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Framework for Solid Waste Management in Steel Fabrication

Abstract: Solid Waste Management (SWM) is a term used to determine greatest energy-efficient and least-polluting ways to deal with the different components and items of community's Solid Waste stream. The solid waste could be either in solid or liquid form. Solid waste could be defined as, "Any material that is not required by the owner, fabricator or processor." Solid Waste could be classified as Domestic waste, Industrial waste, Waste from oil plant, Electronic-waste, Construction waste, Agricultural waste, Food treating waste, Bio-medical waste, and Nuclear waste. Due to social and environmental significances, waste reduces, reuse, and recycle have become necessities in minimizing the environmental damage that could happen through waste disposal. Steel products may be used in various construction and industrial applications, such as machines, bridges, buildings, vessels, highways, machinery, tools, and automobiles. It is estimated that the world's annual production of Steel is 1500 Million tons and that 85% of annual steel production is recycled worldwide. In this research, a framework for steel fabrication waste management is suggested consists of three stages; these stages are scrap classification stage, reusable scrap stage, and non-reusable scrap stage. The framework is applied in one of the Iraqi Ministry of Oil Companies; the Heavy Engineering Equipment Company, which is an important industrial company specialized in steel fabrication and construction work.

Key words: Waste management, steel fabrication, recycling, reuse, scrap

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1. Introduction

The rapid growth iron and steel industries have brought problems in the utilization and disposal materials among these are slag, flu dust, mill scale, scrap iron... etc. Extended researches are reviewed to solve such problems. Waste can be classified into industrial waste that refers to by-product of production and household/commercial waste that refers to the remains of consumption (post-consumer waste). Construction waste is frequently classified under industrial waste. Recycling of waste streams in the industry is an economic requirement. Transfer of waste off-site for treatment would cost much money. Using valuable material as raw materials in industrial out of the solid waste stream as much as possible is attractive for use such as glass, paper, and steel production, which is commonly done. Minor amounts of hazardous waste from households and workplaces are kept separate as much as possible to avoid spreading these elements in the environment. Waste reduce, reuse, recycle and recover are requisites in minimizing the environmental harm that could happen through waste disposal, according to social and environmental consequences [1]. This work deals with the recycling and reuse of iron and steel

scrap in industry. Well organized recycling is an important source for raw materials, create new jobs and wealth, maintain landfill space, reduce cost used and protect the environment. A framework for steel fabrication waste management is suggested in this work uses three stages; these stages are scrap classification stage, reusable scrap stage, and non-reusable scrap stage. The importance of this work includes; scrap processing combining recycling and reuse and how sorted scrap could be an important source or raw materials in industrial companies, focusing on reducing the amount of waste sent to landfills.

2. Solid Waste Management

Waste is any material, which is not needed by the owner, producer, or processor [2]. It could be a solid substance generated as a result of human activities, and, being no longer of value for respective economic. Solid waste in a broader sense is understood as any household, industrial, and agriculture materials that have been used up. Solid Waste could be classified as Domestic waste, Workshop waste, Waste from oil refineries, E-waste, Construction waste, Agrarian waste, Food processing waste, Bio-medical

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waste, and Nuclear-powered waste. The concept of Solid Waste Management (SWM) plan is driven from the essential for looking at different sources of gathering, transportation and disposal to ensure a healthy living environment in cities [3]. Integrated Solid Waste Management (ISWM) is a tool to govern the best energy-efficient, minimum polluting ways to deal with the numerous components & objects of a community's Solid Waste stream. The main goals of ISWM are to:

- Recollect as far as possible of that energy and those materials in a useful state.
- Avoiding release that energy or material into the environment as a pollutant.

Waste management strategy is to apply the waste hierarchy principles in steel industry effectively. The waste hierarchies' states the "4 Rs" reduce, reuse, recycle and restore which categorize waste management strategies due to their attractiveness in terms of minimum waste. The object of the waste hierarchy is to extract the maximum real-world benefits from products and to minimize the quantity of waste [4]. The waste hierarchy, as shown in Figure 1 represents the foundation of most waste minimization strategies.

