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**Safaa Mohammed Hadi Hashim**[1]
**Afrah Oudah Sabeeh**

# A STUDY OF USING STATISTICAL METHODS TO IMPROVES PROCESS PERFORMANCE

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***Abstract:*** *The main purpose of this research is to explore opportunities to integrate manufacturing practices with its processes using the LSS methodology to reduce waste and variability, improve efficiency and enhance quality and thus to improve process performance. Data were collected through interviews conducted by researchers during site visits. These data were processed using a set of quantitative measures by a computer program designed with Microsoft (Excel 2010) as well as the statistical program (SPSS v.17). Finally, develop and control was employed to ensure continuity and improvements. The rates of utilization of the product design capacity were low, with low levels of efficiency and productivity. It was also concluded that the application of the LSS methodology would reduce delivery time. There was notable difficulty of obtaining information, especially concerning the defective production of the final product.*

***Keywords:*** *LSS; Six Sigma; Lean; Waste; Continuous improvement.*

## 1. Introduction and Background

The roots of Six Sigma can be traced back to the early industrial era, during the 18th century in Europe, and by the end of 1970, when Japanese industries had strong competitive styles. These caused threats to Motorola, precipitating its comparison with the Japanese electronics industry, and it was found that many of the Japanese electrical products were at the level of sex sigma, while Motorola's quality products were only 4σ. Such weakness in quality led Motorola to initiate the optimization program (SS), to achieve the 6σ quality level over the next five years, achieving improvements in all processes and eventually, timely excellent results (Abdullah et al., 2021; Yang, 2012). In January 1987, Motorola issued a long-term quality program called the SS Quality Program. In 1998, Jach Welch laid the foundation for GE's SS approach. The application of this method achieved a profit of $ 300 million as a net income from the improvements achieved by the (SS) approach (Al-Abrrow et al., 2019).

According to (Knowles 2011) (SS) has three distinct elements of definition: 1) measurement: statistical definition to what extent the process deviates from perfection; 2) objective: 3.4 per million opportunities and 3) philosophy: the long-term business strategy focused on reducing cost by reducing changes in products and processes. Ray et al. (2011) stated that (SS) is a business strategy that focuses on better understanding customer requirements, business systems, productivity, and financial performance. From what we have presented in advance, we conclude that SS definition is an organized methodology based on information that measures deviations in the process, product or service

[1] Corresponding author: Safaa Mohammed Hadi Hashim
Email: safaa.m.hadi@stu.edu.iq

and attempts to correct these deviations to achieve perfection.

**Table 1**. Level of Performance (Six Sigma) (Lanham, n.d.)

| level Sigma | Disadvantages per million chances | Revenue |
|---|---|---|
| 1 | 691500 | 3085 |
| 2 | 308500 | 69.15 |
| 3 | 66800 | 93.32 |
| 4 | 6200 | 99.38 |
| 5 | 320 | 99.977 |
| 7 | 3.4 | 99.99966 |

## 2. Steps to apply the Six Sigma methodology according to the DMAIC model:

The DMAIC model is used when the project objective can be achieved by improving an existing product, process or service, and the DMADV model is used when the goal is a new development or radical redesign of a product, process or service. (Pyzdek 2003) applied a DMAIC model through the following stages.

Define: At this stage, the goals of the improvement activity are obtained from customers. At the top level, the goals are represented by the strategic objectives of the organization, such as greater customer loyalty, a higher ROI or increased market share, or greater employee satisfaction. At the operations level, a goal might be to increase the throughput of a production department. At the project level, goals might be to reduce the defect level and increase throughput for a particular process. Goals are obtained from direct communication with customers, shareholders, and employees (Pyzdek, 2003).

Measurement: Once the problem of work is identified, the project is moves on to the measurement stage. During this stage, the working procedure for the problem are identified by the project team, after identifying the relevant processes, flow, feedback rings, which can be divided into logical models that provide a quantitative understanding of the process. The process can then be evaluated using real process data to ensure the reliability of the evaluation process (Tikkala,2014).

Analysis: In this stage, the system is analyzed to identify ways of eliminating the gap between the current performance of the system or the process and the target and stage begins by defining the current baseline (Pyzdek,2003). The objective of the analysis step is to identify the largest sources of variance, which can be controlled from specific processes, and then identify opportunities for improvement and root causes of the problem, and this analysis lays the foundation for improving the process (O'Rourke, 2005, Alnoor, 2020).

Improvements: Optimization is the objective or process in which solutions are developed and changes are introduced to improve the operation process and reduce risk values (Snee,2010, Al-Abrrow et al., 2020).

Control: Control of the new system means institutionalization of the system of improvement through the adjustment of compensation systems, incentives, policies, procedures, MRP, budgets, operating instructions and other management systems, and the use of statistical tools to monitor the stability of new systems (Pyzdek,2003; Alnoor et al., 2020).

### 2.1. The Emergence and Evolution of the Concept of Lean

After World War II, with the help of Japanese engineers, TaiichiOhno (Shigeo Shingo), Toyota developed a series of advanced manufacturing techniques designed to reduce the flow of single product resources throughout the production process. These methods were inspired by Henry Ford's concept as early as the 1900s. Toyota created an organizational culture that focuses on systematic identification and elimination of all waste in the production process, called the Toyota Production System (TPS). The Environmental Professional's Guide to Lean

& Six Sigma in 2009.Now this small company has grown into a large company, and the Toyota production system has become known as Lean Production (Poppendieck, 2002).

The pioneering use of the concept was through John Krafcik's "Triumph of the Lean Production "in 1988 (Tad, 2011; Alhamdi et al, 2019). Meanwhile, (Skalle and Hahn 2013) defined lean as a method of continuous focus on understanding and increasing value to the customer by reducing the delivery time of the product or service, which occurs by eliminating all forms of ‘muda’ (a Japanese term for waste), "muri", (overloading individuals and machines), and "mura" (uneven work flow or imbalance of demand) within the organization, and these three concepts are linked in a circular manner, Disparities cause an increase in the burden of waste, as illustrated in Figure 2.3, and therefore it is important to deal with the three concepts to improve system performance. Finally, Hamid et al. (2021), added that the implementation of lubrication focuses on putting things in perspective.

We conclude from the above that the development and implementation of the concept of lean was in the Japanese manufacturers, and then it spread to other sectors and international companies, and the philosophy of lubrication focuses on increasing the speed of the process, and to increase speed, the focus of the trampling is on removing excess steps or processes that do not add value, It is also assumes that once the process is removed, the waste of the process will not only become faster but will become more focused on providing the best value to the customer at the lowest cost and improving the quality of the product (Hadi et al., 2018).

