MAKERERE UNIVERSITY

COLLEGE OF ENGINEERING, DESIGN, ART AND TECHNOLOGY (CEDAT)

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

RESEARCH PROJECT REPORT

OPTIMIZATION OF MATERIAL FLOW AT STEEL AND TUBE INDUSTRIES, UGANDA

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A final year research project submitted in partial fulfillment requirements for the award of the Bachelor of Science in Mechanical Engineering at Makerere University

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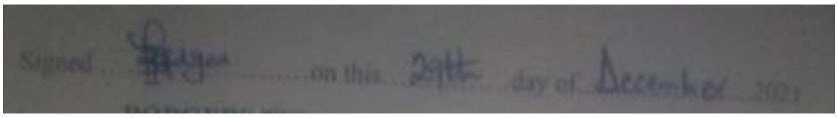
DECLARATION

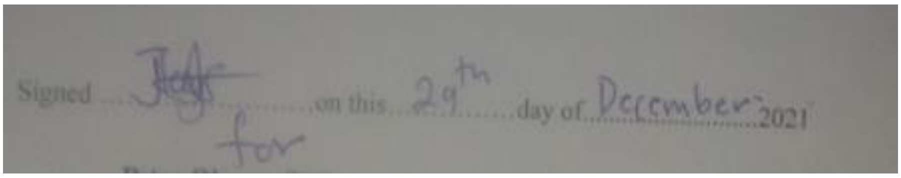
I, TUMWINE Rodgers, here by attest that the study conducted is original and has not been submitted for any other degree award to any other university before. I have therefore, duly referenced any other sources of information. The research involved use of classified information from Steel and Tube industries (Namanve) and hereby agree to the terms and conditions in Non-Disclosure Agreement (NDA) in regard to the confidentiality of the information involved in this research and declare that the research results obtained will be used only to inform STIL and will not be used for other purposes outside academic field.



Signed ………… on this 29th day of December 2021

RODGERS TUMWINE

This report has been submitted with the approval of following university supervisors



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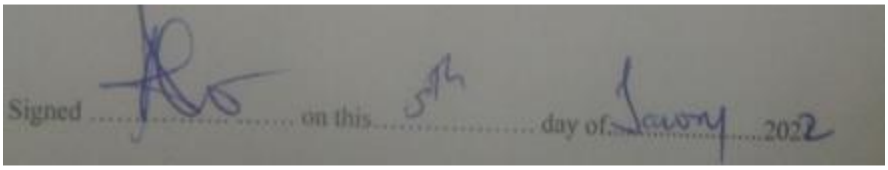

Signed ………… on this 5th day of January 2022

Mr. Andrew Ayor

Co-supervisor

DEDICATION

With great dedication, this report is attributed to my parents Mr. Tumwine Andrew and Mrs. Kyohairwe Beatrace for the financial support that was accorded to me during implementation of the research project and also dedicate this report to the Government of Republic of Uganda for sponsoring my degree program for four years at Makerere University. May the good lord bless them all?

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Rodgers Tumwine

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STIL	Steel and Tube Industries Limited
MFA	Material Flow Analysis
UNDP	Uganda National Development Plan
GDP	Gross Domestic Product

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ABSTRACT

Steel and Tube industries (STIL) - Uganda, faces challenges of varying throughput rate and the production of second quality products. The continued failure to enhance the process incurs high production cost, generation of rework, scrap and time wastages characterized by the long durations. The second quality products can however be sold at relatively low prices compared to prime quality products or recycled to generate new products. There is an extra cost associated with this additional processing and in turn it lowers the profit margin of the steel rolling mill. Therefore, there is a need to identify and address the gaps in material flow and thus minimize company costs in the long run and thus the need for research to inform the company stakeholders. The study utilized a descriptive cross-section design where both quantitative and qualitative approaches were employed and Material flow analysis (MFA) procedure. Using both purposive and random sampling techniques, 15 respondents from SHED1 participated in the research. Systematic designed questionnaires which had closed ended questions were used to extract responses from the respondents interviewed from SHED 1. In addition, the guides to observation were also used in collecting data and QI macros were used to analyze the data and developed graphs using excel software. The main proposed solutions to optimize the material flow in tube manufacturing process were: (a) time inter-campaign. (b) Storage of raw-material and processed materials and (c) Local process time improvements and (d) optimize the output of tube mill. The results of this research as per root cause analysis, it was established that the main root causes of varying throughput included machines, men and methods. The Pareto analysis revealed that the vital few factors resulting to high NVA time at the tube mill section and slitting are inspection of pipes and slitting inspection. In conclusion, STIL should mainstream the emerging innovations through establishment of research and development department and the establishment of planned maintenance program/strategy. The amount this could improve the processes in terms of throughput, processing time and cycle time in production of these steel products using simulation model is worth exploring.

CHAPTER ONE: INTRODUCTION

1.1 Background

Steel industry contributes about 10.7% to the global gross domestic product (GDP) between sectors (Godden, 2019). The steel industry's productivity per worker exceeds USD 80,000 three times the average across all sectors of the global economy (Godden, 2019).The world's material and energy usage, in particular the industrial demand for steel and others has been dramatically increasing over the last 30 years and will increase further (Sygulla et al., 2011). Compared to other cost items, the costs of material and energy use represent with about 50%, the highest portion of costs in the manufacturing industry (Sygulla et al., 2011)

In Uganda, manufacturing sector contributes about 7% to the country's GDP (Calabrese et al., 2019). Uganda's imports of iron and steel products are worth USD 280 million and exports are worth USD 86 million, which represents a trade deficit of USD 194 million.(National Planning Authority, 2018) .The steel consumption/imports inthe EAC region have been on an increase for the past ten years and it was projected to be 4.934 million tons (USD 3.454 trillion) by 2020. In 2018, the value of the iron and steel imports into the region was about USD 1.316 trillion.(National Planning Authority, 2018). Out of the total 165,000 tons of the manufacturing through melting scrap and iron ore, iron ore accounts for only 10% per annum. This implies that 67.11% (485,200 tons) of the raw material for iron and steel making in Uganda are imported. The employment level and total investment for the wholeindustry stands at about 5,000 workers and USD 1 billion respectively (National Planning Authority, 2018).

In the manufacturing industry, the extent of material and energy use as well as material and energy losses mainly depend on the design of the processes which are performed to produce a certain product. The optimum solution with respect to the pursued targets of high material and energy efficiency and low costs has to be found. Material and energy flow analysis has been widely recognized as one important and necessary step for reducing the impacts of human activities on the environment (Brunner and Rechberger, 2004). The expenses of the material flow are assumed to be related to the number of times materials are moved, and the distance; increased movement leads to increased expenses (Aiello, et al., 2002). MEFA utilizes process material and energy input-output data to characterize the use of materials within and between processes. It can be used to reduce the consumption of energy, raw material, water and discharge of effluents by pursuing systematically internal flows of energy and mass inmanufacturing processes (Binder, 2007). The manufacturing industry has over the time grown and is shifting towards increasing resource efficiency of material and energy, a round 26% ofsteel goes into scrap globally. Steel industries incurs high production cost, generation of rework, scrap and time wastage therefore, there is a need to provide an ultimate solution to cater the problem of yield loss and material wastage thus enhancing material flow (Khawar et al., 2015).

1.2 Company Background

Steel and tube industries Limited is among the leading producers of steel products in Uganda and has three production facilities that is Nakawa, Kazinga and the main production facility in Namanve Industrial area, in Wakiso district, central Uganda. The company was incorporated in 2013 and started with bulk manufacture of steel tubes and plates. Steel and tube industries limited performs various operations of casted iron, mild steel and stainless steel. At the Namanve facility, the production runs all day over two shifts in production section that is day/night. STIL employs over 1080 staff on permanent basis up from 580 staff in 2013. The total number of employment beneficiaries is approximately over 6000 including casual laborers as well as various beneficiaries in their value chain.

STIL has an installed capacity of over 300,000 MT and the group processes over 130,000 MT of steel per annum. As the result of revamping of the profiling plant in Namanve and together with full functioning of hot roll and cold roll mill, over 100 jobs have been created, additional tax contribution of Ush10.95billion has been made, foreign exchange saving of Us$3.5 billion have been made from import substitution as well as foreign exchange revenues of Ushs14.2 billion equivalents to 35% of total sales have been earned from re-exportation.

The Namanve facility has four sheds that is producing different steel products particularly SHED1 deals in the production of tube/pipe products and open profile structures like door frames. The STIL mill receives the semi-products (coils that is 1210 mm and 1219 mm width) imported from china and Japan and process them into different products that is

- Round pipes
- Square pipes
- Rectangular pipes

1.3 Problem statement

The manufacturing industry has over the time grown and is shifting towards increasing resource use of material. Most contemporary steel mills are facing many dilemmas, the essence of which is the determination of the ways of acquisition or maintenance of their position in the competitive environment. These steel mills have to continuously increase their resource use efficiency through research and development. One of the ways to get competitive prevalence is analysis and optimization of material flow which contributes to the reduction of the company costs. Currently the company faces the challenges of varying throughput rate and the production of second quality products. The continued failure to enhance the process incurs high production cost, generation of rework, scrap and time wastages characterized by the long durations. The second quality products can however be sold but at relatively low prices compared to prime quality products or recycled to generate new products. The process of recycling itself is expensive in terms of transportation and the cost of production for all products is the same. There is an extra cost associated with this additional processing and in turn lower the profit margin of the steel rolling mill. Therefore, there is a need to identify and address the gaps in material flow and thus minimize company costs in the long run.

1.4 Objectives of the study

1.4.1 General objective

The main objective of this study was to identify options for material flow improvements and handling in the production area of Steel and Tube industries.

1.4.2 Specific objectives

- To assess the impact of plant layout on the material flows
- To identify bottlenecks in material flows in production area
- To identify opportunity areas for improvement in the production area

1.4.3 Research questions

a) Are their challenges in material flow processes in tube manufacturing process?

b) Are there areas of opportunity for improvement in SHED1?

c) How does the current facility layout affect manufacturing cycle time and throughput rate for Shed1?

1.4.4 Time scope and Limitations

Due to the possible difficulties and time frame to implement any proposed solution, the project aims at proposing improvement solutions and might be limited to not carry out their implementation. The whole project had 4 weeks duration.

1.4.5 Scope of the study

The project ranges in scope from investigating the gaps/challenges faced by the company (STIL) in the SHED 1, with respect to the material flow for tube manufacturing processes that's from storage to production area examining movement, manufacturing cycle times, throughput rate and handling of materials

1.5 Justifications

The enhancement of material flow is considered as the means to accelerate the material efficiency and reduced material wastages and therefore enhance the company's cost saving and also reduce related time wastages. The study to optimize material flow for the Uganda's steel manufacturing plants generated vital data that will inform the manufacturing plant on the appropriate course of action in regard to resource use. This would result in an increase in resource efficiency, productivity and reduction in wastes. Thus,reducing the use of material will have positive ecological effects like reduced wastages in terms of time and material as well as energy losses and may result in material, energy and disposal cost savings.

CHAPTER TWO: LITERATURE REVIEW

2.0 Material flow Analysis

The material flow optimization method is material flow analysis. Material flow analysis (MFA) is a systematic assessment of the flows and stocks of materials includingenergy within a system defined by space and time (Brunner and Rechberger, 2004). It is an analytical tool that examines the material stocks and flows coming into and out of a given system, and the resulting outputs from the system (Brunner and Rechberger, 2004; Baccini and Brunner, 1996). MEFA constitutes an important approach to track the use of materials and energy by socio-economy systems from extraction to manufacturing, to final uses anddisposal of emissions and wastes. The material flow approach can be traced back to the second half of the nineteenth century, but current approaches rely on methods developed in the late 1960s and early 1970s (Taulo and Sebitosi, 2016).

The aim is to trace the physical flow of materials, products and wastes associated with particular economic activities. MFA uses the principle of mass balancing to study how material and energy flows interact with the economy and the environment (OECD Guide, 2008). The principle of mass balancing is based on the first law of thermodynamics, which states that matter (mass, energy) is neither created nor destroyed by any physical transformationprocess. Material inputs into a system must therefore always equal material outputs plus net accumulation of materials in the system (material balance principle). Material that flows into the system builds up and maintains the system's material compartments.

All materials required to maintain a system compartment or stock must be considered part of the system's relevant material flows. Material flows can be analyzed on several spatial scales and with different instruments depending on the issue of concern and on the objects of interest of the study.

