia. Most of them use imported raw materials in the form billet, but during production, these imported raw materials are not fully converted to final products, resulting in many losses, like those produced in parting billets into two parts, hard-scale, head-tail cuts, cobble, and off-cuts. So among these losses, off-cut and head-cut take on much more weight. The goal of this research is to increase raw material productivity by reducing the major losses caused by head-cut and off-cuts. And the methods this paper uses are Taguchi loss functions to show the saved off-cuts, electric, and furnace fuel consumption. and a JavaScript application to display a preview of the number of products in a given raw material size. In the results, get the optimum or productive length of raw materials for every product type, such as

- The optimum length of billet for ϕ10=5619mm the remain length of billet 6377mm used for ϕ12 rebar from 12-meter length of billet
- The optimum length of billet for ϕ12=6457mm the remain length of billet 5539mm used for ϕ24 rebar from 12-meter length of billet
- The optimum length of billet for ϕ14=6122mm the remain length of billet 5874mm used for ϕ24 rebar from 12-meter length of billet
- The optimum length of billet for ϕ16=5817mm the remain length of billet 6179mm used for ϕ24 rebar from 12-meter length of billet
- The optimum length of billet for ϕ20=5661mm the remain length of billet 6335mm used for ϕ20 rebar from 12-meter length of billet

And reduce the length of head-cut then make it uniform .In the current situation, the total percentage of losses for the case company is 6.7% of the weight per billet, and the research improved these losses by 2.23%; therefor, the material productivity increased by 4.5%, and the saved electric power is 2172.25 kwh and the saved furnace fuel consumption is 897.53 liters are per shift.

Key words: - Productivity improvement; scrap reduction rebar's manufacturing; steel industries

CHAPTER ONE

1. Introduction

In an era of worldwide economic downturn, the survival and competitiveness of manufacturing firms depend on their practices and capabilities to adapt to external environments, which are attributed to changes in customer preferences, government regulations, technology and competitors (Jayanthi, 2001). This strategic alignment of internal resources and external market requirements enables not only survival, but also competitiveness (Bates et al, 2001, Sun and Hong, 2002; Machuca, 2011). Manufacturing strategies determine the deployment of resources to build capabilities for creating and sustaining costs and product advantages in order to maintain a high level of profitability and strong market position. This reflects the ability to successfully define their scope, to manage and coordinate the core functions and operations within the enterprise as well as relationships with suppliers and customers, and to respond to market demand (Bennett and Vaidya, 2005).

On the other hand, companies would have to think about both local and international competition in order to be competitive or even survive. In today's global competitive environment, continuous improvement programs are considered a fundamental tool for industries to improve and optimize their performance. This leads to the improvement of companies' production and manufacturing processes, increasing the efficiency and effectiveness of their systems, reducing costs and improving cycle times. However, continuous improvement is a philosophy and a system that provides organizational improvements for their successes and reduces failures. These continuous improvement processes require the ability to understand the processes that affect the organization's objectives, to measure the effectiveness and efficiency of the processes; corporate performance and global competitiveness.(Grayson and Funjika-mulenga 2016)

The importance of productivity the growth has been discussed by numerous studies. At the firm level, productivity growth shows that resources have been used efficiently and this situation causes costs to decrease. A company can therefore lower the prices of its products while maintaining or increasing its profit margins. At the national level, productivity is one of the most important determinants of economic growth and progress. Productivity growth reduces the rate of inflation and also enhances the competitiveness of domestic enterprises. Productivity growth therefore increases the wealth of a nation.(Afsharian, Mirghasemi, and Khodabakhshi 2013)

In terms of Productivity it is an important factor on which the existence of a company is based. The main goal of a company is to satisfy the customer while making a profit. Companies are always trying to maximize profits. But to maximize profits, a company must be efficient, where efficiency is measured by the company's ability to increase the productivity of existing resources in a way that reduces the cost per unit of production. Since cost and productivity are reciprocal, an increase in productivity implies a decrease in production costs, with a consequent increase in profit. (Kendrick .G. 1965)Productivity, productivity Growth and improvement is a common theme for business, industrial companies, managers, economists, media and politicians as a solution to improving living standards, but there is a difference in this what productivity actually is, how it is measured appropriately, what they are real factors that affect it and how it can also be improved.(Derbe and Ababa 2018)

Metal and metal products industry plays a major role in promoting the economic development of both developing and industrialized countries. However, competitive technology, management and institutional structure are needed to make products internationally competent. In fact, competitiveness is determined by the productivity with which a nation uses its human, capital and natural resources. Productivity, on the other hand, depends on both the value of products and services and the efficiency with which they are produced..(Box and Ababa 2015)

The aim of this study was to find the optimal length of billets and minimize over long of head-cut for Ø 10,12,14,16,20,24mm rebar which have not produce excessive scrap by using mathematical formulas (length, area, volume and mass), micro soft excel and develop an application which uses to pre- viewing the product from the given raw materials(billet) size before the production will start.

1.1 Back ground and Justification

The three consecutive five years' development plans of the Imperial regime (1930-1974) were formulated that the development of the industrial sector and policies and strategies pertinent to materialize it were formulated. The Dergue Government (1974-1991) and its claimed socialism led to planned means of production, production targets and allocate resources based on the deliberate decision of the authorities. Production of large scale goods was almost entirely state owned. As a result, there was little room for private sector development. Later on, the Ten- Year Perspective Plan of the same regime (1984/85-1993/94) sought to promote the production of intermediate and capital goods, and expansion of small-scale industries (Sarah and Mesfin, 2011).

In case of manufacturing industries as well; manufacturing industries are the backbone in the economic structure of a nation, since they contribute to both increasing gross national product and gross domestic product [GDP/GNP] and providing employment. The efficiency with which manufacturing firms/organizations and industries, convert inputs (labor, capital, and raw materials) into output is determine their Productivity grows when output grows faster than inputs, which makes the existing inputs more productively efficient. Since the level of productivity in manufacturing firm's increases, the overall output value increases, resources are used efficiently and their contribution in the whole economy will increase. (Derbe and Ababa 2018)

In Ethiopian essential metal businesses bargain with generation of metal from metal, scrap and transformation of billet, pieces etc. into essential metal items such as, tubes bars, hot rolled ribbed and plain fortification bars, wire pole, points, cold rolled tubes of different profiles, cold rolled sheets, galvanized sheets and tubes. The essential metal items created by essential metal businesses are hence crude materials (inputs) for the downstream building industries.(Aw, Kitaw, and Ebinger 2017)

Currently, there are about ten operational re-bar manufacturing plants in Ethiopia. A look into their geographical distribution of medium and high scale re-bar manufacturing industry indicates that most of them, about 90%, are located at Oromiya region and Addis Ababa city administration. Ethiopian re-bar manufacturers are currently producing re-bar of grade 40, 60 and 75 with product size ranges of diameters from 8 to 32 mm (Demoz, 2014)(To 2018)

The research focuses on the productivity improvement through scrap reduction Ethiopian rebar manufacturing industry. Analysis of the production system and productivity play a vital role for the development of the manufacturing sector and the overall economy. It can assure the efficient resource utilization through systematic approach and techniques that can analyze and improve the specified manufacturing industries and address the inefficient and ineffective utilization of raw materials/billets of each product types. Therefore, analyzing the productivity of the rebar manufacturing sector can signify the sectors productivity level especially material productivity and thus lead to a better productive production and manufacturing environment

1.2 Statement of the Problem

In the case of Steely RMI manufactures rebar with diameters of 10, 12, 14, 16, 20, and 24 mm by importing raw materials 130mm*130mm*12000mm, direct cutting two equal parts, and its annual manufacturing capacity is about 340,000 tons. But in material productivity, the current scenario has been found in the poorest condition because of the amount of scraps/off-cuts estimated about 10 tons collected in each production shift for rebar diameter 16, besides the normal products and it used to prepare raw materials/billets for the rolling mill 01 which manufacture rebar diameters 8,10.12mm , and every staff member said the scraps is not our concern because we have a continuous billet casting plant used to prepare other types of inputs and the only concern is hard-scale. Finally, producing more output with a reduced level of input will result in increased productivity. As an example, rolling plant-2 has a capacity to roll 458 tons of billets for diameter 16 rebar in one shift. And the produced scrap collected in tons, besides of this scrap the losses of electric and fuel consumption should be relook.

1.3Research questions

The major research question to be raised in the process of the research preparation could be generalized in the following areas.

1. What is the existing material productivity performance for each rebar types?
2. Identify the main problems in materials productivity on manufacturing
3. How to improve materials productivity based on the existing performance?

1.4Objective of the study

1.4.1General objective of the study

The general objective of this study is to improve productivity of rebar manufacturing industry through scrap reduction by finding the optimum lengths of billets and head-cuts.

1.4.2 Specific Objectives the study

1. To assess and identify produced scrap by using Taguchi loss function to understand the influence of productivity.
2. To evaluate the factors that impact on the material productivity with different aspects.
3. To propose a solution to reduce scrap and indicate how to improve material productivity.

1.5 Scope of the project

This study focuses on the productivity improvement of product or output and minimization of the defects and scraps on Ethiopian steel rebar manufacturing industry (steely RMI-2). It is based on the data obtained through research methodologies described. The research assessment considers on the following working area of the company namely the measuring the dimensions of raw materials, the cutting of raw material, the rebar manufacturing process like the main material losses area around preheating furnace, rough mills, hot shear, intermediate mills, finishing mills, punch rolls, fly shear, cooling bed, cold shear, final product and off-cut/scrap collecting areas. Because these are the research has been focused to correct. The study is limited on the assessment and analysis issues of rebar manufacturing industries specifically on utilization of raw materials, rebar manufacturing process, local billet manufacturing methods and productivity improvement: to meet the objectives of this thesis.

1.6 limitation of the study

This research emphasizes analyzing the losses that affect productivity improvement, specifically excessive scrap in Steely RMI, and proposes recommendations for improving productivity based on its reduction or elimination of the scrap or off-cuts; by utilizing proper length of billet and the head cut on hot shear machine are more weighted. This study focuses on ϕ 12,16,20,24 mm rebar's because during the time of data collection there is no order and production of ϕ 10 and 14 mm rebar. So that on the data analysis cannot use the result comparison among the current company output, the research results. But on the productive/optimal lengths of billets and the solution on the application included both ϕ 10 and ϕ 14 rebar.

1.7 Significance of the Study

The significance of this research is to explore a solution to problems related to a raw materials' preparation in Ethiopian Steel bar manufacturing Industries. It can improve proper materials preparation and productivity by addressing the concerns associated with a profit reduction of the company and a new mechanism by developing suitable application and mathematical formulas. Since the research result will depict improper raw materials' a preparation, concern and improve productivity; the research will have considerable importance in being acquainted with the factual decision making an approach through a fact gathering, analyzing, measuring, interpreting, and controlling the preparation the whole raw material and improved the companies' a production system. Hence, Ethiopia Steel bar manufacturing Industries added value of protects the looseness materials in the form an excessive scrap and head-cuts. In general, this research will benefit if it is applied by a similar steel bar manufacturing industries for the improvement of productivity and the profit to increments through.

1. To identify the scraps which is produced in each product type.
2. To reduce repetitive manufacturing process.
3. Predict pre-production viability that shows the output billets/raw materials for every product types and used to select optimum billets/raw materials size that has minimum scrap or off-cut before the production will start.
4. Develop appropriate techniques to maximize the system/operational productivity of the case firm.
5. Suggesting possible solutions to improve productivity of the Ethiopian metal manufacturing industries especially case company

1.8 Organization of the study

The study was organized in six chapters. The first chapter is about Problem and Its Approach which contain introductions, problem statement, objective of the study, significance of the study, and scope of the study, Scope of the project, limitation of the study, Significance of the Study. The second chapter deals with related Literature Review. Past research and article review will be conducted related to productivity improvement and productivity improvement techniques. The chapter three deals methodology used for the study. The fourth chapter data collection, presentation and analysis with Taguchi loss function method of the Steely RMI PLC -2 based on the survey questioner about the case company. Chapter five presents the proposed system improvement & the mathematical description and application. Chapter six presents the conclusion; recommendation and future works.

CHAPTER TWO

2. Review of related literature

2.1 Introduction

A literature review in its most comprehensive form includes a synthesis of quantitative findings stemming from quantitative research studies and qualitative findings stemming from qualitative research studies. Synthesizing both quantitative and qualitative findings within the same literature review automatically renders the literature review process as a mixed research study (Onwuegbuzie, Collins, et al., 2010).(Of and Literature n.d.) In this chapter, studies on material productivity and the impact on waste and scrap from theoretical and observational studies are examined from different technical points of view. Systematic approaches to writing control mainly focus on the contribution of different theoretical and observational ideas about productivity factors within the manufacturing industry, steelmaking methods and domains based on rebar production processes. In finding the research knowledge gap, assumptions, methodologies and their findings are carefully considered. When reviewing past research, an effort is made to relate the work as closely as possible to the topic under study and to give priority to the most recent work. In the following section, various topics related to the course are discussed.

2.1.1 Definitions of the term

• Productivity is the certainty of being able to do better today than yesterday, and less well than tomorrow.

• Productivity is the will to improve on the present situation, no matter how good it may seem, no matter how good it may really be.

• Productivity is the constant adoption of economic and social life to changing conditions.

• Productivity is the continual efforts to apply new techniques and new methods.

• Productivity is the faith in human progress"

Improvement is the process of a thing moving from one state to a state considered to be better, usually through some action intended to bring about that better state. The concept of improvement is important to governments and businesses, as well as to individuals.

Productivity Improvement is the process of achieving more output from an hour of work.

Productivity improvement can be achieved in a number of ways. If the level of output is increased faster than that of input, productivity will increase. Conversely, productivity will be increased if the level of input is decreased faster than that of output.(Yadav and Marwah 2015)

Scrap a small piece or amount of something, especially one that is left over after the greater part has been used:

Reduction the action or fact of making something smaller or less in amount, degree, or size

Rebar (short **for reinforcing bar),** known when massed as reinforcing steel or reinforcement steel, **is** a steel bar used as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension

Rebar manufacturing process is a metal forming process in which metal stock is passed through a pair of rolls. The process involves plastically deforming a metal work piece by passing it between rolls. In the hot rolling process, the billet is passed through a series of rolling stands where its section is continuously reduced to the required dimensions.

Productivity in industry is usually defined as the manufacturing output compared with an input. Output from the production process is compared with a chosen input and is usually expressed either as a ratio or as a per- cent. Labor productivity is typically measured as the number of production units of product manufactured per labor-hour. This is one example of a measurement of productivity. However, the input need not be labor- hours, as other aspects are relevant to productivity. Material productivity is the quantity of production output per quantity of material inputs. Total productivity can be calculated as total output quantity of units of product divided by total quantity of resources input. Any measure of productivity is simply the total saleable output compared to the chosen resource input, whether it is labor hours, material, or whatever.(Blank 2018)

Productivity is broadly defined as the ratio of outputs to inputs. With respect to the economy, productivity measures how efficiently goods and services can be produced by comparing the amount of economic output with the amount of inputs (labor, capital, etc.) used to produce those goods(Productivity and Measures 2021)

Productivity is a broad concept that refers to the relationship between economic output and inputs. The level of productivity is the amount of output produced per unit of inputs consumed. It measures how an economy is using resources (labour and capital) in the production process in order to deliver a final output (goods and services).(Treasury and Note 2011)

Productivity improvement

'Productivity' has become a widely used term, with almost everyone mentioning it. For different people, "productivity" means different things. As a result, it ranges from efficacy to efficiency. Productivity is a measure of a company's or an enterprise's ability to convert available resources (inputs) into finished goods or services (necessary outputs). (Singh and Singhal 2016)

And the productivity and quality of steel billets and pieces fabricating prepare is moved forward with the application of a created hereditary calculation and most extreme rate of casting and defect-free items is accomplished by controlling the method parameters.(Khawar et al. 2015)

In other way assembly line balancing is how to allocate tasks to jobs in order to achieve the specified goal. Minimizing the number of workstations and maximizing the production rate are the most common objectives. Specifically, various components are manufactured in industries where improving productivity is a primary concern and where there is a need to balance operations at various strategic workstations in order to apply group technology and minimize costs. overall production and the number of workstations.(N. Kumar and Mahto 2013)

Also Productivity is the ratio of output and input. This actually means increasing the value of the input in order to increase the value of the output. Productivity can be achieved by increasing the added value of products / services, or by decreasing the unit cost of production, or a combination of both. (Erlendsson, J. 2006).

The other authors at present all process is considered from the angle of productivity to reduce the non-value activities to give optimized output to the possible extent. It is a total concept that addresses the key elements of competition, for example is innovation, cost, quality and delivery.(Chandurkar, Kakde, and Bhadane 2015)

In today's competitive world, planning productivity is one of the key ingredients of successful industrial organizations. Productivity gains can reduce the labor costs of the production unit or increase production. Productivity depends on various factors such as manpower, machines, capital, temperature, raw materials, quality etc. So each factor has its own contribution.(Mill 2016)

In manufacturing plants throughout the world, lean manufacturing strategies are being used to meet growing demands placed on manufacturers. The main intention of the manufacturers is to amplify the productivity, decrease value and maximize patron cost and to limit waste at the equal time.(Ansari et al. 2018)

Line performance depends on many factors. For example: cycle time, number of stations, traffic problems, station space, transport networks, intergroup communication, complexity of activities, reliability. A process's waste can be divided into various categories; this waste increases production lead times while decreasing productivity and work quality. Overproduction, waiting times, unnecessary travel, over processing, excess raw materials, unneeded travel, flaws, and underutilized staff ingenuity are the largest wastes.(Sharma, Qureshi, and Bansod 2017)

An important factor in the growth of the nation's economy is the apparel industry. The current state of the industry needs to be improved; its productivity and efficiency must be at an ideal level in order to satisfy client demand and remain competitive. An industry can lower expenses and quality changes, increase production, throughput, and efficiency by minimizing waste by using lightweight tools. Losses can be systematically eliminated by employing several lean tool strategies by following a comprehensive and consistent process.(Talukder et al. 2013)

The analysis of the operations required to produce an article in a factory, with the aim of increasing efficiency. Each operation is studied minutely and analyzed in order to eliminate unnecessary motions and thus reduce production time and raise output, which increases productivity. (Marri and Shaikh 2012)

2.1.2 The measures of productivity

There are many different productivity measures. The decision between them is influenced by the goal of productivity measurement and, frequently, the data's accessibility. The broadest category for productivity measurements is single factor productivity measures. (relating a measure of output to a single measure of input) or multifactor productivity measures (relating a measure of output to a bundle of inputs).(Meas. Product. - OECD Man. 2001)

Single-factor productivity measures Single-factor productivity measures reflect units of output produced per unit of a particular input. (Syverson 2011)

Multi- factor productivity at the industrial level, measures of production and input growth as well as derived variables like multi-factor productivity. The input measures include various categories of capital (K), labor (L), energy (E), material (M) and service inputs (S). (O'Mahony and Timmer 2009)

Multi-factor productivity multi-factor productivity (MFP) means that more output is obtained from the same set of inputs or that fewer inputs can be used to produce the same output (What Creates Multi-Factor Productivity ? Nicholas Crafts 2008)

Capital productivity the amount of output (in euros) produced for every euro invested in manufactured capital. Capital productivity measures how effectively a given capital type is put to use in the production of products and services. An in- crease of capital productivity means that for a given level of production less capital is needed.(Stocker et al. 2015)

