
THE ROLE OF GREEN PROCESS REENGINEERING IN IMPROVING THE PERFORMANCE OF TOTAL PRODUCTIVE MAINTENANCE

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Abstract

In light of the contemporary developments in all the different sciences and technological changes, and the increase in the environmental impacts of production processes, it is required of the Iraqi economic units to use modern technologies applied in the world, to keep abreast of these developments and adhere to the legislation related to environmental protection on the one hand, and to increase the efficiency and effectiveness of labor activities and techniques, and this leads to consequently reduce production costs, and providing environmentally friendly production processes at the same time, and this requires the application of modern and advanced methods and methods, and accordingly, this research came to clarify the application of one of the modern techniques in cost management, which is the technique of re-engineering green processes and its role in improving the overall performance of the economic unit in particular, and the performance of in particular Total productive maintenance, Thus, the aim of the research is to highlight that green process reengineering technology has a role in improving the performance of Total productive maintenance. To develop the Iraqi industrial sector, the sulfuric acid plant in Al-Furat Company for Chemical Industries and Pesticides was adopted as a sample for research, as it is one of the Iraqi industrial economic units seeking development and facing great and growing competition. Total production maintenance, this hypothesis has been proven by applying green process reengineering to the production processes of the research sample factory. The research reached several conclusions, the most important of which is that the application of green process reengineering technology steps contributes to reducing costs by improving the performance of

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Total productive maintenance, and helps the research sample to protect the environment, and presented a set of recommendations that contribute to the development of the research sample and environmental protection.

Keywords: green process re-engineering, performance improvement, Total productive maintenance.

1. Introduction

The successful economic units at present are the ones that keep pace with the developments in the production processes and adhere to the regulatory laws. And that its continuity in its activity requires it to reconsider its production processes in a manner consistent with environmental goals through re-engineering of its operations away from the traditional methods on which re-engineering of operations is based, To achieve a competitive advantage, based on the dimensions of high quality and low costs, in light of the increasing demand by the customer for products that do not affect the environment negatively, The content and concept of re-engineering green operations include achieving these goals, and thus achieving improvement in the performance and activities of economic units. One of these activities is Total productive maintenance. Where the research problem is represented by the low general performance of the Total productive maintenance in the research sample factory, as well as in most Iraqi factories, and to achieve the objectives of this research, it was divided into four sections, The first includes the philosophical aspect of Total productive maintenance, and the second deals with the cognitive aspect of green process reengineering. While the third section dealt with the practical application of it to improve the performance of Total productive maintenance, and the fourth section included the conclusions that were reached and the necessary recommendations that could help the research sample achieve its goals.

2. Methodology

2.1 Research problem

The problem of the research is the poor general performance in the Iraqi industrial sector and the lack of commitment to environmental legislation, and the re-engineering of traditional processes does not meet the contemporary requirements in terms of improving performance and applying environmental legislation.

2.2 Search target

1. Identify the philosophical concept of Total productivity maintenance, its objectives, and implementation requirements.
2. Create a cognitive concept for re-engineering green processes, the steps to apply them, and determine their role in improving the performance of (TPM).

2.3 research importance

Its importance comes from the fact that it discusses process re-engineering while meeting environmental requirements through the application of green process re-

engineering technology in the Iraqi industrial sector. As well as the use of this technology to improve the performance of Total production maintenance, especially since the research sample sulfuric acid plant produces many environmental pollutants and suffers from interruptions for maintenance purposes and its high costs.

2.4 Research Hypotheses:

The main hypothesis: is that the application of green process reengineering contributes to improving the overall productive maintenance performance.

2.5 Description of the research sample

The applied side of the research will be conducted in the sulfuric acid factory, which is one of the factories of the Al Furat General Company for Chemical Industries and Pesticides, which is one of the companies of the Iraqi Ministry of Industry and Minerals.

In this aspect, we will discuss the application of green process re-engineering technology on the technological path of production processes in the research sample factory, which contributes to improving the efficiency and effectiveness of the performance of Total production maintenance.

