# Assessing the performance of a sustainable manufacturing system through sustainable value stream maps:A case study in a diesel power plant north of Diwaniyah

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***Abstract :***The current research seeks to prove the possibility of evaluating the sustainable manufacturing system in the North Diwaniyah Diesel plant using the sustainable value stream map, and how it can contribute to improving the performance of the station case study and reducing pollution in its operations, by understanding the sustainable manufacturing system in terms of methods and practices used in its application as A modern and contemporary administrative entrance, and what this system reflects from the important aspects represented in reducing the pollution processes occurring in the station's activities, case study, and improving the performance of its operations, in a way that contributes to the elimination of harmful environmental waste and by highlighting the sustainable value stream map in the station case study.

Focusing on the environmental issue and trying to protect the environment is crucial and thus sustainability became attractive concepts in the industry and manufacturing system during these years. In recent years, the concept of sustainability has gradually developed and begun to gain international attention. An environmentally friendly product and completely sustainable manufacturing system helps the organization reduce the use of materials and enhance the competitiveness of the business. In other words, sustainability is a weapon used to help organizations perform well, not only environmentally, but also socially and economically.

**Key words: Sustainable Manufacturing - Sustainable Value Stream Map**

**INTRODUCTION:** In recent years, researchers have begun to focus seriously on sustainable manufacturing. Nowadays, the term sustainable manufacturing is becoming more and more recognizable in the academic field. Since sustainable manufacturing takes into account environmental, social and economic factors, many researchers have focused on these issues during these years. Moreover, due to decreasing non-renewable resources, stricter environmental and occupational safety/health regulations, increasing consumer preferences for eco-friendly products, etc., the issue of sustainability, in industrial activities, has become critical. Moreover, having an "environmentally friendly" or "environmentally friendly" product became the main demands of the society in these decades. Hence, in order to have a sustainable manufacturing system, it is necessary to take into account the relevant levels which are product, process and system.

## Methodology

### First: Research Problem

The increase in environmental pollution as a result of the emission of toxic gases and the use of hazardous materials in production processes and the harmful waste that they cause has led to the interest of governments and civil society organizations in preserving the environment, and this was reflected in increasing pressures on organizations to reduce the pollution caused by their work and the products they provide, which It is required to work on providing products that are not harmful to the environment using green raw materials and production processes with less energy consumption. Governments and civil society organizations have applied pressure to implement requirements that require environmental obligations to reduce pollution and obtain materials that are less harmful and less energy consuming, as well as the possibility of reusing products after expiry Its life cycle, and based on the foregoing, the following problem can be posed: What is the possibility of evaluating the sustainable manufacturing system through sustainable value stream maps, and the following sub-questions emerge from it:-

1- What is the level of sustainable manufacturing system in the organization under study? And what are the implications of that?

2-Does the application of the sustainable value stream map with its quantitative and descriptive standards achieve the success of industrial performance in the case study station?

3- What is the contribution of sustainable value stream maps in evaluating sustainable manufacturing in the case study station?

## Second: Importance Of Research

The main objective of the study is determined in the light of its problem, which is to diagnose and analyze the relationship and impact between sustainable industrialization and the sustainable value stream map. From this goal, a number of sub-goals can be indicated that it seeks to achieve, as follows:

1-The importance and the great role of industrial organizations in any society, which calls for identifying the various scientific methods used in these organizations, and working to improve decision-making by using various modern production methods, which contributes to reducing the risks of environmental pollution.

2 - Understand the significant role of the sustainable manufacturing system in improving the performance of the plant case study

## Third: Research objectives

The sustainable manufacturing system is one of the main pillars of business organizations that adds value to them by focusing on a set of tasks that improve their products and reduce environmental waste, so the main objective of the study is determined in the light of its problem, which is to diagnose and analyze the relationship and influence between the sustainable manufacturing system and maps The sustainable value stream, and from this goal a number of sub-goals that it seeks to achieve can be indicated as follows:-

1-Evaluating the reality of the North Diwaniyah diesel plant to determine the extent of commitment to improving sustainable industrialization and protecting the environment, by calculating the environmental impact, productivity, and the sustainable productivity index (evidence) as a step towards enhancing the success of the plant's industrial performance and improving it for the better in order to increase the chances of its success by calculating the sustainable manufacturing index.