## 2.2. The Emergence and Evolution of Lean Six Sigma

The concept of the combination of Lean and SS began in the mid-late 1990's and developed rapidly, and there are many examples of manufacturing companies that carried out a joint effort of lubrication and SS. For instance, in 1997, it was implemented by the Aircraft Control Company in Indiana.

Combining the principles of lean manufacturing with quality tools for SS has been suggested in literature (Furterer,2004). Today, it is recognized that LSS has become known as "A strategy of action and methodology that will increase the performance of the process, resulting in enhanced customer satisfaction and improved final results” (Laureani,2012). Instead of choosing between SS and Lean, many companies have developed both, and given the popularity of the two methodologies, organizations have begun to integrate them (Pojasek, 2003). The integration of the two methodologies could achieve better results than if both methodologies worked alone (Antony,2011). As for the concept of LSS methodology, there are many definitions in books and by researchers, some of which are listed below:

- An integrated portal that works better than previous entries because it integrates people (e.g., leadership, customer focus, cultural change, etc.) and practical aspects (practical ability, process management, and statistical thinking) for improvement (Antony, 2011).
- The LSS methodology refers to smarter management of the organization, which first takes into account customer satisfaction by using data and facts to develop short-, medium- and long-term strategies (Pamfilie et al., 2012).
- LSS includes many common features of lubrication and SS, such as - focus on customer satisfaction, culture of continuous improvement, root cause search, employee
- Menagement, training and education from senior management of the workshop floor (Maleyeff, 2007).

We conclude from the previous presentation that the LSS methodology has recently emerged and comes through an effective combination of two major new technologies. LSS incorporates two large methodological tools, principles, and models for continuous improvement in one way to improve business processes. Thus, this leaves a systematic methodology based on the elimination of waste and variation, increasing the speed and effectiveness of the workflow, and reducing costs, which in turn improves the performance of the process, regardless of product and industry. Table 2 shows the most important differences between lubrication and SS and LSS.

**Table 2.** The difference between (Lean), SS) and (LSS) (Muthukumaran et al., 2013)

| Pur//Issues//Problems pose | (SS) | Lean | (LSS) |
|---|---|---|---|
| Focuses on customer value stream | NO | Yes | Yes |
| Focuses on creating a visual workplace | NO | Yes | Yes |
| Creates standard work sheets | NO | Yes | Yes |
| Attacks work-in-process inventory | NO | Yes | Yes |
| Focuses on good housekeeping | NO | Yes | Yes |
| Process control planning and monitoring | NO | NO | Yes |
| Focuses on reducing variation and achieving uniform process outputs | NO | NO | Yes |
| Focuses heavily on the application of statistical tools and techniques | NO | NO | Yes |
| Employs a structured, rigorous and well planned problem solving methodology | NO | NO | Yes |
| Attacks waste caused by waiting, over processing, motion, over production, etc. | NO | Yes | Yes |

## 2.3. The Benefits of Applying Lean Six Sigma Methodology

Although lean and SS evolved from different paths, combining them can provide organizations with many benefits, as lean brings work and intuition to the work floor, allowing staff to make rapid improvements It also helps increase productivity, change culture, and clean the factory. SS uses statistical tools, on the other hand, detect root causes, and its programs are popular, focused and effective. The use of both methodologies enables organizations to be distinct, resulting in continuous improvement of business (Pojasek, 2003). A number of benefits are given to individual employees (e.g., focus on minimum management, senior management, customer focus, project teams, culture change) to boosting process improvement, variance analysis, disciplined input, quantitative measures, methods and statistical thinking and process management (Raifsnider& Kurt,2004). The benefits of improvements to the manufacturing process through the LSS methodology are numerous, and they include greater efficiency, faster response, enhanced customer service, reduced costs and increased quality.

## 2.4. The Concept of Process Performance

Operations performance is important to any organization because the operations manager is enabled to choose between keeping the business going or finishing it; in other words, 'make or break'. This is not only because the function of operations is large and, in most organizations, represent the bulk of its assets and the majority of its members, but also because the function of operations provides competitive advantage by providing the ability to respond to customers and to develop the capabilities of the organization that will remain at the forefront of future competition (Slack et al.,2010). Authors and researchers have cited numerous definitions of operational performance, with some defining it as the strategy of operations that create a system of competitive priorities of high value for the customer in an efficient and appropriate manner and upon which the operations managers make decisions to achieve competitive priorities in light of three strategies namely differentiation, cost leadership, response (Heizer& Render,2011). Some believe that the performance of operations is the organization's ability to perform the function of operations, which is based on knowledge and experience and consists of providing wide service, high quality, fast delivery and low cost thus helping the organization to create a sustainable competitive advantage (Russell & Taylor,2011). We conclude from the above that the performance of operations is the result of operations performed by organizations, whether productive or service, and this performance is to achieve the objectives of the organization and the objectives of performance in reducing cost, increasing quality and enhancing flexibility, reliability and speed (Jabbar et al., 2020; Petera et al., 2020).

### 2.5. Process Performance Indicators

This study focuses on performance indicators (i.e., quality, cost, speed, productivity), which are described here theoretically. The measurement and analysis of the results are under the practical aspect:

- Quality: quality is the constant conformity of customer expectations. In other respects, quality is the most obvious part of what a process does, but it is something that the customer finds relatively easy to judge the process (Slack et al.,2010).
- Cost: for companies that compete directly for the price, the cost is clear in their main operations, and low cost can enable the company to offer a satisfactory price to customers. In this regard, even companies that do not compete for the price is concerned with keeping costs down, with every euro or dollar removed from the base of the cost of the transaction being EUR or USD added to its earnings (Slack et al.,2010; Aymen et al., 2019). Manufacturing costs can be classified into two main categories: (i) fixed costs and (ii) variable costs (Groover, 2002).
- Speed: refers to the time between the beginning of process processing and the end of the process, from the time the customer requests the product or service to the time the customer receives the product or service. This may be used to describe the process internally; for example, the time between material entry into the process and the end of its complete processing (Slack & Lewis, 2011). Speed in product development, speed in production, delivery speed and the operations manager who develops fast response systems can provide competitive advantage (Heizer et al.,2017).
- Productivity: is a measure of the efficiency of converting inputs into outputs, and productivity measures are used to determine how well resources are used (Reid & Sanders,2010). Furthermore, efficiency of the production system is an indicator of the utilization of factors of production (land, capital, labor, and energy) (Kumar & Suresh, 2008).