3 The concept of Total Productive Maintenance

There was a great deal of literature that mentioned the concept and definition of (TPM), and several concepts emerged, according to the point of view of each researcher and his intellectual roots. Table (1) will review the most important of these concepts.

Table 1 (TPM Concepts)

NO.	Author	year	page	definition
1	Ahuja & Khamba	2008a	715	An innovative method that increases equipment efficiency, eliminates breakdowns, and facilitates operator-independent maintenance through routine activities involving the entire workforce.
2	M.Y	2012	4	It is part of the overall development of maintenance management and plays an important role in maintaining assets in good condition to further improve manufacturing performance.
3	Maran et al.	2016	40	It is a combination of total employee involvement and the Japanese ideology of TQM and American Preventive Maintenance.
4	Al-Mansur	2020	33	It is an integrated system to achieve maximum gains in production capacity and focuses on increasing the effectiveness of

				equipment in general and the participation of workers to improve the performance of machines and the ability to perform their functions in a way that does not disrupt production.
5	Abdul Ali	2021	35	It is a systematic approach to better manage and maintain equipment and carry out maintenance work using the principle of involving all employees from top management to middle management and executive management.
6	Kumar	2021	5	It is a culture that focuses on improving efficiency by enabling people to keep all machines in good condition for the longest possible period of their useful life. TPM is also called the medical science of machines.

Despite the diversity of concepts presented by writers and researchers to convey the concept of Total production maintenance, it does not go beyond being a strategy through which integration is achieved between machines, equipment, workers, and supporting processes to maintain and improve production quality and safety of systems, with a focus on involving all workers in the economic unit to achieve Maximizing the overall effectiveness of machinery and equipment to achieve the optimal cost for the life cycle of production equipment.

3.1 Objectives of Total Productive Maintenance (TPM)

That (TPM) seeks to achieve a set of objectives that move away from the traditional perspective of maintaining production equipment, as its objectives are linked with the strategic objectives of the economic unit, among these goals is that it seeks to achieve efficiency throughout the production system, and also aims to improve the efficiency and effectiveness of manufacturing units as a whole. In other words, the goal of Total productive maintenance (TPM) is to achieve zero-loss performance (Prabowo et al., 2018:13-14), eliminate internal failures in production processes, and improve the system by eliminating losses and waste (da Silva & de Souza, 2020, 289).

It provides solutions that achieve a reduction in costs related to maintenance itself by reducing the ineffective use of resources involved in production and the cost of labor in maintenance, as well as the delay in identifying faults and problems (Fadel, 2020: 108), And it seeks to reduce the total costs of production borne by the economic unit, as well as reduce or eliminate losses related to the environment (Al-Hashlamoun, 2017: 21), It seeks to create an environment that achieves a reduction in the various costs related to manufacturing, labor and energy (Alorom, 2015:38). The goals (TPM) revolve around

improving and developing the performance of economic units in all respects by reducing maintenance costs and reducing time costs and thus achieving the highest return through its endeavor to maintain equipment and improve its effectiveness and the involvement of maintenance workers or improving their culture by focusing on continuous improvement of all activities and operations Economic unit.

3.2 Requirements for adopting total productive maintenance

Most writers and researchers agreed that (TPM) includes a set of basic requirements or pillars (Charantimath, 2011:435), (Adesta et al., 2018:2), (Zlatić, 2019:584), (Luthra et al., 2020:156), (Jana & Tiwari, 2021:357), (Al -Refaie et al., 2022: 1500). There are eight basic pillars on which total productive maintenance is based. These pillars are based on the organization of the work site (5S), and these pillars are:

3.2.1 Autonomous Maintenance (AM)

Levitt, (2010:51) determines the goal of (AM) is to find a rapprochement between the worker and the equipment, and that this convergence leads to early detection of faults, and (Charantimath, 2011:435) considered this pillar directed towards developing workers to be able to take care of small maintenance tasks, thus freeing up experienced maintenance personnel to spend time on more value-adding activities and technical repairs. That Autonomous Maintenance as an idea came from (Jishu Hozen) is a Japanese term that means independence in judgment or mind, and it is similar to what the worker does in terms of taking care of the equipment that he uses or himself, and he constantly monitors the performance of the equipment and maintains its cleanliness and performance (Al-Mansour, 2020: 38), (Khan et al., 2020:8-9) indicates that the predominant goal of (AM) is to reduce system downtime and maintenance costs, which is achieved by achieving the following objectives:

- Understand the functions (components) of the system and discover the causes of failures.
- Identify potential quality issues and identify their root causes.
- Timely detection of problems and self-solution.