2-Calculation of the economic dimension and the environmental and economic dimension of the sustainable manufacturing ratio to locate the North Diwaniyah diesel plant from the sustainable production portfolio.

3-Identifying the level of availability of the possibility of applying the sustainable manufacturing system in the station, the case of the study.

4- Recognizing the ability and potential of sustainable value stream maps in evaluating the sustainable manufacturing system

## Fourth: Hypotheses

The first main hypothesis: Sustainable manufacturing contributes to improving production and eliminating pollution inside the station, the case of the study.

## Fifth: Materials and Methods

The diesel power station north of Diwaniyah was chosen as a field to test the model and hypotheses of the study as a community to conduct the study as it is the important facility in the middle Euphrates region, which faces serious problems in the field of environmental, economic and social sustainability, and it is also one of the stations that use heavy fuel (gas oil and black oil) to generate electricity.

## Literature Review

## First: Concept Of Sustainable Manufacturing

Manufacturing in particular is one of the main drivers of sustainable industry and that sustainable manufacturing is a rapidly developing field and a growing body of knowledge is expected. The literature shows evidence of sustainable work in the areas of product design supply chain, production technology and waste avoidance activities. Manufacturers publish metrics showing improvements significant environmental performance at a high level (Despeisse, et al, 2012:1). (Campana et al., 2017: 25) explains that sustainable manufacturing works on the concepts of lean and green manufacturing and provides a new way to design innovative products and deploy manufacturing processes using methodologies that reduce harmful environmental impacts, improve energy and resource efficiency, and generate a minimum amount of waste, optimizing operation and maintaining worker health, while maintaining and/or improving process and product quality while taking advantage of total life-cycle costs. While Roni et al., 2014: 1460) indicated that it is the provision of goods and services to meet the demands of customers in society while accelerating economic growth and slowing environmental damage. (Moldavska & Welo, 2017:747) also defines sustainable manufacturing as a strategy or approach, while others define it as a model, system, innovation or production of goods and services. (Moldavska, 2016:413) adds that sustainable manufacturing is a process that transforms a manufacturing company into a sustainable company through an ongoing process that consists of evaluating the current

sustainability performance, identifying areas for improvement, proposing specific actions across the company, and implementing these actions.

### Second: Importance Of Sustainable Manufacturing

The importance of adopting sustainable manufacturing measures and strategies by companies lies in its ability to address problems, and therefore climate change is one of the problems facing industrial organizations and has very serious consequences (Gunasekaran & Spalanzani 2012:17). Water is often subject to scarcity and is not renewable and can affect operations as well. The global economic crisis in the past several years has raised questions about the feasibility and sustainability of current business practices aimed at economic growth. On the other hand, we find that many organizations do not pay attention to As a result, pressures for the use of sustainability in manufacturing have increased by many stakeholders, employees, investors, suppliers, customers, competitors, communities, governments and regulators (Rosen & Kishawy, 2012:164). Innovative sustainable manufacturing can become an engine for sustainable growth not only by fostering economic growth, but also by enabling social welfare and environmentally conscious practices, and value creation through sustainable manufacturing will require at product, process and systems levels across the total life cycle and through multiple life cycles( Jawahir et al.,2013:15).

### Third Benefits of sustainable manufacturing

That sustainable manufacturing creates tangible and intangible benefits for the company and has the potential to increase the financial performance as well as the market value of the company, however, the value of sustainability increases with the size of the company as well as the marketing efforts of the company (Gunasekaran & Spalanzani, 2012:17). Intangible benefits are not always seen as something of importance to the company. Most companies that care about their reputation or brand equity form CSR strategies believing that they will create goodwill with stakeholders. A sustainable strategy provides the company with flexibility in meeting the needs of future generations through Innovation, reorganization and proactive strategic planning, and interest in intangible benefits can be increased if there is a method or tool to measure these benefits, making them measurable (Karlsson, 2011:91).