MFA can be applied to various scales and types of systems, especially companies, economic sectors, households, national economies, the world economy, or villages, cities, river basins, nation states and world regions. MFA may include different types of materials. According to different subjects and various methods, MFA covers approaches such as product flowaccounts, material balancing, and overall material flow accounts.

The principal concept underlying the MFA approach is simple model of the interrelationship between the economy and the environment, in which the economy is an embedded subsystemof the environment and similar to living being's dependent on the constant throughput of materials and energy (Baccini, P. and P.H. Brunner, 1996).

2.1 Material flow analysis, MFA definitions

To understand the construction and quantifications of the MFA approach it is important to recognize the definitions applied. The review uses the definitions (Table 1) from the Practical handbook of Material Flow Analysis (Brunner and Rechberger, 2004)

Table 1 Terminology used in MFA

Term	Definition
Material flow	Material flow means transportation of raw materials, components, work-in-progress inventory, and final products through the production chain from inbound to outbound.
Material	Generic term for substances and/or goods flowing through the system
Process	The transformation, transport or storage of material
Flow	An inflow (input) is entering a process and an outflow (output) is exiting a Process.
Transfer coefficient	The division of a substance in a process. The percentage of a process's input that is directed to each output
Parameter	The data used for describing the process, that is flows, concentration, area and mass
System Boundary	The geographic or organizational border of the defined system

2.2 Materials used in tube mills

Inputs for the tube manufacturing process

- Roll Coils and slits

Outputs for tube mill process (Diameter et al., 2020)

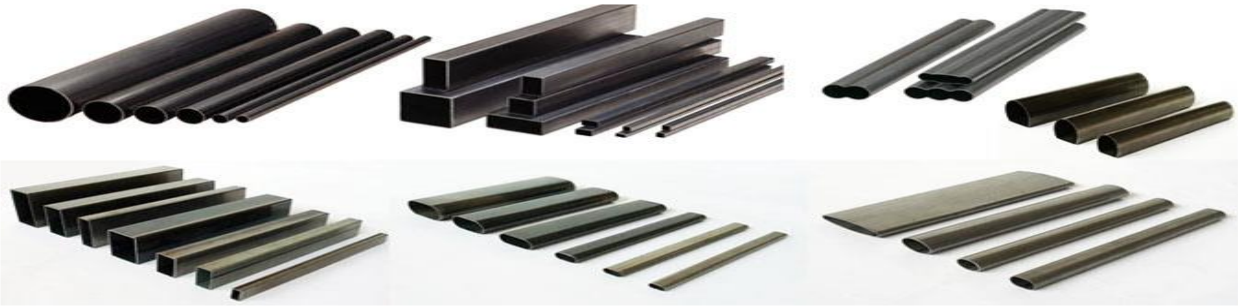

Figure 1 Final products of tube mill process

2.3 Cold rolling process for tube manufacturing

In this unit slits are fed into the accumulator and then into tube mill until the required tube diameter and length are produced (Diameter et al., 2020)

Figure 2:Layout of tube manufacturing section

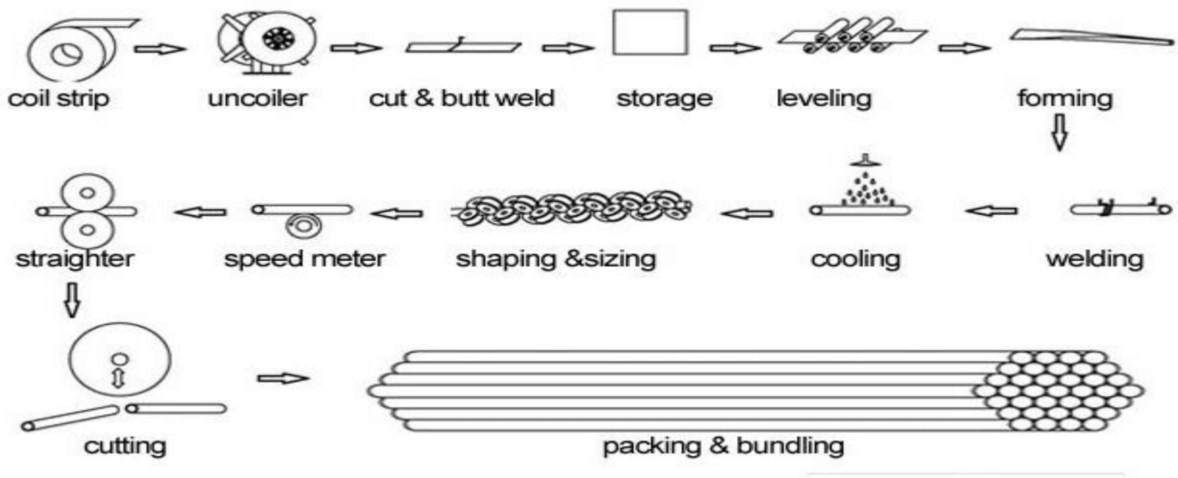

Figure 3 Process flow of tube Manufacturing

2.4 Process description

Step 1: Coiling slitting

Coil Slitting is a shearing process in which the width of an original, or master, coil is reduced into multiple narrower coils. A wide range of materials and thicknesses can be slit, ranging from thin foils to thick plate. Normally, the outside edges of the master coil are trimmed. This creates an accurate register cut, providing a reference point from which the other cuts can be made. Slitting is performed on slitting lines which consist of four basic devices: (Objective et al., n.d.)

- The un-coiler, or pay-off reel, which tightly grips the master coil on its inside diameter using an expandable mandrel. The coil is fed into the slitter by either rotating or jogging the mandrel.
- The slitter, which consists of two parallel arbors mounted with rotary cutting knives. These knives partially penetrate the coil stock causing a crack or fracture on both sides of the stock, separating the material.
- A tensioning device, which is placed between the slitter and the subsequent re-coiler. A tensioning device is needed because the master coil is crowned or larger in diameter in the center of its width than at the edges. Without a tensioning device the slit material from the center of the master coil would take up more quickly while the outboard strips would hang loosely.
- The re-coiler, which takes up the slit coils on a driven, expandable mandrel. The re-coiler mandrel is fitted with separator discs which prevent interleaving of the narrower coil widths.

Figure 4: Master coil slitting machine

Step2 Un-coiler

Function: support rolled plate and strip tension for tube manufacturing, by the frame, main shaft, increases of drum, brake. There are 3 types: pneumatic, hydraulic and manual.(Diameter et al., 2020)

Figure 5: Un coiling operation

Step3: Shear and Butt-welding

Function: Shear the end of each strip coil, then welding them together, so that tube manufacturing process can be continue production and there are two types Automatic and Manual

Figure 6: welding operation after de-coiling the slit

Step 4: Strip Accumulator

Function: storage strip to keep continue production and are two types that is horizontal / Vertical Advantage: Horizontal type can be larger storage. Vertical type is much cheap and small space occupied.

Figure 7: strip accumulation

Step 5: Forming Section

Function: forming the tube mill process from strip

Figure 8: Tube forming process

Step 6: High Frequency Welding

Function: Welding the pipe, different thickness & diameter, the power of the tube mill process welder

Figure 9: Induction welding process

Step 7: Sizing Section

Function: sizing the tube to precise size

Figure 10 shape and sizing rollers

Step 7: Flying saw / Cold Saw

Function: cutting the tube mill line tube to right length. Fly saw: easy to operation, low investment.
Cold saw: no noise, no burr cutting precision and cross section.

Figure 11: Fly saw during operation

Step 8: Run Out Table.

Function: run out the pipe, packing the pipe for tube mill process
Type: Automatic or manual

2.5 Material flow

In this report, the term flow refers to any dynamic variation of material with time. Material flows present the dynamic movement and transformation of steel materials include steel coils, blooms, slab, billets and finished steel products. Material flow involves describing the physical flow of materials and the way it is moved and transported (Harrison, et al., 2014).Mulchy (1999) argues that the materials handling and movement should support an effective material flow throughout the whole facility. The design of material handling and flow should ensure low operating costs, an efficient flow of material with a maximum of volume handled. Green et al. (2010) describe theimportance of a well-working flow of material in manufacturing processes in order to meet customer demand on time and maintain customer satisfaction.

The choice of a suitable material handling system is very important, which can increase productivity (Green, et al., 2010) and reduce the total manufacturing costs (Drira, et al., 2007). “Materials handling is a system or combination of methods, facilities, labor, and equipment for moving, packaging, and storing of materials to meet specific objectives”.

According to Mulcahy (1999) reduces a proper structured way of handling and moving material unnecessary double handling over the same path, lowers waiting time for machines and employees, reduces damage of products and equipment, and injuries of employees. Material handling can be costly and is regarded as a non-value adding function (Green, et al., 2010), however necessary to ensure that material is delivered to the appropriate location (Drira, et al., 2007) at required time.

A material handling activity can be value-adding, as stated by Mathisson-Öjmertz (1998a) “an activity has a value-adding component if it contributes to the materials approaching the state desired in the final position, why it should not only be regarded as waste argues however that not all materials handling activities add value and that those activities should be reduced.

2.6 Lean Manufacturing

Lean Manufacturing Lean manufacturing is the term coined after a 5-year MIT study of the automobile industry back in the 90’s (Hopp & Spearman, 2008). James Womack and Daniel Jones were some of the pioneers to describe the lean philosophy through a couple of books: The Machine that Changed the World and Lean Thinking. This broader philosophy incorporates the Just in Time (JIT) techniques that had been developed in Japan from the 1970’s. The different conditions in market, environment, geography and people had as a consequence a very different evolution of the Japanese manufacturing industry compared to the American one.

JIT results as the challenge for a more flexible and faster adaptation to a market demanding a more mixed variety of products and, in comparison to America, with much less volume. Thus JIT, and later on Lean as well, greatly focused on constantly reducing defects, setups and inventories

Toyota became the flagship of Lean Manufacturing with its Toyota Production System (TPS) and names like Taiichi Ohno and Shigeo Shingo rapidly became widely popular. Lean manufacturing is a philosophy that took JIT as one of its pillars but the TPS house of principles adds Jidoka (automation with human touch) as another pillar and they all rest in standardized procedures, visual management and leveled production as a foundation. In contrast with JIT, Lean puts a very strong focus on people and teamwork since their engagement is crucial to the continuous improvement goal (kaizen in Japanese). In a summarized way, Lean tackles Muda (waste in Japanese) and promotes thinking of Flow and Value Stream to avoid Mura (unevenness) and muri (overburden). It defines 8 types of Muda or waste (Liker, 2004):

- Over production: producing products for which there are no customer orders
- Waiting (time on hand): workers just waiting for a process to finish or for upstream products to arrive, tools and so on
- Unnecessary transport or conveyance: moving work-in-progress (WIP) more than needed
- Over processing or incorrect processing: Carrying unneeded processing steps or not doing it correctly due to poor design, tools

- Excess inventory: excess of WIP, Raw material or finished products hide problems like damaged products, production imbalances, late deliveries and many others that ultimately result in longer lead-time, higher costs and lower service levels.
- Unnecessary movement: any wasted motion that workers have to perform during their course of work like reaching for, looking for and so on
- Defects: production of defect parts or their correction
- Unused employee creativity: loosing time, ideas, skills, improvements and learning opportunities by not engaging or listening to your employees Some of the tools that Lean manufacturing promotes in order to tackle these wastes are the 5 whys, 5s and kaizen.

The 5 why's aims at reaching the real root cause of a problem by not getting satisfied with the first answer but rather digging deep into the problem until finally reaching its source. The 5s are (Liker, 2004)

- Seiri (Sort): sort through items to keep just what is needed
- Seiton (Straighten, orderliness): everything has its place where they should be
- Seiso (Shine, cleanliness)
- Seiketsu (Standardize): create procedure to maintain and monitor the points above
- Shitsuke (Sustain): make a habit maintaining and improving such environment

The objective of this order and cleanliness is not just to have a tidier and more comfortable environment but more importantly, aims at having an environment that easily helps to identify any abnormal situation that might lead to a problem later on. Kaizen is the Japanese word for continuous improvement. TPS argues that this should be part of every employee's mindset from shop floor to top management. Thus, it should be normal practice to feel uncomfortable with status quo and always look for a way to do things in a better way. These were just a few of the most common tools that Lean promotes to deal with the above-mentioned wastes. In essence these tools are quite simple and that is why some companies think that by just using some of them they have become a "Lean company". This just highlights the poor comprehension that certain companies (or even consultants) have got from this comprehensive philosophy that above all puts people as a central topic in order to keep improving.