3.2.2 Continuous improvement

KAIZEN is a Japanese word made up of two syllables: “Kai” meaning change, and “Zen” meaning good or better. Kaizen is all about striving for small improvements that are implemented continuously, which consists of people across each level of the hierarchy of economic units (Parikh & Mahamuni, 2015:127), According to (Mazzocato et al., 2016:2) the Kaizen principle relates to striving for perfection through the continuous involvement of workers in practices that enable them to incrementally propose ideas for improvement, solve problems, and maintain results over time. Kaizen can be defined as an organized project that is implemented by a multidisciplinary team with the aim of improving a targeted area or work within a specific time frame (Bortolotti, 2018:2). According to (Rusdiana & Soediantono, 2022:43) the motto of Kaizen is “to preserve and

motivate the human resources of the economic unit as much as possible, to encourage them to continue participating in Kaizen activities". Where the application of Kaizen in the economic unit requires the cooperation of various parties, from the level of senior management to the level of basic workers.

There are advantages to applying (KAIZEN) in economic units as follows: (Goyal et al., 2019:102).

1. Increase productivity.
2. Cost reduction
3. Quality improvement.
4. Optimal use of resources.
5. Better communication between management and employees.
6. Improving workers' morale.

3.2.3 Planned maintenance

The purpose of the (PM) pillar is to detect faults early by working to provide spare parts, maintenance tools, and the rest of the parts that help in carrying out maintenance, even electronic ones, to reduce the time for searching for the information required to identify faults and repair them (Al-Mansour, 2020: 39), Alesia, (2021:56) has specified that the goal of (PM) is to provide a guarantee that machines and equipment will operate more efficiently while achieving a reduction in traditional maintenance costs and bringing machines and equipment to an optimal level of operation in light of the compatibility of preventive and corrective maintenance added by total Productive Maintenance.

3.2.4The quality of maintenance

The goal of quality management is to develop a set of plans and procedures that prevent internal failure due to machinery and equipment to reach the ideal state for the purpose of maintaining the ideal quality of products (Venkutesh, 2007: 14). Quality maintenance is implemented in two stages: the first stage is to eliminate problems related to the quality of processes and products by analyzing the internal failure of quality and working to find and determine the optimal conditions that prevent the occurrence of that failure, With a focus on continuous improvement processes, as for the second stage, it ensures the maintenance of quality by standardizing standards, methods and methods to achieve a flawless system and matching designs and plans related to processes and products (Singh et al., 2013: 2011-2012), And that there is an essential link between quality and maintenance, without machines and equipment that are properly cared for and maintained, there is no quality in product specifications, Accordingly, (Alesia, 2021:56) described quality management as (TPM), and added that according to the Japanese Institute for Factory Maintenance (JIPM), QM creates conditions that help prevent product defects and continuous control of conditions to achieve zero defects (Al-Mansour, 2020:39).

3.2.5 Training and education (TE)

And that the behavior of workers is influenced by education and training programs, which is a very important factor for the successful implementation of comprehensive productive maintenance (Graisa, 2011:63). Training is defined as an ongoing process that is constantly reviewed and modified to take into account changing circumstances, past experience, and new developments (Dadzie, 2019:96). As long as (TPM) works to improve the performance of machines, reduce their breakdowns, improve working conditions and procedures, and encourage full participation of management and workers, it requires continuous improvement and training commitments (Dadzie, 2019:97), If the trainer is from within the economic unit, this leads to strengthening the relationship between individuals and cooperation between them, while (Al-Refaie et al., 2022:1501) mentions that (TE) includes:

- Training of personnel on the principles of maintenance.
- Training of personnel to operate and maintain the equipment.
- Increase awareness of the concept of teamwork and the foundations of continuous improvement.
- Enables workers to carry out simple maintenance tasks.