## 3. Methodology

### 3.1. The Study Problem

The study problem is reflected in the following questions:

1. Does applying LSS methodology eliminate deviations in the product, which in turn increases the defect-free production?

2. Does the DMAIC (define, measure, analyze, improve, control) model help identify the most important problems, and deviations in the product and develop appropriate treatments?

3. Does the adoption of a methodology (LSS) lead to a reduction in delivery time in the general company for the fertilizer industry, and thus, reducing costs and increasing profits?

4. How can an LSS methodology be used to improve the performance of the process?

### 3.2. The Study Objectives

The objectives of the study are as follows.

1. To explore opportunities for integrating LSS manufacturing practices with manufacturing processes to reduce waste, contrast, improve efficiency, enhance quality, and thus improve process performance.

2. To emphasize the importance of using the LSS methodology and the manufacturing process in successful performance by reducing the defects to a minimum of 3.4 defects per million chances, which is the ultimate goal of this system. The LSS methodology is a control and administrative criterion that controls the variation in products.

3. The adoption of this methodology achieves financial savings for the company by obtaining high quality products, which reflects its positive effects in reducing the cost of the product and adopting an acceptable competitive price.

4. To implement the LSS methodology through the DMAIC model in the target company to encourage the public and private sectors to adopt it in contribution to upgrading Iraqi institutions towards globalization and business excellence.

### 3.3. The Study Importance

Improving the process involves a series of successive activities to achieve goals such as, improving performance, reducing costs and increasing profits. Such activities follow a specific technique or methodology to increase the likelihood of successful results, and LSS methodology is one of the techniques that make these improvements. Therefore, the importance of this study lies on its focus on the role played by the industrialization process in promoting the state of the economy from recession to prosperity and moving it from underdevelopment to development. It can be seen that the developed countries that reaped the fruits of economic progress are the countries that have worked to develop the industrial sector and have been at the forefront of strategic priorities. Thus, the organizations found themselves in competitive positions that must be proactive in launching initiatives to enhance competition and address the risks they face in the markets.

### 3.4. The Study Hypotheses

A thorough review of relevant literature dedicated to the integration of Lean/Six Sigma and process performance, with the help of DMAIC method showed scarcity of studies. In this regard, (Eneizan et al., 2019) stated that Lean/Six Sigma can form a core part in the performance process, particularly in assisting the economic, social and environmental process performance among companies. There have been several frameworks, models and methods proposed for Lean Six Sigma and performance in comparison to other frameworks but for their integration, only two were encountered, which was by (AL-Abrrow et al., 2020).

Specifically, the framework proposed by (Abbas et al., 2021) integrated Lean, Six Sigma and performance philosophies in the construction industry context and the framework structure was built on the DMAIC improvement cycle. In relation to this, there are five phases to the DMAIC cycle namely, define, measure, analyze, improve and control. Considering the five stage framework and its role in process improvement, this study proposes the following main hypothesis for testing.

H1: Using DMAIC with LSS enhances process performance.

The above hypothesis is sub-divided into five sub-hypothesis addressing DMAIC's five phases (define, measure, analyze, improve and control). The sub-hypotheses are discussed as follows;

In the first phase, called define, the problem and objectives are defined to enhance the process performance of the company. In this regard, the first problem of the company is represented by the data gathered by the researchers from the quality department records. From the data, it was evident that a deviation existed in the concentration of urea formed at the reactor stage from the allocated limits, and such deviation resulted in increased defects. In turn, such defect caused low level of effective production, decreased productivity and increased costs. The second problem of the company is related to the delivery period's relative length and the consequential increased costs. The primary objectives of enhancing the process performance are to enhance quality and minimize product manufacturing time, in an attempt to reduce costs, enhance productivity and increase delivery time of the product to the user. Ultimately, the process performance is improved.

After the identification of the work problem, the project moves on to the measurement stage. The team members begin gathering data about the process and measuring the customers interests. There are two aspects focused on – 1) limiting the lead time and 2) enhancing quality. In the measurement stage, the team re-defines the measurement definitions and identifies the current performance and the process baseline. Quality, speed, productivity and cost are measured. Quality measurement is important for process and performance increase, speed has to be maintained with productivity. Improving all three elements should be in terms of cost consideration. In this stage, the working procedures highlighted in the problems discussed are identified by the members of the project, following the determination of the processes, flow and feedback rings, divided into logical models that present a quantitative process understanding. This is followed by the evaluation of the process with the use of real process data in order to make sure that its reliability is maintained (Tikkala, 2014). The following hypotheses are thus validated;

H1a: Using DMAIC for LSS methodology improves quality.

H1b: Using DMAIC for LSS method reduces costs.

H1c: Using DMAIC for LSS method leads to increased productivity.

H1d: Using DMAIC for LSS method increases speed.

## 4. Practical Side

After the theoretical study of this research, we move on to testing the practical side by conducting a field study of the General Company for the manufacture of fertilizers in Basra/Khor Al-Zubair, and highlight the aspects related to the subject of our study.

### 4.1. Reality of Production in the General Company of the Fertilizer Industry

Urea fertilizer is the main product of the company and is produced entirely within the company, with the two main substances being ammonia ($NH_3$) and carbon dioxide ($CO_2$). These are produced within the company through the ammonia plant, and the raw material for the production of ammonia is natural gas, which is purchased from the Ministry of Oil. Table 3 tabulates the consumption rates of raw materials for production per ton of ammonia and urea product and for the first and second production lines according to the design energy of the per capita consumption rate as well as the actual consumption rates.

**Table 3**. The consumption rate of the two main products of raw materials and production rates

| Production rate | Design capacity | Consumption of raw material according to actual situation | Consumption of raw material by design | Statement |
|---|---|---|---|---|
| 600 tons/day | 1000 tons/day | 1325 m3 of natural gas | 1084 m3 of natural gas | Per ton of ammonia |
| 1100 tons/day | 1600 tons/day | 0.6 tons of ammonia | 0.58 tons of ammonia | Per ton of urea |

From the table above which contains the consumption rates of raw materials and production rates of the company, there is a variation in the consumption of raw materials for the company's main products between the designed and the actual consumption, and the difference between the actual consumption of natural gas and the production of one tone of ammonia. The volume of design consumption is estimated at (241 m3) per ton, and the daily production volume (600 tons/day), indicating a difference of (144,600 m3/day). The difference in consumption per ton of ammonia to produce one ton of urea is 0.02 tons, even if the daily production volume (1100 tons/day) becomes 22 tons/day. As for the difference in production rates between design capacity and actual production, for ammonia, it is (400 tons/day) and for urea production, there is a difference of (500 tons/day). In other words, the company is not working at full capacity.

