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Measuring Aspects of Sustainable Manufacturing Practices in Steelmaking Plant Industry in Iran

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Abstract:- Since Bruntland Comission report established the concept of sustainable development , the manufacturing and mine industry have been in effort to obtain and extend their planning in implementing sustainable manufacturing for them to meet the sustainable management criterion laid down by ISO 14000 series standards. These criterion have been explained and established to determine and evaluate the key performance indicators for manufacturing flow. The aim of this paper is to examine a case study in order to understand manufacturing procedure stages of steel industry in the context of its sustainable practices. Energy analysis and natural minerals such as Iron ore have been shown as main key performances for this paper.

Keywords:- *Sustainable manufacturing, steelmaking, key performance, indicators.*

Contribution/Originality:- *This is one of the few conducted research which have examined performance factors of the current sustainability standing for industrial production and other manufacturing process which has been a struggle for sustainable development in Iran.*

I. INTRODUCTION

Steelmaking Industries are the backbone of the economy in any industrialized nations. Iran, after becoming the part of globalization, quickly emerged as the manufacturing power house in the region and one of the important in the global world. Today, it's high time for the steelmaking industries as it is witnessing a major concern on sustainability management because of depleting energy and natural resources, challenging global environment deterioration and rising observation remark for personnel health and operational safety.

Manufacturing activities are the main source of consuming natural resources with toxic byproducts and waste which often detrimental to the environment affecting the sustainability of the process. Sustainable manufacturing practice is a competitive issue in all manufacturing sectors including steelmaking. Brutland commission report by united nation has stated that sustainable management development is to meet present needs without compromising the ability of future generation to meet their needs. Based on the United States department of commerce, the emerging concept of sustainable manufacturing practices is to create a manufactured products within a strategy that has minimal negative impact on the environment, preserve energy and essential natural resources and element on planet earth, provides safety measure for operation and employees security and at same time it is economical profitable sound (Gutowski ,2008). The conceptual for manufactured products should have consideration on the entire product life cycle, including the manufacturer's economic advantage and the impact of a product for the society (Harris, 2006). Sustainability of any manufacturing process is to be determined, evaluated, and measured in terms of main key performance as shown in figure below

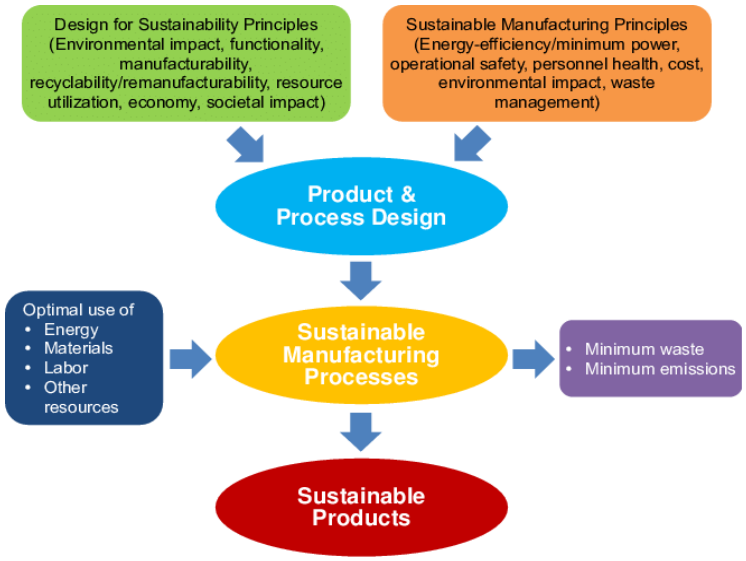

Fig 1:- Proposed methodology for sustainable manufacturing process
Source: https://www.semanticscholar.org/paper/A-Framework-of-Product-and-Process-Metrics-for-Lu-Gupta/4b2238734169783a96f2d5038ceaa140c807219b

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The sustainable manufacturing within industrial process is new and emerging stream of sustainability management in Iran which has lots of potential to offer in business and society on individual and corporate level. The first written article regarding sustainable manufacturing process was at end of 2010s. However, between 2008 and 2018 only 25 articles were written and published in international journals. In facing the challenges of reducing harmful environmental and societal impacts created by current Unsustainable business practices, sustainability management (or sustainable manufacturing process) is increasing in importance because it can lead to a socially, economically, and environmentally sustainable society. Firms can solve social and environmental problems and be economically self-sustaining at the same time. Innovation is seen as key to find new solutions for environmental sustainability. Furthermore, scholars see stakeholder engagement as a new solution to create innovations for sustainability and environmental sustainability in particular. Since there have only been few empirical studies in sustainable manufacturing development in industry ,the conditions, processes, features and outcomes that distinct this form of management are yet to be defined. Sustainability manufacturing is new breed in strategy in the Iran and they are very limited researchers have taken regarding such issue. More researchers need to be done to provide conceptual basis for stimulating scholarly thought and improving the understanding of this concept as an important field.