3.2.6 Development management

The issues addressed in this pillar are enhancing the skills of workers to reach the minimum level of problems and work in a timely manner (Ahuja & Khamba, 2008a: 722), while (Singh et al., 2013: 2012) determined that (DM) consists of two parts: Early equipment management and early product management, and (Parikh & Mahamuni, 2015:128) states that (DM) aims to benefit from previous learning in developing maintenance practices for new systems, by reducing problems that occurred in the current system to avoid recurrence in the new system, And he adds (Zlatić, 2019: 586). That (DM) aims to reduce the time required to start up new equipment, and (Alesia, 2021:56) indicated that this pillar is also called preventing maintenance or early management.

3.2.7 Safety, health, and the environment (SHE)

SHE activities aim to effectively eliminate the root causes of incidents that have occurred, to prevent their recurrence, and proactively reduce the risk of potential future incidents by targeting near misses and potential risks (Singh et al., 2013:2012), Jain et al., (2014:17) shows that safety is a very important factor in economic unity, and (SHE) plays an active role in each of the other pillars on a regular basis, while (Adesta et al., 2018:2) describes (SHE) on It provides an ideal work environment free of accidents and injuries, helps eliminate abnormal conditions, and seeks to maintain the health of the workforce. Zlatić, (2019: 586) stated that the goals of (SHE) are clear, which are to achieve zero accidents, zero injuries, and zero fires. So (SHE) is already included in all other substrates. This pillar requires each economic unit to form a separate safety

department and should be able as soon as possible to prevent any injuries, and to carry out safety awareness work, by organizing slogans, posters, etc. at regular intervals (Kachhadiya, 2020:3296).

3.2.8 Total Productive Maintenance Office

(Office TPM) should be started after activating four other pillars (AM, Kaizen, QM, PM), and if these pillars are not implemented, (Office TPM) cannot be implemented (Ahmed et al., 2010:189), and he also adds (Singh et al., 2013:598) requires the implementation of Office TPM to improve the productivity and efficiency of administrative functions, including analysis of processes and procedures that can be automated. The (Office TPM) has multiple benefits represented by involving all workers with support functions to implement the (TPM) and focusing on improving unit performance, reducing repetitive work, reducing administrative costs, reducing inventory costs, and reducing customer complaints (Al-Mansour, 2020: 44). (Office TPM) can be adopted and applied in the operational sectors, not only in the maintenance of equipment, but as well as in administrative-organizational work, and the basic idea includes eliminating losses, improving productivity, and stimulating efficiency in administrative functions. Thus, the process involves processes and procedures to reduce or completely eliminate issues and losses in administrative work in administrative positions (Alesia, 2021:57).

3.2.9 Organizing the work site

This concept was developed by Osada in the early 1980s, and has been widely practiced in many Japanese economic units. And that (5S) contributes to maximizing efficiency and effectiveness, and the application of (5S) can reveal hidden problems that remain unnoticed, and that (5S) means five Japanese words (Naik et al., 2015: 1217-1218), and the table shows (2) These components to organize the work site.

Table 2 Components (5S)

Japanese term	Seiri 1	Seiton 2	Seiso 3	Seiketsu 4	Shitsuke 5
English translation	Organization	arrangement	cleaning	profiling	discipline

Source: Fadel, Ahmed Maher M. (2020). *The role of achievement accounting in light of the accelerated manufacturing strategy to reduce product costs.* (PhD thesis). Accounting Department, College of Administration and Economics, University of Baghdad.