### 4.2. Application of DMAIC in the General Company of Fertilizer Industry

Stage1: Define

This phase includes the definition of the problem and objectives to improve the performance of the process of the company under study. The company's first problem is reflected in the data obtained by the researchers from the quality department records indicating that there is a deviation in the concentration of urea formed at the reactor stage from the permissible limits and this deviation leads to the increase of the defect, which causes low rate of good production, decreased productivity and increased costs. The second problem of the company is the relative length of the delivery period and the consequent increase in costs. The main objectives of improving the performance of the process are to improve quality and reduce product manufacturing time, thus reducing costs, improving productivity and increasing the speed of delivery of the product to the customer. In order to achieve these objectives, the research focuses on the quality and speed of the urea plant.

The cost and productivity is focused on the company as a whole, including the ammonia plant. The definition phase also includes the definition of processors, process inputs, processing stages, outputs and customers, which represent the supply chain. This is illustrated in Figure 1 (SIPOC).

Stage 2: Measurement

This phase includes the measurement of data obtained from various departments of the company and they are detailed as follows:

• The Quality:

The researchers obtained data from the quality department of the company for 2016, which was for only (84) days.

This presents the results of the examination of the concentration of urea at the reactor stage, which contained deviations from the permissible limits defined by the company's quality department. The upper limit was 36.8, the minimum = 31.1 and the central line = 33.95. When processing the data in the Excel program, Figure 2 shows that there were deviations of 13 limits of the minimum standard.

| Customer | Outputs | Process | Inputs | Supplier |
|---|---|---|---|---|
| Iraqi Ministry of Agriculture | Urea fertilizer | Manufacture of urea fertilizer | Liquid gas | Oil Ministry |

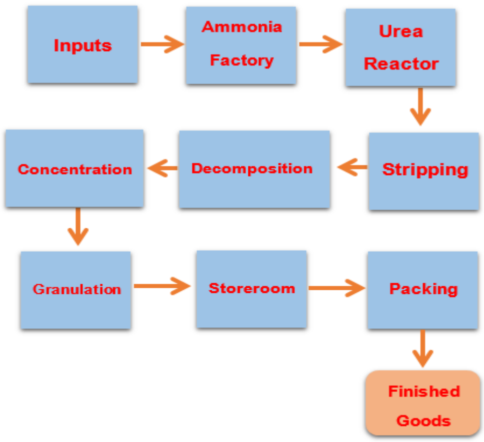


**Figure 1**. SIPOC layout of basic processes

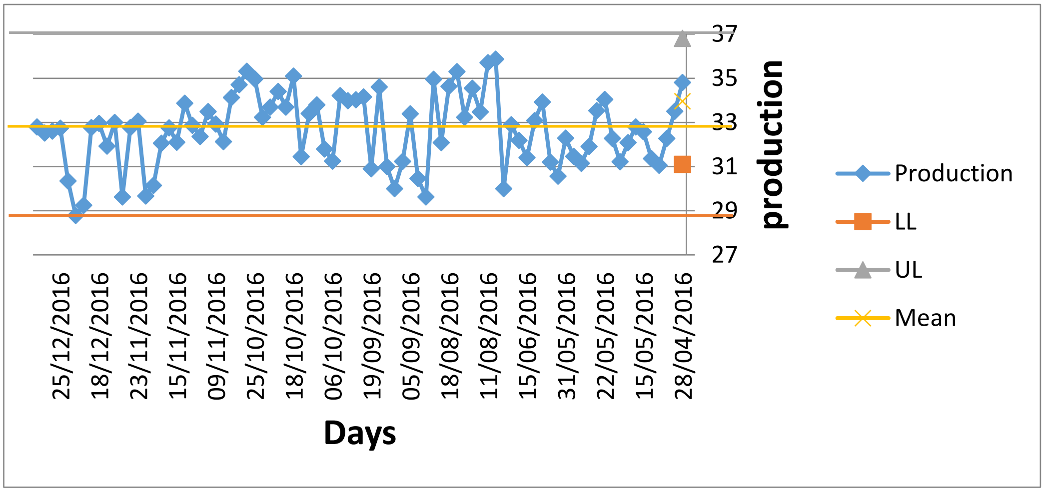


**Figure 2.** Deviations of the concentration of urea at the reactor stage

• <u>Sigma level:</u>

To determine the level of Sigma of the stage of the urea reactor operated by the company, the following formula is used:

The number of production days for the year (2016) was (84) days and the production of urea was 235,350 tons for the year 2016, with production per day:

The production rate per day for the year 2016 = Production quantity for the year 2016 / Number of production days for the same year

= 235.35/84=2.801 ton/day

If we take the total number of defects (24) 24 * 2801.7 = 67240.8 ton/year (defects)

Percentage of defects = 67240.8/235350 * 100 = 28.57%

Precision ratio in operation = 1 – 28.57% = 71.43%

Defects per opportunity = 67240.8/235350*3 = 0.0952351

Defects per million opportunity (DPMO) = 0.0952351* 1000000 = 95235 ton

The Sigma level, which includes the reactor urea plant and three types of defects, is approximately 2.8% with defects of 28.57% and accuracy in the performance of its operations being 71.43%.

• Speed:

The researcher considered the speed dimension only based on the urea plant, due to the limited study time, and as such, to this end, the researcher used value stream mapping (VSM). The urea plant is used in this study for speed calculations, and reliance on cost calculations at the time of the operation. We calculate the transaction time costs from calculating the annual cost stream costs, through which, we can link the costs and the time to be explained later and after taking into account all the costs in the value stream and calculating them. The direct and indirect costs are not distinguished because all costs in the value stream are direct costs.

The company's total costs for the year 2016 = 82,914,275,700 dinars, the number of days of production = 84 days to extract the number of minutes for 84 days we do the following (the company operates the system (shafts) that work within 24 hours a day and 7 days a week): 84 * 24 * 60 = 120,960 min production.

Cost per minute = Total cost/ Number of minutes= 82914275700dinars/120960minute = 685469 dinar/minute

We can determine the size of the costs to provide by knowing the cost per minute, and if the delivery time was reduced by reducing or eliminating waste within the value chain. This is possible by calculating the activity time that does not add value and deleting or reducing it. Based on the information obtained from the production department. Activities that add value from activities that do not add value are identified, with the latter eliminated or reduced in order to increase product delivery speed and reduce costs. This can improve the performance of the process as illustrated in Figure 3. From the figure, the total delivery time is 53 hours and 2 minutes, allocated to the production of 132 tons, while the time added value is 5 hours and 46 minutes.