Labor productivity defined as output per unit of labor input (persons engaged or hours worked). Labor productivity measures the efficiency of a country with which inputs are used in an economy to produce goods and services and it offers a measure of economic growth, competitiveness, and living standards within a country.(ILO 2015)

Energy productivity Energy productivity (EP) of an industry is measured by relating the energy consumption of an industry (input) to its output:(Office, Paper, and Efficiency 2011)

Materials productivity The cost of materials used in production of ten surpasses, in this view materials are treated as the first factor in production or manufacturing. "Raw materials are the major inputs in an organization and form the bulk which gets converted in to output.(Zala 2010)

Productivity Measures that only account for one of the two, inputs or outputs, present an incomplete picture of productivity. This means that common data like the quantity of students enrolled or the number of credits earned, the number of degrees awarded, and the cost or "profit" per faculty member shouldn't be used to measure productivity. The decision of whether to assess comes last. “single-factor productivity” (e.g., output per labor hour) or “multifactor productivity” (output related to total resource usage). (Massy, Sullivan, and Mackie 2012)

2.1.3 The factors affecting productivity.

Fabrication and Manufacturing and industry mainly faces problem of Productivity improvement. There are many factors which are critical to Productivity of these industries like Project Cost Overruns, Time management, Training method, Changeover time / set-up time of jobs, added work lead to poor quality, Lack of focus and priorities about works, Inadequate resources at right time, Productivity is a measure of the rate at which outputs of goods and services are produced per unit of input (labour, capital, raw materials, etc.). Productivity measures are used at the level of firms, industries and entire economies.(Raut 2014)

There is quite a variety of factors which can affect productivity, both positively and negatively. These include: 1. Capital investments in production 2. Capital investments in technology 3. Capital investments in equipment 4. Capital investments in facilities 5. Economies of scale 6. workforce knowledge and skill resulting from training and experience 7. Technological changes 8. Work methods 9. Procedures 10. Systems 11. Quality of products 12. Quality of processes 13. quality of management 14. legislative and regulatory environment 15. General levels of education 16. Social environment 17. Geographic factors. The first 12 factors are highly controllable at the company or project level. Numbers 13 and 14 are marginally controllable, at best. Numbers 15 and 16 are controllable only at the national level, and 17 is uncontrollable. (Yadav, Pooja Marwah, Col Sachin 2015)

Productivity increase is a crucial commercial and economic market value indicator. Therefore, in the fiercely competitive and constantly evolving world of technology, it is vital for company executives to recognise and manage the elements that affect productivity. Productivity is viewed as a key to success by managers and politicians. There are numerous techniques to boost productivity, each of which differs depending on the circumstances and culture of each firm. Human resources and employees are the most significant components that boost productivity.(Afsharian, Mirghasemi, and Khodabakhshi 2013)

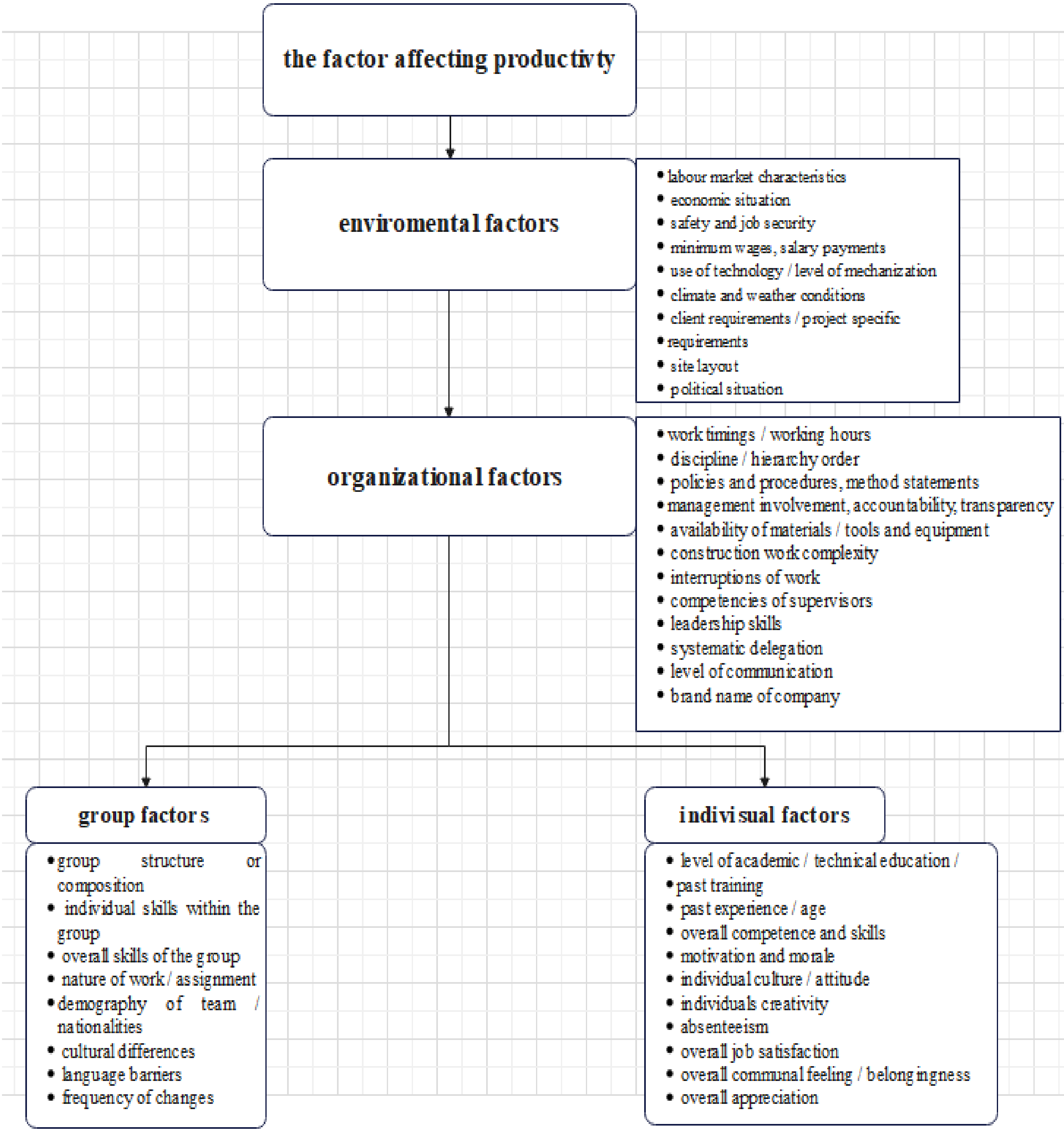

Figure2. 1the factors affecting productivity sited:(Afsharian, Mirghasemi, and Khodabakhshi 2013)

2.1.4 Productivity improvement technics

That there are numerous methods for enhancing productivity, including method analysis, labor measurement, cost-cutting, modernization, investment in machinery and equipment, and reengineering.(Nimawat and Shrivastava 2016).

Productivity Improvement Techniques (PIT) is one of the alternative that most of the organization is employing to assist them continuously striving for excellence in everything they do.(Plt 2021)

For increasing the productivity and efficiency, an integrated form of lean, green and six sigma techniques are suggested.(Yogesh and Simon 2017)

Work and time study techniques is raising the efficiency of utilization of the factors of production have been used for all manufacturing and service sectors as a scientific approach.(Duran, Cetindere, and Aksu 2015)

To increase productivity through better management of human resources by understanding various tools and techniques to better use through effective applications.(Workshop 2015)

Table 2. 1 show the methods/techniques of productivity improvement

No	Author	Objective	Factors/Cause	Methods/techniques
1	(Purba and Aisyah 2018)	to increase productivity in the process of picking order through reduction of processing time.	Order Picking is the most expensive activity in warehousing and can reach 55% of the total cost of warehousing operations, so it is considered a top priority in increasing productivity, even reaching 65% of total warehouse operating costs.	Visual Stream Mapping (VSM)
2	(R.Blank, 2018)	Cross-Functional Productivity Improvement describes how improvement efforts can be undermined by errors and incompleteness.	different departments can affect productivity by incorrect Lean manufacturing, material flow, efficiency, ergonomics, quality policies, issues of malpractice, and counterproductive procedures..	traditional productivity improvement methods.
3	(Almström 2013)	the productivity at shop-floor level can be improved through improving the method, increasing the performance, and increasing the utilization.	The design of the products and the amount of scraped products also affects the productivity in both manual tasks as well as work performed by machines.	the theoretical model and the industrial applications presented.
4	(Glacian 2017)	use the software tool to make a productivity improvement suggestions for the system.	a lack of a scientific work, which summarizes all the different methods	new simulation software tool developed by Dassault Systems, namely DELMIA 3D

5	(Soham Ravishekhar Deshpande 2020)	To reduce the waste and non- value added activities. and deciding the best suitable lean manufacturing tool with low cost and maximum profitability.	the variety, cost, quality and fulfillment of delivery limits	lean manufacturing techniques(Value Stream Mapping (VSM), Single Minute Exchange of Dies (SMED), Overall Equipment Efficiency (OEE), Cellular Manufacturing (CM), Assembly Line Balancing (ALB), Kanban system, Total Productive Maintenance (TPM), and Maynard Operation Sequence Technique (MOST).
6	(Inge S 2013)	to identify reason for low productivity level of production in food processing industries and to propose methods to increase productivity level of production in food processing industries.	the problem caused by low productivity, and the process in the product.	method use the brainstorming methods
7	(Al-Shayea et al. 2011)	improving the productivity of the whole production process by changing the technique of performing significant operations in the process.	risk magnitude of the new technique on the workplace environment and the fatigue level that affect human's health like on work injuries caused by heavy lifting, awkward postures, and repetitive motion.	PIM(Productivity Improvement Model) Model without increasing the risk and the fatigue that affects the worker performance.
8	(B.Power, 2018)	to develop enterprise-level best practices for implementing productivity improvement programs.	influence the effectiveness of trillions of dollars spent in construction around the world.	six program Elements: Leadership, Resources, Structure and Communications,

				Planning for Productivity, Productivity Monitoring and Control, Continuous Improvement.
9	(Sharma, Qureshi, and Bansod 2017)	to study and improve the current plant layout and are analyzed & designed by using string diagram.	The lead time observed is too high to handle or bear with respect to cost and resources utilized.	software simulation techniques. using ARENA software.
10	(Babu and Prabha 2015)	improving the productivity of the seat welding and assembly plant by reducing the down time using lean tools. to identify and reduce the downtimes.	Execs wait time, queue time, move time, administrative time, and other delays.	lean tools.
11	(Taifa and Vhora 2019)	the reduction of cycle time for productivity improvement in the manufacturing industry.	longer cycle time and takt time have a negative impact on various companies or manufacturing industries	lean manufacturing tools, value stream method, method-time measurements, just in time for inventory control, motion study, process study, VAT plant classification, total productive maintenance, improved MRP (material requirements planning)-based production planning, theory of constraint, linear programming and other simulation related techniques.
12	(Patel 2019)	productivity improvement and strategy identification.	the area/market level inefficiency	two-dimensional efficiency decomposition (2DED, Network

				Data Envelopment Analysis (Network DEA) and stochastic programming DEA (SPDEA) approach
13	(Khorsheed 2017)	to look at some of the tools to maximize productivity in any organization.	wasteful activities	tools in Lean Six Sigma(Value stream mapping , Cause and effect analysis, The Five whys analysis, Pareto chart and 5S
14	(Bondhare, Pawar, and Deshpande 2016)	methodology developed for standardization in the process activities in wiring harness industry by using Maynard's Operation Sequence Technique. (MOST)	applying MTM (Methods Time Measurement) system into manufacturing operations is that it is time consuming. (MOST) Due to high uncertainty in demand, most accurate forecasting is difficult. It is very difficult to meet the demand with existing supply especially in labor intensive operations.	MOST (Maynard Operation Sequence Technique)
15	(C. Prakash et al. 2020)	time and motion study employed in construction sector.	Poor efficiency productivity, tool time, support time and idle time	the application of time and motion study
16	(Kádárová, Janeková, and Suhányiová 2022)	to show the effects of balancing the current assembly line and proposed solutions for the arrangement of an automated assembly line on the amount of hourly assembly production and the cost of one piece of product on the assembly process of	installation of throttle valves was associated with waste, non-systematic and unbalanced work in individual workplaces.	scientific methods (measuring time consumption, balancing workplaces, the introduction of automation of welding and sealing operations)

		throttle valves, type FD 160.		
17	(UNMESH VISHWAS TAMHANKAR,2017)	implementation of productivity improvement solution as a standard for similar SMEs to achieve quick results with minimum cost incurred.	wastes of unnecessary inventory , waste of transportation and excess motion	Lean, Six Sigma, Total Quality Management
18	(Manikandaprabu and Anbuudayasankar 2019)	identify the different type of wastes producing in the organization and possibilities for eliminating/reducing	Wastes like inventory, lead time reduction and scrap	lean tools such as bottleneck analysis, value stream mapping, kaizen
19	Patel Ankit R 1, Patel Anish B 2, Patel Nishant R 3, Malek Sarhan A 4, Makwana Kashyap K 5 (Students,2019)	to reduce wastage of paper in a manufacturing company	Waste	Lean Manufacturing, Total Productive Maintenance (TPM), Six Sigma, Kaizen and Just in Time (JIT)
20	(N. Kumar and Mahto 2013)	the actual case different components manufactured at industries in which productivity improvement is a prime concern and there is a necessity for balancing the operations at various strategic workstations in order to apply group technology and minimize the total production cost and number of workstations.	the lines are not properly balanced.	Line balancing techniques
21	.(Marri and Shaikh 2012)	the implementation of work study and motion study for	Un-balance engagements of workers on	time and motion study methods were

		productivity improvement methods during the manufacturing process.	manufacturing machines	
22	.(Ms, Yue Wu2015)	The company improving the productivity in the competitive smart cards market without adding any unvalued equipment or additional labor. by increasing the yield and maintaining the decent qualities of smart cards.	The company was undergoing a downturn times due to the competitive pressure and bottleneck process on assembly line.	Six Sigma DMAIC (Define, Measure, Analysis, Improve, Control)

According to (Purba and Aisyah 2018) he studied to increase productivity in the process of picking order through reduction of processing time. Uses Visual Stream Mapping method, is needed because by using that can be seen that need to change the method of picking from by heuristic method became to the zoning method. To survive in marketplace, companies need to be able to deliver products on time, maintain market credibility and services faster than competitors.

And the other author (R.Blank, 2018) Cross-Functional Productivity Improvement describes how improvement efforts can be undermined by errors and incompleteness. Uses traditional productivity improvement methods. when the errors happened different departments can affect productivity by incorrect Lean manufacturing, material flow, efficiency, ergonomics, quality policies, issues of malpractice, and counterproductive procedures. And Companies can increase productivity in a variety of ways. The most obvious and more traditional methods involve automation and computerization that minimize the tasks that must be performed by employees.

Also (Almström 2013) the productivity at shop-floor level can be improved through improving the method, increasing the performance, and increasing the utilization. uses the theoretical model (the true motives for an entire society and for the industrial organizations to increase the productivity at the shop floor level.) and the industrial applications presented. To solve the design of the products and the amount of scraped products also affects the productivity in both manual tasks as well as work performed by machines.

(Glacian 2017) use the software tool to make a productivity improvement suggestions for the system. uses new simulation software tool developed by Dassault Systems, namely DELMIA 3D. when a lack of a scientific work, which summarizes all the different methods. Therefore, the first propose method is the elimination of the disturbances. production equipment such as failure of CNC machines, Robotic equipment etc. Another proposed strategy for the improvement of efficiency of the industrial units is the elimination of the defects of the products from the design phase. The implementation of lean strategies like 5S inside the industrial manufacturing cells, has been found as another strategy for the improvement of productivity of production systems and applied additional strategies of productivity improvement in manufacturing systems are the detection of shifting bottleneck machine.

(Soham Ravishekhar Deshpande 2020) uses to reduce the waste and non- value added activities. and deciding the best suitable lean manufacturing tool with low cost and maximum profitability. uses methods/technics that lean manufacturing techniques (Value Stream Mapping (VSM), Single Minute Exchange of Dies (SMED), Overall Equipment Efficiency (OEE), Cellular Manufacturing (CM), Assembly Line Balancing (ALB), Kanban system, Total Productive Maintenance (TPM), and Maynard Operation Sequence Technique (MOST) when problem the variety, cost, quality and fulfillment of delivery limits are faced.

(Inge S 2013) to identify reason for low productivity level of production in food processing industries and to propose methods to increase productivity level of production in food processing industries. use the brainstorming methods. when the problem caused by low productivity, and the process in the product.

(Al-Shayea et al. 2011) states to improving the productivity of the whole production process by changing the technique of performing significant operations in the process. uses PIM (Productivity Improvement Model) Model without increasing the risk and the fatigue that affects the worker performance. When risk magnitude of the new technique on the workplace environment and the fatigue level that affect human's health like on work injuries caused by heavy lifting, awkward postures, and repetitive motion.

(B.Power, 2018) to develop enterprise-level best practices for implementing productivity improvement programs. Uses the technics which are six program Elements: Leadership, Resources, Structure and Communications, Planning for Productivity, Productivity Monitoring and Control, Continuous Improvement. and the that faced are influence the effectiveness of trillions of dollars spent in construction around the world.

(Sharma, Qureshi, and Bansod 2017) to study and improve the current plant layout and are analyzed & designed by using string diagram. Uses software simulation techniques. using ARENA software
When the problem that faced are the lead time observed is too high to handle or bear with respect to cost and resources utilized.

(Babu and Prabha 2015) both studied improving the productivity of the seat welding and assembly plant by reducing the down time using lean tools. to identify and reduce the downtimes. And uses lean tools. For solving a problem like Execs wait time, queue time, move time, administrative time, and other delays. Were happened

(Taifa and Vhora 2019) both studied the reduction of cycle time for productivity improvement in the manufacturing industry. And the causes were longer cycle time and tact time have a negative impact on various companies or manufacturing industries. The solving technics their used lean manufacturing tools, value stream method, method-time measurements, just in time for inventory control, motion study, process study, VAT plant classification, total productive maintenance, improved MRP (material requirements planning)-based production planning, theory of constraint, linear programming and other simulation related techniques.

(Patel 2019) he studied that productivity improvement and strategy identification. And the case was the area/market level inefficiency. The he used two-dimensional efficiency decomposition (2DED, Network Data Envelopment Analysis (Network DEA) and stochastic programming DEA (SPDEA) approach.

(Khorsheed 2017) studied to look at some of the tools to maximize productivity in any organization. And the case was the wasteful activities. Used tools in Lean Six Sigma (Value stream mapping, Cause and effect analysis, The Five whys analysis, Pareto chart and 5S

(Bondhare, Pawar, and Deshpande 2016) describe methodology developed for standardization in the process activities in wiring harness industry by using Maynard's Operation Sequence Technique. (MOST). Used MOST (Maynard Operation Sequence Technique) and applying MTM (Methods Time Measurement) system into manufacturing operations is that it is time consuming. (MOST) Due to high uncertainty in demand, most accurate forecasting is difficult. It is very difficult to meet the demand with existing supply especially in labor intensive operations
(C. Prakash et al. 2020) the objective of the study was time and motion study employed in construction sector. And used technic was the application of time and motion study. The main causes are Poor efficiency productivity, tool time, support time and idle time

(Kádárová, Janeková, and Suhányiová 2022) the objective of the study to show the effects of balancing the current assembly line and proposed solutions for the arrangement of an automated assembly line on the amount of hourly assembly production and the cost of one piece of product on the assembly process of throttle valves, type FD 160. And used technic were scientific methods (measuring time consumption, balancing workplaces, the introduction of automation of welding and sealing operations). the main causes were installation of throttle valves was associated with waste, non-systematic and unbalanced work in individual workplaces.
(UNMESH VISHWAS TAMHANKAR,2017) the objective of the study to implementation of productivity improvement solution as a standard for similar SMEs (small manufacturing enterprises) to achieve quick results with minimum cost incurred. And used technic were Lean, Six Sigma, Total Quality Management. the main causes were wastes of unnecessary inventory, waste of transportation and excess motion.