That (TPM) cannot work without applying formal and functional pillars, and that one of the problems facing the implementation of (TPM) is the implementation of the concept of organizing the work site (5S) and ensuring its stability for the pillars of (TPM) (Pačaiová & Ižaríková, 2019:52), And that the eight pillars or requirements of total productive maintenance (TPM) are based on a basic rule represented in the organization of the work site known as (5S), which is the cornerstone and foundation for the implementation of (TPM) (Fadel, 2020: 91), As for (Al-Mansour, 2020: 41), it indicates that the organization of the work site (5S) is the continuous improvement tools

(KAIZEN), and it is applied in production sites and administrative areas, and indicates (Jana & Tiwari, 2021: 357). KAIZEN's approach focuses on eliminating waste, reducing defects, increasing efficiency, and enhancing flexibility in production processes.

When applying the elements of (S5), the economic unit can achieve multiple benefits, including obtaining a cleaner and safer workplace and better organization of the work site, which enhances the efficiency of workers and their participation in creating an ideal work environment and thus increasing productivity, and creating an environment or foundation that helps implement the pillars and pillars of total productive maintenance.

The implementation of (TPM) is a very complex task, since its main pillars are not compatible with all units in general, and the implementation and its level of success varies from one economic unit to another. Which requires following certain methods and procedures to improve the performance of its activities in particular, and the general performance of the economic unit in general, coupled with this improvement by adhering to the regulatory legislation related to environmental protection and preservation, and among the techniques that help to achieve this is the technology of re-engineering green processes.

4. The concept of green process reengineering

The term green process reengineering (GPRE) is a neologism to describe the application of process reengineering (P-RE) concepts coupled with a contemporary performance measure of environmental impact (Schatzberg et al., 1997:1), Like all reengineering efforts, Green Reengineering (GPRE) initiatives challenge core organizational values and culture by transforming operations, Green Process Reengineering (GPRE) is fundamentally improving the operations of an economic unit from environmental aspects, Hence, the community and the natural environment surrounding the economic unit became a category of high value (Speshock, 2010:85). Table (3) shows some of the most important concepts of (GPRE).

Table 3 GPRE Concepts

No.	Author	year	page	
1	Speshock	2010	86	It is a type of process re-engineering that radically changes the core and support of operations to achieve significant improvements in the environmental sustainability goals of economic units.
2	Kranzlmüller & Tjoa	2011	151	It is an expansion of the re-engineering of traditional processes by following contemporary methods that adequately meet green requirements for efficient use of resources and overall improvement of the environmental impact of economic units.

3	Nowak et al., 2011	190	An approach that includes a set of independent actions to fundamentally and comprehensively redesign the operations of the economic unit, infrastructure and organization to create a clean and energy-efficient ecosystem.
4	Funk et al., 2013	146	It is the application of process re-engineering concepts taking into consideration the environmental impact, by redesigning and improving manufacturing, packaging and distribution processes, to become more sensitive to the natural environment.
5	Maciel, J. C. 2017	1529	It is a system that provides appropriate concepts, methods and tools to support process modeling, implementation, monitoring and continuous change, taking into account the environmental impact of the operations of the economic unit.

GPRE provides a new way to look at how to improve operations to increase efficiency and effectiveness, in addition to helping to reduce negative environmental impacts while improving performance as the goal of any economic unit should always be to achieve maximum productivity while minimizing its environmental impact or becoming “green”. Green Process Reengineering (GPRE) is a system or technology to improve the overall environmental impact of an economic unit by redesigning its operations, more specifically to reduce waste and pollution, achieve optimal use of energy and resources, and achieve compliance with governmental and regulatory requirements.

4.1 Green Process Reengineering Steps

Similar to traditional process reengineering, the success of Green Process Reengineering (GPR) relies heavily on a step-based, performance-driven approach applied to the entire economic unit (Unhelkar, 2016:157), so Green Process Reengineering (GPRE) For its success and achieving its goals, a set of steps must be followed, namely:

4.1.1 Examination of processes with green process characteristics

This step focuses on verifying processes and their compliance with the basic green characteristics. Here, a full set of processes is checked and validated using the five characteristics of green processes (Necessary, Efficient, Effective, Flexible, and Measurable).