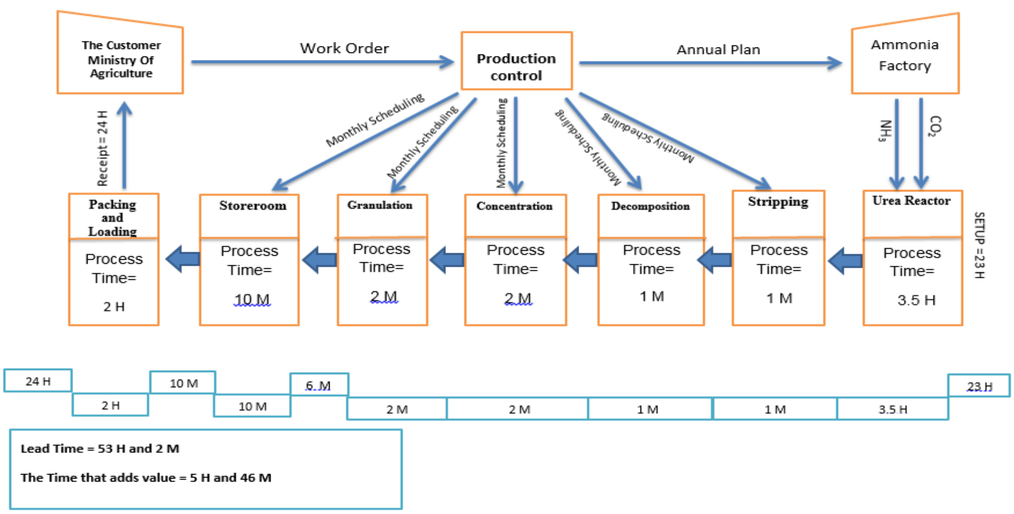


**Figure 3.** Value Stream Map (VSM) for the Urea Factory

• Costs:

The other dimension of the performance of the process is the cost and to explain the impact of the methodology (LSS) on the company, the researchers dealt with some of the financial and productivity data of the company for the year 2016. Data was obtained from the records of the finance department, showing the details of the cost component per ton of urea product (refer to Table 4).

**Table 4.** Details of the cost element per ton of urea for 2016

| Manufacturing cost | Sum of variable cost | Variable cost | | | Sum of fixed cost | Fixed Costs | | | Product |
|---|---|---|---|---|---|---|---|---|---|
| | | Other expenses | Spare parts | Raw materials for packing and packaging | | Other expenses | Depreciation | Labor cost | |
| 352302 | 133605 | 74658 | 13277 | 45670 | 218697 | 10085 | 25476 | 183136 | Tons of urea |

**Table 5.** Some financial and productivity data for the General Company of Fertilizer Industry for 2016

| Quantity, Price, Value | Statement |
|---|---|
| 235350 ton | Amount of urea production |
| 450000 ID | Selling price per ton |
| 133605 ID | Variable costs per ton |
| 218697 ID | Fixed costs per ton |
| 352302 ID | Total costs per ton |

Through the above data, we derive the following:

Revenue= Production Quantity*Selling Price

= 235350 *450000 = 105907500000 ID Total costs = Production quantity * Total cost per ton

= 352302 * 235350 =82914275700 ID

Profit = Revenue – Costs

= 105,907,500,000 – 82,914,275,700

= 22,993,224,200 ID

Ratio of Revenue to Costs = Revenue / Costs * 100= 105,907,500,000 / 82,914,275,700 * 100= 127.73%

The profit achieved here is the result of the company's revenues obtained through the sale of its production of urea fertilizer, which was a defective product (67240.8 tons/year). The company sold it by mixing it with the product conforming to the specifications with revenue of 105,907,500,000 ID, and if the company had paid for it, its revenues would have reached 75,649,050,000 ID, which is less than the costs. The main objective of the extraction of the amount of profit achieved is for the purpose of comparing the current situation with what the company may gain from the implementation of the methodology (LSS) and this is explained later.

• Productivity:

Productivity can be measured through the quantitative data shown in the table 6 and extracted from the Company's records, which are inputs to the production process.

We calculate productivity as follows:

Total productivity in amuont = Output/Input

=Production conforming to specifications*selling price / Input

=450000 * 168109 / 79080930000 = 0.95

Using the above equations in extracting the results and using them in the Excel-designed software, we produce results for the types of productivity whose data and results are summarized in the table 7.

**Table 6**. Some financial statements of the General Company of Fertilizer Industry for the year 2016

| Value in Dinars | Statement (input) | |
|---|---|---|
| 20439520000 | Cost of raw materials | |
| 58375305000 | Salaries and wages | |
| 40221000 | Transfer expenses | Expenses |
| 225884000 | Other expenses | |
| 266105000 | Total expenses | |

**Table 7.** Data and results productivity dimension for the year 2016

| Productivity | Productivity Type | Value in ID | Details |
|---|---|---|---|
| 0.95 | Total productivity | 75,649,050,000 | Output |
| | Partial productivity | | Input |
| 3.7 | Productivity of raw materials | 20,439,520,000 | Raw materials |
| 1.3 | Employee productivity and wages | 58,375,305,000 | Wages & salaries |
| 284.28 | Productivity expenditure | 266,105,000 | Expenses |
| | Multi-factor productivity | | |
| 0.96 | For raw materials, salaries and wages | | |
| 3.65 | For raw materials and expenses | | |
| 1.29 | For salaries, wages and expenses | | |

The main purpose of extracting the results of the productivity indicators for 2016 is to compare them with the productivity indices obtained when applying the methodology of LSS in the company under study and to extract the difference between the two cases. This is explained in the analysis and improvement stages.

Stage 3: Analysis

The first problem of the study shows that the stage of the reactor is not statistically controlled, which is illustrated in Figure 3.

The figure shows the deviation of the concentration of urea from the permissible limit, leading to the presence of defects (15.47%), and level of accuracy (84.53%) in the performance of operations. The amount of defects is 36422 tons/year and the product defects resulted in the company having reached Sigma level (3.1). The figure 4 identifies the reasons for the deviation of the concentration of urea at the reactor stage, with varying degrees of effect, indicated in the fishbone diagram.