### Fourth: Concept sustainable value stream map

Value Stream Planning (VSM) is a diagnostic technique that originated from the principles of Lean Manufacturing, and its purpose is to identify value-added and non-value-added activities in the value stream so that wasteful activities can be eliminated, and production matches demand (Norton, 2009:7). Where the use of the value-flow planning tool in evaluating the performance of the company is lacking in terms of environmental and social sustainability, as Torres and Gatti worked in 2009 to develop value-stream maps with a tool called the Environmental Value Stream Map (E-VSM) (Vippianto, 2017:13). Value Stream Diagram is a diagnostic technique that originated from the principles of Lean Manufacturing, whose purpose is to identify value-added and non-value-added activities in the value stream so that waste can be eliminated and production is aligned with demand .Because the manufacturing sector is a major contributor to the economy, unfortunately, there are many industries Transformationalism has a negative impact on the environment and society. However, the manufacturing process consumes excessively large resources and produces hazardous waste and emissions. Therefore, many efforts have been made to assess sustainability in the manufacturing sector, so Simons & Mason, 2002 suggested a method called sustainable value flow maps. Stream Mappin (SVSM) as a way to enhance sustainability in product manufacturing by analyzing greenhouse gas emissions, carbon dioxide, as well as value addition times throughout their flow (Hartini et al.,2021:2).

### Fifthly Metrics of the sustainable value stream map

The sustainable value stream map includes three measures of sustainability performance and identification of improvement opportunities at the manufacturing line level, which are (Sparks, 2014:41):-

1-Economic metrics

Including revenue, operating profit, net profit, tax payments, operating costs, and comparison of wages to the value determined by the market and local suppliers (Lee et al.,2021:4). And (Hartini et al., 2020:2) indicated that it represents time and work in the process, cost and defect.

2-Environmental Standards

They are used to treat environmental waste (water consumption, material consumption, energy consumption) and gas emissions to improve sustainability, and (Faulkner &

Badurdeen, 2014:10) adds that they are energy tool maps to monitor energy consumption for each process in the manufacturing system. Energy consumption measures are important in environmental sustainability because The use of non-renewable resources and gas emissions as well as energy consumed between operations for transportation and storage or due to machine inefficiency, and Wills (2009) worked on expanding the concept of value flow to environmental value stream maps

3-Social Standards

Sustainable growth is defined as the economic growth that the physical and social environment can support in the foreseeable future. Therefore, sustainability requires studying the impact on the social environment by taking into account all stakeholders such as employees and the risks to which the employee is exposed. This aspect is evaluated by measuring and monitoring employee health and safety risks On an ongoing basis, whether these risks are the daily risks to the employee or the potential risks to the employee in a particular process, social measures have been classified into two categories (physical work and work environment) (Faulkner et al.,2012:5)

## Applied Aspect Of Research

### First: - Testing the independence of random numbers and good matching

The randomness of the generated numbers was tested according to the following hypothesis-:

randomly generated random numbers: H0

Non-random random numbers: H1

As 100 random numbers were generated using Matlab language and according to the following program:

```
clc clear
For i=1 : 100
R= rand; end R
```

| **0.9454** | **0.5211** | **0.2433** | **0.7803** | **0.4231** | **0.8332** | **0.8223** | **0.2105** | **0.4663** | **0.6611** |
|---|---|---|---|---|---|---|---|---|---|
| 0.1544 | 0.2782 | 0.3123 | 0.3654 | 0.1545 | 0.6555 | 0.9970 | 0.9769 | 0.0539 | **0.7977** |
| 0.41821 | 0.7744 | 0.8212 | 0.2545 | 0.9222 | 0.3454 | 0.9005 | 0.0046 | 0.2356 | **0.5444** |
| 0.4210 | 0.7223 | 0.0124 | 0.4909 | 0.1654 | 0.5003 | 0.2567 | 0.7749 | 0.9101 | **0.3221** |
| 0.4011 | 0.6776 | 0.0432 | 0.6085 | 0.4706 | 0.4532 | 0.1562 | 0.8173 | 0.1832 | **0.1756** |
| 0.3102 | 0.1744 | 0.1543 | 0.1433 | 0.4765 | 0.0760 | 0.1466 | 0.8687 | 0.8655 | **0.6013** |
| 0.5010 | 0.3112 | 0.6112 | 0.9533 | 0.3766 | 0.2654 | 0.8666 | 0.0844 | 0.5421 | **0.2451** |
| 0.5499 | 0.6763 | 0.7331 | 0.9899 | 0.6765 | 0.1323 | 0.5676 | 0.9562 | 0.3454 | **0.6122** |
| 0.8122 | 0.7031 | 0.9887 | 0.5643 | 0.3456 | 0.1928 | 0.5947 | 0.2344 | 0.0572 | **0.6111** |
| 0.7348 | 0.0554 | 0.4651 | 0.0698 | 0.1211 | 0.2543 | 0.1610 | 0.8104 | 0.4239 | **0.7108** |