(Manikandaprabu and Anbuudayasankar 2019) the objective of the study to identify the different type of wastes producing in the organization and possibilities for eliminating/reducing. And used technic were lean tools such as bottleneck analysis, value stream mapping, kaizen. the main causes were Wastes like inventory, lead time reduction and scrap.

(N. Kumar and Mahto 2013) the objective of the study the actual case different components manufactured at industries in which productivity improvement is a prime concern and there is a necessity for balancing the operations at various strategic workstations in order to apply group technology and minimize the total production cost and number of workstations. And used technic were Line balancing techniques. the main causes were the lines were not properly balanced.

(Marri and Shaikh 2012) the objective of the study the implementation of work study and motion study for productivity improvement methods during the manufacturing process. And used technic were time and motion study methods. the main causes were Un-balance engagements of workers on manufacturing machines.

(Ms, Yue Wu2015) the objective of the study The smart card company increasing efficiency without adding any unnecessary machinery or extra manpower in the highly competitive smart card market. by boosting production while preserving the good attributes of smart cards. employed the Six Sigma DMAIC technique (Define, Measure, Analysis, Improve, Control). primary factors Due to intense competition and an assembly line bottleneck, the business was going through hard times.

Table 2. 2 shows the studies, the frequency and the ranks of productivity improvement methods

Sn No	methods/technics	Studies	redundancy	scale
1	Lean-manufacturing techniques(Value Stream Mapping (VSM), Single Minute Exchange of Dies (SMED), Overall Equipment Efficiency (OEE), Cellular Manufacturing (CM), Assembly Line Balancing (ALB), Kanban system, Total Productive Maintenance (TPM), and Maynard Operation Sequence Technique (MOST), time and motion study methods	(Taifa and Vhora 2019), (Babu and Prabha 2015), (Soham Ravishekhar Deshpande 2020), (Purba and Aisyah 2018), (Khorsheed2017) ,(UNMESH VISHWAS TAMHANKAR,2017) , (Manikandaprabu & Anbuudayasankar, 2019), (Bondhare, Pawar, and Deshpande 2016), (C. Prakash et al. 2020) and (Marri and Shaikh 2012)	10	1st
2	Six sigma program	(B.Power, 2018), (دیخورش 2017), (UNMESH VISHWAS TAMHANKAR,2017) and .(Ms, Yue Wu2015)	4	2nd
3	new simulation software tool developed by Dassault Systems,	(Glacian 2017), (Sharma, Qureshi, and Bansod 2017),	2	3rd

	namely DELMIA 3D, software simulation techniques. using ARENA software.			
4	time and motion study methods	(C. Prakash et al. 2020) and (Marri and Shaikh 2012)	2	3rd
5	PIM(Productivity Improvement Model) Model without increasing the risk and the fatigue that affects the worker performance and traditional productivity improvement methods.	(Al-Shayea et al., 2011) and (R.Blank, 2018)	2	3rd
6	scientific methods (measuring time consumption, balancing workplaces)	(Kádárová, Janeková, and Suhányiová 2022)	1	4th
7	Line balancing techniques	(N. Kumar and Mahto 2013)	1	4th
8	two-dimensional efficiency decomposition (2DED, Network Data Envelopment Analysis (Network DEA) and stochastic programming DEA (SPDEA) approach	(Patel 2019)	1	4th
9	method use the brainstorming methods	(Inge S 2013)	1	4th
10	the theoretical model and the industrial applications presented.	(Almström 2013)	1	4th

Therefore, from the analysis of the above research work the following technics and methods uses more solution making tools for productivity improvement purposes of the case sectors.

1. Lean manufacturing technics: - It was mainly derived from Toyota Motor Corporation's Production System, and the word "lean", in this context, was first mentioned in James Womack's book (Womack et. al., 1991), The Machine That Changed the World. Lean practices have become popular among large- size companies (Abdelhadi, 2016). However, small and medium companies can learn and benefit from the application of lean practices in order to detect and reduce waste. Lean production systems focus on continuous improvement of processes, and respect for workers, customers and other contributors in the production process. This continuous improvement quest consists of identifying all possible types of waste and working on eliminating them or at least minimizing their impacts on the values provided. At first, lean principles were perceived to be exclusive for manufacturing firms.(Alhisan et al. 2019)
2. Six sigma program: -The Six Sigma method is a complex and flexible system of achieving, maintaining and maximizing the business success. Six Sigma is based mainly on understanding the customer needs and expectation, and responsible approach to managing, improving and establishing new business, manufacturing and service processes. (SIX SIGMA APPROACH : APPLICATION , 2013).

Six Sigma is a method to improve quality through the reduction of process errors continuously. It emphasizes a comprehensive understanding of the design and production process based on customer satisfaction (Antony et al. 2018). Errors are a source of costs and dissatisfied customers, and great savings can be achieved by eliminating or significantly reducing critical errors. (Text 2012).

3. PIM (Productivity Improvement Model) :- The productivity improvement model formulation is based on considering all the necessary aspects for selecting the best techniques to perform significant operations that improve the productivity of the production process without increasing the risk, the fatigue, cost and time associated with the implementation of the selected techniques.(Al-Shayea et al. 2011).

The main components of productivity improvement method for garment SMEs are identified based on the research analysis, intensive literature surveys and previous similar research works. These are; paradigm shift, management commitment, supply chain improvement, intensive education and training, continuous improvement and improved government support.(Henok Tamrat 2019)

4. Motion and time study: -Motion and time study technique is one of the productivity improvement techniques used in many manufacturing companies. Motion and time study is defined as a scientific analysis method designed to determine the best way to execute the repetitive task and to measure the time spent by an average worker to complete a given task in a fixed workplace. In manufacturing industries, assembly line is also another major area to be taken into consideration for increasing productivity.(Sai Nishanth Reddy, Srinath Rao, and Rajyalakshmi 2016)
5. ARENA and Dassault Systems, namely DELMIA 3D, - ARENA, the world's leading simulation software has been used successfully by organizations the world over to advance the efficiency and productivity of their business. ARENA is designed to provide the power required tor successful simulation within an easy-to-use modelling environment. (Azhar 2008)

The DELMIA product portfolio allows for increased productivity, predictable cost and schedule performance, and reduction in cost and project cycle-times. At the same time, you will also gain improved team collaboration, risk mitigation, and better Health, Safety & Environment performance.(Eum n.d.)

6. Two-dimensional efficiency decomposition (2DED, Network Data Envelopment Analysis (Network DEA) and stochastic programming DEA (SPDEA) approach: - Data envelopment analysis (DEA) is a linear programming based approach for measuring relative efficiencies or performances of peer decision making units (DMUs). The performance or efficiency of a DMU is expressed in terms of a set of measures which are classified or coined as DEA inputs and outputs. (Mescher and Müller 2002)
7. Line balancing techniques: - The line balancing technique is industrial engineering concept to balance the work load among workers and stations. (M et al. 2018)
8. Method use the brainstorming: - Brainstorming can help eliminate systematic errors by flushing out logic early on.(Visual Aural Read / Write Kinesthetic 2021)
9. The theoretical model and the industrial applications presented: -Employment relations is the study of the regulation of the employment relationship between employer and employee, both collectively and individually, and the determination of substantive and

procedural issues at industrial, organizational and workplace levels (Odogwu and Peter 2012).

10. scientific methods (measuring time consumption, balancing workplaces) :-The main reason to determine standard time is to establish adequate workloads of workstation in order to increase productivity.(Sari 2016)

From reviewing different articles and journals papers it‘s founded that Lean manufacturing technics, Six sigma program, PIM (Productivity Improvement Model), Motion and time study, ARENA and Dassault Systems, namely DELMIA 3D, Two-dimensional efficiency decomposition (2DED, Network Data Envelopment Analysis (Network DEA) and stochastic programming DEA (SPDEA) approach, Line balancing techniques, Method use the brainstorming , The theoretical model and the industrial applications, and scientific methods (measuring time consumption, balancing workplaces) are methods/technics covered in most of the paper to productivity improvement tools used in the manufacturing and service firms. On the other hand, there is additional method that uses as a productivity improvement tool is Taguchi loss function consider from the case sector because according to the data’s which collected during the research more favorite to used Taguchi loss function method.

Taguchi QLF is employed to calculate the performance loss relative to the goal value (s). The goal values in the ensuing analytical optimization technique will be derived from the optimal values discovered during the application of the suggested empirical optimization procedure..(Tshibangu 2018).And Using Taguchi's experimental design technique and the Six Sigma DMAIC technique, productivity of the operation and product quality are both sought after goals (Shanmugaraja, Nataraj, and Gunasekaran 2011).Also Engineering quality effectively uses Taguchi's loss function. When the product deviates beyond the standard limit and becomes unacceptable, quality losses happen.(A. Kumar 2015). In other options The main applications of Taguchi Methodology Are Optimize Designs using analytical Experiment, simulation studies, select better alternative in Development and Testing, optimize manufacturing Process Designs, & solve manufacturing problems.(Mittal 2018). and using a Taguchi loss function is a way to monitor and promote a multidimensional approach in an enterprise. Its effectiveness is increased when it is implemented during the design and development of products and the pre-production planning process. Another way it helps to increase effectiveness is by basing quality improvements on reductions in variability in performance.(Budaj and Hrnciar 2016)

This study seeks to Productivity improvement through scrap reduction with optimize materials by using Taguchi loss function method in rebar's manufacturing industries (case company Steely RMI –Rolling -2).and identify factor that the main causes of scraps and losses which are separate in, can be minimize and cannot be minimize /avoidable in the current thesis work. The above literature review Taguchi loss function methods is not found for productivity improvement. And Then Appling

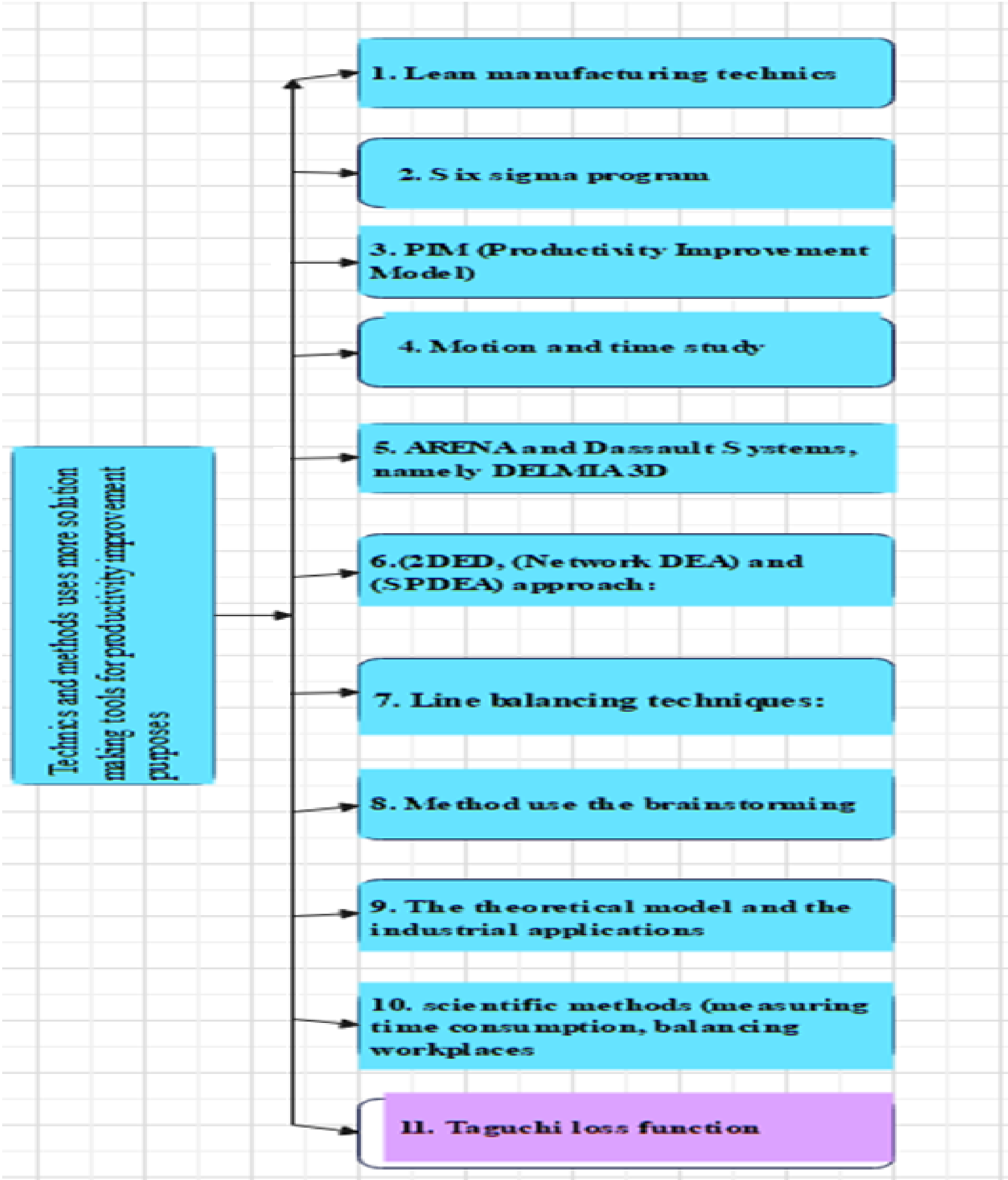

Figure2. 2methods and technics used to productivity improvement tools

CHAPTER THREE

3. Research Methodology

In the previous chapter, we have discussed definitions, the improvement and factors affecting of productivity in different techniques, concepts about raw materials utilization and different factors affecting materials utilization gap reviewed. This chapter presents how data for this study is obtained and the research design is taken. The topics include in this chapter are the detail methodology, data collection methods, sampling technique and the data analysis techniques

3.1 Background of the study area

According to some documents, heavy steel industries in Ethiopia started some few decades before downfall of King Haileselassie's regime with Italian investors with re-bar manufacturing. The first re-bar factory was owned by an Italian investor, named Mr Risso. That company was founded in 1959, by the name Ethiopian Iron and Steel Factory (EISF) which is located in the south border of Addis Ababa, (Akaki Kaliti sub-city). Until recently, EISF was active in operation with a total of annual capacity of 12,000 ton. (Metal and Mining, 2018). In addition to imported billet, the foundry had been using smelting steel scrap for its re- bar and wire-rod production.(To 2018)

The reinforcement bar manufacturing companies in Ethiopia are very much growing in number and installed capacity. 25 years ago there was only one factory named Ethiopian Iron and Steel Foundry, which is located at the Akaki-Kality sub-city with a capacity of 12,000 tons per annum; but today there are about 10 factories with a total of more than 2 million tons per annum installed production capacity (Fitea, 2017).

3.2 Research Design

Research design always determines the kinds of analysis that are to be done so as to get the desire results. It articulates what data is required, what methods are going to be used to collect and analyze the data and how it is going to answer the research questions.(Asenahabi 2019)

The overall desire of this research is to improve Ethiopian metal industries productivity after conducting a survey analysis on their productivity concept, measurement practice, the related problems and their improvement activities in the industries, after that investigation of the existing productivity practices using a case manufacturing company was carried out. In order to that, an appropriate way has been adequately devised, so that it can ensure its outcome as per Productivity measurement and analysis. Literatures were considered to discuss the concepts and identify reasons and gaps in analysis of manufacturing companies‟ productivity and both qualitative (to identify the nature of the causes of the problems) and quantitative (for quantification of variables) data were used. Integration of the following methods is used to achieve the objectives.

The research starts on productivity improvement with materials optimization tools and the required data is gathered by direct visiting the case company, taking production data during the manufacturing process and adding additional documents for the company and interview questions. The purpose of the study is to increase the efficiency of raw materials with scrap reduction and the focus on the plant site the places where the raw materials are prepared, billet preheating furnace, around the roughing mills, hot shear, intermediate mills, finishing mills, on fly shear, cold shear, the final finished products and scrap collecting areas. The data collection takes about one month and six days. The collected data includes four product types out of six. The sampling techniques are direct measuring of the raw material over all dimensions and the size of losses; counting the number of products of each product type and its off-cuts; and the methods of data collection are observing the production process and interviewing; analyzing using the Microsoft Excel and Taguchi loss function methods; the expenditure used for the research, transport fees, and working time; and the specific nature of the research. It has some challenges to collecting the real data because the factory is too huge and there are some dangerous situations when the coble is occurring and must wear safety clothes and shoes. and should require safety for every moment at the plant sites.

3.3 Source of Data

According to the case company, the source of data for the research was more on primary data, which are physical observation and interview for diameter 16,20,24 and 12mm rebar because during data collection the only products in production schedule. However, the necessary information and data also collected through a secondary source, which are journal, report, government publication, sector documentary, the internet, and other texts.

3.4 Sampling Technique

A sample consists of a smaller, finite number of "units" (e.g., people, cases, events, sites, organizations, counties, etc.) that are extracted from a larger population of interest (e.g., a population or group of program participants, events, cases, agencies, counties, or state residents).(Sampling et al. n.d.) In this study, the researchers will use both primary and secondary data to get qualitative and quantitative information that is relevant to the study. Plant (Rolling) 02 is the most technologically advanced and easy-to-use platform for producing rebar diameters of 10, 12, 14, 16, 20, and 24 mm. It manufactures reinforced steel by assigning 60 workers to a 7 m by 12 m preheating furnace using imported raw material measuring 130 mm by 130 mm by 12000 mm. As a result, during my stay at the factory from January 26, 2022, to March 8, 2022, which was governed by the factory production schedule, I was able to get the data of the products for diameter 16 in about 12 samples in three days, for diameter 20 in about 36 samples in nine days, for diameter 24 in about 8 samples in two days, and also for diameter 12 mm in about 56 samples in fourteen days, on two morning samples and two afternoon samples. because there were no orders for production of other products such as diameter 10 and 14 rebar types.

3.5 Methods of Data Collection

It is necessary in all data collection that elements of the research process be 'neutral' and not interferes with measurements of the variables. After selection of a principle of data collection, consistent application of standards within that method must be developed so that the measurement reflects the intended variable and is not biased by the methodology employed. The terms 'method' and 'methodology' are frequently used in the context of allowed research. In this study, the research will use both primary and secondary data to get qualitative and quantitative information that is relevant to the study. Primarily some qualitative data from Ethiopia steel bar manufacturing Industries (STEELY RMI PLC-2) concerning the issue will be collected via interviewing the production & technical manager, Human resource manager, production Forman's furnace operator, discharge pusher operator, rough mill operator, hot shear operator, intermediate mill operator, finishing mill operator, cooling bad operator , cold shear operator and bundling area operator This helps to know and assess the existing condition about the production efficiency of the company.

Then appropriate data from both primary and secondary sources, required for the study will be gathered through appropriate data collection methods:

The primary data are collected through direct observation and face-to-face interview.