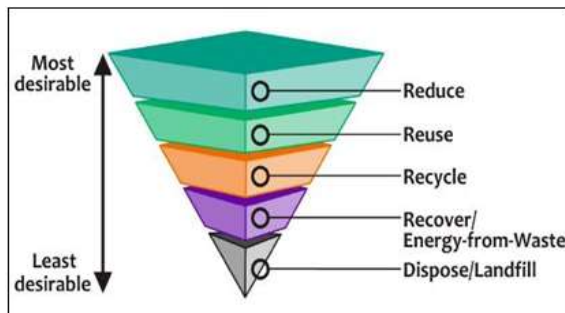


Figure 1: The waste hierarchy [4]

3. Steel Life Cycle

Many steel products are produced every day, such as cars, cans and machines; when these products come to the end of their beneficial lives, their steel is recycled. Recycling minimizes the consumption of raw materials and power. The used scrap is an end waste that can be recycled to obtain valuable products and it involves the separation and collection of materials for processing and remanufacturing into new products [5]. To identify the performance of any product, its overall life cycle must be considered. A life cycle assessment for a steel product takes into consideration resources, energy and emissions, from the steel production phase up to its end of life phase, containing recycling [6]. It is found that steel which is used in constructions has a rated lifespan of 50 to 60 years while that

employed for bridge structures would have a life span of approximately 100 years. A car has a life span of about 15 years. Packaging materials are recycled within a year, while steel cans are recycled within six months [7]. Steel can be recycled over and over again, indefinitely, with no loss of its essential properties. Figure 2 shows a steel life cycle from raw material extraction to the end-of-life [8].

Figure 2: Steel's Life Cycle [8]



The steel industry is an important part of the global recycling economy, which promotes scraps steel, reduction in the quantity of used materials, encourages the reuse and recycling of materials [6, 8].

4. Scrap Classification and Steel Waste

Scrap is sorted in not less than four categories, which are metal scrap, glass scrap, plastic scrap, paper scrap and others [9]. The classified categories are described as follows:

- I. Glass Scrap: Glass is very easy to be recycled; waste bottles and jars can be melted down and used again and again, i.e., it is 100% recyclable. Domestic bottles and jars are produced from a melted combination of silica (sand), soda ash and limestone. Glass producers can reuse old glass in such process. Multi-fill bottles are rewashed and refilled. Single-fill bottles, made of thinner glass, are parted into a pure and colored glass then cracked down.
- II. Plastic Scrap: Recycling and reuse of plastics waste enclosed many advantages. Recycling and reuse of plastics waste guides to a reduction of using valuable raw materials and power besides the reduction of carbon dioxide emissions. Reusing plastic is preferred due to using smaller amounts of energy and fewer resources besides avoiding

their accumulation in landfills. Their small density and lateness to decompose make them a visible pollutant of public fear. Recycle plastics scrap by manufacturers and investors has been extremely successful and economical. The energy saved by recycling one plastic drink bottle [9] will power a computer for 25 minutes. Rasool et al. [10] in their research uses waste plastic water bottles to improve the asphalt mixture properties and to decrease the environmental.

III. Paper Scrap: Paper is usually used for many purposes, and much of it is thrown into trash cans to be ended up in landfills. We are reducing scrap paper by reusing accumulate paper in everyday life and learning to use a piece of paper to its fullest. By recycling and reusing paper, we not only save money, but we also reduce our carbon and impact on global warming.

IV. Metal Scrap: About 100% of steel scrap from manufacturing and downstream processing is collected and recycled immediately into steel products, but old scraps have to be collected and prepared. The steel scrap is valuable, and its economic motivations assist in keeping high recycling level. Steel is the best recycled industrial material in the earth, including new and old scrap. Jabar [11], in her thesis, studied the fundamental knowledge of recycling aluminum cans in Iraq.