2.7 Facility Layout

Companies are constantly aiming for improvements, being cost efficient and meeting customers' expectations. Logistics operations need to be efficientto enable a company's competitiveness in a market with a wide product variety and short response times. This increases the pressure on manufacturing companies to optimize their production by lowering costs and increasing productivity (Denkena, et al., 2014), where the costs of logistics operations is a part of the overall productioncosts (Rouwenhorst, et al., 2000). The costs are dependent on inventory and the way material is monitored and managed (Christopher, 2011). Depending on the layout of the facility there will be different costs related to manufacturing, work in progress, productivity and lead times(Drira, et al., 2007). The efficiency of material flow and handling is also affected by the layout

A facility layout can, according to Drira et al. (2007) relate to the arrangement and location ofa production group or manufacturing cell where production of goods or services are performed. Designing a facility layout is a complex task for two reasons; the constraints of the facility andits necessity to support and ease the materials handling and movement. In a manufacturing system there can be different types of layout problems, often related to the location of facilities, for instance machines, in a plant. Finding a suitable location of facilities will increase the efficiency of operations as well as reducing its expenses (Drira, et al., 2007).

The best design of a layout should, according to Drira et al. (2007), be a combination of the most efficient related to the interaction of different facilities, such as production units, and thematerial handling system. The expenses of the material flow are assumed to be related to the number of times materials are moved, and the distance; increased movement leads to increasedexpenses (Aiello, et al., 2002). Production units should be placed so that the available space ishighly utilized and that the location of machines and production groups should bring as low costs of material handling and slack area as possible in order to be optimized and increase efficiency (Drira, et al., 2007). The layout should also suit the material handling system and the material flow through and between facilities (Drira, et al., 2007), sincethe shape of the facility impacts on the efficiency of the movement of material and the materialshandling system.

CHAPTER THREE: METHODOLOGY AND IMPLEMENTATION

3.1 Research Design

The research was carried out following quantitative and qualitative research designs. Involvement of cross-sectional research design was considered to capture the time element in the study. The research relied on quantitative and qualitative data related to stages in tube product manufacturing processes. Data collection was through primary and secondary sources. Observations, interview and questionnaire techniques were used to capture information in relation to material flow. Analysis was mainly by descriptive.

3.1.1 Case study

The research method used in this research project was a case study design. The case study research was based on one case company; Steel and Tube industries. The case study was conducted at the company's facility in Namanve (SHED1) where the material flow was investigated. The material flow was analyzed between storage and production area, and the way the material is handled in tube manufacturing section. The manufacturing layout was studied concerning its impact upon the material flow and handling. The choice of case study design was based on its appropriateness for studying one specific case, with the possibility of in-depth information gathering and trying to solve one specific problem. The problem identified at the case plant was however, related to other companies operating in similar markets and structured ways of working in a manufacturing process.

3.1.2 Data Types and Sources

Both primary and secondary data was collected and analyzed for this study. Primary data was collected through multi-stakeholder engagements. These included operators, and data was collected through face-to-face interviews and through observations as well as industrial data base in regard material flows. The data includes Steel tube products manufacturing processes, material flows and so on. Secondary data was obtained from the existing literature in research articles. The data collected during the detailed study includes; material input, material balance data Process, material flow diagrams, processing time, material handling and cycle times and throughput and industrial wastes/defects.

3.1.3 Data Collection techniques and Procedures

Tools were designed in tandem with the study objectives. The selection of data collection techniques was based on the case study design and the case company. Multiple techniques were used to increase the validity of the research by triangulation (Cohen, et al., 2011). Relevant sources of data in case study research were documents, interviews and observations (Cohen, et al., 2011), therefore these techniques were chosen for this research. Secondary data of qualitative and quantitative nature, was collected using literature review guide to support document review, information and documentation from the company on top of qualitative data to be collected during study. Qualitative data was relevant for the analysis of material flow. The interviewers were required to first explain to the respondent the purpose of the study. This included an assurance to them that the data obtained from the industry would be kept confidential.

Table 2:Overview of respondents interviewed at case company (n=number of respondents)

Data collection tool	Respondents, STIL
Semi-structured Interviews	10
Unstructured Interviews	5

3.2 MFA procedure

Definition of the system boundary under study

The first step of material flow analysis was the identification of the industrial plant that is steel and tube industries. This involved the qualitative analysis of the selected process: identification of its limits, definition and description of its stages, and analysis of inputs and outputs and internal flows. This analysis was based on technical visits to the plant and on bibliographic review.

System description

The material flow analysis system under consideration was defined with regard to space, processes, time horizon that is steel tube manufacturing, Steel and Tube industries, 2021 and materials where necessary, the system was divided into subsystems.

Data acquisition

The flows and stocks were determined by direct measurements, expert judgment, best estimates, and interviews, databases of the manufacturing company and technical handbooks.

Modelling and scenario building

The flows and stocks were determined by direct measurements, expert judgment, best estimates, and interviews, databases of the manufacturing company and also data from technical hand books. The empirical data of this study will be collected from SHED 1.

Modelling and scenario building

Material balances were performed on those processes where no data is available. Mass balances can be expressed in the rate form as given by the following general Eq. (1)

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Where m is the mass flow rate, and the subscripts *in* stands for inlet and *out* for outlet.

Material balances for each step of tube production shown in Fig.1 can be described by Eq. (2)

$$\sum_{j=1}^{p} \dot{m}_{in,j} = \sum_{k=1}^{n} \dot{m}_{out,k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...$$

Where j represents the type of material inputs with a total of p inputs, and k represents the type of material outputs with a total of n outputs

Results and discussion.

The results obtained were compared with the ideal/expected output from the planned orders. All of them contributed to design control measures, to identify new problems and best of all, new solution.

3.3 Assessing the impact of plant layout on material flow.

This criterion was used to assess the impact of the process layout on material flow, analyzed using both Qualitative and quantitative methods. The processing time, waiting times and material handling times were analyzed using Excel software applications and the cycle times and throughput were determined.

3.3.1 Cycle time analysis

The total time taken by a batch of products to go through all the processes of production was determined using time studies method. This included processing times, waiting times and material handling times. Time studies was determined and performed for the processes which are highly repetitive and have relatively short cycle times. A stop watch was used to collect data for process and activity times. The observed time for each process and activity was determined by taking the average of 5 observations.

From this, the normal time and standard time were obtained as described and adopted from Stevenson (Stevenson, 2009) as shown in Eq. (3) and Eq. (4):

Normal Time NT = Observed Time OT $*$ Average Rating.. (3)

Standard Time ST = NT/ (1 − allowances)... (4)

Where average rating of 80% and allowances of 10% included personal needs, unavoidable delays and basic fatigue, was considered. The times for long-cycle processes was obtained by recording the start time and end time of each long-cycle process and calculating the difference. The total manufacturing cycle time was calculated by adding up the times for all the activities and processes. Pareto analysis was performed to determine the vital few factors leading to high Non-Value Adding time for the selected study process.

3.3.2 Throughput analysis

The company's' actual throughput rate was determined using the procedure outlinedbelow:

- Production records for a period of 1 month were examined and data for quantity of each product produced per month in a period of 4 weeks collected and recorded.
- The total production per week was computed and tabulated based on the data obtained in step one.
- The actual weekly throughput rate was compared to the theoretical weekly throughput rate to indicate the deviation of the actual from the theoretical rate.
- Root cause analysis was performed to establish the root causes of varying weekly throughput rate in relation to material flow and material handling.

3.4 Material flow analysis: Application to steel tube manufacturing

Definition of the system boundary under study

This study focused on steel and tube industries (Namanve). The study has storage to production area system boundary and starts from bond customs area where imported coils are received and ends at the packing of tube products produced in the production area. The function unit for this study is 1 tube of mild steel, Fig.12 also shows the processes and stages included in the system boundary. This analysis was based on technical visits to STIL and on bibliographic review.

System description

Tube manufacturing process consists of the following main steps: slitting, de-coiling, shear and butt welding, Accumulator, forming section, High frequency welding, sizing and cutting, coils imported to the country and are brought to the factory where they are first slitted. Silting is an important processing step applied to reduce the width of master coils to narrower slits depending on customer order and pipe size required from 3x148mm (coil) to 3x51mm (slit) or 4x1219 mm to 4x391 mm and then lifted to the de-coiler where it supports rolled plate and strip tension for tube manufacturing, by the frame, main shaft, increases of drum, brake .Shear& Butt-welding Shears the end of each strip coil, then welding them together, so that tube manufacturing process can be continue production .The strip the goes to horizontal Strip Accumulator for storage to keep continue production. The strip is then passed through forming rollers for forming the tube mill process from strip and the pipe is then welded, different thickness & diameter, the power of the tube mill process welder. The tube then goes through the calibration rollers to form the required shape and size. Flying saw / Cold Saw cut the tube mill line tube to right length. Fly saw: easy to operation, low investment. And Run Out Table run out the pipe, packing the pipe for tube mill process. Process steps and also second quality products and wastes generated from these steps are given in fig.12

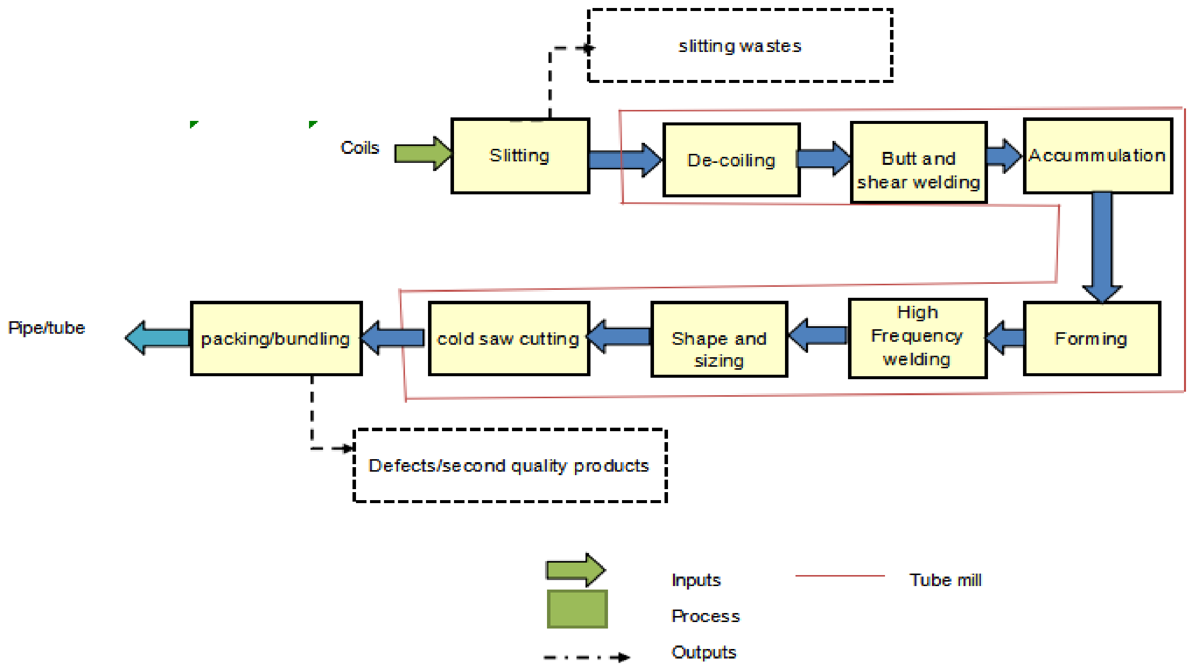

Figure 12 Process flow of tube/pipe manufacturing process

Data acquisition

The empirical data of this study was collected from SHED 1. The SHED (1) has different processing capacities of tubes ranging from 100 to 240 pipes per hour. Data was collected from SHED1 through weekly plant reports, direct on-site measurement and literature review. The inventory data which consisted of raw materials, material consumption and wastes were obtained from plant reports. Data analysis included material inputs and outputs of tube production. Finally, mass balances for a complete process and the unit processes were established.

Modelling and scenario building

Material balances were performed on those processes where no data is available. Mass balances can be expressed in the rate form as given in Eq. (1) and Eq. (2).