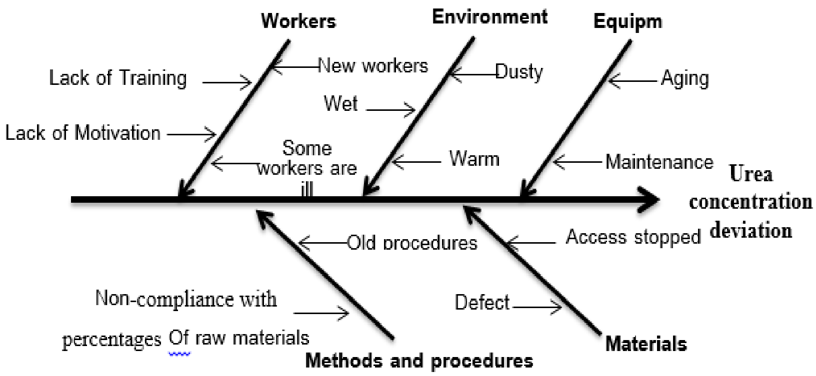


**Figure 4.** Fish bone Flow Chart

The causes of the problem described in the cause and effect diagram (fish bone) demonstrated in Figure 5 were analyzed, depending on the study of the researchers in the company's affairs, field visits, and meeting with engineers and managers of production who provided their answers to the questionnaire prepared. The analysis obtained the percentages of each reason behind the cause of the problem mentioned earlier and are shown in Table 8.

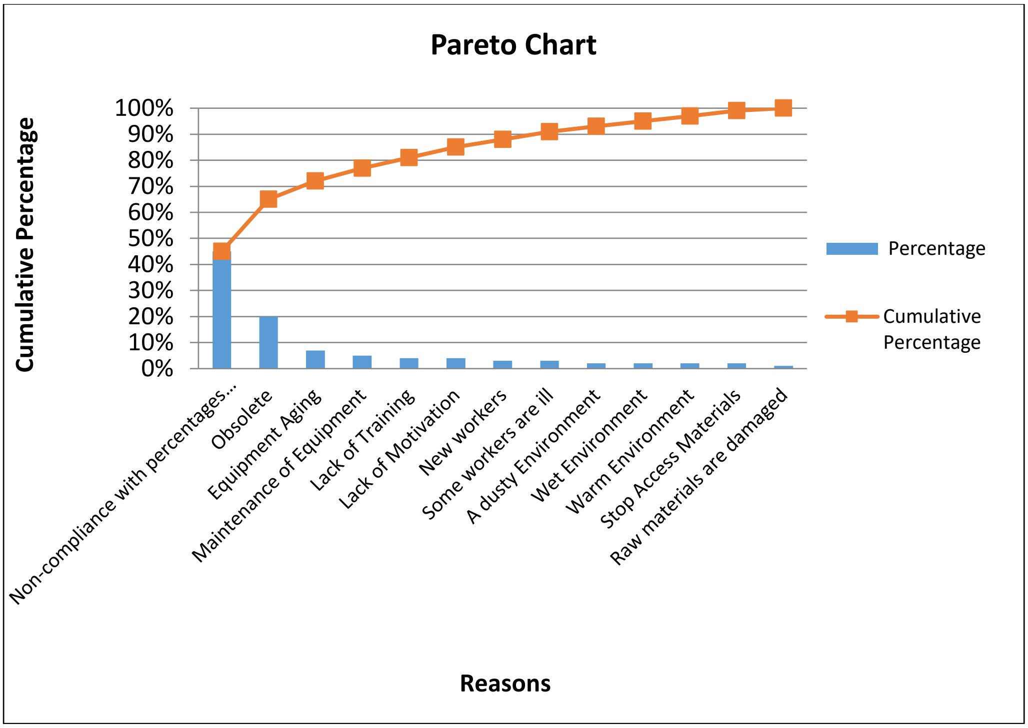


**Figure 5.** Pareto Chart shows the percentages of the causes of the problem

**Table 8**. Percentages of causes of the problem

| Total main cause ratios | Percentage | Sub-reason | The main reason |
|---|---|---|---|
| 14% | 3% | New workers | Workers |
| | 4% | Lack of training | |
| | 4% | Lack of motivation | |
| | 3% | Some workers are ill | |
| 6% | 2% | Dusty | Environment |
| | 2% | Wet | |
| | 2% | Hot | |
| 25% | 20% | Obsolete | Equipment |
| | 5% | Maintenance | |
| 52% | 7% | An old | Methods and procedures |
| | 45% | Non-compliance with the exact proportions of raw materials | |
| 3% | 2% | Access stopped | Materials |
| | 1% | Defective | |

From the above table, we operate the Pareto chart as in the Excel program, which shows the highest percentage of the problem to be lack of commitment to the exact proportions of raw materials entered in the interaction. This is due to the company's non-use of standards to control the input quantities of $NH_3$ and $CO_2$.This is followed by the predetermined ratios of the interaction, the equipment aging factor and the use of modern equipment and advanced technology - which had the most influence.

And through the study of the researcher in the company's affairs, and interviews with the engineers and managers of production, the main reason for the deviation of the concentration of urea is found to be the operational conditions of the reactor, specifically, high temperature and pressure. The reaction needs high pressure and low temperatures, and these conditions are affected by the percentage process input of $NH_3$ ($NH_3$, $CO_2$ carbon dioxide), the molecular ratios of ammonia to carbon dioxide 3:1, and the control of the amount of $NH_3$ and $CO_2$ entering the reaction.

The second problem is the length of the delivery period. By examining the value stream map (VSM) painted at the measurement stage in Figure 3. The total amount of delivery time is 53 hours and 2 minutes, while the time that adds value is 5 hours and 46 minutes. The value stream map (VSM) shows that there are activities that do not add value that if deleted could reduce the delivery period and costs. This includes the store that causes damage to the final product due to lack of correct procedures for proper storage, which could cause damage to the inventory (due to exposure to an inappropriate atmosphere in the form of dust and moisture). If we delete the waiting times between the stages, the delivery time is reduced from 24 hours to 2 hours. The time accounted for was spent in loading from the store to the packing units via Bucklin, which puts it on the conveyor belt for packing. The delivery time becomes 30 hours and 36 minutes, instead of 53 hours and 2 minutes, with the amount of time that adds value is being 5 hours and 36 minutes if the storage phase is deleted, with the phase taking 10 minutes. If the final product goes immediately to loading, wastage of time is eliminated by 22 hours and 26 minutes. Since the cost of the pre-extracted minute is equal to 685,469 ID, if we multiply it with the minutes of the time it was subtracted to extract the amount of costs to be reduced; deleted time = (22 * 60) + 26 = 1346 minutes, then the amount of reduction in costs would be = 1346 * 685,469 = 922,641,274 ID.

Stage 4: Improve

After identifying and defining the main problems in the company and defining the company's Sigma level (3.1), the improvement phase begins, in order to know the effect of applying the LSS methodology on improving the performance of the process.