Steel is definitely the crucial material of modern technology-driven society. Since steel covers a class of over 2500 different grades presently produced and used, there is a wide range of properties leading to a wider extent of uses. Steel is 100% recyclable and can be recycled infinite times, saving energy and raw materials any time it is re-processed. The major raw material for steel fabrication is steel scrap. Steel scrap covers a range of different materials and qualities, most domestic scrap arising during steel production, process scrap of steel use and obsolete scrap at the end of the products' life. They vary extensively in quality [12]. Nkansah, Attiogb, and Kumi focused on a scrap of metals to improve the economy, reduce the use of virgin materials by transfer scrap into appropriate collection sites and foundry stations for recycling [13].

The recycling process for metals involves several key steps; understanding the process may encourage people to maximize their recycling efforts. The materials for recycling may be brought to a collection center or picked up from the curbside, then classified, cleaned, and reprocessed into different materials bound to be manufactured as shown in Figure 3 which illustrate the three recycling processes; collection, sorting, and remanufacturing [4].



Figure 3: Recycling Process [4]

5. Proposed Framework

In this research, the use of scrap term differs from the waste term. Scrap consists of recyclable materials left over from product manufacturing and consumption. Waste is any substance, which is discarded after primary use, defective and of no use, i.e., non-reusable scrap. Unlike waste, scrap has monetary value, especially recovered metals, and non-metallic materials are also recovered for recycling. Scraps which come from different sources in many unlike forms must be processed to assist efficient utilization. The main roles of the scrap processor are to be collected, sorted, and remanufactured [2].

The suggested framework based on its outlines on Smol's paper [14] but prepared by the researcher. The Suggested framework defines three stages; these stages are scrap classification stage, reusable scrap stage, and non-reusable scrap stage. The recycled reuse material (RR) material will be used as a term in this work, which means the material that is being rehabilitated in order to be reused benefiting from scrap. Figure (4) shows the details of the proposed framework. The stages of the proposed framework are discussed below, where (A) represents workshops for manufacturing and assembly, and (B) represents (RR) stores.

I. First stage: Classifications of scrap materials stage:

Classifications of unclassified scrap materials generated from manufacturing processes are performed in this stage according to the following steps:

a. Scrap classification: In this site, unclassified scrap for all over the factory is sorted in not less than four categories which may be metal scrap, glass scrap, plastic scrap, paper scrap, and others.

b. Further classification: In this step, further classification is accomplished for each scrap material. The scrap metal is classified as ferrous and non-ferrous.

c. Ferrous: The ferrous metals and alloys contain iron. Iron and steel scrap arises from the end of a product's life (obsolete or old scrap) as well as scrap produced from the manufacturing process. Ferrous metals comprise carbon steel, mild steel, stainless steel, cast iron, and wrought iron. These metals are mostly used for their durability and tensile strength. Obsolete ferrous scrap is recovered from vehicles, steel constructions, domestic appliances, railroad tracks, ships, farm equipment, housing construction, industrial containers, large-scale piping, most of tools and hardware used around the house, and other sources. Today, ferrous scrap is almost the greatest recycled material worldwide [16].

d. Non-ferrous: The non-ferrous scraps include metals that do not have iron. New changes of new technology reduced considerably the amount of non-ferrous scrap generated as products which are made from thinner metal. The most common non-ferrous metals that could be recycled and are usually found in waste in great quantities are aluminum, copper, lead, and brass. Aluminum is the most plentiful metal in volume found in waste, consisting mostly of drink cans. Sources of non-ferrous scrap of aluminum contain vehicle and transportation, construction and building sites, aluminum packaging besides wire cables and electronic equipment.

e. Asking, could the classified scrap be used as (RR) material: In this step and after further classification evaluation for reusing of these categories is performed by asking (could scrap be reusable?).

If the answer is (yes) then moving to the Reusable scrap stage, but if the answer is (no), the movement is toward Non-reusable stage.