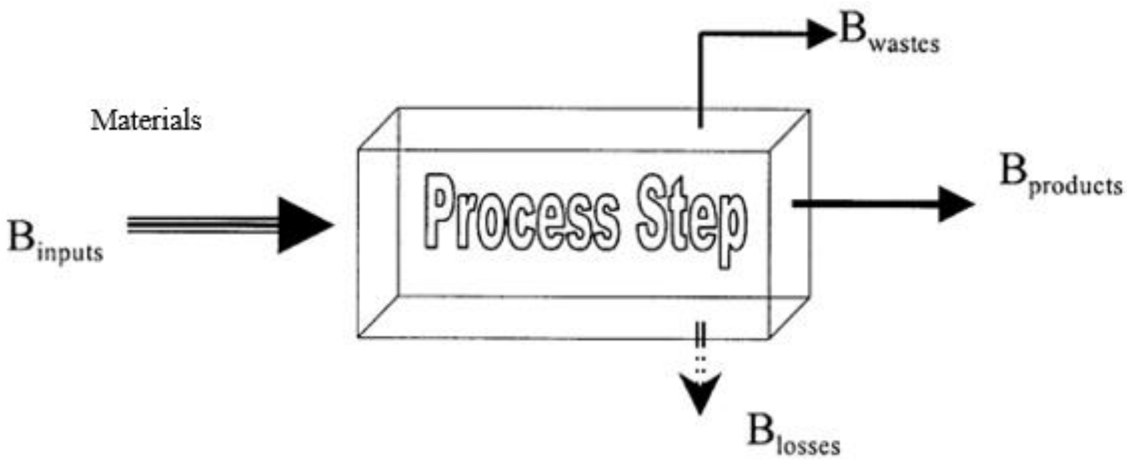

Figure 13 Material accounting for a process step

Given the material inputs, B for each step of agiven production process, calculated material losses according to the following material balance, depicted in Fig. 13,

$$B_{\text{inputs}} = B_{\text{products}} + B_{\text{losses}} + B_{\text{wastes}}.$$

The material resources are denoted by *B*inputs. The prime quality products are included in *B*products. The rejects/second quality products are denoted by B_{wastes}. The term B_{losses} includes scrap.

3.5 Research process

The research study was carried out in October and November 2021. In the beginning of the study, documents of the company and general information about the company were studied. Afterwards a tour of SHED1 and discussions with the production manager were carried out. A comprehensive literature study of mainly material flow and handling was carried out. The analysis of the current state was conducted and after the analysis with suggested improvements for the future state were established. During the whole process, data collection and literature study was carried out in parallel. Discussions were held, when needed, with the production manager and production planner to gain detailed information. The access and availability of an office space at STIL during the research process enabled contact with managers and operators as and when needed.

3.5.1 Literature overview

Based on the purpose of the research and research questions, related literature was selected. Main sources of literature were books and journal articles. Access to articles was gained from Google Scholar. Keywords used were: facility layout, material handling and material flow

3.5.2 Study at case company

The study at STIL (SHED1) began late October 2021, where discussion was held with the production manager concerning the problem description and research questions. Afterwards discussions were held with selected managers when needed, as well as operators before data collection for. Therefore, establishing an overview of the process flows was important. Observations were performed before collecting data to establish an overview of the processes and data collection. Next step was discussion with the production planner regarding the shift scheduling to plan the study of SHED1 and the process flow of tube products. The current flow and handling of material were noted to identify the Non-value Adding, NNVA and Value Adding activities. The data collection process was based on discussions with the operator regarding operation time and flow of the chosen Method. The study was conducted on one specific batch consisting, from start to end of production, which was labelled for identification and traceability. The choice of the specific batch was made to ensure dependable results of the movement and handling of the material throughout the flow. Following one batch of product enabled data collection of all activities where material was handled and moved before, during and after all operations. Such activities could be overlooked if different batches were studied.

During observations, movement and times were measured. Notes were taken during observations and transcribed afterwards. Since the amount of information forgotten increases as time passes it, important to transcribe as soon as possible. Risk of biases in observations were considered, such as the selective attention of the observer, selective data entry and memory, and how the participants react to being observed. Recording enables structured analysis of interview data, to draw conclusions, and lowers the risk of missing details while taking notes. All recorded interviews were transcribed. It is an important step to perform. The transcriptions were read several times to ensure no important data was missed.

3.5.3 Data analysis

Analyzing qualitative data involved organizing and making sense of the data. The data analysis is dependent upon fitness. The data analysis was organized into three steps, where the first was to analyze the mapping conducted. The analysis of the data collected during observations was conducted in two ways. All data collected were structured in an Excel spreadsheet where total time, movements and motions were calculated. Process activity mapping were used for further analysis. The next step was to analyze the data collected during semi-structured interviews. The semi-structured interview data was analyzed according to what was said, both in comparison between employees.

CHAPTER FOUR: SURVEY RESULTS

Data collection was carried out at Steel and Tube industries, Namanve, which was later screened to correct or eliminate inaccurate records and a total of 17 Questionnaires were issued to different workers, only 15 responded positively, and hence giving 88% response towards the study. The answered copies were picked from respective respondents and their opinions quantitively assessed. These survey results are broadly categorized according to the question format as discussed in the methodology.

4.1 Material flow information

Material flow information is necessary factor in a production company because products are created from materials. Therefore, it is important to understand the imperativeness in regard to movement of material between the appropriate steps of value chain. About 20% of the respondents agreed that there were problems associated with unnecessary movement (Fig 14) and this was due to movements during inspection of pipe length and weight, the person in charge has to frequently adjust the length on the control panel of the Tube mill C.

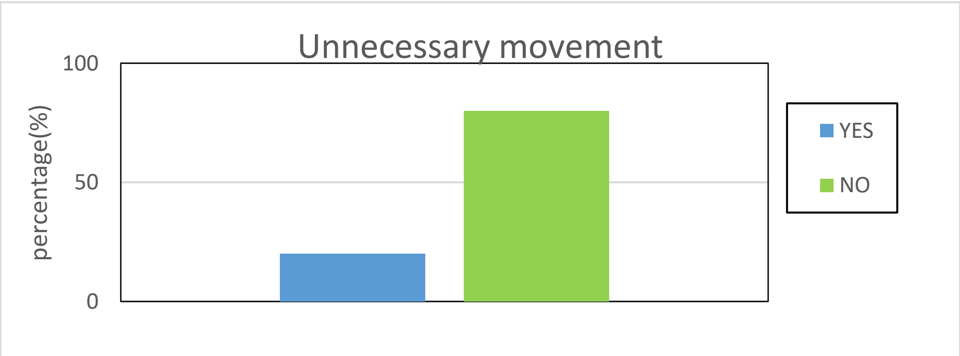

Figure 14: Unnecessary movement in shed1

All respondents according to Fig.15 answered in the affirmative, with 100% responses that storage of materials closer to the machines reduces the handling and movement.This was evident in Shed 1 where slits were arranged closer to both Tube mill B and C,and material handling activities were minimal since the slits were picked and dropped on the un-coiler and this made work more simpler with reduced movements.

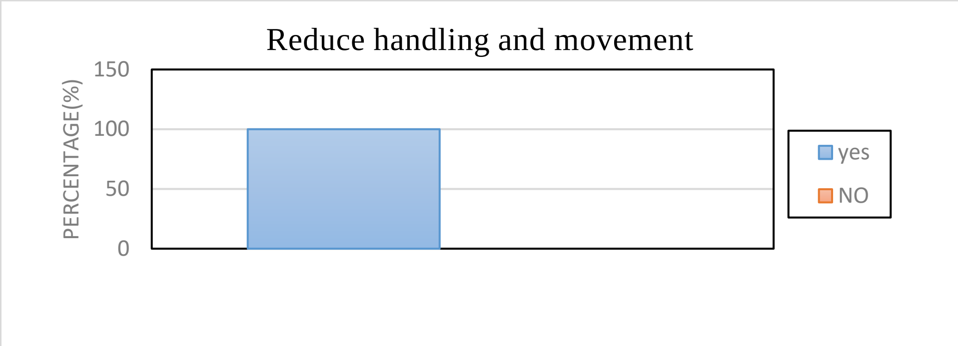

Figure 15: Storing the materials closer to the machines reduce the handling and movement

Descending order of reasons for the closeness of the departments according to respondents: Flow of material (accounting for 46.7 % of the responses), Ease of supervision 33.3% and common personnel (Fig.16). The reasons given for this order are; short distance and time durations and the versatile in inspecting products from different departments.

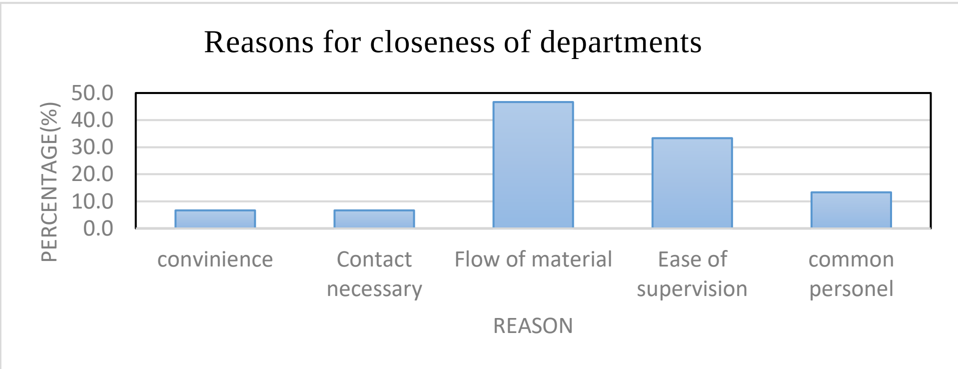

Figure 16: Order for Reasons for closeness of the departments

4.2 Plant layout information

The plant layout is a significant factor in the timely execution of orders. An ideal layout eliminates such causes of delays as shortage of space, long distance movement of material, spoiled work and thus speed execution of orders. The survey results in relation to the plant layout as shown below;

All respondents according to Fig.17 answered in the affirmative, with 100% responses that facility design has relevant impact on the productivity and cost reduction of the company and most respondents stated a well designed facility reduces material handling activities and mantains easy flow of material.

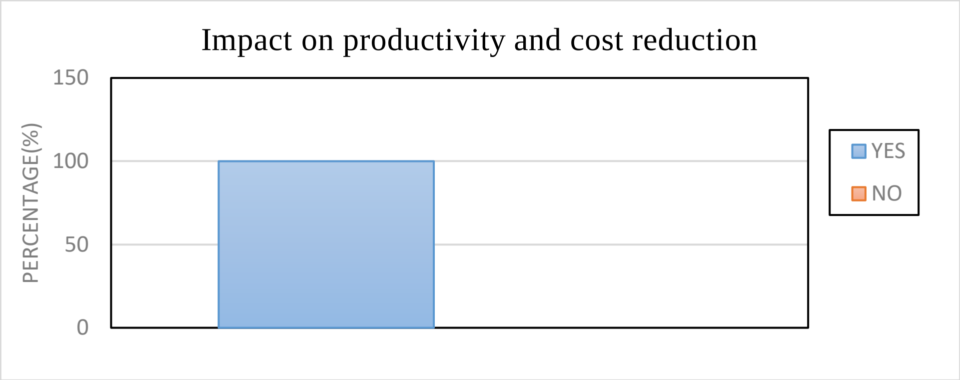

Figure 17: Relevant impact of facility design on the productivity and cost reduction of the company

All respondents according to Fig.18 responded that there would be no impact of changing current plant layout on improving material flow since the plant was established using modern technigues on the basis of lean manufacturing. However, some of the respondents highlighted it as a greater opportunity in the establishment of future company facilities in case of expansion.

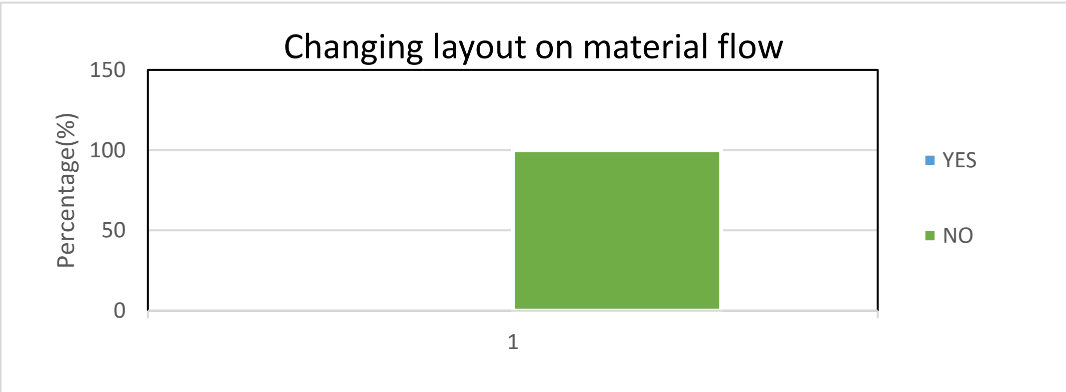

Figure 18: The impact of changing plant layout on improving material flow

About 80% of the respondents agreed that the Flow pattern was designed over other considerations of productivity and costs (Fig.20) and this was attributed to the closeness of machines, Flow Forward tracking, closeness of storage area and the design of the internal transport means.