The result of generating 100 random numbers was shown in Table (1), and these numbers were also tabulated for the purpose of performing a good match as shown in Table (1).

**Table (1) Random Numbers Generated**

### Second, modeling simulations

1- Determining the daily generation of electricity using the Monte Carlo method

Table (2) Monte Carlo method for determining the daily generation of the station

The results of Table (2) indicate that if a random number is chosen according to the Monte Carlo method for general distribution and the number is for example (0.49), the generation is (3371613) mica.

| Range | F(X) | f(x) | scenes repetition | Daily Obstetrics/Mica |
|---|---|---|---|---|
| 0-0.14 | 0.14 | 40.1 | 1 | **1969695** |
| 0.14-0.28 | 0.28 | 0.14 | 1 | **1597595** |
| 0. 28-0.42 | 0.42 | 0.14 | 1 | **2470645** |
| 0.42-0.56 | 0.56 | 0.14 | 1 | **3371613** |

2- Determining the daily generation of black oil using the Monte Carlo method.

**Table (2) Monte Carlo method for determining the daily generation of the station**

| | | | | |
|---|---|---|---|---|
| 0.56-0.70 | 0.70 | 0.14 | 1 | **3522000** |
| 0.70-0.84 | 0.84 | 0.14 | 1 | **2495016** |
| 0.84-1 | 0.98 | 0.14 | 1 | **1608064** |

The results of Table (3) indicate that if a random number was selected according to the Monte Carlo method for general distribution and the number was for example (0.34), the generation was (466948387) liters.

**Table (3) Monte Carlo method for determining the daily oil consumed for the station**

| Range | F(X) | f(x) | scenes repetition | Daily Obstetrics/Mica |
|---|---|---|---|---|
| 0-0.14 | 0.14 | 0.14 | 1 | **5063749356** |
| 0.14-0.28 | 0.28 | 0.14 | 1 | **408032333** |
| 0. 28-0.42 | 0.42 | 0.14 | 1 | **466948387** |
| 0.42-0.56 | 0.56 | 0.14 | 1 | **649503807** |
| 0.56-0.70 | 0.70 | 0.14 | 1 | **664741567** |
| 0.70-0.84 | 0.84 | 0.14 | 1 | **606782452** |
| 0.84-1 | 0.98 | 0.14 | 1 | **392946333** |

The results of Table (3) indicate that if a random number was selected according to the Monte Carlo method for general distribution and the number was for example (0.34), the generation was (466948387) liters.

**Third: Run the model to know the reality of the station's performance**

The model has been run in order to know the reality of the performance of the current station, using the station's physical and human components itself, where the operation was repeated (1000) times for a period of 214 days, and the results shown in Table (4) were reached.