II. Second stage: Reusable scrap stage:

After the classification stage, evaluation is performed to check whether produced scrap could

be reusable. Useable scrap means the scrap that has an acceptable shape within specification, known characterization, and can be used as a raw material. The steps of this stage are:

a. Determine measurement and specification: The scrap generated and classified previously requires measurement and specification determination, which is done in this step.

b. Asking could scrap be used without any processing: Another evaluation is performed to check whether the measured and specified scrap could be used without any processing, i.e. scrap with uniform shapes. If The answer is (yes), final measurement and inspection are followed, but if the answer is (no) the next step is the preparation process.

c. Final measurement and inspection: The uniform shape scrap is further measured and inspected to be described and labeled in the next step for reuse.

d. Description and labeling: The measured and inspected pieces are described as shape, dimension including thickness weight, and the type of metal. Labeling is then performed for storing in the (RR) material store as recycled reuse material.

e. Preparation process: If the gained measured and specified scrap could not be used without further processing, then the preparation process is adopted. This type of scrap is not uniform in shape, which requires preparation processes such are cutting, welding, and machining processes.

f. Cutting, welding and machining processes: If the scrap pieces include increases or irregular shape as shown in Figure (5) which is sketched by the researcher, processing using cutting, machining or welding is adopted. Then final measuring and inspection, description, and labeling are performed for storing in the (RR) material store.

g. Scrap due to the preparation process: Scrap generated due to preparation processes is to be treated in the third stage as non-reusable scrap.