II. LITERATURE REVIEW

Even though they have been widely debated in the literature, there is no definite accepted definition of the concept for sustainable manufacturing practices (Yang, 2012). The concept of sustainability first emerged in 1970s when the issue ethics in businesses came under question mark (Smith, 2016). Regarding to the global issues of resource distribution, inequality and population influence, world commission on environment and development proposed a new concept needs of the present without compromising the ability of future generation to meet their needs (Zailani, 2012). While this explanation is general, it is yet most comprehensible adopted definition to explain sustainability management in variety of frameworks. Previously, few experts stated the concept of sustainable manufacturing practices as production methods or technologies that simultaneously focus on enhancing economic and environmental performance. For example, Dillon (2017) defined the sustainable manufacturing practices as to add the most value to their products and services by creating the most efficient use of the earth's limited mineral resources at same time generating the least pollution to the environment to target a clean production system. Allwood (2015) described term as upgrading technologies to transform raw materials without emission greenhouse gases and use non renewable materials and minimize the waste during production activities. US Department of Commerce viewed such practice as the conception of manufactured products that use processes that are non-polluting, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers. Following economic and environmental improvements at same time promoting social well being in broader perspective, this study defines sustainable manufacturing as business's interactive practices to environmental, economic and social aspects into strategic operation (Pagell, 2014).

➢ *Sustainable manufacturing*

Sustainable Manufacturing can be defined as the incorporation of processes and systems competent to produce high value products and services with less and more sustainable resources such as energy and materials, being safer for employees, and communities surrounding, and being able to alleviate environmental and social impacts all over its whole life cycle. The usefulness of sustainable manufacturing strategy contain in cost reduction through resource efficiency and regulatory compliance improvement, better brand reputation, new market access, a lesser number of labor turnover by creating attractive workplaces, and long-term business approach by creating opportunities to access financing and capital (Bonvoisin, 2017;).

Bonvoisin, Stark, and Seliger (2017) describe the sustainable manufacturing extent in four areas with its respective objects and applied regulation, that were used to categorize the papers in the sample:

- Manufacturing technologies (how things are manufactured) with focus on process and equipment (machine-tool, facility); linked disciplines are production engineering, factory planning, and operations management;
- Product lifecycles (what is to be produced) with focus on product and services' design; linked discipline is engineering design;
- Value creation networks (organisational context) with focus on organisations of companies and manufacturing networks; linked disciplines are business economics and knowledge management;
- Global manufacturing impacts (transition mechanisms towards sustainable manufacturing) with focus on studies about manufacturing impacts on the world, including society, environment, and economy.

Different aspects can contribute to a positive sustainable manufacturing strategy implementation, among others, the development of sustainability indicators, policies and procedures, companies' cultures and internal conditions for sustainability, sustainable design strategies, and stakeholders' engagement for sustainability and technologies (Bogle, 2017).

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➢ *Industry*

Industry concept is connected with the technical point of view of a Cyber-Physical-System (CPS) embedded into manufacturing operations and with technologies into the industrial processes, which can be represented by smart factories, smart products, and extended value networks – vertical, horizontal and end-to-end addition. People, machines, and resources are vertically linked, while companies are linked horizontally across the value chain as in a social network created by CPS (Kagermann, 2013)

Terms including Industrial Internet (Bungart 2014), Integrated Industry (Bürger and Tragl 2014), Factory of the Future (Heynitz, 2016), Smart Industry and Smart Manufacturing (Kusiak, 2018) are also used to address similar requirements and are considered by the concept of 'Industry It is however seeming that they connect the desirable features linking to being supple and reconfigurable, low cost, adaptive or transformable, responsive and lean (Radziwon et al. 2014).

➢ *Links between Industry and sustainable manufacturing*

Digitalization and sustainability are intersecting system of themes crossing all parts of the production chain. In fact, both approaches offer practices' convergence including : design for disassembly, remanufacturing, and recycling applied in the life cycle management; reverse logistics for circular economy, 'lean and green management' for resource efficiency; sustainable design reducing safety risks for workers' and consumers' eliminating the use of toxics parts in the product and production processes (Waibel,2017).