**Table (4) The results of running the model with the components of the current station to identify the reality of the performance of the current station**

| Oil ratio | water ratio | Ratio of black oil to generation | Gasoline ratio | daily delivery rate |
|---|---|---|---|---|
| **0.0004** | **0.007** | **204** | **6.9** | **2443215** |
| **pollution rate** | | | | |
| **SO2** | **N2** | **CO** | **CO2** | **H2O** |
| **75.04** | **54.22** | **20.06** | **33.38** | **18.05** |

## Fourth: - Implementation and testing the credibility of the model

In order to test the reliability of the simulation model, the model will be implemented using the Matlab program for a certain period of time, then by adopting the method of repetition of attempts and for ten attempts (the number of attempts was chosen according to the spacing and convergence between the real parameter and the parameter extracted from the simulation model) the average is extracted in each attempt Then it is relied upon in evaluating the performance of the treatment or improving it, so a test of control maps and for different parameters was conducted in order to validate the model:-

**Average daily generation of electricity**

The simulation model was implemented for a period of 214 days 10 times, and each time the process was repeated 1000 times, as the arithmetic mean was calculated once and a daily arrival rate of (2443209) mica per day was obtained, which is highly acceptable compared to the daily real generation rate of (2433518), which It is within the limits of the control map and for three standard deviations, as shown in Figure (1)

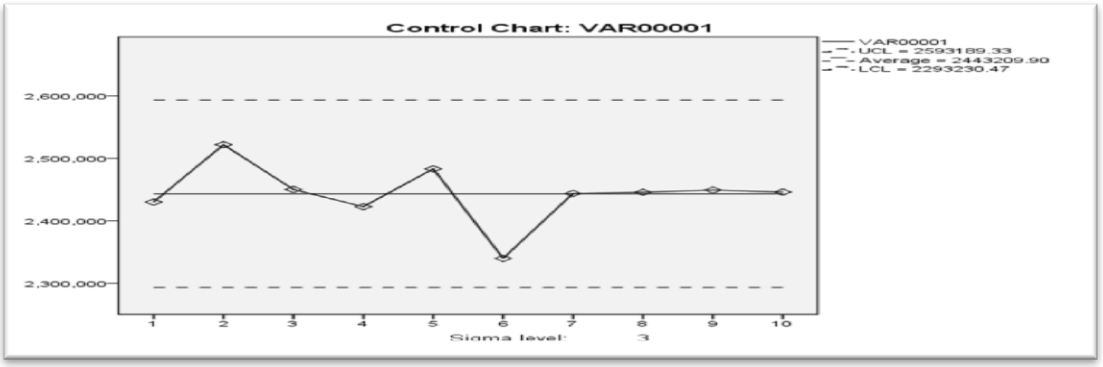


Figure (1) is a control map for the daily rate of electricity generation

## Conclusions and Recommendations

### First: Conclusions

1-The results of the study showed that there is a weakness in the case study station in the application of the sustainable manufacturing system, which is a newly applied system in our local environment, as it lacks allocating a lot of funds for the development and training of its human resources responsible for sustainability operations and keeping pace with developments in the field of environmental security. .

2-The results of the study indicated that there is a significant correlation between sustainable manufacturing and the sustainable value stream map, and this indicates that the increased interest of the station management in sustainable manufacturing will contribute to achieving its competitive advantage and increasing its production of electrical energy.

3-It is inferred from the achieved results that the study station adopts some of the sustainable manufacturing tools in varying degrees in the sustainable value map, which proves the validity of the research orientation in choosing the current variables and the appropriateness of the field of study.

4-The station works in the case of the study at low levels to adopt the concepts of environmental protection by using environmentally conscious manufacturing systems and by adopting clean production methods and integrated environmental preventive strategies on processes and products to reduce risks to humans and the environment in order to preserve raw materials and remove harmful ones and reduce toxic substances.

### Second: Recommendations

**1**-The necessity for the station, in the case of the study, to have the appropriate awareness of its role in protecting the environment and not to harm it, and to have effective programs to achieve sustainable industrialization that it implements and what benefits the station and the environment, based on its moral and legal responsibilities.

2-The need for the station to establish a case study awareness of the involvement of workers in training courses and according to their specializations, which will reflect positively on reducing the risks of the environment, and to improve and develop their skills.

3-The necessity of strengthening the orientation towards creating the requirements for adopting modern manufacturing systems (sustainable manufacturing).

4-Educating all employees about the concepts and requirements of implementing sustainable manufacturing, and the great benefits expected from it.

5-Adopting the basic principles of sustainability as much as possible in the various production processes, focusing on manufacturing flexibility, and standard models of operations that lead to ensuring environmental safety.

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