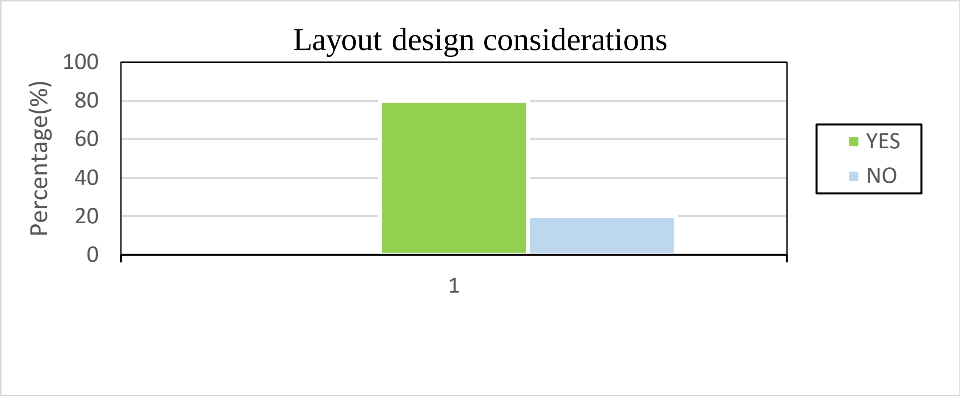

Figure 19: Flow pattern or the layout design development over other considerations

According to Fig.20, respondents answered in the affirmative with 100% responses that different size loads were being used in the tube manufacturing processes especially in tube manufacturing,master coils of 1210 and 1219 mm width were being used and processed into different slit width depending on the customer orders received thus different unit loads.

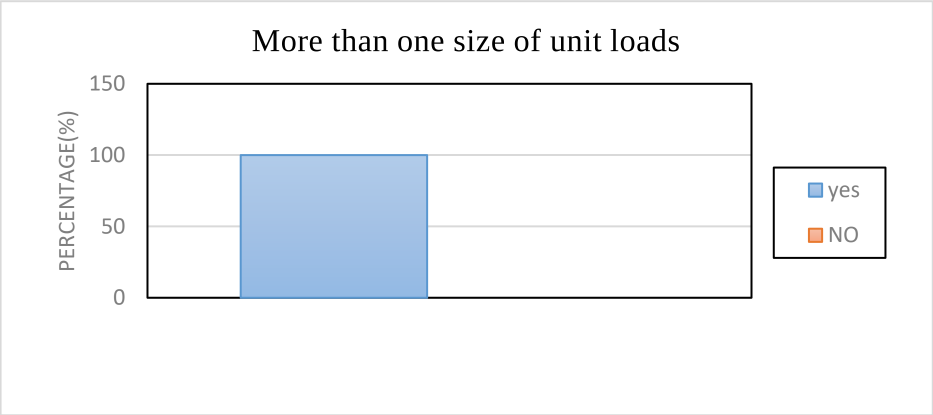

Figure 20: Size of unit load currently used in the manufacturing process and if different

4.3 Material handling Information

Material handling information is necessary as it involves the movement, protection, storage and control of products throughout manufacturing and ware housing and from the survey results as discussed below; Most of the respondents, 66.7% highlighted that Equipment was the major cost in the transportation of materials (Fig.21) and this was due to the fact that in shed1 there were a few personnel involved in transportation of materials thus more costs go into operating and maintaining equipment's such as overhead cranes.

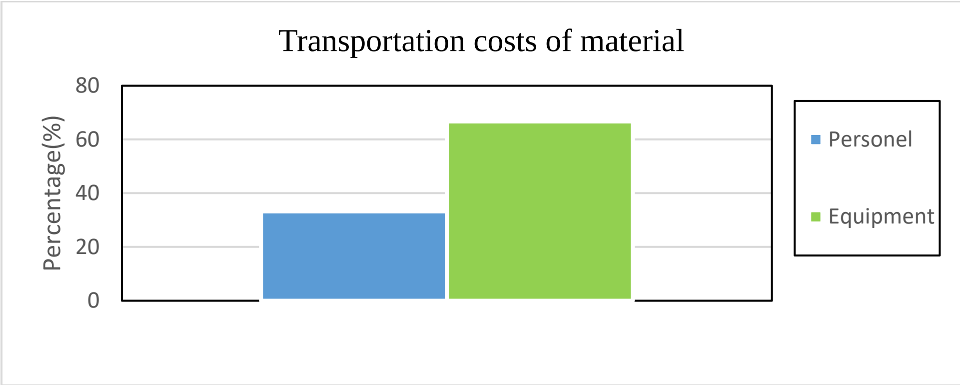

Figure 21: Two main costs in the transportation of materials: the personnel involved and the equipment and the more relevant in the processes mentioned

All respondents highlighted that there were no disadvantages for the storage area to be located in the same area as that of manufacturing (Fig.22) and this was attributed to minimal travel distances and less durations in delivering the processed materials to the machines for further processing.

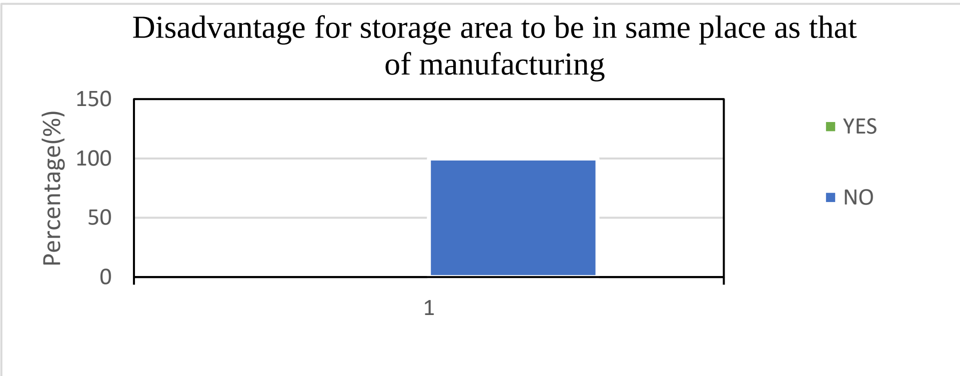

Figure 22: The storage area is in the same place that the manufacturing process and if it's a disadvantage

All the respondents highlighted that it was not feasible to re-arrange the current processes (Fig.23) and it was just because most processes were developed under design considerations and only afew difficulties exist which may not necessarily require re-arrangement instead upgrade of the processes especially installing sensor measurement system on run out table to automatically detect weight of the pipes.

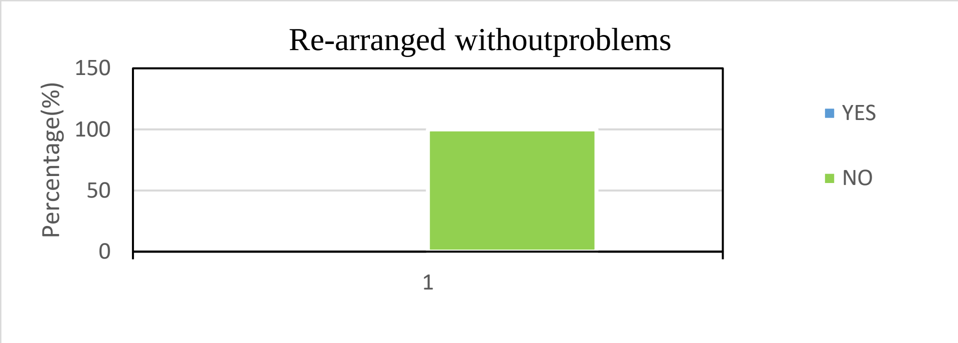

Figure 23: Current processes can be rearranged without any problems and the feasibility

About 50 workers (Day/Night) were involved in the manufacturing process in Shed 1 and about 8 workers were assigned to material handling especially bond customs area and packing of steel pipes as in Fig.24 below;

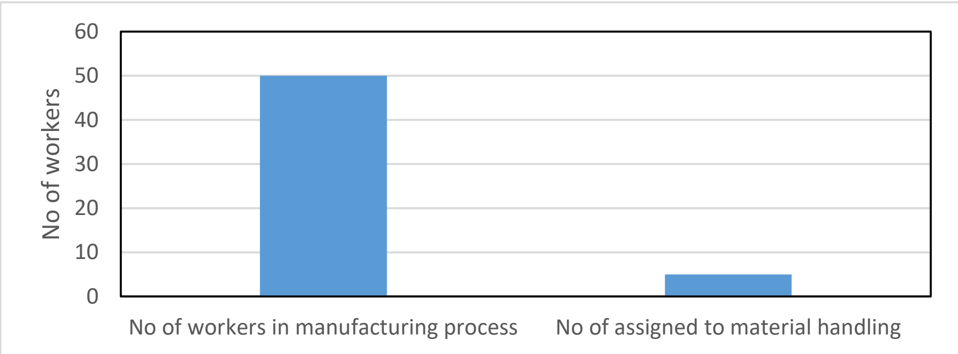

Figure 24: Workers are assigned only to material handling aspects and workers are in the entire manufacturing process

About 25% of the respondents agreed that there were possibilities to use other material handling equipment's (Fig 25) and this was due to the fact that bundling of pipe on the tube Mill c is handled Manually and there was possibility that automatic bundling equipment could quicken the process as in the case of tube mill B.

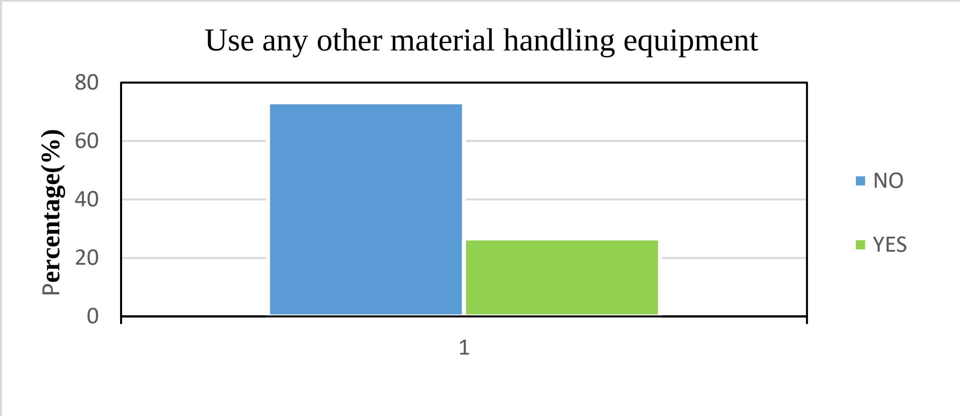

Figure 25: Appropriateness to use any other material handling equipment(s)

4.4 Intuitive Observations and industrial visits

Plant visits were made to Steel and Tube industries, operational site in Namanve where the research was proposed to be conducted. Critical observations were focused on material flows for processing of steel pipes in SHED1.

CHAPTER FIVE: EMPIRICAL RESULTS AND DISCUSSION

5.1 Initial Interviews

As earlier described, the initial step was to conduct a series of interviews to get properly introduced to the project that is the information about the plant like products, customers and departments was collected properly grasping how the plant operates and to whom it supplies.