In overall, the benefit that brings with adaptation of sustainability into core process of Industry are expected on improving productivity, flexibility, and resource efficiency such as big data for predictive maintenance and fast production systems reconfiguration , reduction of waste, energy consumption, and overproduction. Stock (2016) states that the Industry can become sustainable abundant and this matter they need to identify key factors , such as : (1) development of business models driven by smart data, offering new product-services; (2) closed-loop product life cycles and industry symbiosis creating value networks; (4) trainings and competence development supported by ICT technologies, (7) sustainable process design using new technologies (additive manufacturing) promoting closed-loop life cycles and cradle-to-cradle approaches.

To support effects of a solution on the sustainability dimensions, Stark (2019) claimed that each sustainability element stand for a specific system evolving around a digital value-creation key, so one adopted solution can generate direct impacts on one dimension system, but also have indirect effects on the other dimension systems of sustainability. The interactions between sustainability systems can occur in three different types: causal relations (effects between a solution and its direct and indirect impacts); magnitude and scale driver (internal and external impact is determined by the magnitude and scale of a solution's dissemination); and latency and timely duration dependencies (between effects and impacts).

III. SUSTAINABLE MANUFACTURING PRACTICES (SMP)

Adapting to the changing conditions over years, the development of sustainability management perception has given grow to a series of sustainable practices in manufacturing industries, from the application of technology for pollution control and treatment to more integrated systems of production which encourage cross functional relationships among the organizational members as well as inter- organizational collaborations (Ebrahim, 2015). Instead of Having one dimensional approach, the progress of the sustainable practices can be defined based on the integration of the three levels, including products , process and system (Hackert, 2012). Altering paradigm from single life cycle to multiple life cycle, traditional 3 R concept which was reduce, reuse and recyle has been in transsion to a more sustainable 6R framework which stands for ***" Reduce, reuse , recycle , recover, redesign, remanufacture"*** within production level(Hami, 2015). Whereas various attempts have been take in the process level o optimization technological improvement and process for decreasing waste and consumption of resources and occupational hazards as much as increasing product life in which the context was expanded from organizational to a broader supply chain and industrial relation Considering a variety of practices for chasing diverse objectives and goals, Sustainable manufactured practices can be distinguished into two types based on the direction of sustainable thinking, namely internal SMP and external SMP. Internal SMP refers to the sustainable practices within company's level to promote cleaner production and eco-efficiency. The external part concentrates industrial practices within value system and further the chain of production to advance economic, environmental and social sustainability withs supplier relation, customer and industrial relation and close-loop production.

Practice	Definition
Internal SMP:	
Cleaner production	Preventing pollution at source (in the product and the manufacturing processes) rather than remove it after it was created
Eco- efficieny	Producing more products with simultaneously minimizing resource intensity and reducing ecological impact
Employee Relation	Implements a set of plans/ programs to improve employees' well being
External SMP:	
Supplier relation	Monitors and collaborates with suppliers to improve suppliers performance
Customer Relation	Manages customers to improve customers' well being
Community relation	Implements a set of plans/ programs to improve communal performance
Closed-loop production	Closing the material cycle in order to achieve greater sustainable in managing the supply chain
Industrial Relation	Collaborates with neighborhood organizations to improve environmental and social performance

Table 1:- Sustainable practices and definition
Source: Impact of sustainability practices (Norsia Hami, 2015)

IV. IRAN'S STEELMAKING INDUSTRY OVERVIEW

The establishment of iron and steel plants in Iran has been in the mind of the country's government since the early decade of the 20th century. The first serious attempt was made in late 1930s with the assistance of German companies. But the outbreak of the World War II brought the construction works to standstill and the project was never completed. Almost two decades after the World War II due to recovery in economic situation and increasing demand for steel products, the establishing of a steel plant was brought up again. Now this industry is one of the most strategic sectors of the Iranian economy , as it constitutes an unavoidable link in total supply chain of automotive, metal products, building and instracture and other equipments. This industry currently consists of over 90 companies with a total production capacity of 1,920,000 tons per year (Aytenko, 2014). Iran's manufacturing industry including iron and steel has allocated to itself more than 31 percent of whole energy consumption and natural resources in raw materials including alloys that is so crucial and yet rare that development of the business is heavily depends on it as much as environment (Central bank, 2015).

➢ *Arfa Iron & Steel co.: Profile*

Arfa Iron & Steel is a Public limited company which was established in 2005 in Tehran, Iran. The firm operates in the iron & steel segment. The company's ownership is held by Iranian based enterprises.

The products of the company are sponge iron produced by the project`s DRI plant (used as transition product in the project`s steel making plant) and steel billets produced in steel making plant (EAF).