- Direct observation at plant site which guided by the factory production schedule for one month and 6 days to collect data related to raw material preparation and measure its length, production process, count the number of product and measure its size, count and measure the losses. By observing the existing manufacturing processes.
- Interviewing the production, marketing department head, and the factory managers to gather information which is not traced through the other data collection methods like electric and fuel consumption per ton.

The secondary data are collected through

- The secondary sources of data that the research used are different relevant books, Journals, Articles, senior thesis work, manuals and available documents (such as productivity improvement journals, company inauguration magazines and bulletins), so as to develop understandings and concepts for the literature survey and for gathering quantitative and qualitative data like productivity improvement measures, techniques, methods, the standard weight and cross section area per meters of rebar types.

3.6 Methods of Data Analysis

In this study, the researchers will use both primary and secondary data to get qualitative and quantitative information that is relevant to the study. After collecting raw data on current production conditions and identifying the causes of scrap and losses, as well as their influence, it will be sorted into five categories of losses: the cutting torch, which is used to cut the length of raw material in two parts; hard scale, which develops on the surface of billet after being heated in a preheating furnace; the head-tail cut, which occurs on the hot shear machine in a place between the rough and intermediate mills, cobble or deformed bar was produced during power outages, with the last loss focusing more of this research on off-cuts. And specify avoidable and unavoidable losses in this research, after which they are analyzed and evaluated with Microsoft Excel and Taguchi loss function methods. In the result sections, we provide solutions to the primary causes of poor raw material performance and increase productivity with visible results.

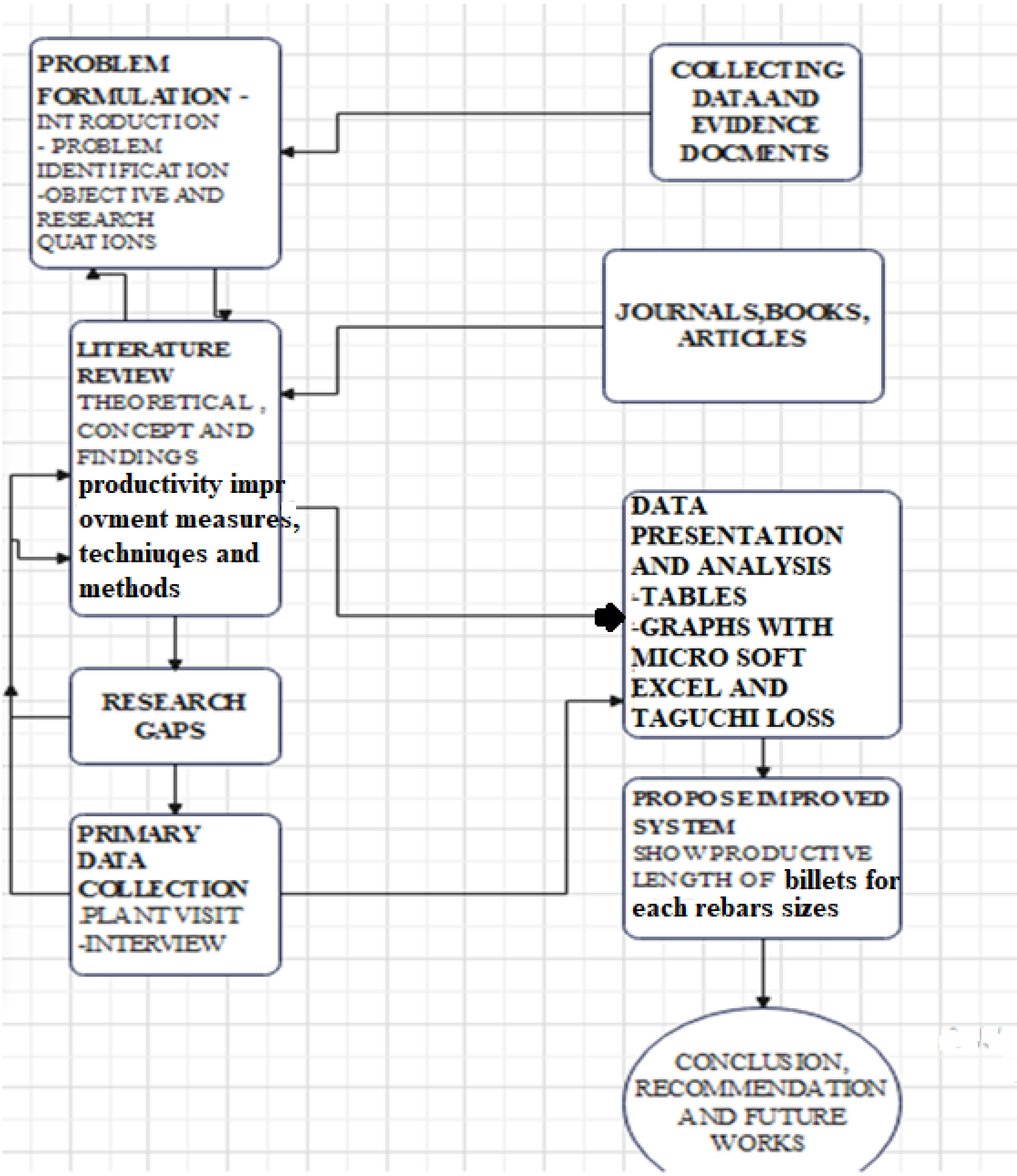

Figure3. 1 methods and technics used to productivity improvement tools

CHAPTER FOUR

4. over view of rebar manufacturing industry (case company)

4.1 About Steely RMI

October 2004 may be a verifiable scene that Steely RMI started its travel as a development steel producer in Ethiopia. It started operation with a speculation capital of 38 million USD, at a plant capacity of 120,000 tons per annum, which was one of the greatest capacities within the division at the time. Since2004 onwards, Ethiopian economy has been developing persistently with noteworthy rates. Hence, such noteworthy financial developments in Ethiopian history spurred Steely RMI to labor tirelessly on its portion towards satisfying the booming national request for development steel products. In line with this, Steely RMI built its huge plant at 178,000 sq. with full-fledged offices within the Oromia territorial State, Bishoftu town, 45 km absent from the capital to the East. To the prove of its sound key choice, Steely RMI seem work effectively within the final twelve successive a long time with strong monetary and financial status. Industry Thus, in 2011 Steely RMI encourage extended its capacity to 360,000 tons per annum with a add up to speculation taken a toll of 71m.USD. Since at that point, with more than 2000 coordinate laborers, and 30 Megawatt power control utilization, Steely RMI is creating its fundamental items of support bars and wire poles of different sizes with the leading review steel. Its items quality is certified with suitable congruity appraisal organization. It too produces oxygen gas with more than 99.6% virtue for its claim utilization. APOLO, brand title for Steely's items, is well known among its clients and conclusion clients. The solid administration framework, the state of the craftsmanship innovation, and the world course imported crude fabric, along with the well-organized quality testing research facility abetted Steely RMI to stand upright year-to-year within the middle of firm competition within the showcase with developing customers' desire for superior benefit in 'quality', 'price', and 'time'. On beat of this, Steely RMI is exceedingly committed for corporate social obligations other than its center commerce. To this conclusion, the company has been including in setting up different societal back programs, like Schools, Clinics, Consumable water supplies, etc. Thus, all these effective ventures of Steely RMI induced because it would never halt some time recently accomplishing its distant coming to vision of being the driving steel producer in Africa by the year 2025.

4.1.2 Laboratory and Product Quality Assurance Processes

Steely RMI is well prepared with chemical and physical property testing offices in its in-house quality affirmation division staffed with fitting specialized specialists and essential research facility inputs. As the development materials delivered by Steely RMI are among required benchmarks, the company gives a due consideration for standard similarity some time recently discharging its items to the showcase. In this way, each clump of generation is checked for its fulfillment of standard parameters in Chemical composition, Ductile quality, abdicate point, ductility, mass per length, and other Building model set forward by the national benchmarks office, and other universal standard bodies.

4.1.3 Technology

Steely RMI is prepared with the most recent Roll-forming innovation bundle, Thermal Mechanical Treatment (TMT), Programmable Rationale Controllers (PLC), Ceaseless Casting Machine (CCM), Tall stack fabric dealing with framework, Physical and chemical testing offices, etc. Hence, its well introduced sate of the expressions innovation has made the company successful and productive in any viewpoint of efficiency measures.

4.1.4 Production Capacity

Steely RMI has over 360,000 tons per annum installed production capacity of rebar and wire rods with standard Grade of 60 and 75.

4.1.5 Raw Materials and Inputs

Steely RMI employments predominant quality imported Steel billets for its review 60 and 75 Rebar and Wire bar items. The billet is checked for its chemical Com- position some time recently it enters into assist generation professional. The company employments billet to create rebar with in estimate extend of 8mm-24mm distance across, and length of 12meters each piece; and wire bar of breadths 5.5mm to 14mm. The Wire rode generation handle is additionally employments same tall quality imported billets which passes the same testing method. The company too produces tall level of quality oxygen, with 99.6% immaculateness, for its in- house usage.

4.2 Factors that founded in rebar manufacturing process

4.2.1 Hard scale (iron oxide)

The iron oxide scales that form on billets and slabs of hot-rolled steels are usually detached using a hydraulic descaling process. The oxide scales that form on steels include $Fe2O3$,$Fe3O4$,FeO, which form in lamellar strata from the substrate towards the outer layer.(Takeda et al. 2009)

4.2.2 Roller Conveyor

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries. In our case roller conveyor used to transport the hot billet with-in 1200 c^0 from the preheating furnace to the first six roughing mills and cry the finished rebar from cooling bad to cold shear and to the bundling.(Qian, Fang, and Zeng 2014)

4.2.3 Rolling-Bar Process

Rolling process that allows high production rates also for small size bars and a significant reduction of production cost. The slit rolling method enables production of two, three, four or even five bars from one billet. The slitting process uses special passes and guides to prepare, shape and longitudinally separate the incoming billet into two or more individual strands, which will then be further rolled into finished sizes. An efficient slitting process requires continuous upgrades of rolling technology and mill equipment’s in order to obtain the best performance in terms of quality and efficiency.(Republic 2014)

4.2.4 Hot Shear

hydraulic hot shear press it has an effective shearing force rating of 225 metric tons and a clamping force of 25 metric tons at a maximum system pressure of 3550 psi. It is capable of hot shearing

4.2.5 Looper

There are two major specifications which should be satisfied in hot rolling mills; these are the dimensional quality and mass flow of the strip. The dimensional quality specification includes the thickness, width, flatness and profile of the strip. Control is performed by dedicated control systems such as AGC (Automatic Gauge Control), AWC (Automatic Width Control), ASC (Automatic Shape Control) and APC (Automatic Profile Control). Mass flow control is used to balance the input and output flow of a strip in a stand. It enables smooth threading of a strip and stable operation of the process. Control is used to change the stored loop length between stands by manipulating a mill motor speed; looper angle control is used in conventional schemes whereas strip tension control is used in advanced control schemes. The looper was established between the rough and intermediate mills at steely RMI.(To 2018)

4.2.6 Thermo-Mechanical Control processing (TMCP)

Such processes have been in use for quite some time now primarily to improve the strength and ductility in the high strength low alloy (HSLA) steels. TMCP consists of controlled rolling alone or control rolling and subsequent accelerated cooling• The essence of controlled rolling lies in deformation of austenite in the un recrystallized regime thereby producing increased ferrite "nucleation sites". The significance of accelerated cooling on the other hand Iles in super cooling of the deformed austenite and thereby increasing ferrite "nucleation rate". The combination of controlled rolling and interrupted accelerated cooling is called thermo mechanical controlled processing (TMCP). Enhanced ferrite transformation at high temperature region and bainitic or martensitic transformation at low temperature region during TMCP gives a homogeneous fine grained structure.(Ababa 2017; astm.pdf n.d.; No Title 2001; Ta et al. 1964; Tariku 2020; Thomas 2001; Vijayaram 2014)

4.2.7 Fly-shear

During the flying shearing, the two blades have to keep pace with the feeding plates in horizontal direction. Thus, the steel plate is cut along the vertical direction, avoiding the “drag” or “stack” of steels in the fracture region, especially for thick steel plates.(Qian, Fang, and Zeng 2014)

4.2.8 Preferred diameters, nominal cross-sectional area and nominal mass per meter

NOTE 1: The preferred nominal diameters in millimeter are 8, 10, 12, 16, 20, 25, 32 and 40. If a steel reinforcing bar smaller than 8 mm is required, the recommended diameter is 6 mm. If a steel reinforcing bar larger than 40 mm is required, the recommended diameter is 50 mm.

The values for the nominal cross-sectional area and nominal mass per meter of preferred diameters shall be as given in Table

Table 4. 1 Nominal cross-sectional area and nominal mass per meter (sited construction standard CS 2-2012)

Nominal diameter, d (mm)	Nominal cross-sectional area, An (mm2)	Nominal mass per meter (kg)	Nominal mass per 12meter (kg)
8	50.3	0.395	0.395*12=4.74
10	78.5	0.617	0.617*12=7.4
12	113.1	0.888	0.888*12=10.65
14	154	1.2	1.2*12=14.4
16	201.1	1.579	1.579*12=18.95
20	314.2	2.466	2.466*12=29.6
24	452.4	3.55	3.55*12=42.6

The values for the nominal mass per meter are evaluated from the values of the nominal cross-sectional area on the basis that steels have a mass of 0.00785 kg/mm2 per meter run.

4.2.9 Grading of rebar

Grade 40 is also designated as Grade 280 (for yield strength of 280 MPa). Grade 60 is designated Grade 420 and Grade 75 is designated Grade 520. The values, 280, 420 and 520 result in minimum yield strengths of 40.6, 60.9 and 75.4 ksi.(Qian, Fang, and Zeng 2014)

4.3 Factory process flow chart

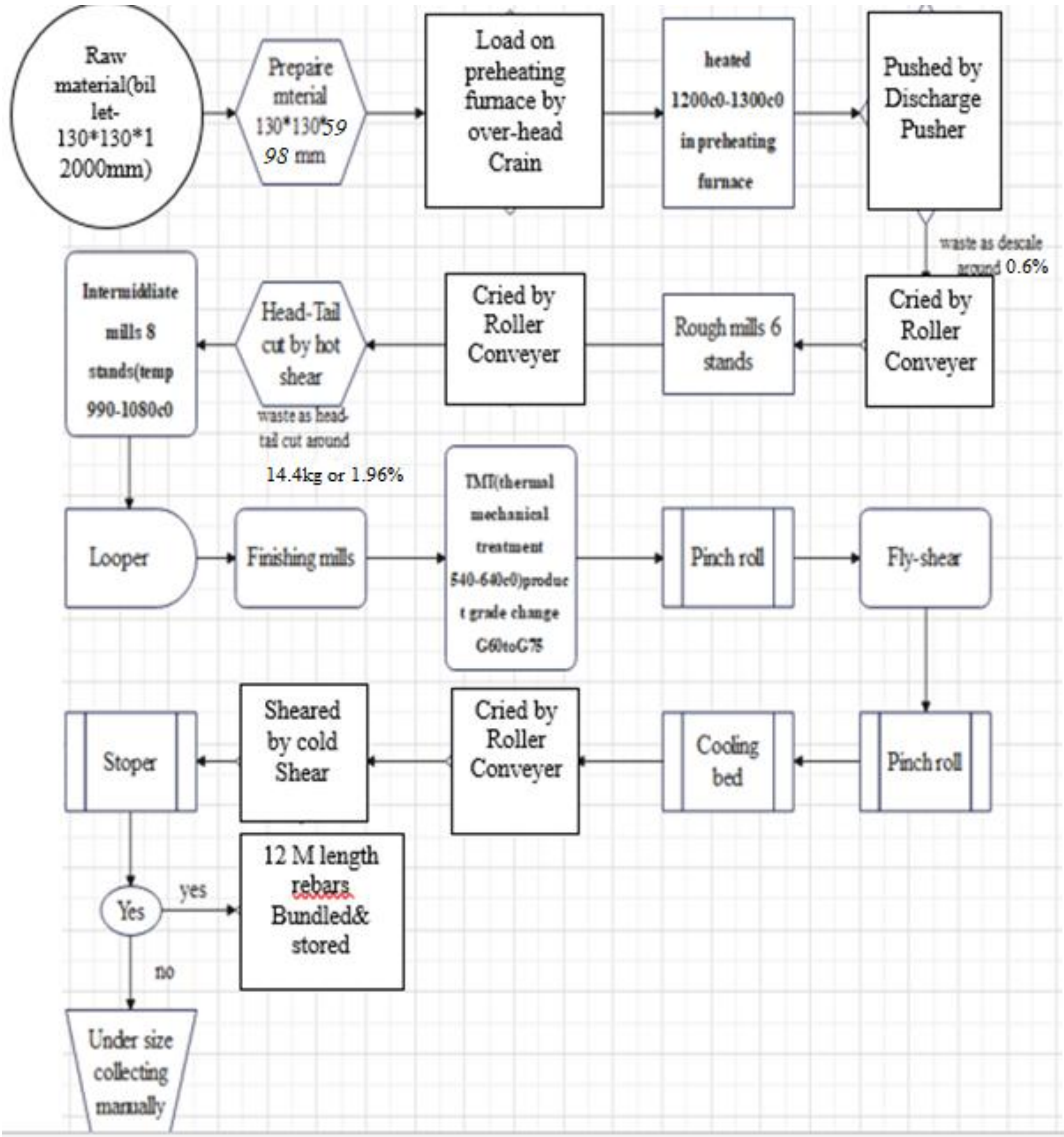

Figure4. 2 process flow chart of case company

4.4 The description collected Data

Steely RMI PLC operates two rebar plants, one continuous casting facility, and one oxygen air plant. It works. Plant (Rolling-01) Ø 8, 10, 12 Reinforced steels employs 68 crew members and has a 4m * 8m broad preheating furnace with local raw material of 120mm * 120mm* 2998mm.

Plant(Rolling-02) is the most technologically advanced and user-friendly platform available, with 5.5mm wire rod and rebar sizes of Ø 10, 12, 14, 16, 20, and 24mm.

It produces reinforced steel by allocating 60 people to a 7 m * 12 m preheating furnace using imported raw material measuring 130 mm × 130 mm * 5998 mm. The two rebar rolling mills (plants 01 and 02) are open 24 hours a day. The first shift has ten hours of production and two hours of preventive maintenance. As a result, I was able to observe the material preparation process for final production during my stay at the factory from January 26 to March 8, 2022.

Work performed during factory inspection and measurement of raw material preparation, the process of loading raw material into the furnace, and the manner in which the heat utilized by the billet is evacuated from the heating furnace after the hard scale is removed.

It is sent to the rough mill at 1200°C, where the head and tail are cut off with a hot sheer, making it easier to work with. The grade of the processed billet will exceed G60 to G75 after passing through a water-filled pipe in a thermal mechanical treatment.