In figure 26, one can observe the range of possible steel options rolled in SHED1, Namanve plant. The possible combinations are very high and the processing time from one combination to as well, thus the most answers in these interviews used to start with "**it depends on the product**"

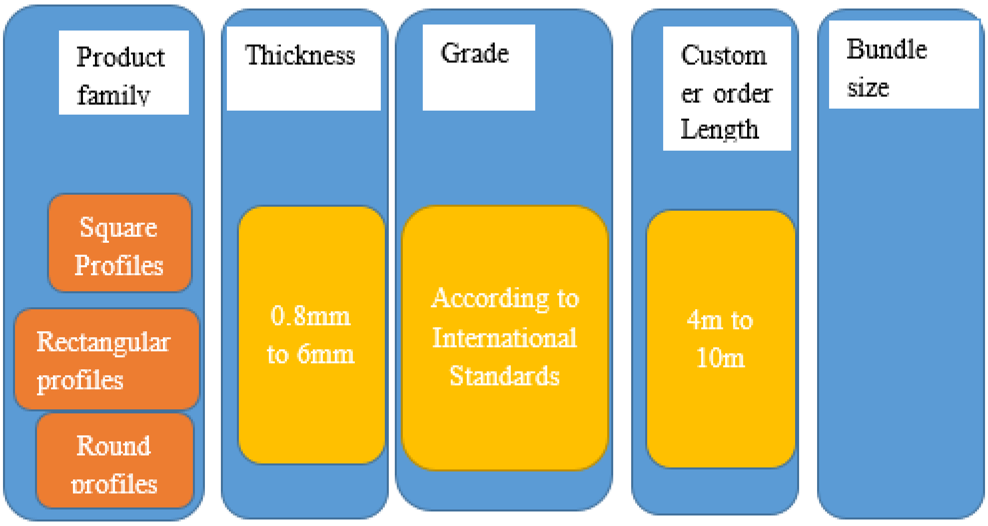

Figure 26: Range of products produced in shed1

These interviews also helped me to gain knowledge about the production planning process. Rolling campaigns are the highest level in the planning hierarchy and simply contains a particular Product Family with a certain coil width that is W1219. These campaigns might be rolled more than once in a week so besides indicating the name of the profile family, they also indicate the week when they have been rolled for easier tracking in the future. Normally roll changes in the mill occur only between rolling campaigns. Within a Rolling Campaign one finds many rolling groups. Even though they are all from the same profile family and width, the differences in sub profile that is grade, thickness and require special adjustment of width that is why they are put together. Finally, within a rolling group specific sub-profile but with the different length and bundle size requirements.

5.2 Existing Material flow and process layout

The standard sequence of processes followed by STIL in steel tube manufacturing is illustrated in Figure No.27

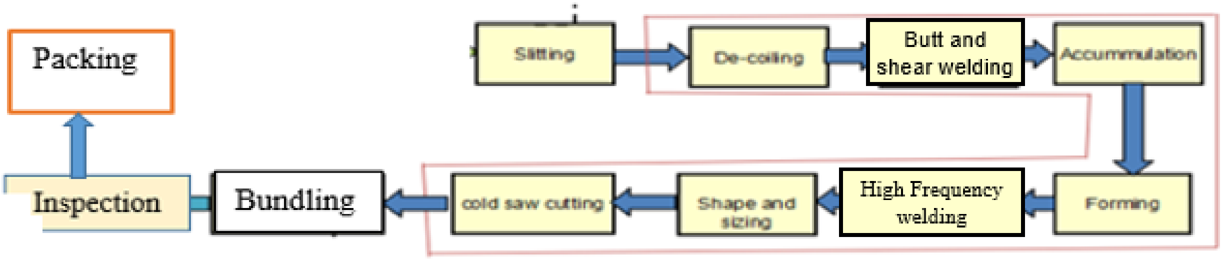

Figure 27 Process flow

- Coil Slitting is a shearing process in which the width of an original, or master, coil is reduced into multiple narrower coils.
- De-coiling -support rolled plate and strip tension for tube manufacturing, by the frame, main shaft, increases of drum, brake.
- Shear& Butt-welding: Shear the end of each strip coil, then welding them together, so that tube manufacturing process can be continue production
- Strip Accumulator storage strip to keep continue production.
- Grinding: This involves the removal of slag created during butt and shear welding
- Forming Section. forming the tube mill process from strip
- High Frequency Welding. Welding the pipe, different thickness & diameter, the power of the tube mill process welder
- Shape and size. Sizing the tube to precise size
- Cutting. This is done using flying saw to cut the right length the tube mill line tube to right length.
- Inspection: The process of verifying the desired parameters meet the requirements.

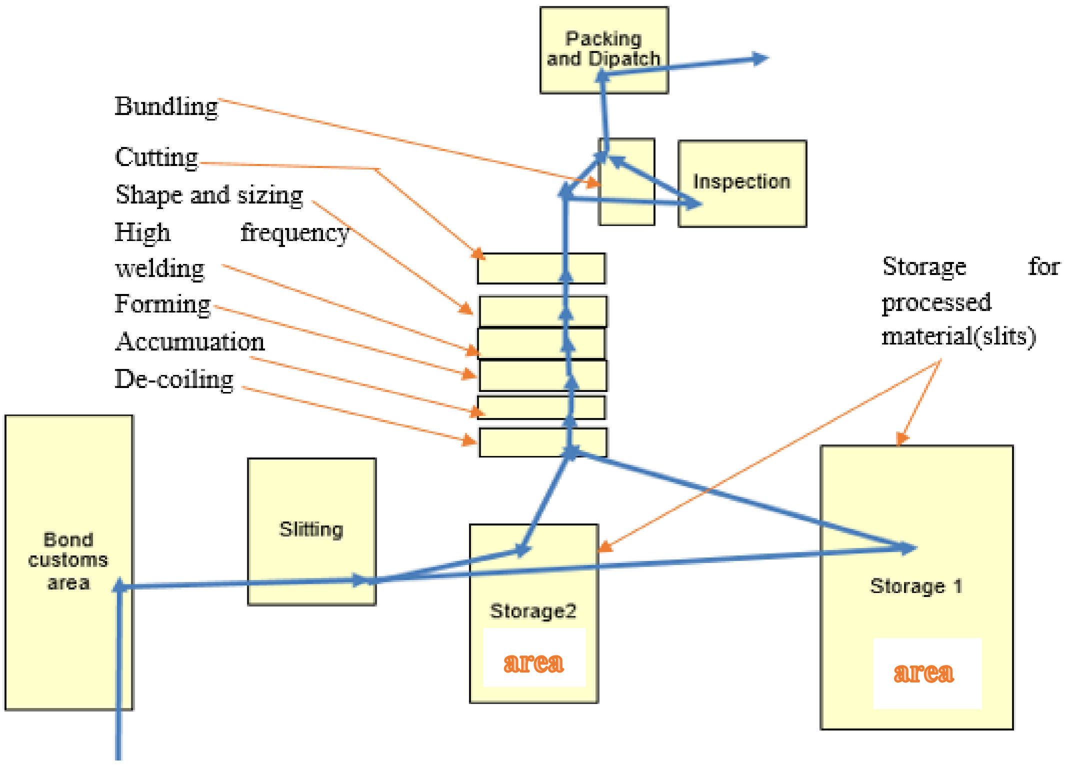

Figure 28 String diagram for the current layout

5.3 Impact of the current facility layout on material flow

This involved the impact assessment of current facility layout on manufacturing cycle time and throughput rate thus material flow.

5.3.1 Cycle time analysis

Time studies were conducted to establish the standard times for each cycle process. Table 3 shows the summary of mean, normal and standard times for the tube manufacturing cycle processes:

Table 3: Times for tube manufacturing cycle processes for article A

Process	**Mean time (min)**	**Normal time (min)**	**Standard time (Min)**
Slitting	25.00	21.25	23.61
De-coiling	10.00	8.50	9.44
Butt and shear welding	5.00	4.25	4.72
Grinding	4.00	3.40	3.78
Forming	0.20	0.17	0.19
High frequency welding	0.53	0.45	0.50
Sizing	0.30	0.26	0.28
Cutting	0.08	0.07	0.08
Measuring	2.50	2.13	2.36

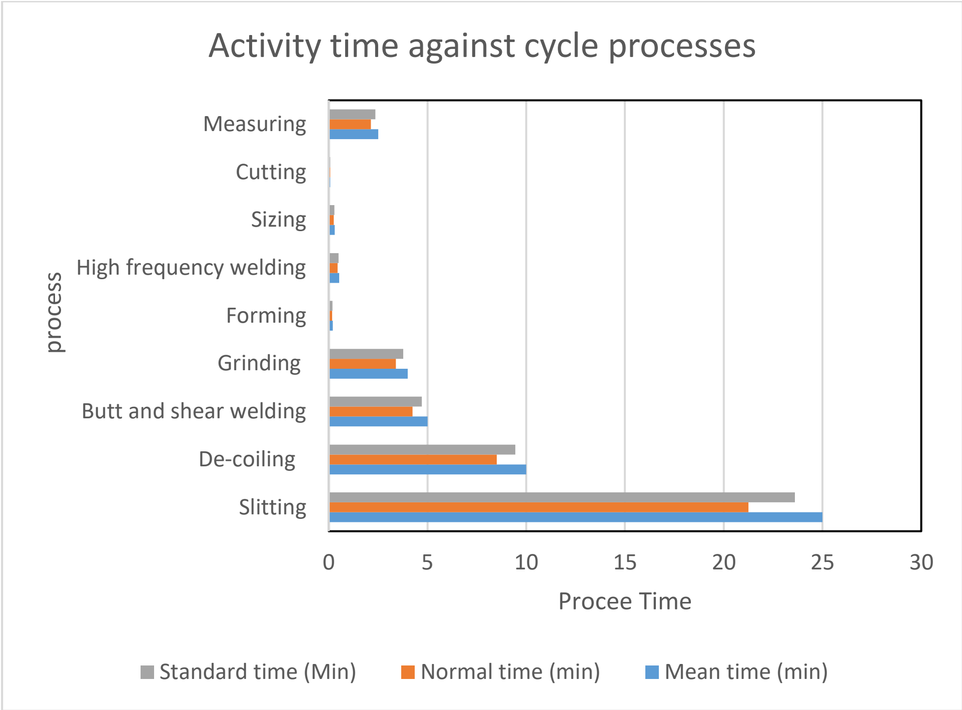

Figure 29 A bar graph of process time against cycle processes in tube processing

The total manufacturing cycle time was obtained based on the assumption that the final product was square tube, Article A (4x100x100mm, 6m length), which usually has the medium production time among all the products produced in SHED1.This analysis was based on processing of a single batch of tubes of approximately 5,000 kg and produces 72 pieces of tubes. The results obtained are as summarized in table 4

Table 4:Manufacturing cycle time

Section	**VA time (min)**	**NVA time (min)**	**Total (min)**
Slitting section	10	15	25
Tube mill C section	73.5	10	83.5
Total	82.5	25	108.5

The cycle time analysis presented in table 4 helped establish that the manufacturing cycle time of tube A, was 108.5 minutes which translates to approximately 2 hours. The total manufacturing time of 108.5 minutes constituted of 25 minutes or 23.04 % non-value adding activities (NVA) and 82.5 minutes or 76.96% of value adding activities. This revealed presence of wastages/gaps that needed to be identified and eliminated or reduced. The slitting section contributed the highest percentage of NVA activities, which is 13.82% of the total manufacturing cycle time and the Tube mill C section which contributed to 9.22 %.

Pareto analysis was performed to establish the critical process that affects the production of article A in shed 1if not well followed during operation (Fig.30).