H1a: Using a DMAIC for LSS methodology leads to improved quality.

In order to validate this hypothesis, the impact of the Sigma upgrade in the company is recognized on the performance of the process. It can be said that raising the Sigma level in the company will reduce the quantity of defects. For example, to reach the level of 5Sigma, in ton per million, for each opportunity of 0.000233, and assuming the stability of costs and applying the equation below, the amount of defects in the company becomes;

Defects per opportunity = Quantity of defects/ Production quantity * Number of defects = 0.0952351

0.000233 = X/235350 * 3

X= 165 ton (defects) equating to 0.07%, with 99.93% accuracy in the performance of operations and this proves the validity of the above hypothesis.

The second sub-hypothesis is:

H1b: Using the DMAIC (LSS) methodology reduces costs.

We validate this hypothesis by knowing the amount of costs decreases due to the low product cost and associated costs of quality. The amount of good production at this level is as follows:

Production corresponding to the specifications for the year 2016 = 235350 - 165 = 235185 tons/year, the reduction in defective production is accompanied by a reduction in the fixed costs per ton that is distributed over a larger quantity of production. Also, the cost of quality, and the costs are also be reduced by reducing the delivery time (this is addressed later). This proves the above hypothesis.

H1c: Using the DMAIC (LSS) method leads to increased productivity.

To verify the validity of this hypothesis productivity of the company when they reach this level is determined, and after processing the data in the software designed in Excel, following table showing contains the new productivity levels obtained.

**Table 9.** Data and results of productivity based on 5Sigma

| Productivity | Productivity types | Value in ID | Details |
|---|---|---|---|
| 2.95 | Total productivity | 233169525000 | Output |
| | Parietal productivity | | Input |
| 11.41 | Raw materials productivity | 20,439,520,000 | Raw materials |
| 3.99 | Wages & salaries of workers' productivity | 58,375,305,000 | Wages & salaries |
| 876.23 | Expenses productivity | 266,105,000 | Expenses |
| | Multi-factor productivity | | |
| 2.96 | Productivity (raw materials, salaries and wages) | | |
| 11.26 | Productivity (raw materials, wage & salaries) | | |
| 3.98 | Productivity (salaries, wages, expenses) | | |

The above table shows the increase in three types of productivity, when reaching the level of (5Sigma) - total, partial or multi-factor - and this increase is due to the decline in the defective production, which leads to increased quantities of good production, and increased output with input stability and this confirms the validity of the sub-hypothesis above. Table 10 shows the comparison between the three types of productivity in the two levels.

**Table 10**. Comparison between productivity in two levels

| Productivity at level (5Sigma) | Productivity at level (2.8 Sigma) | Productivity types |
|---|---|---|
| 1.34 | 0.95 | Total productivity |
| Parietal productivity | | |
| 5.18 | 3.7 | Productivity (raw materials |
| 1.81 | 1.3 | Productivity of employee wages & salaries |
| 397.71 | 284.28 | Expenses productivity |
| Multi-factor productivity | | |
| 1.34 | 0.96 | Productivity (raw materials, salaries and wages) |
| 5.11 | 3.65 | Productivity (raw materials, expenses) |
| 1.80 | 1.29 | Productivity (salaries, wages, expenses) |

H1d: The use of the DMAIC in LSS method leads to increased speed.

This sub-hypothesis, which is related to delivery time, is validated by the result that time is reduced from 53 hours and 2 minutes to 30 hours 36 minutes in producing 132 tons, with a reduction of time of 22 hours and 26 minutes. This was possible by removing some activities that do not add value, as well as deleting the storage phase directly sequencing the production from granulation to packing. In case of product marketing, conveying through conveyor belts to load cars or train carts directly does not only eliminate waste

but also consequences of storage mentioned in the analysis phase, which ensures the survival of the product, keeping it intact without damage. This also reduces the time of receipt of the product, and this supports the validity of the above hypothesis. The reduction in costs associated with the reduction of waste is 922,641,274 ID. This reduces costs in two ways: improving quality and increasing production speed. Figure 6 depicts the map of the new value stream after deletion of waste.

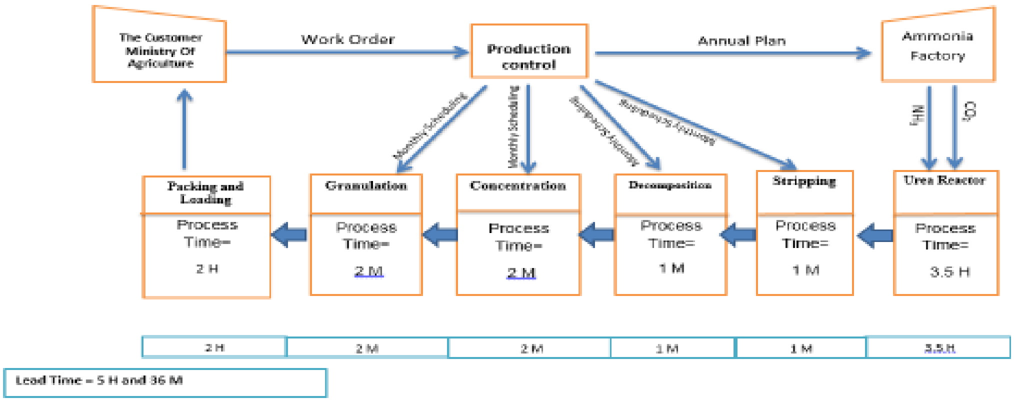


**Figure 6**. Value Stream Map (VSM) for the Urea Factory

In terms of revenue, costs and profits, when applying the LSS methodology and the 5Sigma level and reducing waste through the lean tools, which are present in the DMAIC model, and by reducing costs as a result of the deletion of activities that do not add value, the result can be presented as follows:

Cost at 5Sigma = Cost at 2.8 Sigma - Cost reduction = 82,914,275,700 - 922,641,274= 81,991,634,426 ID

Revenue at (5Sigma) = 105,833,250,000 ID

Profit at (5Sigma) = 105,833,250,000 - 81,991,634,426 = 23,841,615,574 ID

Table 11 shows a comparison between costs, revenues and profits achieved at the two levels.

**Table 11.** Comparison of costs, revenues and profits at the two levels

| Level (5Sigm) ID | 2.8 )Level (Sigma Actual (verified for 2016) ID | Stat. |
|---|---|---|
| 81991634426 | 82914275700 | Costs |
| 105833250000 | 75649050000 | Revenue |
| 23841615574 | 7265225700 | Profits |

Stage 5: Control

The outstanding results of the improvement phase and its sustainability usually need to be implemented to ensure long-term effectiveness of solutions. It is therefore necessary to establish formal procedures that include activities aimed at preventing the causes of disparity and waste that may arise again. Further improvement work should be encouraged and the use of new methods in the company without returning to the mistakes made before. Also, this stage requires the tightening of the control process for control and directing the production processes to serve the objectives set and to achieve advanced levels of Sigma.