Before starting the fill data, it is necessary to describe the factors that found the table

1. The product type mean; a kind of rebar which manufactured in the Steely RMI
2. Output in 12-meter mean: a rebar it length is 12 meter because standard length of rebar is 12 meter
3. Off-cut/scrap length in meter mean; the remain size/length of rebar after cutting number of 12-meter length and measured by meters
4. The length of scraps divided in twelve-meter mean; the founded the length of scrap divide for twelve meter of normal product
5. Output in 12 meter + scrap mean; the total output getting for processed one billet

*Table 4. 2 shows that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 16mm rebar gets during production*

Date 26/01/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	16	38	9.8	0.82	38.82
	16	38	10.1	0.84	38.84
After	16	38	10.2	0.85	38.85
Noon	16	38	9.9	0.825	38.83
Average	16	38	10	0.83	38.83

*Table 4. 3shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 16mm rebar gets during production*

Date 27/01/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	16	38	10.4	0.87	38.87
	16	38	10.5	0.88	38.88
After	16	38	10.5	0.88	38.88
Noon	16	38	10.6	0.88	38.88
Average	16	38	10.5	0.88	38.88

*Table 4. 4 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 16mm rebar gets during production*

Date 28/01/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	16	38	10	0.83	38.83
	16	38	9.4	0.78	38.78
After	16	38	9.3	0.78	38.78
Noon	16	38	9.3	0.78	38.78
Average	16	38	9.5	0.79	38.79

*Table 4. 5 shows the data that average numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 16mm rebar gets from the above tables*

Date	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
26/01/2022	16	38	10	0.83	38.83
27/01/2022	16	38	10.5	0.88	38.87
28/01/2022	16	38	9.5	0.79	38.79
Average	16	38	10	0.83	38.83

*Table 4. 6 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 04/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6	0.50	24.50
	20	24	6.4	0.53	24.53
After noon	20	24	6.2	0.52	24.52
	20	24	6.2	0.52	24.52
Average	20	24	6.2	0.52	24.52

*Table 4. 7 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 05/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6.4	0.53	24.53
	20	24	6.7	0.56	24.56
After noon	20	24	6.8	0.57	24.57
	20	24	6.9	0.58	24.58
Average	20	24	6.7	0.56	24.56

*Table 4. 8 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 06/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6	0.50	24.50
	20	24	5.8	0.48	24.48
After noon	20	24	5.9	0.49	24.49
	20	24	5.9	0.49	24.49
Average	20	24	5.9	0.49	24.49

*Table 4. 9 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 07/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	5.9	0.49	24.49
	20	24	5.7	0.48	24.48
After noon	20	24	5.9	0.49	24.49
	20	24	5.7	0.48	24.48
Average	20	24	5.8	0.48	24.48

*Table 4. 10 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 08/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	5.9	0.49	24.49
	20	24	6	0.50	24.50
After noon	20	24	6	0.50	24.50
	20	24	6.1	0.51	24.51
Average	20	24	6	0.50	24.50

*Table 4. 11 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 09/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6.5	0.54	24.54
	20	24	6.8	0.57	24.57
After Noon	20	24	6.6	0.55	24.55
	20	24	6.5	0.54	24.54
Average	20	24	6.6	0.55	24.55

*Table 4. 12 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 10/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6	0.50	24.50
	20	24	5.5	0.46	24.46
After Noon	20	24	5.4	0.45	24.45
	20	24	5.5	0.46	24.46
Average	20	24	5.6	0.47	24.47

*Table 4. 13 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 11/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6	0.50	24.50
	20	24	5.8	0.48	24.48
After Noon	20	24	6.1	0.51	24.51
	20	24	6.1	0.51	24.51
Average	20	24	6	0.50	24.50

*Table 4. 14 shows the data that numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets during production*

Date 12/02/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	20	24	6.1	0.51	24.51
	20	24	5.9	0.49	24.49
After noon	20	24	6	0.50	24.50
	20	24	6	0.50	24.50
Average	20	24	6	0.50	24.50

*Table 4. 15 shows the data that average numbers of products and length of scrap from (billet-130*130*5998mm) for ϕ 20mm rebar gets from the above tables*

Date	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
04/02/2022	20	24	6.2	0.52	24.52
05/02/2022	20	24	6.7	0.56	24.56
06/02/2022	20	24	5.9	0.49	24.49
07/02/2022	20	24	5.8	0.48	24.48
08/02/2022	20	24	6	0.50	24.50
09/02/2022	20	24	6.6	0.55	24.55
10/02/2022	20	24	5.6	0.47	24.47
11/02/2022	20	24	6	0.50	24.50
12/02/2022	20	24	6	0.50	24.50
Average			6.09	0.51	24.51

Table 4. 16 shows the data numbers of products and length of scrap for ϕ 24mm rebar gets during production

Date 2/21/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	24	16	9.25	0.77	16.77
	24	16	9.13	0.76	16.77
After Noon	24	16	9.1	0.76	16.76
	24	16	9	0.75	16.75
Average	24	16	9.12	0.76	16.76

Table 4. 17 shows the data that numbers of products and length of scrap for ϕ 24mm rebar gets during production

Date 2/22/2022	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	24	16	9	0.75	16.77
	24	16	9.06	0.76	16.77
After Noon	24	16	9.05	0.75	16.75
	24	16	9.05	0.75	16.75
Average	24	16	9.04	0.75	16.75

Table 4. 18 shows the data that average numbers of products and length of scrap for ϕ 24mm rebar the two consequence dates get from the above tables

Date	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
2/21/2022	24	16	9.12	0.76	16.76
2/22/2022	24	16	9.04	0.75	16.75
Average			9.16	0.76	16.76

Table 4. 19 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **23/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.4	0.95	68.95
	12	**68**	11.2	0.93	68.93
After noon	12	**68**	11.1	0.93	68.93
	12	**68**	11.5	0.96	68.96
Average	**12**	**68**	**11.3**	**0.94**	**68.94**

Table 4. 20 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **24/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.4	0.95	68.95
	12	**68**	11.3	0.94	68.94
After	12	**68**	11.4	0.95	68.95
noon	12	**68**	11.5	0.96	68.96
Average	**12**	**68**	**11.4**	**0.95**	**68.95**

Table 4. 21 shows the data that numbers of products and length of scrap for ϕ 24mm rebar gets during production

Date **25/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.4	0.95	68.95
	12	**68**	11	0.92	68.92
After noon	12	**68**	11.3	0.94	68.94
	12	**68**	11.1	0.93	68.93
Average	**12**	**68**	**11.2**	**0.93**	**68.93**

Table 4. 22 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **26/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.9	0.99	68.99
	12	**68**	11.8	0.98	68.98
After noon	12	**68**	11.8	0.98	68.98
	12	**68**	11.7	0.98	68.98
Average	**12**	**68**	**11.8**	**0.98**	**68.98**

Table 4. 23 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **27/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.7	0.98	68.98
	12	**68**	11.8	0.98	68.98
After noon	12	**68**	11.6	0.97	68.97
	12	**68**	11.7	0.98	68.98
Average	**12**	**68**	**11.7**	**0.98**	**68.98**

Table 4. 24 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **28/02/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.7	0.98	68.98
	12	**68**	11.3	0.94	68.94
After noon	12	**68**	11.6	0.97	68.97
	12	**68**	11.4	0.95	68.95
Average	**12**	**68**	**11.5**	**0.96**	**68.96**

Table 4. 25 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **01/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11	0.92	68.92
	12	**68**	10.8	0.90	68.90
After noon	12	**68**	11.2	0.93	68.93
	12	**68**	11	0.92	68.92
Average	**12**	**68**	**11**	**0.92**	**68.92**

Table 4. 26 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **02/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.7	0.98	68.98
	12	**68**	11.3	0.94	68.94
After noon	12	**68**	11.4	0.95	68.95
	12	**68**	11.6	0.97	68.97
Average	**12**	**68**	**11.5**	**0.96**	**68.96**

Table 4. 27 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **03/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11	0.92	68.92
	12	**68**	11	0.92	68.92
After noon	12	**68**	11.2	0.93	68.93
	12	**68**	11.2	0.93	68.93
Average	**12**	**68**	**11.1**	**0.93**	**68.93**

Table 4. 28 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **04/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.8	0.98	68.98
	12	**68**	11.5	0.96	68.96
After noon	12	**68**	11.4	0.95	68.95
	12	**68**	11.7	0.98	68.98
Average	**12**	**68**	**11.6**	**0.97**	**68.97**

Table 4. 29 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **05/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.8	0.98	68.98
	12	**68**	11.9	0.99	68.99
After noon	12	**68**	11.8	0.98	68.98
	12	**68**	11.7	0.98	68.98
Average	**12**	**68**	**11.8**	**0.98**	**68.98**

Table 4. 30 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **06/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.9	0.99	68.99
	12	**68**	11.5	0.96	68.96
After noon	12	**68**	11.6	0.97	68.97
	12	**68**	11.8	0.98	68.98
Average	**12**	**68**	**11.7**	**0.98**	**68.98**

Table 4. 31 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **07/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.6	0.97	68.97
	12	**68**	11.2	0.93	68.93
After noon	12	**68**	11.8	0.98	68.98
	12	**68**	11	0.92	68.92
Average	**12**	**68**	**11.4**	**0.95**	**68.95**

Table 4. 32 shows the data that numbers of products and length of scrap for ϕ 12mm rebar gets during production

Date **08/03/2022**	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
Morning	12	**68**	11.2	0.93	68.93
	12	**68**	11.4	0.95	68.95
After noon	12	**68**	11.2	0.93	68.93
	12	**68**	11	0.92	68.92
Average	**12**	**68**	**11.2**	**0.93**	**68.93**

Table 4. 33 shows the data that average numbers of products and length of scrap for ϕ 16mm rebar the fourteen consequence dates gets from the above tables

Date	product type in ϕ	out put in 12 meter	off-cut /scrap length in meter	The length of scrap divided in twelve meter	out put in 12 (Meter + scrap)
23/02/2022	**12**	**68**	**11.3**	**0.94**	**68.94**
24/02/2022	**12**	**68**	**11.4**	**0.95**	**68.95**
25/02/2022	**12**	**68**	**11.2**	**0.93**	**68.93**
26/02/2022	**12**	**68**	**11.8**	**0.98**	**68.98**
27/02/2022	**12**	**68**	**11.7**	**0.98**	**68.98**
28/02/2022	**12**	**68**	**11.5**	**0.96**	**68.96**
01/03/2022	**12**	**68**	**11**	**0.92**	**68.92**
02/03/2022	**12**	**68**	**11.5**	**0.96**	**68.96**
03/03/2022	**12**	**68**	**11.1**	**0.93**	**68.93**
04/03/2022	**12**	**68**	**11.6**	**0.97**	**68.97**
05/03/2022	**12**	**68**	**11.8**	**0.98**	**68.98**
06/03/2022	**12**	**68**	**11.7**	**0.98**	**68.98**
07/03/2022	**12**	**68**	**11.4**	**0.95**	**68.95**
08/03/2022	**12**	**68**	**11.2**	**0.93**	**68.93**
Average	**12**	**68**	**11.44**	**0.95**	**68.95**

4.5 Description Steely RMI about the manufacturing processes

The factory/Rolling -2 products ϕ10,12,14,16,20 &24 MM rebar and uses (130*130*12000) mm imported raw material billet and prepare it 5998mm length, the factory design shows the output of each product for: -

Table 4. 34 shows the factory production capacity with different perspective

product types in Ø	the size of raw material in mm	production capacity/hr ton	production /shift in tons	electric consu mpsion in kwh	furnace oil consu-mpsion/hr liter
10 mm	130*130*5998	26.7	267	3017.1	1246.89
12 mm	130*130*5998	37.9	379	4282.7	1769.93
14 mm	130*130*5998	39.1	391	4418.3	1825.97
16 mm	130*130*5998	45.8	458	5175.4	2138.86
20 mm	130*130*5998	32.3	323	3649.9	1508.41
24 mm	130*130*5998	39.4	394	4452.2	1839.98
Average		36.87	368.67	4165.93	1721.67

Table 4. 35 the categories of the losses in Steely RMI for ϕ 10, 12, 14 and 16 products types which are believed by the factory staffs

Types of loss	Losses in%	Sources	Remark
The width of billet cutting torch	0.033	production Forman's of two shifts	
Hard –scale	0.6	(S. K. Prakash and Das 2015)	
Head and tail cut for ϕ10,12,14 and 16 rebars	1.09	production Forman's of two shifts	
Off-cuts or scrap for ϕ10,12,14 and 16 rebars	0.973	production Forman's of two shifts	
Coble	0.27	production Forman's of two shifts	1 billet Expected as coble per shift
The sum of losses	3	production Forman's of two shifts	

Table 4. 36 the categories of the losses in Steely RMI for ϕ 20 and 24 products types which are believed by the factory staffs

Types of loss	Losses in%	Sources	Remark
The width of cutting torch 4mm	0.033	production Forman's of two shifts	
Hard –scale	0.6	(S. K. Prakash and Das 2015)	
Head-cut ɸ20 and 24	0.545	production Forman's of two shifts	
Off-cuts or scrap for ɸ20 and 24 rebars	1.518	production Forman's of two shifts	
Coble	0.27	production Forman's of two shifts	1 billet Expected as coble per shift
The sum of losses	3	production Forman's of two shifts	

The factory has two working shift per day, ten hours to production and two hours to preventive maintenance for each shifts. And recommended losses per billet like hard-scale (iron oxide), head-tail cut, coble and off-cuts per billet are 3 % therefore (Hard-scale 0.6%, head and tail cut 1.09%, cobble 0.27% and the remain off-cuts (1.04%) for rebar ɸ 10, 12, 14 and 16. For rebar ɸ20,24 the percentage of off-cut is 0.585% and oxyacetylene cutting gaps is 4mm (0.033%)

- Head and tail cut 8k. g for rebar ɸ 10,12,14 and 16 but the only head cut for rebar ɸ20 and 24 so head weight is 4k. g.

4.6 The categories of main losses

4.6.1 Cutting torch

The billets have size 130mm*130mm*12000mm when its prepare to preheating furnace cuts into two equal parts and the cutting torch take 4mm width of billet length and the lengths are 5998mm.

4.6.2 Hard –scale or iron oxide

Increasing the time that billets are subjected to high temperatures results in excessive formation of scale. Scale is the oxidation of the Fe parent metal to FeO, Fe2C>3 and Fe3C>4 on the surface which is exposed to a hot oxidizing combustion atmosphere. The amount of scale formed, much like the extent of decarburization, is dependent on the temperature, time at temperature, billet metallurgy, and furnace gas composition.

The walking beam reheating furnace has been developed based low specific fuel consumption of about 0.3Gcal/t and scale losses limited to 0.6% and being achieved by bringing operational improvement in the furnaces.(S. K. Prakash and Das 2015)

Figure4. 1 the photos of hard scale take from the case company during data collection

4.6.3 Head-Tail cut

In the roughing mill, the billet size is reduced from 160*160 sq. mt. cross-sections to (48*48) sq. mt. This is conducted by passing the billet through rollers in 5 passes. After this intermediate mill is carried out, in which shear cut operation is performed. Here, the rod will be cut at its head and tail ends to eliminate the alligatoring defect.(Sabiya, Shilpa, and Appaiah 2019)

During production in the case company the head-tail cut for ϕ10mm, ϕ 14mm and ϕ 16mm are 8kg for ϕ20mm and ϕ24mm the only head cut has not tail-cut and it is 4kg of the total weight of the billet. But according to the case company showing on the figure 4.7 photo which taken during data collection the length of tail-cut is (8.6cm*7.5cm*8cm) and the length of head cut is (8.6cm*7.5cm* 20 cm). so that the length difference between the head-cut and the tail cut is about (8.6cm*7.5cm*12cm).

Table 4. 37 show the weight of head and tail cuts

no	Types of cuts	Cuts volume	density of steel	weight of cuts in kg	Source
1	head cut	(8.6cm*7.5cm*8cm)	8.0 g/cm3	4.1	Production Forman's
2	tail-cut	(8.6cm*7.5cm*8cm)	8.0 g/cm3	4.1	Production Forman's
3	Practically head cut	(8.6cm*7.5cm* 20 cm)	8.0 g/cm3	10.3	During data collection

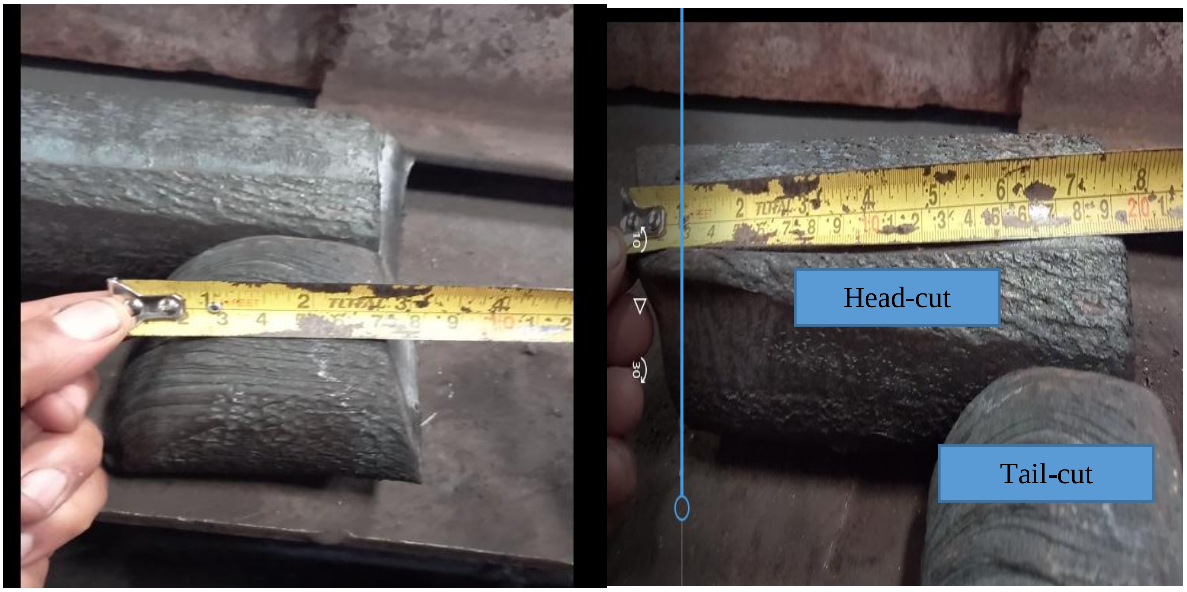

Figure4. 2 the photos of head-tail cut take from the case company during data collection

4.6.4 Cobble or Deformed bar

Among the major operational difficulties faced by the mill operators and managers during hot strip rolling of steel, cobble generation is the most challenging one because it not only makes material loss but also leads to a huge processing delay resulting in decreasing mill utilization and mill productivity which in turn increase the variable cost of the rolled products affecting profitability of steel plants .(Rath et al. 2015)

The percentage of lose from deformed or cobble is 1-billet per shift which convert in percent is 0.27 %. Because average production capacity of billet per shift =368.67 billet (source from the factory production Forman's)

Figure4. 3 the photos of deformed bar (coble) takes from the case company during data collection

4.6.5 Scarp/off-cut

The waste rate of scraps increases when raw materials are ordered without proper bar cutoff plans based on the structural review of drawings. The loss rate of scraps can be even higher as the diameter of rebars increases .(Kim, Hong, and Joo 2018)

4.6.6 The Cause and effect diagram

The Cause-and-Effect or Fishbone Diagram illustrates the causes of a problem or effect by creating a diagram resembling the skeleton of a fish. It is often used to help identify the factors responsible for a problem that needs to be corrected. The diagram may also be used to display the variables that have an effect on a response that is to be optimized.(Cause-and-Effect Diagram 2013)

The factors affecting the productivity of billet

Table 4.38 shows the cause and effects of main losses of billet (raw material)

Case of losses	Cutting torch width	Hard scale	Coble	Off-cut	Head cut	sources
environment			✓			During data collection
materials				✓		During data collection
process	✓	✓		✓		During data collection
people					✓	During data collection
measurement				✓		During data collection
machine					✓	During data collection