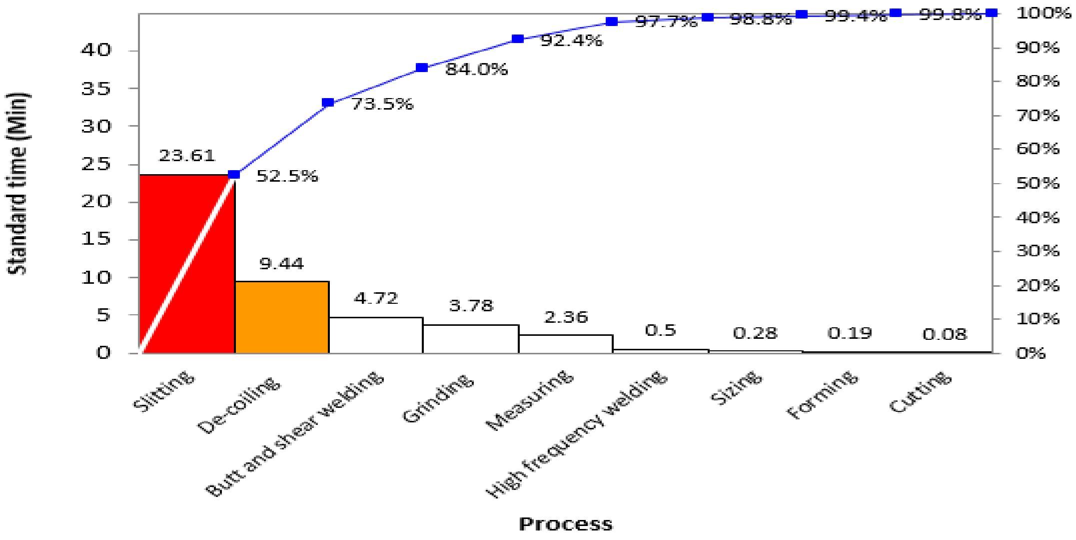

Figure 30 Pareto analysis of factors contributing to high VA time tube manufacturing

Non-value adding activities include those activities that are non-value adding but necessary (NVAN) and those that are non-value adding but unnecessary (NVAU). The tube mill C section activities included transport, picking and dropping which are NVAU as well and packing which are NVAN. Fig.31 shows a Pareto analysis for factors leading to high NVA time in production of article A

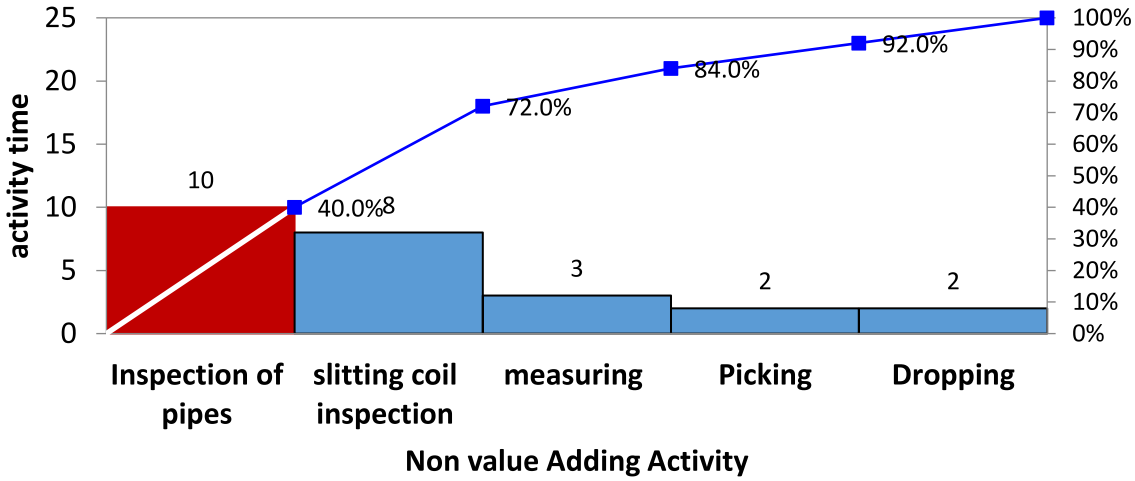

Figure 31 Parato analysis on high non-value adding time

The Pareto analysis in figure 31 revealed that the vital few factors resulting to high NVA time include inspection of pipes and slitting coil inspection. The most predominant cause of NVA time for SHED1 is due to frequent stops of slitting machine during slitting process due to frequent machine breakdown especially failure of slit support arm and the compressor and also inspection of pipe weight and length. Since dropping and picking are necessary non-value adding activities (NVAN), this research recommended re-arrangement of the area to ensure that all similar slit sizes are kept in one place to minimize movements and thus reduced transport and smoothen material flow. The slitting machine is the bottleneck as it supplies STL open profile machine, Tube mill B and C, it should have a preventive maintenance plan to avoid frequent breaks during operation.

5.3.2 Throughput analysis

Throughput analysis was conducted by examining production records for a period of one month for SHED 1 for 4x100x100 mm,6 m length tubes to obtain the actual and expected production. The data obtained is presented in table 5, showing the actual production against the expected capacity for each week at the STIL (shed 1).

Table 5:Actual production against the expected output for month of October, 2021 day shift for square section at STIL

Weeks (October)	Expected output(kgs)	Actual output(kgs)	Rejected(kgs)	Scrap(kgs)
Week 1	802,850.86	788,489.10	13,033.76	1,328.00
Week 2	77,500.35	76,183.60	1,126.75	190.00
Week 3	134,289.85	132,167.25	1,836.6	286.00
Week 4	289,513.55	284,766.95	4,311.60	435.00

From records, there are different rated capacities for each week according to the customer orders but according to Fig.32, the expected capacity is not always achieved for all the weeks. Hence, the company operates way below its expected weekly capacity. It was also observed that the throughput rate varied significantly across the weeks. Root cause analysis was performed to determine the causes of varying throughput across the weeks.

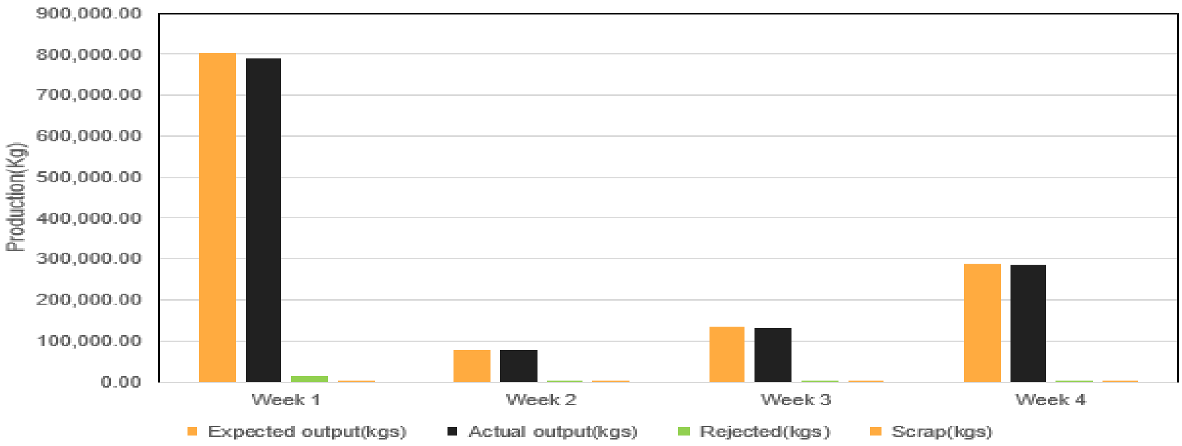

Figure 32 A bar graph showing the October weekly production for square orders

5.3.2.1 Economical lossses on Defects and scrap

The losses incurred due to defects were obtained from the defected pipes times the cost of the pipe

Weight of a pipe=Thickness of the slit*Width of the slit*Length of the pipe *0.0078

For a slit of width 392mm, Pipe length 6000mm, Thickness of the slit ,3.8mm and UNBS standardization value of 0.0078 (1kg costs Ushs 4160)

Loss=Cost of production per kg *Number of kgs of (rejects +scrap)

Table 6:Total Losses due to defects for October

Weeks	Reject + scrap (kgs)	Losses (Shs)/week
Week1	14,361.76	59,744,922
Week2	1,316.75	5,477,680
Week3	2,122.60	8,830,016
Week4	4,746.60	19,745,856

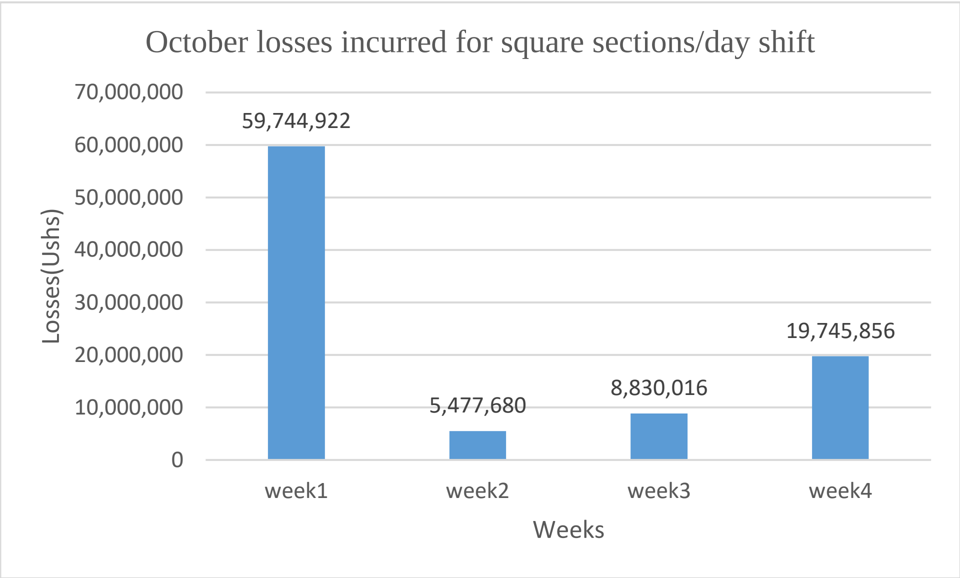

Figure 33: October losses incurred for square sections

5.3.2.2 Root cause analysis for varying Weekly throughput rate (SHED 1)

The RCA for the varying weekly throughput rate was carried out using 6-WHYs RCA tool. The root causes recorded in the 6-WHYs worksheet were analyzed. The fixable root causes were classified into broad classes; man, material, machines and methods and presented on a cause-and-effect diagram shown in Fig.34

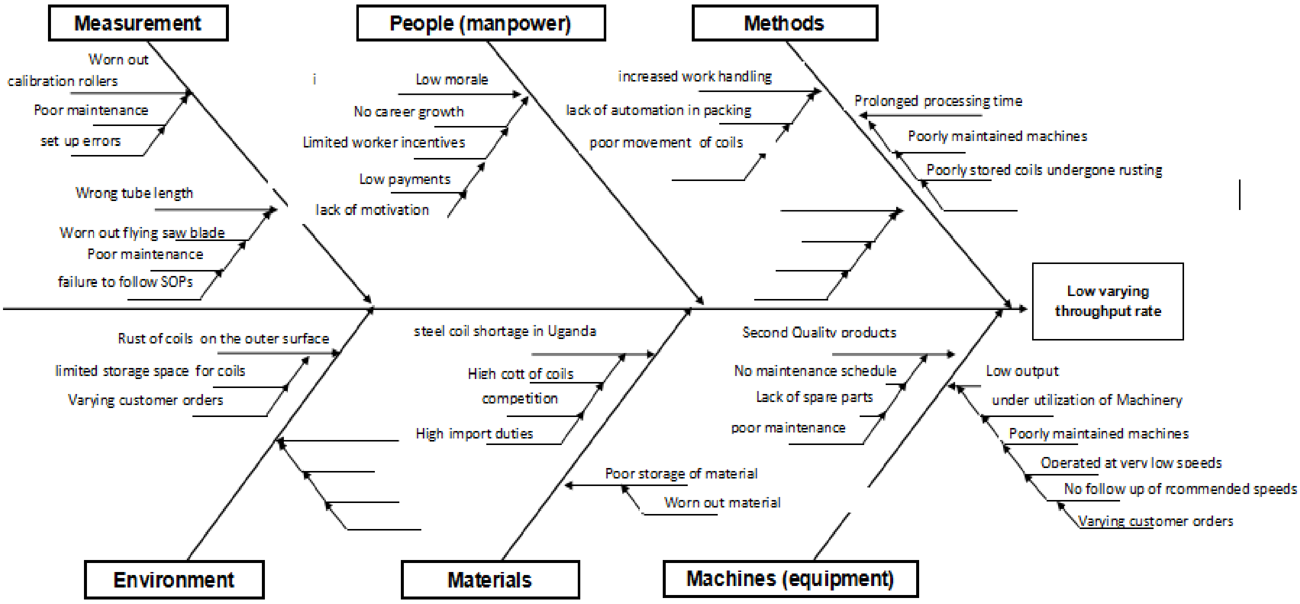

Figure 34 **Cause and effect diagram for varying throughput for Shed1 at STIL**

From the results of root cause analysis, it was established that the main root causes of variation in actual and expected production were to do with machines, men and methods. The most predominant cause of varying throughput due to machine was found to be production of rejected products/defects that is poorly welded pipes as the result of failure of the high frequency welding machine, flying saw cutting more length than the set length by the operator and irregular forming of tubes/pipes due to worn out forming rollers as result of delays to be replaced emanating from lack of spares and Low output of the tube mill C as the result of breakdown during production especially due to broken and worn out bearing of Forming roller . The main root causes of varying throughput rate were found to be related to materials. The most predominant cause was found to poor quality coils during manufacturing process and poor storage of material especially some coils rust and affect the quality of the final produced. Another cause was found to be man as the result of factors such as low morale due to low payments, no career growth and development and lack of motivation. This research recommended the establishment of planned maintenance program/strategy to increase the performance of machines thus shorten the manufacturing cycle time and increase the throughput rate thus optimize material flow.