The firm's goal is to cooperate and complete the production chain in the region, and to strike a equilibrium amongst the raw material and products and market supply; growing the quantity and quality of products;

- Collaborating, supporting, and if necessary affiliate in the formation of upstream and downstream industries;
- Collaborating and working together with steelmaking plants across Iran provided that it could benefit both parties;
- Providing research and struggling to boost output and promote quality, and to use cutting-edge technologies that are adaptable to the conditions at home;
- Continuous training in line with company mission;
- Trying to maximize the profitability of the subsidiaries to uphold and supply the shareholder resources

The company's products are sponge iron produced by the DRI plant (used for transition product in steelmaking plant) and steel billets created in steel making plant (EAF)

- Production Rate :
- Sponge Iron 800,000 tons DRI/year
- Sponge Iron Brackets 60,000 tons CBI/year
- Square Billets 800,000 T, 130/15/200 mm in length

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➢ *Major concerns and struggle of steelmaking industry for development:*

Iran's steel industry industry is arguably the main driving factor of the country's mining sector, taking the spotlight and above of other metal products with most output and overseas sales. Furthermore, the critical role in the development of the industry is instantly under the review of media and research firms within the country (). Since the inception of the steel industry in Iran over a century agao, throughout this timeframe the contributing factors for growth for production and expanding the manufacturing During the inception of the steel industry in Iran over a century ago, the major contributing factors and challenges to boost production and expanding the manufacturing sites have faced challenges and problems. Michael Insulan (2018) stated that immethodical and sloppy trends in demand are major problem within steel industry. Demand is instable widely due to the economic process is not regular in the country (Ayyarrezaei ,2016).He attempts to explain the refereed shortage in ceratin parts of production chain as well as lack of variety in the range of steel products manufactured in the country as other problems. Irregular trends in demand are a major problem in the Iranian steel industry. Demand fluctuates widely because economic growth is not regular in the country, Ayyarrezaei says.He referred to deficiencies in certain parts of steel production chain as well as lack of variety in the range of steel products manufactured in the country as other problems. “Facing shortage of iron ore once the ongoing projects are completed is yet another major concern. Not only will Iran has to suspend exporting iron ore in the future, but they will also have to import it (Ayyarezaei, 2016).

Shortage of electrodes and ineffective ways to provide them for electric arc furnaces due to sanctions,Price controls, Increasing production costs, and Mismanagement and lacking in providing proper strategy for operation. According the Foolad Mobrake Esfehan one of the top 3 leading steelmaking company Iran has outlined other challenges facing Iran's steel industry as follow belows:

- Increasing domestic demand for Iron and steel,
- Huge Dependancy on availablity resources of natural gas and required raw materials, in particular, iron ore and alloys.
- Relative number of Iranian expertise in iron and steel industry for management practices.
- Introduction of new methods of Direct Reduction Process in industrial and commercial scales,

According to the CRU Group (2019), the leading provider analysis and consulting in mining, the country of Iran is placed between Italy ranked 11th with 20.61 million tons and Taiwan ranked 12th with 19.24 million tons. Iranian steel mills produced over of 20.6 million tons of crude steel during the 10 months, up 19% compared with last year’s corresponding period. As of October steel output raised up steadily 10.6% per year reaching 2.07 million tons. These data all signify that potential of Iran as a country with rich energy resources, raw materials, human resources is yet to utilize outdated technologies due to the sanction inures high production cost and low investment in upgrading technologies and research and development as Amir Havasi a local research in mine claims "Increased investment in exploration, especially deep underground exploration in which Iran still has trouble due to lack of required technology. The lifting of nuclear sanctions back in 2016 was expected to help the sector import new technology and court prominent international firms to help. Yet lingering secondary US sanctions have kept things out of reach"

Iran's economy cycle growth is heavily influenced and depended on the development in industry and mine to address the needs of the population and yet this can shape a catastrophe of environment crisis by expanding manufacturing.

➢ *Why Sustainable manufacturing practices in the steel industry:*

Steel production is classified basically as fro, virgin irone ore and from recycling steel scraps and different sources. Various studies have measured the two models on multiple technological basis. Producing over a tone of steel that is recycled from scraps can saves up to 17.3 gigajoule energy. Recycled steel scraps procreates 80% lesser emissions than steel production from iron ores (Jawahir, 2015). The recycle practices can help to reduce the use for extracting such as logging, quarrying and refining raw materials all that generates pivotal water and air pollution. The steelmaking plant is the highly energy intensive manufacturing process as machineries and technologies being use in this industry are not energy efficent and optimized since the input procedure and output analysis suggests numerious factores during different phases of the procedure influence the sustainability if the steelmaking procedure.