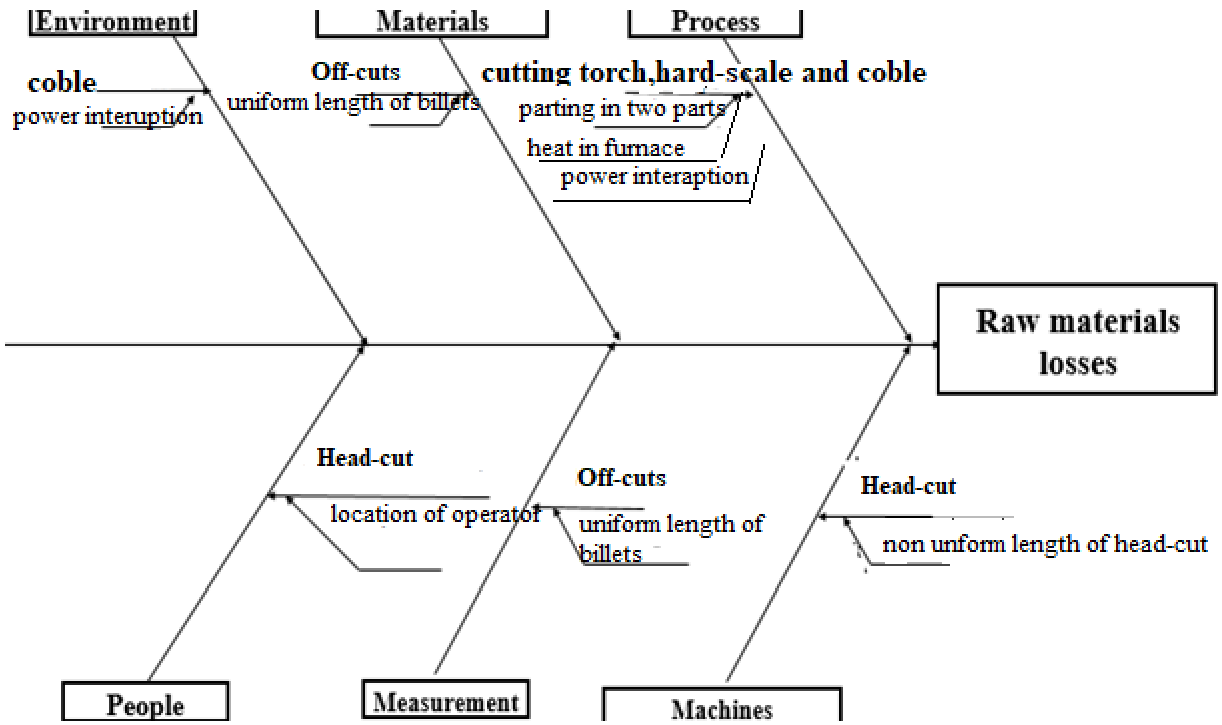

Figure4. 4 the Couse and effect diagram

4.7 Data Interpretation (finding)

Taguchi defined the loss function as deviation as a quantity proportional to the deviation from the target quality characteristic. At zero deviation, the performance is on target and the loss is zero. If Y represents the deviation from the target value, then the loss function L(Y) is:

$L(Y) = k(Y-Y_O)^2$

Where

Y = quality characteristics, such as dimension, performance, and so on

In the case company Y= number of products from a given length of billet

Y_0 = target value for the quality characteristic

In the case company Y_o= average number of products gets in a research

k = a constant, dependent on the cost structure of a manufacturing process or an organization

It is important to note that:

1. The term $(Y – Y_0)$ represents the deviation of the quality characteristic Y from the target value Y_0

2. The equation for the loss function is of the second order in terms of deviation of the quality characteristic.

For this application, the expression of loss in terms of the MSD (mean standard deviation) will be used

$L(Y)= k(Y-Y_O)^2$ for a single sample

$L(Y)= k(MSD)$ for multiple samples

In the case company uses multiple sampling methods therefore uses $L(Y)= k(MSD)$ for multiple samples

The constant k is determined as follows

$L= k(Y-Y_O)^2$

When all parts are made just outside of the specifications, that is, when

$Y = Y_0 \pm$ tolerance,

Then $L = k(Y_0 \pm \text{tolerance} - Y_O)^2$

Following descriptions are the meanings that founded in below tables have got the collected data

1. No of out-put in12 meter mean; the quantity of 12 meter produced rebar
2. The volume of rebar (∏R2L) mean; the total volume of one 12-meter bar but the result is differing as the size of the rebar
3. ((∏R2L) *the number of 12-meter mean; the product of the volume the rebar with the numbers of rebar
4. The size billet (W*H) MM^2 mean; the face area of the billet W=width of the billet, H= height of billet, M M^2= units of measurement square milli meter
5. 1.723% reduction mean; the summation of losses like hard-scale =0.6%, head-tail cut 1.09% and oxyacetylene flam cutting of billet into two parts takes 4mm width=0.033%
6. The size billet (W_1*H_1) MM2 mean; the face area of the billet after reduce the 1.723% of hard scale & head-tail cut W_1=width of the billet after reduce 1.723% of width oxy-actyelen cutting, hard scale & head-tail cut, H_1= height of billet after reduce 1.723% hard scale & head-tail cut, MM^2= units of measurement square milli meter
7. The require length the billet mean; the finding length of the billet which the optimum length of the billet with a little length scrap

Table 4. 39 shows the optimize length of billets for diameter 16 rebar

size of rebar ϕ16 mm	no of out-put in 12 meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter output in MM^3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale, head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)
1	38	2411520	91637760	16900	291.187	16608.813	5517
2	38.03	2411520	91710105.6	16900	291.187	16608.813	5522
3	38.06	2411520	91782451.2	16900	291.187	16608.813	5526
4	39	2411520	94049280	16900	291.187	16608.813	5663
5	39.03	2411520	94121625.6	16900	291.187	16608.813	5667
6	39.06	2411520	94193971.2	16900	291.187	16608.813	5671
7	39.08	2411520	94242201.6	16900	291.187	16608.813	5674
8	40	2411520	96460800	16900	291.187	16608.813	5808
9	40.03	2411520	96533145.6	16900	291.187	16608.813	5812
10	40.06	2411520	96605491.2	16900	291.187	16608.813	5817
11	41	2411520	98872320	16900	291.187	16608.813	5953
12	41.04	2411520	98968780.8	16900	291.187	16608.813	5957
13	41.09	2411520	99089356.8	16900	291.187	16608.813	5966
14	42	2411520	101283840	16900	291.187	16608.813	6098
15	42.02	2411520	101332070.4	16900	291.187	16608.813	6101
16	42.06	2411520	101428531.2	16900	291.187	16608.813	6107
17	42.09	2411520	101500876.8	16900	291.187	16608.813	6111
18	43	2411520	103695360	16900	291.187	16608.813	6243
19	43.02	2411520	103743590.4	16900	291.187	16608.813	6246
20	43.06	2411520	103840051.2	16900	291.187	16608.813	6252
21	43.09	2411520	103912396.8	16900	291.187	16608.813	6256
22	44	2411520	106106880	16900	291.187	16608.813	6389
23	44.02	2411520	106155110.4	16900	291.187	16608.813	6391
24	44.06	2411520	106251571.2	16900	291.187	16608.813	6397
25	44.08	2411520	106299801.6	16900	291.187	16608.813	6400
26	44.09	2411520	106323916.8	16900	291.187	16608.813	6402
	Average 41.3						average 5998

*Table 4. 40 shows the testing data for raw material (billet-130*130*5998mm) in ϕ 16mm rebar*

Average number of bars got during production(data collection)														
38.83					38.875					38.79				
Number of bars got after improve optimum length of billets														
38	38.03	38.06	39	39.03	39.06	39.08	40	40.03	40.06	41	41.04	41.09	42	42.02
42.06	42.09	43	43.02	43.06	43.09	44	44.02	44.06	44.08	44.09				

- Product type ϕ 16 mm rebar
- Targeted number of product in 12 meter=41.3 pieces (from table 4.37)
- Tolerance =maximum length of scrap in expected out-come =0.09*12meter=+1.08 meter
- Scrap in average ≈ 10 meter (from the collected data)
- Production rate = 458 tons/shift (from table 4.33)

From the reference to the data which founded table and Taguchi loss function variable can calculate saved scrap

$L(Y)= k(Y-Y_O)^2$ for a single sample

According to the case company the collected data are multiple sampling so it uses L(Y)= k(MSD) for multiple samples

Mean square deviation (MSD) $L(Y)= R(Y-Y_O)^2$
$Y=Y_0 \pm$ Tolerance
$L= R (Y_O \pm \text{Tolerance} - Y_o)^o$

L in this case equals to the length of scrap (10 meter)

The tolerance is 1.08

$K= 10/(1.08)^2= 8.57$

Now the data is multiple samples so L(Y)= k(MSD) for multiple samples

$MSD=[(38.83-41.3)^2 +(38.875-41.3)^2 +(38.79 -41.3)^2]/3=6.09$

L=8.57*MSD =8.57*6.09=52.2

After improve optimum length of billets

$[(38-41.3)^2 + (38.03-41.3)^2 + (38.06-41.3)^2+ (39-41.3)^2 +(39.03-41.3)^2 +(39.06-41.3)^2 + (39.08-41.3)^2 + (40-41.3)^2\ (40.03-41.3)^2 +(40.6-41.3)^2 + (41-41.3)^2 + (41.04-41.3)^2\ (41.09-41.3)^2\ (42-41.3)^2 +(42.02-41.3)^2 + (42.06-41.3)^2 + (42.09-41.3)^2 +(43-41.3)^2+(43.02-41.3)^2 + (43.06-41.3)^2 +(43.09-41.3)^2+(44-41.3)^2+(44.02-41.3)^2+(44.06-41.3)^2+(44.08-41.3)^2+(44.09-41.3)^2]/26 =106.78/26=4.1$

L=8.57*4.1= 35.14

Total saving per shift= 52.2-35.14=17*458=7814.8 meters

Target or normal value of results 41.3 rebars

Number of test results=26

Weight of 12meter ϕ16 rebar=18.96 kg; (from table 2.1)

» 18.96kg *7814.8/12meter ==12347.38kg or 12.3 tons of scrap is saved

Besides of 12347 kg or 12.3 tons saved scrap, there are other saved losses like electric power and furnace fuel puts as follows.

From table 4.33

For ϕ 16 mm rebar 45.8 tons rolling takes 5175.4 kwh electric and 2138.86 furnace fuel consumption therefore;

For electric power

45.8 tons=5175.1 kwh

12.3 tons =? » 5175.4kwh*12.3tons/45.8tons =1390 kwh electric power saved

For furnace oil

45.8tons =2138.86 liter

12.3tons =? » 2138.86 liter*12.3 tons/45.8=574.41-liter furnace oil saved.

Table 4. 41 shows the optimize length of billets for diameter 20 rebar

size of rebar ϕ20 mm	no of out-put in 12 Meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter output in MM^3	Raw size of billet (W*H)MM2	1.723% Reduction (hard scale, head- cut and flame cutting width)	Net size of billet (W*H)M2	the required length of billet(MM)
1	25.05	3768000	94388400	16900	199.082	16700.92	5652.00
2	25.06	3768000	94426080	16900	199.082	16700.92	5654.00
3	25.09	3768000	94539120	16900	199.082	16700.92	5661.00
4	26	3768000	97968000	16900	199.082	16700.92	5866.00
5	26.04	3768000	98118720	16900	199.082	16700.92	5875.00
6	26.06	3768000	98194080	16900	199.082	16700.92	5880.00
7	27	3768000	101736000	16900	199.082	16700.92	6092.00
8	27.04	3768000	101886720	16900	199.082	16700.92	6100.00
9	27.08	3768000	102037440	16900	199.082	16700.92	6110.00
10	27.09	3768000	102075120	16900	199.082	16700.92	6112.00
11	28.02	3768000	105579360	16900	199.082	16700.92	6322.00
12	28.03	3768000	105617040	16900	199.082	16700.92	6324.00
13	28.04	3768000	105654720	16900	199.082	16700.92	6326.00
	Average 26.6						Average 5998.00

*Table 4. 42 shows the testing data for raw material (billet-130*130*5998mm) in ϕ 20 mm rebar*

Average number of bars got during production(data collection)								
24.51	24.55	24.49	24.48	24.50	24.55	24.46	24.50	24.50
Number of bars got after improve optimum length of billets								
25.05	25.06	25.09	26	26.04	26.06	27	27.04	27.08
27.09	28.02	28.03	28.04					

- Product type ϕ 20 mm rebar
- Targeted number of product in 12 meter=26.6 pieces (from table 4.39)
- Tolerance =maximum length of scrap in expected out-come =0.09*12meter=+1.08meter
- Scrap ≈ 6.09meter (from the collected data)
- Production rate = 323 tons/shift (from table 4.33)

From the reference to the data which founded table and Taguchi loss function variable can calculate saved scrap

$L(Y)= k(Y-Y_O)^2$ for a single sample

According to the case company the collected data are multiple sampling so it uses L(Y)= k(MSD) for multiple samples

Mean square deviation (MSD) $L(Y)= R(Y-Y_O)^2$
$Y=Y_0 \pm$ Tolerance
$L= R(Y_O \pm \text{Tolerance} - Y_o)^o$

L in this case equals to the length of scrap (10 meter)

The tolerance is 1.08

$K= 6.09/(1.08)^2= 5.22$

Now the data is multiple samples so L(Y)= k(MSD) for multiple samples

$MSD=[(24.51-26.6)^2 +(24.55-26.6)^2 +(24.49-26.6)^2 +(24.48-26.6)^2 +(24.50-26.6)^2 +(24.55-26.6)^2 +(24.46-26.6)^2 +(24.50-26.6)^2 +(24.50-26.6)^2]/ 9=39.53/9=4.39$

L=5.12*MSD =5.22*4.39=22.92

After improve optimum length of billets

$MSD=[25.05-26.6)^2 +(25.06-26.6)^2 +(25.09-26.6)^2 +(26-26.6)^2 +(26.04-26.6)^2 +(26.06-26.6)^2 +(27-26.6)^2 +(27.04-26.6)^2 +(27.08-26.6)^2 +(27.09-26.6)^2 + (28.02-26.6)^2 +(28.03-26.6)^2 +(28.04-26.6)^2]/13=14.98/13=1.15$

L=5.22*1.15= 6

Total saving per shift= 22.92-6=16.9*323=5458 meters

Target or normal value of results 26.6 rebars

Number of test results=13

The weight of 12meter ϕ20 rebar=29.5 kg; (from table 2.1)

» 29.5kg* 5458meters/ 12meter =13419kg or 13.4 tons scrap is saved

From table 4.33

For ϕ 20 mm rebar 32.3tons rolling takes 3649.9 kwh electric and 1508.41litre furnace fuel consumption therefore;

For electric power

32.3 tons=3649.9 kwh

13.4tons =? » 3649.9kwh*13.4tons/32.3tons =1513.8 kwh electric power saved

For furnace oil

32.3 tons =1508.4 liter

13.4 tons =? » 1508.4 liter*13.4tons/32.3=625.7-liter furnace oil saved.

Table 4. 43 shows the optimize length of billets for diameter 24 rebar

size of rebar ϕ24	no of out-put in 12 Meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter out put in MM^3	Raw size of billet (W*H)MM2	1.178% Reduction (hard scale, head-cut and flame cutting width)	Net size of billet (W*H)M2	the required length of billet(MM)
1	17.04	5425920	92457676.80	16900	199.082	16700.918	5536.00
2	17.05	5425920	92511936.00	16900	199.082	16700.918	5539.00
3	17.07	5425920	92620454.40	16900	199.082	16700.918	5546.00
4	17.08	5425920	92674713.60	16900	199.082	16700.918	5549.00
5	18	5425920	97666560.00	16900	199.082	16700.918	5848.00
6	18.05	5425920	97937856.00	16900	199.082	16700.918	5864.00
7	18.08	5425920	98100633.60	16900	199.082	16700.918	5874.00
8	18.09	5425920	98154892.80	16900	199.082	16700.918	5877.00
9	19.02	5425920	103200998.40	16900	199.082	16700.918	6179.00
10	19.04	5425920	103309516.80	16900	199.082	16700.918	6186.00
11	19.05	5425920	103363776.00	16900	199.082	16700.918	6189.00
12	19.06	5425920	103418035.20	16900	199.082	16700.918	6192.00
13	19.07	5425920	103472294.40	16900	199.082	16700.918	6196.00
14	19.08	5425920	103526553.60	16900	199.082	16700.918	6198.00
15	19.09	5425920	103580812.80	16900	199.082	16700.918	6202.00
16	20	5425920	108518400.00	16900	199.082	16700.918	6498.00
17	20.01	5425920	108572659.20	16900	199.082	16700.918	6501.00
	Average 18.5						Average 5998

*Table 4. 44 shows the testing data for raw material (billet-130*130*5998mm) in ϕ 24 mm rebar*

Average number of bars got during production(data collection)								
16.77			16.76					
Number of bars got after improve optimum length of billets								
17.04	17.05	17.07	17.08	18	18.05	18.08	18.09	19.02
19.04	19.05	19.06	19.07	19.08	19.09	20	20.01	

- Product type ϕ 24 mm rebar
- Targeted number of product in 12 meter=18.5 pieces (from table 4.41)
- Tolerance =maximum length of scrap in expected out-come =0.09*12meter=+1.08 meter
- Scrap ≈ 9.16meter (from the collected data)
- Production rate = 394 billets/shift (from table 4.33)

From the reference to the data which founded table and Taguchi loss function variable can calculate saved scrap

$L(Y)= k(Y-Y_O)^2$ for a single sample

According to the case company the collected data are multiple sampling so it uses $L(Y)= k(MSD)$ for multiple samples

Mean square deviation (MSD) $L(Y)= R(Y-Y_O)^2$

$Y=Y_0 \pm$ Tolerance

$L= R(Y_O \pm \text{Tolerance} - Y_o)^o$

L in this case equals to the length of scrap (9.16 meter)

The tolerance is 1.08

$K= 9.16/(1.08)^2= 7.85$

Now the data is multiple samples so $L(Y)= k(MSD)$ for multiple samples

$MSD=[(16.77-18.5)^2 +(16.76-18.5)^2]/ 2=6.02/2=3.01$

$L=7.7*MSD =7.85*3.01=23.63$

After improve optimum length of billets

$MSD=[(17.04-18.5)^2 +(17.05-18.5)^2 +(17.07-18.5)^2 +(17.08-18.5)^2 +(18-18.5)^2 +(18.05-18.5)^2 +(18.08-18.5)^2 +(18.09-18.5)^2 +(19.02-18.5)^2 +(19.04-18.5)^2 +(19.05-18.5)^2 +(19.06-18.5)^2 +(19.07-18.5)^2 +(19.08-18.5)^2 +(19.09-18.5)^2 +(20-18.5)^2+(20.01-18.5)^2]/17=15.81/17=0.93$

$L=7.85*0.93= 7.3$

Total saving of scraps per shift= 23.63-7.3=16.33*394=6434 meters

Target or normal value of results 18.5 rebars

Number of test results=17

The weight of 12meter ϕ24 rebar=42.67 kg; (from table 2.1)

» 42.67kg* 6434 meters/ 12meter =22876kg or 22.8 tons scrap is saved

From table 4.33

For ϕ 24 mm rebar 39.4 tons rolling takes 4452.2kwh electric and 1839.98 furnace fuel consumption therefore;

For electric power

39.4 tons=4452.2 kwh

22.8tons =? » 4452.2kwh*22.8tons/39.4tons =2576 kwh electric power saved

For furnace oil

39.4tons =1839.98 liter

22.8tons =? » 1839.98 liter*22.8 tons/39.4=1064-liter furnace oil saved.