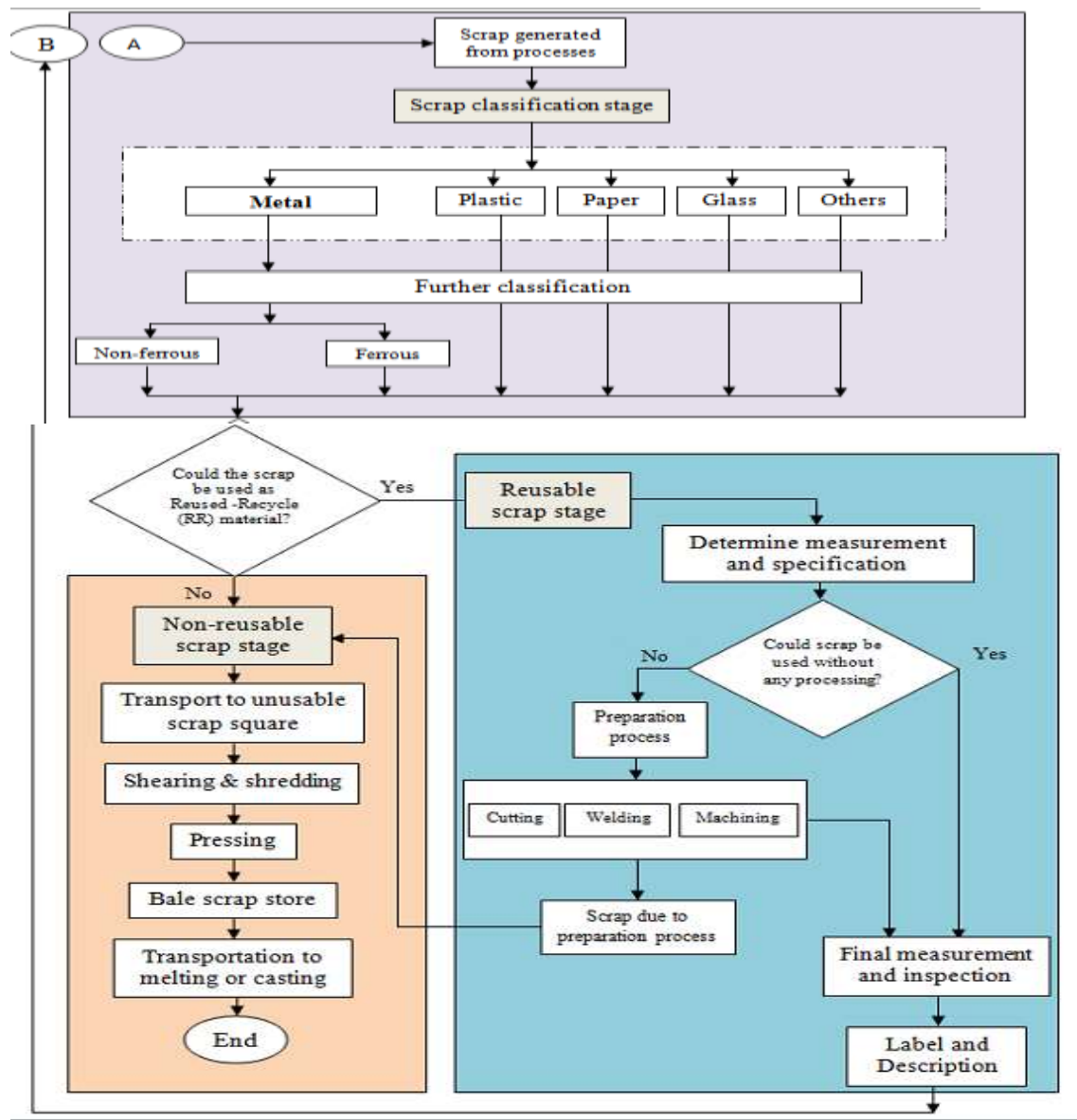


Figure 4: Details of the suggested framework

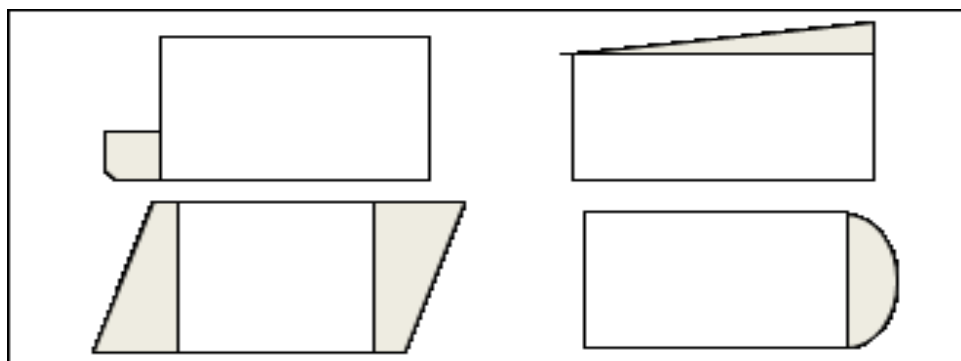


Figure 5: Parts with irregular shapes to be processed

III. Third stage: Non-useable scrap stage:

This stage is the last stage of the suggested framework where scrap gained from two sources. The first source is due to unusable scrap after classification stage directly. The second source is related to the renewable scrap

stage after performing preparation processes for (RR) materials.

a. Transport to unusable scrap square: The first step of this stage is the transportation of non-useable scrap to the unusable scrap square in order to be stored for further

processing in the next step. The storage site must be dry to prevent oxidation of the metal. Also, dedicated storage areas should be built for scrap metal to prevent soil pollution. Some times non-useable scrap could be stored outdoor.

b. Shearing and shredding: Shearing is dividing the material to slips by a powerful blade. Shredding is used for thin iron and steel that may have other materials such as glass, plastic, rubber and non-ferrous metals; besides automobile and house appliances, etc. Hardened iron and steel hammer or knives, driven by electric motors of massive energy, reduce the object to little pieces that can further be sorted.

Figure 6 shows one type of shredding machines. The shearing and shredding processes depend on the type of nonusable scrap, which will be followed by pressing.

c. Pressing: The worst forms of scrap forms that might be fed into the melting furnace are large and rusty sheet scrap of iron and steel. An influential mechanical and hydraulic pressing machine is required to produce a cubical mass called bales. Figure 7 shows a type of such a hydraulic machine.



Figure 6: Type of shredding machine [15]

d. Bale scrap store: Storing material must be in suitable stores near the pressing workstation. The benefits of baling could be:

- Increased weight can be overloaded on trucks for transportation.
- More scrap can be stored in less space. Storage process and transport are easier.
- Handle, and load is easier, faster, and cheaper.
- Non-oxidizing metal with environmental factors.
- Lack of pollution soil and the surrounding environment.

e. Transportation to melting or casting: Shredded materials and pressing in the form of bales is performed for easy transport and storage. Accordingly transported to melting or

casting workshops is followed whether these workshops are near by or not. Figure 8 illustrates two methods for storing and transferring of scrap.