It is suggested that measurement panels are used to control the input ratios of $NH_3$ and $CO_2$ entering the urea reactor to be within the required ratios so that concentration is controlled within the upper and lower limits, and an appropriate training system is applied to serve as an invaluable tool that maintains a continuous improvement culture. This enables staff to learn skills and maintain the best practices proposed in the improvement phase and the development of methods for monitoring the production process at the reactor stage based on internal audits. It is also suggested that laboratory reporting system is used in addition to Excel macros to create daily reports and charts, reviewed by laboratory supervisors and managers on a daily basis with front-line staff.

## 5. Discussion of Findings

After examining the factory, the researchers reached numerous conclusions that helped in answering the study problems and questions and in testing and validating the proposed hypotheses. One of the main conclusions is that the first problem faced by the company is the concentration of urea in the mixture generated at the reactor stage, accounting for 80%. This is a direct cause of increased defect and deviation from product specifications. The analysis shows that the problem is due to the non-compliance to ratios. Second, the total amount of delivery time is 53 hours and 2 minutes, with the allocation of production of 132 tons. From the time, value added time is 5 hours and 46 minutes, indicating time wastage that has led to increased costs and reduced responses to requests. There is an evident different in the level of total productivity at the current level in comparison to the index following the LSS methodology implementation.

The Sigma upgrade effect is reflected in the process performance. In other words, raising the Sigma level of the company reduced the quantity of defects and decreased the product cost related and related quality cost. In relation to this, the production relating to the specifications for the year 2016 is 235350 - 165 = 23185 tons/year. The reduced defective production is coupled with reduced fixed costs per ton, distributed over a larger span of production, quality costs, with costs reduced following the reduction of delivery time. The related sub-hypothesis is related to delivery time, reducing time from 53 hours and 2 minutes to 30 hours and 36 minutes in producing 132 tons, marking a reduction of 22 hours and 26 minutes. This was achieved by deleting activities that had no added value and by deleting the storage phase, sequencing the production from granulation directly to packing. In the context of product marketing without filling, relaying the products directly through conveyer belts to cars/trains eliminates time and storage, ensuring that the product remains intact. This also reduces the time of product receipt, supporting the sub-hypothesis. Costs reduction related with waste reduction amounts to 922,641,274 ID. Reduction of costs was realized through quality improvement and increased speed of production.

## 6. Conclusion

This study aimed at determining the importance of using the LSS method in the manufacturing process in the Iraqi industrial sector companies in general and in the general company for the production of fertilizers at Basra-Khor Al-Zubai. The researchers, after studying the case of the factory, reached several conclusions that contributed to solving the problem of the study and answering its questions and hypotheses. The most important of these conclusions are the following: First, one of the main problems faced by the company is the concentration of urea in the mixture produced at the reactor stage, which accounted for 80% as a direct cause of the defect and deviation of the product from the required specifications. Through the analysis, this problem is shown to be caused mainly by non-compliance ratios, control of raw material entering the interface, as well as the obsolete equipment and lack of use of modern equipment and advanced technology.

Second, the company under study is at the stage of the reactor at the level of 3.1 Sigma, with a quantity of defects of about 36422 tons/year and the proportion of defects is 15.47% with level of accuracy of 84.53% in the performance of its operations, and the number of days deviation is 13 for one type of defect. Meanwhile, for other types of defects, Sigma (2.8) works including the urea plant at the reactor stage, with a quantity of defects 67240.8 tons/year, a defect rate of 28.58% and level of accuracy of 71.42%. Third, the total amount of delivery time is 53 hours and 2 minutes, allocated for producing 132 ton, and this was relatively long. The amount of value added time is 5 hours and 46 minutes, indicating a waste of time, which has led to increased costs and reduction in rapid response to requests.

Finally, there was a clear difference in the level of total productivity at the current level of the company compared to its index after the implementation of the LSS methodology. This is evident by the total productivity of 0.95 at 2.8 Sigma, and 1.34 at 5 Sigma level.

## 7. Implications

In accordance with the results reached within the theoretical framework as well as from the field reality of the case study, the following recommendations were made: first, the General Company for Fertilizer Industry in Basrah, Iraq, should adopt the LSS methodology, and interest should be promoted in the concept and its dissemination of theoretical thoughts and applications. Also, the possibility of use in the Iraqi manufacturing sectors should be emphasized because of their importance in reducing errors, reducing the amount of defective production, and increasing efficiency and productive efficiency. This may be observed through practical application, as the percentage of defective production at the level of 5Sigma decreased from 28.58% to 0.07%, with related revenues of 105,833,250,000 dinars, and decreased costs from 82,914,275,700 dinars to 81,991,634,426 dinars during the period of the application of LSS methodology.

Second, through the LSS application, and fully adhering to the specific timing of the production process, seeking to delete times that do not add value, including delivery time, production time is reduced from 53 hours and two minutes to 30 hours and 36 minutes, and this is accompanied by a reduction in costs by 922,641,274 ID. This reduction came through the removal of some activities that do not add value, as well as the deletion of the storage phase that negatively affects the quality of the product. Third, there is a need to work with the 5Sigma lean tools (seirri, regulation; seiton, arrangement; seiso, cleaning; seiketsn, maintenance; and shitsuke, discipline) to maintain a safe, clean and orderly working environment, and help the company to reduce waste in the production process.

Fourth, there is a need to use measurement plates to control the input ratios of NH3 and CO2 that enter the reactor to be within the required ratios. Preventive maintenance (periodic) should also be made in accordance with the schedules prepared for this purpose for machinery and equipment to ensure the continuation of the production process and the implementation of production program within the specified time frames. Finally, the company examined under this study should focus on preventing problems and crises before they occur instead of waiting for them to occur and then addressing them, to achieve the lowest possible cost of excellence and access to a competitive price without compromising on quality or service – in other words - to provide a product of quality comparable to competitors, with lower prices.

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**Safaa Mohammed Hadi Hashim**
Southern Technical University,
Management Technical College/Basrah,
Iraq
safaa.m.hadi@stu.edu.iq

**Afrah Oudah Sabeeh**
Southern Technical University,
Basrah Engineering Technical College,
Iraq
Afrah.almalki@stu.edu.iq