Table 4. 45 shows the optimize length of billets for diameter 20 rebar

size of Rebar ϕ12 mm	no of out-put in 12 Meter	the volume of the rebar (∏R2L)MM3	(∏R2L)*the number of 12 meter output in MM3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale, head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)
1	68.04	1356480	92294899.2	16900	291.187	16608.813	5557
2	69.02	1356480	93624249.6	16900	291.187	16608.813	5637
3	69.08	1356480	93705638.4	16900	291.187	16608.813	5642
4	70	1356480	94953600	16900	291.187	16608.813	5717
5	70.06	1356480	95034988.8	16900	291.187	16608.813	5722
6	70.08	1356480	95062118.4	16900	291.187	16608.813	5724.00
7	71.04	1356480	96364339.2	16900	291.187	16608.813	5802
8	71.06	1356480	96391468.8	16900	291.187	16608.813	5804.00
9	72	1356480	97666560	16900	291.187	16608.813	5880.00
10	72.02	1356480	97693689.6	16900	291.187	16608.813	5882
11	72.04	1356480	97720819.2	16900	291.187	16608.813	5884.00
12	72.06	1356480	97747948.8	16900	291.187	16608.813	5885
13	72.08	1356480	97775078.4	16900	291.187	16608.813	5887
14	73	1356480	99023040	16900	291.187	16608.813	5962
15	73.06	1356480	99104428.8	16900	291.187	16608.813	5967
16	74.04	1356480	100433779.2	16900	291.187	16608.813	6047
17	75.08	1356480	101844518.4	16900	291.187	16608.813	6132
18	76	1356480	103092480	16900	291.187	16608.813	6207
19	76.06	1356480	103173868.8	16900	291.187	16608.813	6213
20	77.04	1356480	104503219.2	16900	291.187	16608.813	6292
21	78.02	1356480	105832569.6	16900	291.187	16608.813	6372
22	78.08	1356480	105913958.4	16900	291.187	16608.813	6377
23	79	1356480	107161920	16900	291.187	16608.813	6452
24	79.02	1356480	107189049.6	16900	291.187	16608.813	6454
25	79.06	1356480	107243308.8	16900	291.187	16608.813	6457
	Average 73.4						Average 5998

*Table 4. 46 shows the testing data for raw material (billet-130*130*5998mm) in ϕ 12 mm rebar*

Average number of bars got during production(data collection)								
68.94	68.95	68.93	68.98	68.97	68.95	68.92	68.95	68.92
68.97	68.98	68.97	68.95	68.93				
Number of bars got after improve optimum length of billets								
68.04	69.02	69.08	70	70.06	70.08	71.04	71.06	72
72.02	72.04	72.06	72.08	73	73.06	74.04	75.08	76
76.06	77.04	78.02	78.08	79	79.02	79.06		

- Product type ϕ 12 mm rebar
- Targeted number of product in 12 meter=73.4 pieces (from table 4.43)
- Tolerance =maximum length of scrap in expected out-come =0.08*12meter=+0.96 meter
- Scrap in average ≈ 11.44meter (from the collected data)
- Production rate = 379 bundle/shift (from table 4.33)

From the reference to the data which founded table and Taguchi loss function variable can calculate saved scrap

$L(Y)= k(Y-Y_O)^2$ for a single sample

L(Y)= k(MSD) for multiple samples

Mean square deviation (MSD) $L(Y)= R(Y-Y_O)^2$
$Y=Y_0 \pm$ Tolerance
$L= k(Y_O \pm \text{Tolerance} – Y_o)^o$

L in this case equals to the length of scrap (11.44 meter)

The tolerance is 0.96

$L=K(\text{Tolerance})^2$

$K=L/(\text{Tolerance})^2$

$K= 11.44/ (0.96)^2= 12.41$

According to the case company the collected data are multiple sampling so it uses L(Y)= k(MSD) for multiple samples

$MSD= [(68.94-73.44)^2 +(68.95-73.44)^2+(68.93-73.44)^2 +(68.98-73.44)^2+(68.97-73.44)^2 +(68.95-73.44)^2+(68.92-73.44)^2 +(68.95-73.44)^2+(68.92-73.44)^2 +(68.97-73.44)^2+(68.98-73.44)^2 +(68.97-73.44)^2+(68.95-73.44)^2 +(68.93-73.44)^2]/ 14=257.3/14=18.37$

L(Y)=12.41*MSD =12.41*18.37=228

After improve optimum length of billets

MSD= $[(68.04-73.44)^2 +(69.02-73.44)^2+(69.08-73.44)^2 +(70-73.44)^2+(70.06-73.44)^2 +(70.08-73.44)^2+(71.04-73.44)^2 +(71.06-73.44)^2+(72-73.44)^2 +(72.02-73.44)^2+(72.04-73.44)^2 +(72.06-73.44)^2+(72.08-73.44)^2 +(73-73.44)^2 +(73.06-73.44)^2+(74.04-73.44)^2 +(75.08-73.44)^2+(76-73.44)^2 +(76.06-73.44)^2+(77.04-73.44)^2 +(78.02-73.44)^2+(78.08-73.44)^2 +(79-73.44)^2+(79.02-73.44)^2 +(79.06-73.44)^2]/ 25=289.39/25=11.57$

L(Y)=12.41*MSD= 12.41*11.57=143.60

Total saving per shift= 227.6-143.65=83.95*379=31993 meters

Target or normal value of results 73.4 rebars

Number of test results=25

The weight of 12meter ϕ12 rebar=10.65 kg; (from table 2.1)

» 10.65kg* 31993 meters/12meter =28394 kg or 28.4 tons' scrap is saved

0.733ton = One billet weight

28.3 tons=? » 1billet*28.3tons/0.733ton=38billets

From table 4.33

For ϕ 12 mm rebar 37.9 tons rolling takes 4282.7kwh electric and 1769.93 furnace fuel consumption therefore;

For electric power

37.9 tons=4282.7 kwh

28.4tons =? » 4282.7 kwh*28.4tons/37.9tons =3209 kwh electric power saved

For furnace oil

37.9 tons =1769.93 liter

28.4tons =? » 1769.93 liter*28.4 tons/37.9=1326-liter furnace oil saved.

According to the findings of the data analysis, a lot of off-cuts that might easily be converted into a normal product, electric power and furnace oil have been saved.

Table 4. 47 summary of saved losses

No	Types of rebar	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
1	ϕ 16 mm	12.3	1390	574.4	16.7
2	ϕ 20 mm	13.4	1514	625.7	18
3	ϕ 24 mm	22.8	2576	1064	31
4	ϕ 12 mm	28.4	3209	1326	38
Average		19.225	2172.25	897.525	25.925

Table 4. 48 the summary of saved losses for ϕ 16 mm and ϕ 12 mm (have head-tail cut)

No	Types of rebar	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
1	ϕ 16 mm	12.3	1390	574.4	16.7
2	ϕ 12 mm	28.4	3209	1326	38
Average		20.35	2299.5	950.2	27.35

But in the smooth production condition the average rolling capacity of the two kind of products 418 billets per shift and saved billets in % »27.35*100/418=6.54%

Table 4. 49 the summary of saved losses for ϕ 20 mm and ϕ 24 mm (have head-cut not tail cut)

No	Types of rebar	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
2	ϕ 20 mm	13.4	1514	625.7	18
3	ϕ 24 mm	22.8	2576	1064	31
Average		18.1	2045	844.85	24.5

But in the smooth production condition the average rolling capacity of the two kind of products 358 billets per shift and saved billets in % »24.5*100/358=6.84%

Table 4. 50 average comparison of the current and research results of scraps

No	Types of rebar	Current scrap /billet in meter	Scraps getting from research /billet in meter	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
1	ϕ 16 mm	10	1.08	12.3	1390	574.4	16.7
2	ϕ 20 mm	6.09	1.08	13.4	1514	625.7	18
3	ϕ 24 mm	9.16	1.08	22.8	2576	1064	31
4	ϕ 12 mm	11.44	0.96	28.4	3209	1326	38
Average		9.17	1.05	19.225	2172.25	897.525	25.925

Table 4. 51 average comparison of the current and research results of scraps for ϕ 16 mm and ϕ 12 mm (have head-tail cut)

No	Types of rebar	Current scrap /billet in meter	Scraps getting from research /billet in meter	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
1	ϕ 16 mm	10	1.08	12.3	1390	574.4	16.7
2	ϕ 12 mm	11.44	0.96	28.4	3209	1326	38
Average		10.72	1.02	20.35	2299.5	950.2	27.35

Table 4. 52 average comparison of the current and research results of scraps for ϕ 20 mm and ϕ 24 mm (have head-cut not tail cut)

No	Types of rebar	Current scrap /billet in meter	Scraps getting from research /billet in meter	Saved scraps in tons/shift	Saved power in kwh/shift	Saved fuel in liter/shift	Saved in terms of billets/shift
2	ϕ 20 mm	6.09	1.08	13.4	1514	625.7	18
3	ϕ 24 mm	9.16	1.08	22.8	2576	1064	31
Average		7.63	1.08	18.1	2045	844.85	24.5

Table 4. 53 shows the losses categorize into can be improve and cannot be improve for ϕ12 and ϕ16 the current research

no	Types of losses	Cuts volume	% of losses in terms of the size of billet	Can be improve	Cannot be improve	% of improve	The % of losses difference between before and after research
1	The width of cutting torch	(130mm*130mm*4mm)	0.033		✓	no	
2	Hard-scale		0.6		✓	no	
3	Head-cut	(8.6cm*7.5cm* 20 cm)	1.4	✓		0.841	
4	tail-cut	(8.6cm*7.5cm*8cm)	0.559		✓	no	
5	Cobble	One billet/shift	0.27		✓		
6	Scrap		3.68	✓		3.33	
The total actual losses getting in research			6.54			4.17	2.37

Table 4. 54 shows the losses categorize into can be improve and cannot be improve for ϕ20 and ϕ24 the research

no	Types of losses	Cuts volume	% of losses in terms of the size of billet	Can be improve	Cannot be improve	% of improve	The % of losses difference between before and after research
1	The width of cutting torch	(130mm*130mm*4mm)	0.033		✓	no	
2	Hard-scale		0.6		✓	no	
3	Head-cut	(8.6cm*7.5cm* 20 cm)	1.4	✓		0.841	
5	Cobble	One billet/shift	0.27		✓		
6	Scrap		4.54	✓		3.9	
The total actual losses getting in research			6.84			4.74	2.1

Average losses 6.54+6.84/2=6.69%

Average reduced losses 2.37+2.1/2=2.24%

CHAPTER FIVE

5.1 Proposed improvement system & the mathematical formulation and description

The primary discovery in this chapter is the optimum length of raw materials that can effectively convert to the product with little scraps. It has to use as references number of normal product that was obtained during production data of the four product types such as Ø 12, 16, 20, and 24 mm. therefore for Ø 12 rebar number of normal product=68 pieces, for Ø 16 rebar number of normal product=38 pieces, for Ø 20 rebar number of normal product=24 pieces and for Ø 24 rebar number of normal product=16 pieces as a result, the formula of volume, area, and length is used as the primary factors of this chapter.

1. No of out-put in12 meter mean; the quantity of 12 meter produced rebar
2. The volume of rebar (∏R2L) mean; the total volume of one 12-meter bar but the result is differing as the size of the rebar
3. ((∏R2L) *the number of 12-meter mean; the product of the volume the rebar with the numbers of rebar
4. The size billet (W*H) MM^2 mean; the face area of the billet W=width of the billet, H= height of billet, M M^2= units of measurement square milli meter
5. 1.723% reduction mean; the summation of losses like hard-scale =0.6%, head-tail cut 1.09% and oxyacetylene flam cutting of billet into two parts takes 4mm width=0.033%
6. The size billet (W_1*H_1) MM2 mean; the face area of the billet after reduce the 1.723% of oxyacetylene cutting width, hard scale & head-tail cut W_1=width of the billet after reduce 1.723% of oxyacetylene cutting width, hard scale & head-tail cut, H_1= height of billet after reduce 1.723% oxyacetylene cutting width, hard scale & head-tail cut, MM^2= units of measurement square milli meter
7. The require length the billet mean; the finding length of the billet which the optimum length of the billet with a little length scrap
8. 12M-required length mean; the remained of billet from 12-meter imported billet to the optimum length of the billet with a little length scrap.
9. Input for ɸ X rebar mean; finding the other optimum length from the remain lengths of billet

Table 5. 1 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 10mm rebar

size of rebar ϕ10 mm	no of out-put in 12 meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter output in MM^3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale, head-tail cut and flame cutting width	Net size of billet (W_1*H_1)MM2	the required length of billet(MM)	12M-Required length (X)	input for ϕ x rebar	no of out-put in 12 m from remain length
1	98.07	942000	92381940	16900	291.187	16608.813	5562.00	6434.00	X	
2	99.07	942000	93323940	16900	291.187	16608.813	5619.00	6377.00	ϕ 12	78.08
3	100.01	942000	94209420	16900	291.187	16608.813	5672.00	6324.00	X	
4	100.09	942000	94284780	16900	291.187	16608.813	5677.00	6319.00	X	
5	101.06	942000	95198520	16900	291.187	16608.813	5732.00	6264.00	X	
6	102.03	942000	96112260	16900	291.187	16608.813	5787.00	6209.00	X	
7	103	942000	97026000	16900	291.187	16608.813	5842.00	6154.00	X	
8	103.09	942000	97110780	16900	291.187	16608.813	5847.00	6149.00	X	
9	104.06	942000	98024520	16900	291.187	16608.813	5902.00	6094.00	X	
10	105.03	942000	98938260	16900	291.187	16608.813	5957.00	6039.00	X	
11	106	942000	99852000	16900	291.187	16608.813	6012.00	5984.00	X	
12	106.09	942000	99936780	16900	291.187	16608.813	6017.00	5979.00	X	
13	107.06	942000	100850520	16900	291.187	16608.813	6072.00	5924.00	X	
14	108.03	942000	101764260	16900	291.187	16608.813	6127.00	5869.00	X	
15	109	942000	102678000	16900	291.187	16608.813	6182.00	5814.00	X	
16	109.09	942000	102762780	16900	291.187	16608.813	6187.00	5809.00	X	
17	110.06	942000	103676520	16900	291.187	16608.813	6242.00	5754.00	X	
18	111.03	942000	104590260	16900	291.187	16608.813	6297.00	5699.00	X	
19	112	942000	105504000	16900	291.187	16608.813	6352.00	5644.00	X	

20	112.09	942000	105588780	16900	291.187	16608.813	6357.00	5639.00	χ	
21	113.06	942000	106502520	16900	291.187	16608.813	6412.00	5584.00	χ	
22	114.03	942000	107416260	16900	291.187	16608.813	6467.00	5529.00	χ	

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs

Table 5. 2 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 12mm rebar

size of Rebar ϕ12 mm	no of out-put in 12 meter	the volume of the rebar (∏R2L)MM3	(∏R2L)*the number of 12 meter out put in MM3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale,head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)	12M- Required length (X)	input for ϕ x rebar	no of out-put in 12 m from remain length
1	68.04	1356480	92294899.2	16900	291.187	16608.813	5557	6439	X	
2	69.02	1356480	93624249.6	16900	291.187	16608.813	5637	6359	x	
3	69.08	1356480	93705638.4	16900	291.187	16608.813	5642	6354	X	
4	70	1356480	94953600	16900	291.187	16608.813	5717	6279	X	
5	70.06	1356480	95034988.8	16900	291.187	16608.813	5722	6274	X	
6	70.08	1356480	95062118.4	16900	291.187	16608.813	5724.00	6274	X	
7	71.04	1356480	96364339.2	16900	291.187	16608.813	5802	6194	X	
8	71.06	1356480	96391468.8	16900	291.187	16608.813	5804.00	6192	X	
9	72	1356480	97666560	16900	291.187	16608.813	5880.00	6116	X	
10	72.02	1356480	97693689.6	16900	291.187	16608.813	5882	6114	X	
11	72.04	1356480	97720819.2	16900	291.187	16608.813	5884.00	6112	X	
12	72.06	1356480	97747948.8	16900	291.187	16608.813	5885	6111	X	
13	72.08	1356480	97775078.4	16900	291.187	16608.813	5887	6109	X	
14	73	1356480	99023040	16900	291.187	16608.813	5962	6034	X	
15	73.06	1356480	99104428.8	16900	291.187	16608.813	5967	6029	X	
16	74.04	1356480	100433779.2	16900	291.187	16608.813	6047	5949	X	
17	75.08	1356480	101844518.4	16900	291.187	16608.813	6132	5864	ϕ 24 mm	18.05
18	76	1356480	103092480	16900	291.187	16608.813	6207	5789	x	
19	76.06	1356480	103173868.8	16900	291.187	16608.813	6213	5783	x	

20	77.04	1356480	104503219.2	16900	291.187	16608.813	6292	5704	x	
21	78.02	1356480	105832569.6	16900	291.187	16608.813	6372	5624	x	
22	78.08	1356480	105913958.4	16900	291.187	16608.813	6377	5619	x	
23	79	1356480	107161920	16900	291.187	16608.813	6452	5544	x	
24	79.02	1356480	107189049.6	16900	291.187	16608.813	6454	5542	x	
25	79.06	1356480	107243308.8	16900	291.187	16608.813	6457	5539	ϕ 24 mm	17.05
	73.4						5998			

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs

Table 5. 3 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 14mm rebar

size of rebar ϕ14	no of out- put in 12 meter	the volume of the rebar (∏R2L)MM3	(∏R2L)*the number of 12 meter output in MM3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale, head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)	12M- Required length (X)	input for ϕ x rebar	no of out- put in 12 m from remain length
1	50.03	1846320	92371389.6	16900	291.187	16608.813	5562	6434	X	
2	50.08	1846320	92463705.6	16900	291.187	16608.813	5567	6429	x	
3	51.02	1846320	94199246.4	16900	291.187	16608.813	5672	6324	X	
4	52.01	1846320	96027103.2	16900	291.187	16608.813	5782	6214	X	
5	52.06	1846320	96119419.2	16900	291.187	16608.813	5787	6209	X	
6	53	1846320	97854960	16900	291.187	16608.813	5892	6104	X	
7	53.05	1846320	97947276	16900	291.187	16608.813	5897	6099	X	
8	53.09	1846320	98021128.8	16900	291.187	16608.813	5902	6094	X	
9	54	1846320	99701280	16900	291.187	16608.813	6003	5993	X	
10	54.04	1846320	99775132.8	16900	291.187	16608.813	6007	5989	X	
11	54.08	1846320	99848985.6	16900	291.187	16608.813	6012	5984	X	
12	55.03	1846320	101602989.6	16900	291.187	16608.813	6117	5879	X	
13	55.07	1846320	101676842.4	16900	291.187	16608.813	6122	5874	ϕ 24 mm	18.08
14	56.02	1846320	103430846.4	16900	291.187	16608.813	6227	5769	x	
15	56.06	1846320	103504699.2	16900	291.187	16608.813	6232	5764	x	
16	57.01	1846320	105258703.2	16900	291.187	16608.813	6338	5658	x	
17	57.05	1846320	105332556	16900	291.187	16608.813	6342	5654	x	
18	58	1846320	107086560	16900	291.187	16608.813	6448	5548	x	
19	58.04	1846320	107160412.8	16900	291.187	16608.813	6452	5544	x	
20	58.09	1846320	107252728.8	16900	291.187	16608.813	6458	5538	x	