5.4 Bottlenecks in material flows in production area

One of the most findings is the one regarding the bottleneck at each campaign, however there is no single process being the bottleneck of every campaign. There is no specfic pattern governing which process will be the bottleneck but rather some vague trends according to the size of the material.

5.4.1 Bottlenecks in processes

- Bigger profiles start having some slow downs in tube mill due slowing forming processes involved but the accaumulator and de-coiler remain with higher utilization.
- As the profile gets heavier the cooling bed on Tube mill C starts to present high utlization levels.
- Coils with larger thicksness have their bottleckneck in the slitting sector and forming rollers
- Slitting sector is abottleneck for the tube manufacturing process since it takes more time compared to other processes

5.4.2 Bottlenecks in production

- Delays in delivery of the spares which result into ineffeciency of the equipment/stoppages
- Low employee morale that affects throughput
- Outdated tube mill parts, and Unsheduled downtime of tube mill

5.5 Opportunity areas for improvement in production area

Along with the support of material flow analysis various areas of opportunity for improvement have been identified and these include;

5.5.1 Optimize the slitting of larger coils in the slitting section

Discussion about results shown in the previous sections highlighted the limitation imposed by the slitting for certain coils and, as a consequence, for certain thickness campaigns. This is particularly common in 3-6 mm thickness campaigns where there are large metric weight differences across coils that is 1210mm width (8.9 tones) or 1219 mm (14 tones). Depending on the thickness of coils of each sub-profile, there will be a dominating factor in terms of slitting. Normally "1-2 mm" coils have no inconvenient in the slitting machine but "3-6" or coils do require lot more setting and processing time and therefore it is common to observe the slitting process as their bottleneck. The production department realized that there were no standardized rules to optimize the slitting process for certain coil thicknesses and that it was actually a great opportunity area.

5.5.2 Local Process time improvement

Lean philosophy promotes the thinking of production as flows and therefore improvements efforts should be aligned to bring a flow improvement and not just isolated ones that might not bring any global results. The bottleneck at the plant is not in just one same process. Thought that might sound very discouraging, it could also be seen as a great opportunity because improvements in almost every process will improve the bottleneck throughput rate for a particular profile. Also improving non-bottleneck processes can have a positive impact if they reduce the probability that the bottleneck will be starved or blocked. In this spirit, there are some areas of opportunity that have been recognized:

Between the de-coiler and the accumulator is Butt and shear welding machine. In this stage according to the welding plan decided by the welding operator. There is an opportunity area concerning its process time's. Currently, the Metal Arc Welding (MIG) machine does not work and the welding process is done manually by the operator. This slows down the process that the process time has increased from 1minute for automation to 4-6 minutes when the operator does it manually.

Other area of opportunity regarding bundling. During the bundling process the quality controller, picks like two pipes, measures their weight and length to see if it corresponds to the required ordered length and expected weight of the particular pipes, however this is time consuming to measure for every bundle or move from bundling area to reset length of the pipe on the tube mill control panel in case of in process adjustments results into time wastages.

5.5.3 Cleanliness, Storage of raw-materials and processed materials

The plant has implemented a strategic program, most areas are well organized and standardized, however there were a couple of opportunity areas found:

The first area of opportunity regards the plants overall cleanliness. Steel production creates vast amounts of dust and therefore it is common to associate a steel plant with dirt. While this is true, it should not be taken for granted and do nothing about it. A big advantage of cleanliness is that helps observe abnormal situations more easily and in such an industry, abnormal situations may very well lead to accidents that could be even fatal. Cranes, suspended loads and high temperatures are a few examples of the conditions at which every employee is exposed working there. When cleaning is scheduled, employees use brooms to sweep the dust and from the floor and use air blowers to clean machines such as slitting machine but the efficiency is very low since it blows dust everywhere.

The second area of opportunity regards the storage of the raw-material. Steel production requires vast space for the storage of raw-materials such as coils. The bond custom area is not sufficient to accommodate the imported raw materials, some are piled up in the production area and the rest of the raw-materials are left outside the production area. The steel material is exposed to rain or moisture and sunlight which results into rusting of the steel degrading its quality though they provide temporary covering its not sufficient and some are left exposed. During production this may result into poor quality products increasing the number of rejects thus production losses (1kg=Shs 4,160) or affect the machine parts during processing.

The third area of opportunity regards the storage of processed material(slit). The processed material(slits) is placed in the left-lower part of the production area but the slits in most cases are not arranged according to the slit sizes and priority of orders. A random storage of slits is used in Shed1, higher space utilization but lower performance for the Overhead cranes when picking processed material from the storage area and placing them in the de-coiler. The downside remains that slit are pilled without arranging them in their respective sizes and whenever a slit from an extreme position is required; all the others on the side must be removed resulting in a significant time loss.

5.5.4 Time inter-campaign

This focuses not on optimizing production time but in the existing opportunity with the changeover time that is the time between two rolling campaigns. This would be a Campaign-to-Campaign time that includes not only the roll change time but any other delays and activities performed to get the next campaign started. From observation the average inter-campaign time was 50 min with a standard deviation, σ, of 25 min. Normally, the setup time of one campaign is independent from which campaign was being rolled just before. That is, the time it takes for the whole roll change procedure is not influenced by rollers that were being used in the previous campaign. The coefficient of variation is 0.50. According to Hopp and Spearman, this corresponds to a low to moderate variation and reducing it implies having more productive time in average. Therefore, the improvement of this changeover time is equivalent to a corresponding production time improvement for a certain profile. Looking closer at the data, it can be observed a minimum of 24 minutes and a maximum of 1 hour and 10 minutes. Then the question is why sometimes the whole changeover takes 24 min (such as changing cutter) and some other takes more than 1 hour. The answer for most cases is that there are other maintenance jobs that have a certain degree of urgency so they cannot wait for the maintenance stop day. The next reason is that normally the roll change is manual and thus require manual operations resulting in a considerable waste of time.

5.5.5 Optimize the output of the tube mill

The optimal yield from a mill starts with getting the maximum yield from each coil. This means matching the original coil to the capacity of the slitter so that the ensuing product, the slit mult, matches the capacity of the mill’s entry equipment. The tube mill has the capacity to increase the actual output and reduce on the rejected values. In the current state the rejects are produced due to worn out forming rollers as the result of delayed shipment of spares, delays during change over, stoppages due to breakdown, power surges increase scrap and bottlenecks due to core functions of the mill (forming, welding, sizing and straightening the product).

CHAPTER **SIX: RECOMMENDATIONS AND CONCLUSION**

6.1 RECOMMENDATIONS

- An optimal solution to increase throughput of tube mill recommends carrying out preventive maintenance inspections (PMIs) during periods with low orders and mill alignments are supremely important. PMIs will be equally critical for the mill, peripheral equipment, and consumables, bottlenecks must be eliminated and reducing mill stops and starts is one of the most effective ways to reduce scrap.

- Also recommend the construction of shed for the storage of raw-materials or provide immediate temporary covering every time new coils are imported and unloaded to maintain the quality of the coils and reduce the amount of the second quality products produced. This would also reduce on adverse effect of the raw-materials to machine parts during production processes.

- The bundling on tube mill C is done manually and also consumes time and could be improved by automating the system as in case of Tube mill B and would reduce on the laborers required thus saving.

- Reserving an area for scrap, allocating an area for each slit size considering order priority would have a positive impact. With a larger area there would be fewer slits mixing up with each other so pickup time could be improved and this will increase the performance for the Overhead cranes when picking processed materials from the storage area and placing them in the de-coiler.

- Personnel need to be motivated, thoroughly trained, and follow written procedures. Consistency is crucial in all areas.

- Recommend the maintenance of automatic systems especially the MIG welding machine and display panels especially for slitting machine to use the automatic mode and this would reduce the process time and thus manufacturing cycle time.

- Cleaning the floor should be made taking advantage of the characteristics of this dust: it is an iron-based dust and therefore could be picked magnetically. Passing a magnet by the floor would pick most of the dust but would have the problem of removing it later from the magnet. Therefore, using a thin layer of non-ferromagnetic material like plastic covering the magnet would still allow a strong magnetic field but as soon as the material wants to be removed, it is as simple as removing the non-ferromagnetic layer and all the dust will fall down. Later it was found that there are already "broom-like" devices that use exactly this principle but using aluminum instead of plastic. This would be an economical solution that is worth trying.

- The use of sensor-controlled measurement system on the run-out table to automatically detect the weight of the pipe and send a signal in case of variations would reduce movements and time wastes due to manual inspections.

- This research recommends the establishment of planned maintenance program/strategy to increase the performance of machines thus shorten the manufacturing cycle time and increase the throughput rate thus optimize material flow.

6.2 CONCLUSION

The purpose of the research was to identify improvement opportunities for material flow and handling in the production area of steel and tube industries. Based on the material flow analysis conveyed, it can be concluded that multiple areas of opportunity were found and improvement solutions were proposed which included optimizing output of the tube mill, time-inter campaign, local time process improvement, cleanliness, storage of raw-materials and processed materials and optimizing the slitting of larger coils in slitting sector. Results from Pareto analysis performed, established that slitting is the most critical process that affects the production of article A in shed1 if not well followed during operation. From the results of root cause analysis, it was established that the main root causes of variation in actual and expected production were to do with machines, men and methods. Finally, several bottlenecks were idenfied which include low employee morale that affects the throughput, delays in delivery of spares and unscheduled downtime. Future involvement of the company into mainstreaming proposed solutions in the production area of tubes/pipes in SHED1 would optimize the process and thus increase throughput. The amount this could improve the processes in terms of throughput, processing time and cycle time in production of these steel products using simulation model is worth exploring.

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APPENDIXES

Appendix I: Sampled-Interview questions

PREAMBLE

This survey is being conducted for the purpose of exploring options for material and energy flow improvements on the company level for minimizing resource use and optimizing economic benefits for Uganda's steel manufacturing plants. We are collecting data on materialflow, process layout and material handling in regard to production costs, material and energy wastes

You have been identified as a key contributor to this process. Please take a few minutes to contribute to this research. The results will be beneficial to manufacturing plant. Your co-operation will be highly appreciated.

This questionnaire you 10-20 minutes

Thank you

If you have any information regarding the questionnaire contact

0702535498/0755632765 (Tumwine Rodgers)

polupot@cedat.mak.ac.ug (Dr. Peter)

SN	QUESTION	ANSWER
1.	Interview Subject:	
2.	Date of interview:	
3.	Name of the company: Optional	
4.	Name of the respondent: optional	
5.	Position in the company:	
6.	In your opinion, which are the main processes in the steel Manufacturing?	
7.	Do you think that facility layout design could have a relevant impact on the productivity and cost reduction of the company? Why?	

8.	What is your opinion about flow backtracking problems? Do you have any?	

9.	Is there any movement that is unnecessary?	
10.	Would it be more appropriate to use any other material? handling equipment(s)	
11.	Could storing the materials closer to the machinesreduce the handling and movement?	
12.	In what way do you think the material flow can be improved? Why?	
13.	Can a change in layout design improve the material? flow? If YES; in what way?	
14.	Do you think a flow pattern or the layout design was developed over other considerations? Assessing the Impact of Facility Layout Design over the Process Productivity and Costs	
15.	There are several processes involved in the manufacturing of steel processes. Could you relate this process with the activity relationship scale (shown to the interviewee) between?	
16.	In your opinion, which of the following reasons for closeness between departments are the relevant ones and in which order would you establish them?	

Code	REASON
1	Flow of material
2	Ease of supervision
3	Common personnel
4	Contact necessary
5	Convenience

17.	There are two main costs in the transportation of materials: the personnel involved and the equipment. Which do you think is more relevant in the processes mentioned? Why?	

18.	What size of unit load do you currently use in the manufacturing process? Do you have more than one size of unit loads?	
19.	The storage area is in the same place that the Manufacturing process, do you think this is a disadvantage?	
20.	How many workers are assigned only to material handling aspects and how many workers are in the entire Manufacturing process?	
21.	The steel manufacturing process, as any steel process, leaves a large amount of chips and does this waste have a negative effect on your product and does it affect any other relevant issues?	
22.	Which of the current processes can be rearranged without any problems? Is it feasible?	