- *Current Steel Industry manufacturing process in Iran*

The majority numbers of companies in steel industry in Iran rely on raw material supply from ship breaking activities carried out at central provinces of Iran including Yazd, Esfehan and Kerman. Authors have taken the inputs for this case study of steel industrial cluster of Ardakan city in Yazd located central of the country in . Current practices steel manufacturing strategies have been observed and examined for understanding the current status of sustainability performance within industry. Table no.1 evalutes and categorizes the sustainability indicators of steelmaking plant in the industry. According to current the inputs, raw material consumption, steel waste generation and energy consumption selected as the sustainability key performance indicators (KPI) for the case study.

Waste produced during various stages of steelmaking process and associated temperature and energy consumption have been reviewed per ton of steel material as illustrated in figure below:

Sustainability manufacturing indicators	Key Performance indicator
Environmental Impact	Emission and various types of waste and oil , water, slugs , dust and ash produced affects environment, GHG emission, waste matter
Operational Safety	Radiation effects and skin burning to workers due high temperature
Waste Management	Slug, Ash , dust , waste water, scales, cutting scrap, used furnace oil management
Manufacturing Cost	Laborious process, waste produce, energy consumed
Energy Consumption	High energy intensive process.

Table 2:- Sustainable Manufacturing key performance indicator

V. SUSTAINABLE MANAGEMENT ANALYSIS: ARFA IRON & STEEL CO

- *Energy Consumption analysis factors:*

The total energy being required for consumption in phases of steelmaking process in Arfa is acquired either through coal or direct electrical energy. From data obtained from the company case study signifies approximately of 1200 KW/h of energy is consumed for 1 ton of steel ingot from steel scrap. One of the The major key sources of energy for steelmaking are metallurgical or coking coal electricity, and natural which are mainly used for converting iron ore into iron by eliminating oxygen fuel oil for heating, carbonization, and firing; and electricity for rolling, oxygen production, air blowing, and transportation that takes 70% of total energy consumption. The reheating furnace is another major contributing factor of energy usage which contains 20-25% of total consumption. In steel industry of Iran, using natural gases and reheating furnaces is up to standard efficiency and poses serious concern in terms of ecological impact, personnel health due to emission on fine coal dust, toxic gases metallic vapors, handling and slag production. The company needs to optimize the furnace incineration air requirement and auxiliary power system that is needed in order to reduce power consumption by over 35%. By investing in technological upgrades in the manufacturing phases can make it possible to optimize the cooling system and size of motor that would provide equivalent performance and as a result a lower required energy consumption (Bante, 2016).

- *Mineral Waste Management*

Raw material used for steel specially for rolling is essentially steel scraps acquired from wastes of a range of steel industries or steel ingots gain from steel foundries. Present case study deals with rolling that is produced from a scrap which is from ship recycling. It has been experimented that through different phases of rolling process nearly 210 kg of material waste is generated per ton of raw steel scrap that is being utilized within manufacturing process (Bante, 2013)

That is equivalent to 15% of material waste. In meantime, it has been debated in case of rolling from ingot of steel; nearly 8% of total wastes are generated during full cycle. The waste caused is in different types and most of the wastes are not being reclaimed as post manufacturing process. Present-day practices are to either dispose the waste in close to landfills or sell to other countries. The main sustainability Issue of Arfa with the rolling manufacturing is the quantity of wastes made, their lack of knowledge about its reclaiming practices within Research and Development of the company. The wastes that is being generated within current primary manufacturing of the company such as waste water, scales, cutting scrap, used furnace oil management, slug and dust can be used as contributing factor for economic production as sustainability measures .

VI. CONCLUSION

Steel industry has been of those activities where principles and management evaluation is not intended to be firmly accurate or reliable for every situation rather than analyzing system engineering obligation. The steel industry in Iran has cooperation with small private business which this phenomena established concrete target that is generating revenues and profits are given significant importance than implementing best practices available. Such lack of awareness and knowledge of a well-known company such as Arfa in regards to latest technologies available in field and also incapability the management cost to invest for upgraded technologies and sustainable practices is major concern for steel industry in Iran at moment. Anyhow, with growing global concern, it is now vital to implement ISO 14000 series environmental management standards.

The author of this paper through the company case study emphasized to certain key performance indicators such as energy consumption and wasted raw materials to measure sustainable practices process in order to reach efficiency in day to day operation. There is a cirtical research gap in this particular field and papers like this can be a constructive work steel sustainable manufacturing process In Iran as motivating strenght to search for some strategical and engineering solution on top management level to address sustainability issues in the industry. Based on the findings in this paper by author performance efficiency through machinery and adapting to energy optimization dicipline are the main areas to look at.

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