The suggested framework will be implemented in a case study in an industrial firm in Iraq.



Figure 7: A type of hydraulic machine for producing bales [15]



Figure 8: Two methods of store and transfer scrap [15]

6. A Case Study in the Heavy Engineering Equipment Company

The suggested framework is applied in the Heavy Engineering Equipment Company (HEESCO). This Company is specialized in fabrication of storage tanks, pressure equipment for petrochemical, oil, gas and power industry besides fabrication of steel structures and steel bridges. The company's design capacity is 28000 Ton/Year, and the percentage of the metal waste is about 20% [17]. That means 5600 Ton/Year of metal could be treated with the suggested framework. Following up the current situation for manufacturing and dealing with the scrap generated, the details are explained below to be followed by applying the suggested framework.

I. The current situation in the company: To implement the suggested framework explained above for the three stages Scrap Classification Stage, Reusable Scrap Stage and Non-Reusable Scrap Stage; the current situation in the company is

presented focusing on finding out the reasons of scrap generated as follows:

a. Scrap Classification Stage: Classification stage of scrap generated from manufacturing processes is not followed in the company, and no sorting of the metal is found, i.e., this stage is missing.

b. Reusable Scrap Stage: Reuse of scrap is used in the company but very rarely due to lack of metal plates and sheets provider information in the factory where the scrap is found. Additionally, the amount and dimension of the scrap are not well recognized and defined.

c. Non-Reusable Scrap Stage: The current situation for non-reusable scrap in the company follows a random not organized collection of waste, which means that there is no plan for preparing for further recycling. Scrap due to this non organized storing face oxidation and decreasing in its value when resold. Figure 9 shows photos taken by 6th the researcher that illustrate the problem of random scrap metal storage in the company .



Figure 9: Problem of random metal scrap metal storage

I. Applying the suggested framework: Applying the suggested framework aiming to reduce scrap, reusing and recycling for the scrap classification stage, reusable scrap stage and non-reusable scrap stage as follows:

a. Scrap Classification Stage: After collecting scrap generated from the manufacturing and assembly stages and according to the suggested framework, classification stage is adopted depending on the type of material that might be metal or non-metal such as plastic, glass and

paper, etc. The company is specialized in the fabrication of metals. Thus scrap is classified into ferrous and non-ferrous metals. This classification is necessary to evaluate the type and weight of scrap metals that might be further used. According to the classifying stage scrap might follow one of the following two routes:

- Re-useable scrap stage.
- Non-re-useable scrap stage.

The suggestion provided to the company is the classification of scrap in each factory according to the type, size, and shape of the metal within two categories; first, the ferrous re-useable and second non-ferrous non-re-useable. Three areas for scrap generation and classification are suggested.

a. The first area is behind the heavy equipment and boilers factories, as shown in the illustrative map of the factory site in Figure 10 for scrap generated in both factories. The second suggested area for scrap generated from the heat exchanger factory is to the left of the factory, as shown in the illustrations map of the factory site in Figure 11. The place for the collection of non-reusable scrap generated in the factory of vessels and storage tanks is the square behind the fifth and sixth line; in Figure 12 an illustrative map of the suggested square site is shown. These illustrative maps are prepared by the researcher.

b. Reusable Scrap Stage: This stage follows the classification stage according to the metal classification for the reuse possibility and material recycling. There is another type of reuse materials to be weighed and measured to select the largest dimension or largest effective area within the main form. If it was an appropriate area, it does not need to be processed, for example, a plate of dimension (1m*1m) with square angles. According to its dimension, type and weigh this plate is transferred to the reused material store as a material for reuse.

The remaining scrap of these irregular parts shown in Figure 14 after processing could be utilized to manufacture small parts for the same storage tank or for other products.