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs

Table 5. 4 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 16mm rebar

size of Rebar ϕ16 mm	no of out-put in 12 Meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter out put in MM^3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale,head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)	12M-Required length (X)	input for ϕ x rebar	no of out-put in 12 m from remain Length
1	38	2411520	91637760	16900	291.187	16608.813	5517	6479	X	
2	38.03	2411520	91710105.6	16900	291.187	16608.813	5522	6474	x	
3	38.06	2411520	91782451.2	16900	291.187	16608.813	5526	6470	X	
4	39	2411520	94049280	16900	291.187	16608.813	5663	6333	X	
5	39.03	2411520	94121625.6	16900	291.187	16608.813	5667	6329	X	
6	39.06	2411520	94193971.2	16900	291.187	16608.813	5671	6325	X	
7	39.08	2411520	94242201.6	16900	291.187	16608.813	5674	6322	X	
8	40	2411520	96460800	16900	291.187	16608.813	5808	6188	X	
9	40.03	2411520	96533145.6	16900	291.187	16608.813	5812	6184	X	
10	40.06	2411520	96605491.2	16900	291.187	16608.813	5817	6179	ϕ 24 mm	19.02
11	41	2411520	98872320	16900	291.187	16608.813	5953	6043	X	
12	41.04	2411520	98968780.8	16900	291.187	16608.813	5957	6039	X	
13	41.09	2411520	99089356.8	16900	291.187	16608.813	5966	6030	x	
14	42	2411520	101283840	16900	291.187	16608.813	6098	5898	x	
15	42.02	2411520	101332070.4	16900	291.187	16608.813	6101	5895	x	
16	42.06	2411520	101428531.2	16900	291.187	16608.813	6107	5889	x	
17	42.09	2411520	101500876.8	16900	291.187	16608.813	6111	5885	x	
18	43	2411520	103695360	16900	291.187	16608.813	6243	5753	x	
19	43.02	2411520	103743590.4	16900	291.187	16608.813	6246	5750	x	

20	43.06	2411520	103840051.2	16900	291.187	16608.813	6252	5744	x	
21	43.09	2411520	103912396.8	16900	291.187	16608.813	6256	5740	X	
22	44	2411520	106106880	16900	291.187	16608.813	6389	5607	X	
23	44.02	2411520	106155110.4	16900	291.187	16608.813	6391	5605	X	
24	44.06	2411520	106251571.2	16900	291.187	16608.813	6397	5599	X	
25	44.08	2411520	106299801.6	16900	291.187	16608.813	6400	5596	X	
26	44.09	2411520	106323916.8	16900	291.187	16608.813	6402	5594	X	
	41.3						5998	5998		

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs

Table 5. 5 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 20mm rebar

size of Rebar ϕ20	no of out-put in 12 meter	the volume of the rebar (∏R2L)MM^{3}	(∏R2L)*the number of 12 meter out put in MM^{3}	Raw size of billet (W*H)MM2	1.723% Reduction hard scale,head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)	12M- Required length (X)	input for ϕ x rebar	no of out-put in 12 m from remain length
1	25.05	3768000	94388400	16900	199.082	16700.92	5652.00	6344.00	X	
2	25.06	3768000	94426080	16900	199.082	16700.92	5654.00	6342.00	X	
3	25.09	3768000	94539120	16900	199.082	16700.92	5661.00	6335.00	for it self	28.08
4	26	3768000	97968000	16900	199.082	16700.92	5866.00	6130.00	X	
5	26.04	3768000	98118720	16900	199.082	16700.92	5875.00	6121.00	X	
6	26.06	3768000	98194080	16900	199.082	16700.92	5880.00	6116.00	X	
7	27	3768000	101736000	16900	199.082	16700.92	6092.00	5904.00	X	
8	27.04	3768000	101886720	16900	199.082	16700.92	6100.00	5896.00	X	
9	27.08	3768000	102037440	16900	199.082	16700.92	6110.00	5886.00	X	
10	27.09	3768000	102075120	16900	199.082	16700.92	6112.00	5884.00	x	
11	28.02	3768000	105579360	16900	199.082	16700.92	6322.00	5674.00	x	
12	28.03	3768000	105617040	16900	199.082	16700.92	6324.00	5672.00	x	
13	28.04	3768000	105654720	16900	199.082	16700.92	6326.00	5670.00	x	
	26.6						5998.00	5998.00		

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs

Table 5. 6 show numbers 12 meter out-puts rebar, the productive length and remain billet length of the billet for ϕ 24mm rebar

size of Rebar ϕ24	no of out-put in 12 Meter	the volume of the rebar (∏R2L)MM^3	(∏R2L)*the number of 12 meter out put in MM^3	Raw size of billet (W*H)MM2	1.723% Reduction hard scale,head-tail cut and flame cutting width	Net size of billet (W*H)M2	the required length of billet(MM)	12M-Required length (X)	input for ϕ x rebar	no of out-put in 12 m from remain length
1	17.04	5425920	92457676.80	16900	199.082	16700.918	5536.00	6460.00	X	
2	17.05	5425920	92511936.00	16900	199.082	16700.918	5539.00	6457.00	ϕ 12 rebar	79.06
3	17.07	5425920	92620454.40	16900	199.082	16700.918	5546.00	6450.00	X	
4	17.08	5425920	92674713.60	16900	199.082	16700.918	5549.00	6447.00	X	
5	18	5425920	97666560.00	16900	199.082	16700.918	5848.00	6148.00	X	
6	18.05	5425920	97937856.00	16900	199.082	16700.918	5864.00	6132.00	ϕ 12 rebar	75.06
7	18.08	5425920	98100633.60	16900	199.082	16700.918	5874.00	6122.00	ϕ 14 rebar	55.07
8	18.09	5425920	98154892.80	16900	199.082	16700.918	5877.00	6119.00	X	
9	19.02	5425920	103200998.40	16900	199.082	16700.918	6179.00	5817.00	ϕ 16 rebar	40.06
10	19.04	5425920	103309516.80	16900	199.082	16700.918	6186.00	5810.00	x	
11	19.05	5425920	103363776.00	16900	199.082	16700.918	6189.00	5807.00	x	
12	19.06	5425920	103418035.20	16900	199.082	16700.918	6192.00	5804.00	x	
13	19.07	5425920	103472294.40	16900	199.082	16700.918	6196.00	5800.00	x	
14	19.08	5425920	103526553.60	16900	199.082	16700.918	6198.00	5798.00	x	
15	19.09	5425920	103580812.80	16900	199.082	16700.918	6202.00	5794.00	X	
16	20	5425920	108518400.00	16900	199.082	16700.918	6498.00	5498.00	X	
17	20.01	5425920	108572659.20	16900	199.082	16700.918	6501.00	5495.00	X	
	Average 18.5						Average 5998.00	5998.00		

N.B the length of imported billet 12000mm and" X" mark show the remain length of billet not uses as an inputs .

Table 5. 7 show the summary of productive length billets and the number of rebar from the total length of billets (12000mm)

	ϕ 10 rebar					ϕ 16 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
99.07	5619.00	6377.00	12mm	78.08	40.06	5817	6179	24mm	19.02
	ϕ 12 rebar					ϕ 20 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
75.08	6132	5864	24mm	18.05	25.09	5661	6335	20mm	28.08
79.06	6457	5539	24mm	17.05					
	ϕ 14 rebar					ϕ 24 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	no of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
55.07	6122	5874	24mm	18.08	17.05	5539	6457	12mm	79.06
					18.05	5864	6132	12mm	75.08
					18.08	5874	6122	14mm	55.07
					19.02	6179	5817	16mm	40.06

ϕ 12 rebar has two option of billet length 6132 and 6457 and the number of rebar 75.08 and 79.06 respectively.

75.08 means 75 twelve meter *ϕ 12 rebar and 0.08*12=0.96meter scrap*

79.06 means 79 twelve meter *ϕ 12 rebar and 0.06*12=0.72meter scrap .in the two cases scrap 0.72meter is less scrap and the remain lengths have the same size scrap 0.05*12=0.6meter so avoid length 6132mm from the lists of ϕ 12 rebar* and *ϕ 24 rebar*

Table 5. 8 show the last summary of productive length billets and the number of rebar from the total length of billets (12000mm)

	ϕ 10 rebar					ϕ 16 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
99.07	5619.00	6377.00	12mm	78.08	40.06	5817	6179	24mm	19.02
	ϕ 12 rebar					ϕ 20 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
79.06	6457	5539	24mm	17.05	25.09	5661	6335	20mm	28.08
	ϕ 14 rebar					ϕ 24 rebar			
numbers of rebar	length of billet	remain length of billet	as an input for ϕ	no of rebar	numbers of rebar	length of billet	remain length of billet	as an input for ϕ	numbers of rebar
55.07	6122	5874	24mm	18.08	17.05	5539	6457	12mm	79.06
					18.08	5874	6122	14mm	55.07
					19.02	6179	5817	16mm	40.06

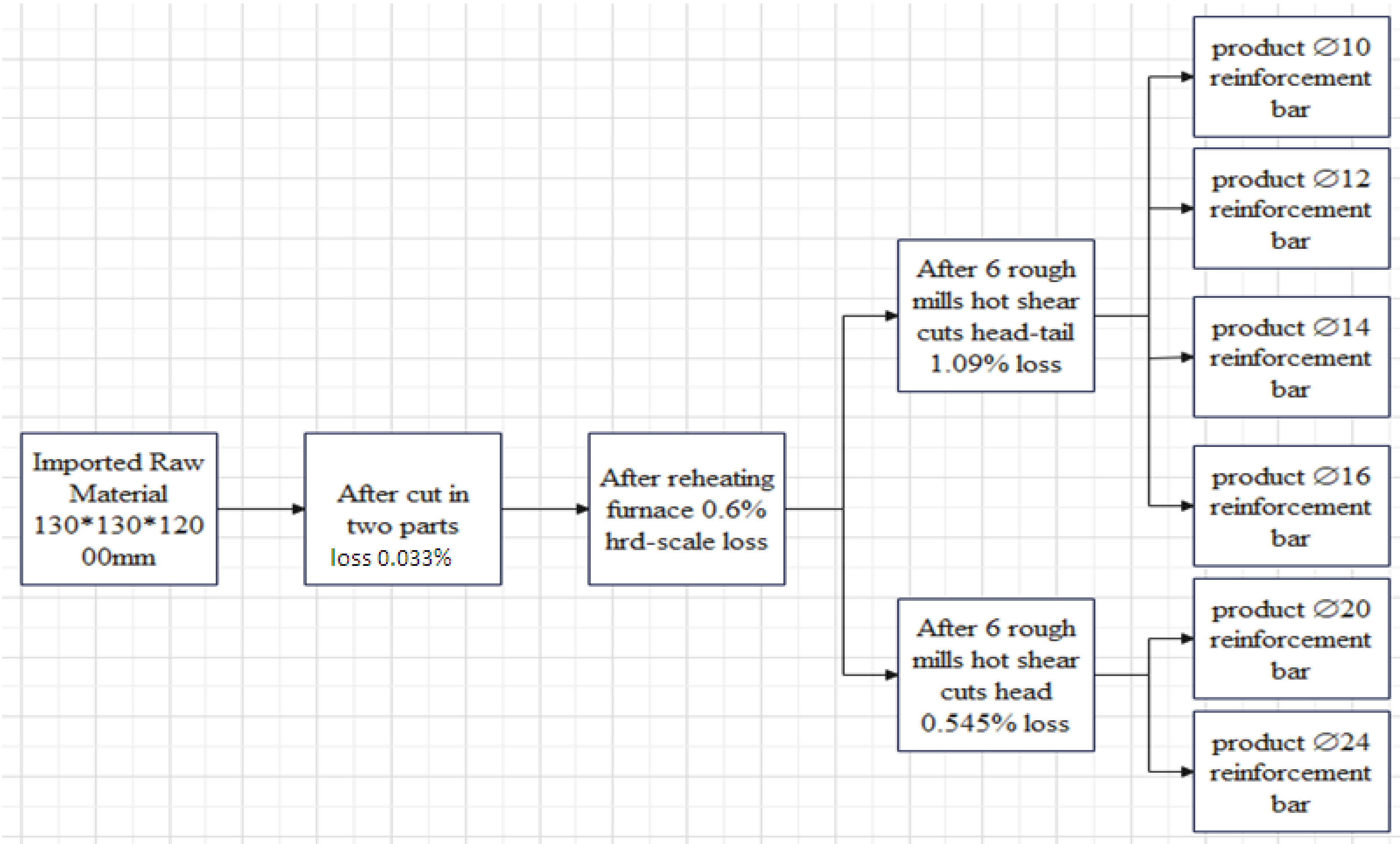

Figure5. 1 shows the flow diagram of raw materials up to finished products of each types of reinforcement bar

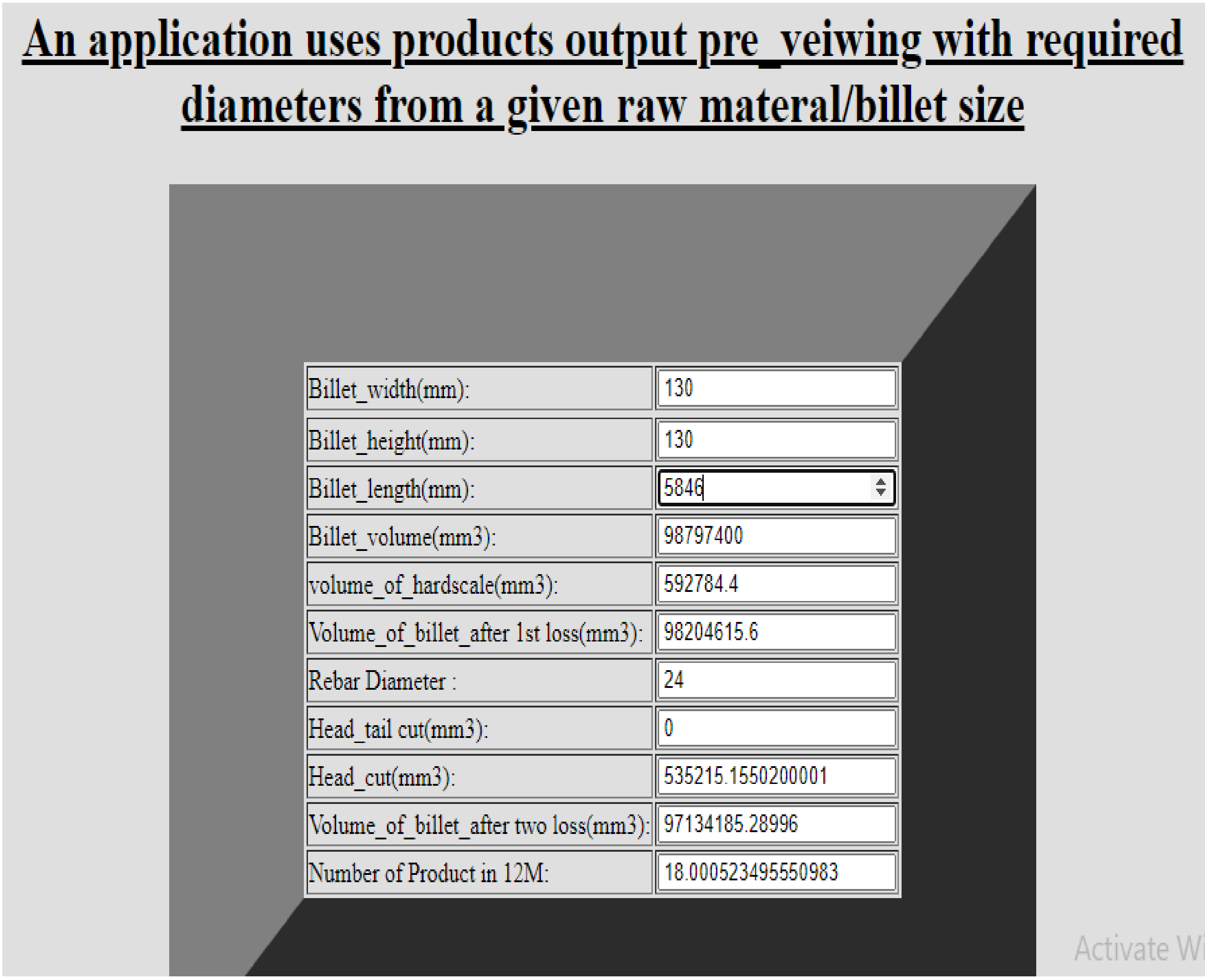

Figure5. 2 shows an application developing used to out-put pre-view of ϕ10, 12,14,16,20 1nd 24mm rebars from the given raw material

This application is developed by JavaScript and provides a preview of how much output can be generated per products like ϕ10, 12,14,16,20 and 24 mm by simply measuring the amount of raw material or billet that goes into before production, uses as an inputs for a clear annual planning and uses for continuous casting machine to produce non off-cut or productive billets. In addition, it is a very useful application that allows that to determine the amount of scrap-free raw material and determine the exact amount of billet size in the continuous casting process.

CHAPTER SIX

6.1 Conclusion

According to the factory's plan, the total loss percentage shouldn't be more than 3% of the weight of the billet. However, the research has produced two distinct outcomes, the first type of rebar diameter 12, 16 are the losses about 6.54% and the second rebar diameter 20,24 the losses about 6.84%.so that according to the research out come

- The optimum length of billet for ϕ10=5619mm the remain length of billet 6377mm used for ϕ12 rebar
- The optimum length of billet for ϕ12=6457mm the remain length of billet 5539mm used for ϕ24 rebar
- The optimum length of billet for ϕ14=6122mm the remain length of billet 5874mm used for ϕ24 rebar
- The optimum length of billet for ϕ16=5817mm the remain length of billet 6179mm used for ϕ24 rebar
- The optimum length of billet for ϕ20=5661mm the remain length of billet 6335mm used for ϕ20 rebar
- And the other loss head cut is about 6.2 kg per billet is out of the product, this also should correct and back to the normal product types.

  By correcting the above main problems, the average percentage of losses reduced from 6.7% to 2.23% and the consumption of electric and fuel reduced by 2172.25 kwh and 897.53 liters per shift

6.2 Recommendation

Overall, the factory is very modern and productive, as during the research, and the work ethic of the staff is very good. However, in terms of input productivity, there is a big gap that seem small. Because a piece of off-cut or scrap is not weighed on time. Thus, probably this is because the scrap metal can be used as an input for the smelting plant to prepare other raw materials for rolling mill number 01. Earn daily income by improving productivity of raw material by adjusting the size according to the type of product, which has resulted in significant revenue loss in terms of productivity and profitability. Through the findings there is recommend the following main focusing areas to improve.

1. During billets preparation, uses an appropriate/optimal length of billet for each product types
2. Hot shear / head-tail cut; during the research there is no length uniformity of head- tail cut it depending on the operator consciousness because the location hot shear prevents an operator to properly see the length of head cut, instead of this use automatic hot metal detector shear machine or change the place of operator.
3. On the two pinch roll which founded between fly shear should serious works

6.3 FUTURE WORKS

The primary material productivity losses identified in the study are billet cutting torch width, hard-scale, head-tail cuts, cobble, and off-cuts. Among them is a solution to reduce off-cut for all product types by optimizing raw material length and making ahead cut length uniform for 10, 12, 14, 16, 20, and 24, improving raw material productivity, and lowering electric power and furnace oil consumption costs. However, there are still losses, such as hard scale, Cobble, and billet cutting torch width. So in the future, the next researcher will fill in the gaps left by these unsolved losses.

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