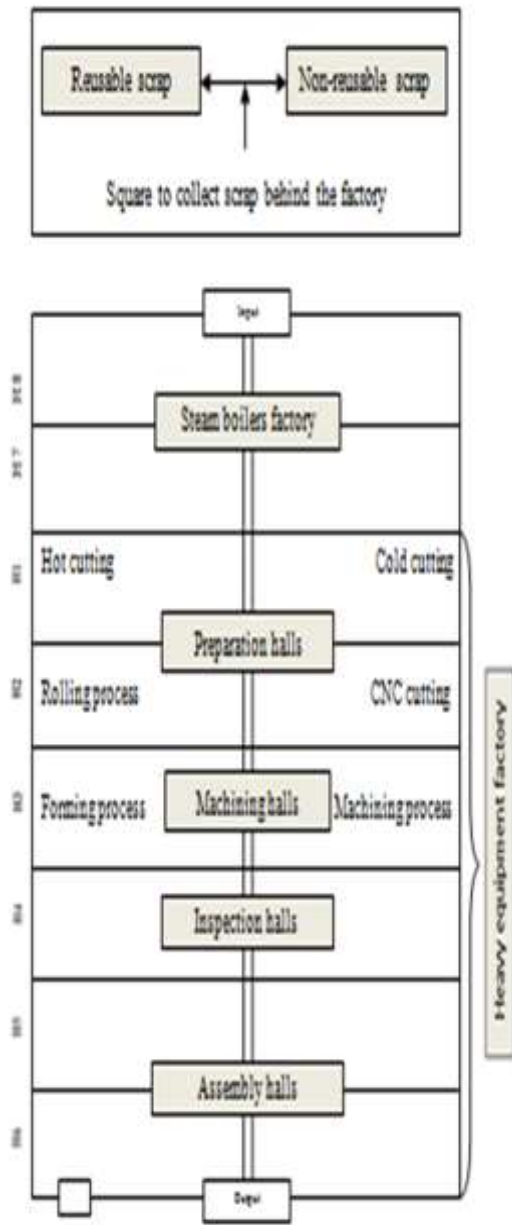


Figure 10: Illustrative map of the heavy equipment factory site

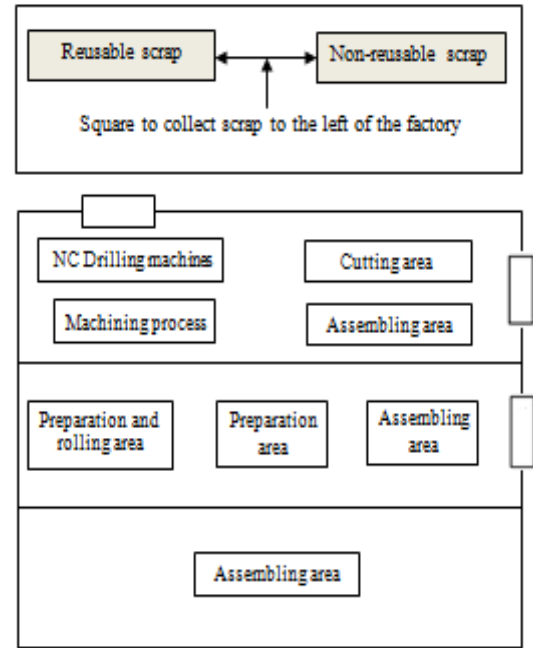


Figure 11: Illustrative map of the heat exchanger factory site

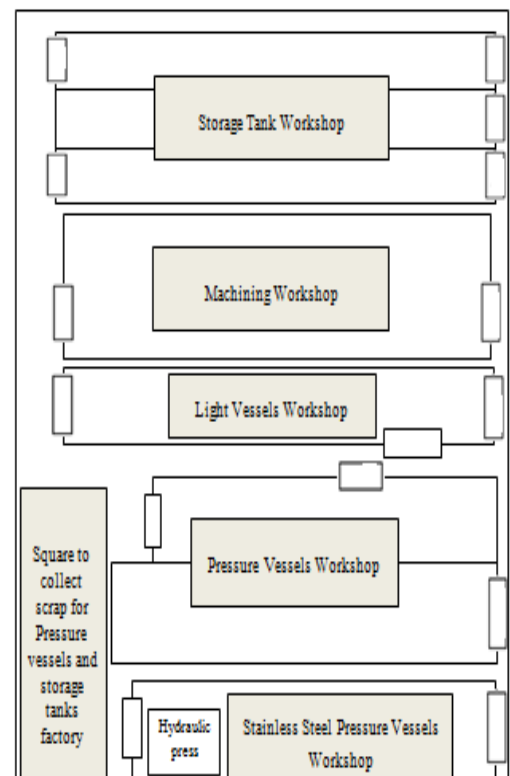


Figure 12: Illustrative map of the factory vessels and storage tank

Figure 1) shows some of these parts such as lifting lug, base plate, lifting pad, flange, blind flange and ring flange, etc. The Figure is prepared by the researcher based on the drawings of HEESCO.

The rest of non-useable waste scrap is to be added to fragments or chips that have no possibility for reuse following the suggested framework the third stage.

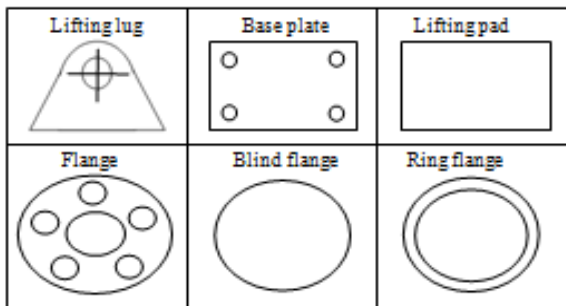


Figure 13: Exemplified shapes manufactured from remaining scrap of irregular parts

c. Non-Reusable Scrap Stage:

Non-reusable materials such as the welding remnants, scrap waste, solder joints, chips of cutting from machining process or remains, and rejected parts are sources of generated scrap during manufacturing and assembly process; will be processed according to the suggested framework in the company. To apply the proposal, the following facilities are suggested to be added:

- Shearing and Shredding:

A proposal to the company is to supply an alligator shear machine that can cut up to (20cm) thickness, in addition to the existing cutting machines in the company to be used for scrap cutting. Larger shears are even more powerful. Figure 14 shows the alligator shearing machine type.



Figure 14: Type of alligator shearing machine [15]

- Pressing

Transportation to the machines for shearing and shredding is an essential process to obtain small pieces. These small pieces are pressed within the dimensions to the standard form of bales for the possibility of transportation to be melted or cast.

Mechanical pressing processes are common in the company, accordingly mechanical and hydraulic presses are available to be used in bale preparing for iron and steel scrap.

The proposal to the company is to install a shearing machine in the square of non-reusable scrap collection, for cutting large pieces and then turned into the existed hydraulic presses with a capacity of (3,500) tons to obtain the bale shape for storage and transportation to be melted and re-casted.

7. Discussion and Conclusions

In this paper proposed Framework is applied in a Heavy Engineering Equipment Company (HEESCO), which is an important industrial company specialized in steel fabrication and construction work. According to the current situation in the company, it was noticed that the classification of scrap generated from manufacturing processes is not followed and no sorting of the metal is found. Classification for steel scrap is adopted as ferrous and non-ferrous in each factory to facilitate recycling. Classification of scrap in each factory is according to the type, size and shape of the metal within two categories; first the ferrous re-useable and second non-ferrous non-re-useable. Reuse of scrap is noticed rarely in the company due to lack of metal plates and sheets provider and the amount and dimension of the scrap are not well recognized and defined. Reuse materials are to be weighed and measured, selecting the largest dimension or largest effective area within the main form. According to its dimension, type and weigh this plate is transferred to the reused material store after inspection and labeling. The rest of waste scrap is to be added to fragments that have no possibility for reuse, welding remnants, solder joints, chips of cutting from machining process or remains, and rejected parts as a source of non-reusable materials; which will be processed according to the suggested framework in its third stage.

8. Suggestions

Three areas for scrap generation are suggested; the first one is behind the heavy equipment and boilers factories for both factories. The second area for the heat exchanger factory is to the left of it. The third area for the collection of non-reusable scrap generated in the factory of vessels and storage tanks is the square behind the fifth and sixth lines. Suggestions to the company are to add a new facility as a shearing machine for cutting large pieces and then turned into the existed hydraulic presses to obtain the bale shape for storage and transportation to be melted and cast.

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