- Necessary: Operations are necessary when they add value, create value for the economic unit, and meet the legislative and regulatory requirements for environmental protection. Non-essential operations are those that do not add value and do not comply with environmental protection legislation.

- **Efficiency:** This characteristic represents the implementation of operations in the best and most appropriate way, with the best tools, techniques, and personnel, with the aim of reducing pollution from operations by improving or eliminating the activities that cause it.
- **Efficiency:** This feature focuses on verifying the validity of operations to ensure that they achieve the objectives that they are supposed to achieve, and that ineffective operations do not achieve business objectives and cause environmental pollution and energy waste.
- **Flexibility:** This characteristic is the ability of operations to change in response to and depending on the conditions they are going through and required by the environment surrounding the operations, whether they are external or internal requirements. This feature makes operations green because they will easily change in response to and in compliance with governmental and legislative requirements for the environment.
- **Measurable:** This feature focuses on the ability to monitor, control, verify and verify the success of operations, the impact of these operations on the environment, and the extent to which environmental pollution is reduced.

In this step, all processes are tested and only those that meet the green process characteristics dimensions are transferred to the next step, Operations that do not pass the test will be reported to the executive officer of the economic unit for review. (Lan, 2011:4).

4.1.2 Integration of product-related processes with environmental dimensions

This step focuses on the integration of the economic unit's operations with the environmental requirements and dimensions. It is considered a complex stage because it does not only require a comprehensive and insightful understanding of the operations and how it helps the economic unit to compete and achieve its objectives. But also, the involvement of environmental dimensions with each activity in the operations, and here appropriate methodologies should be developed to understand the amount of pollution that is generated through the activities, and issues and challenges will be identified in obtaining measures that reduce emissions (Ganesh, 2012: 5), this step includes two elements: (Lan, 2011: 5).

The first: dividing each process into different activities: by sequencing, the work flows from the starting point of the process to the endpoint.

Second: the application of environmental dimensions. The activities will be implemented through developing a program that matches and harmonizes the environmental specifications and dimensions.

4.1.3 Re-Engineering "Green" Processes.

It includes a comprehensive analysis of operations, whereby the activities of each process are analyzed into smaller elements to determine the environmental impact of the activities that make up the operations, the energy intensity and pollution generated for each activity, the importance of this activity, and the extent to which it contributes to the achievement of efficiency in the course of the process. With the possibility of adjusting, it to reach a low concentration of pollution, and developing alternative process designs, (Ganesh, 2012:6), the workflow for each process is also checked against the required resources and time, and thus the outputs of the process analysis will be used to develop alternative “green” processes, while reducing emissions (Unhelkar, 2016:157). This step faces a challenge in that there is difficulty in re-designing or restructuring some operations due to their nature or due to other internal constraints. This is on the one hand, and on the other hand, the challenge is to find an appropriate solution to compensate for the environmental impact without changing the process. (Nowak et al., 2011c:4).

4.1.4 Develop training programs and change management

This step focuses on developing and implementing training programs for workers with the aim of managing change. After completing the redesign of operations to comply with green specifications, the economic unit will have to start dealing with change and preparing training programs (Lan, 2011:8). Green training programs provide the development of employees and skills to gain access to the knowledge needed to redesign green operations. Participants acquire basic skills and knowledge in green operations and continue to implement the training program (Hashmi & Choudhury, 2020:503). Communication is one of the basic processes for skill development, knowledge transfer, and organizational improvement is supportive (Ray, 2011:227), and it is at the core of the organizational change management process for any effective management (Madhukar, 2017: 423). The other essential element that should be taken into account in the change management phase is measuring the effectiveness of communications and encouraging a culture of knowledge exchange within the economic unit. Effective communication provides a common platform for all stakeholders to exchange information and knowledge and more efficient and effective cooperation between the departments of the economic unit (Unhelkar, 2016:158).

4.1.5 Performance Monitoring and Process Improvement

This step emphasizes performance monitoring and continuous improvement of operations by updating related services and facilities (Maciel, 2017:1530), and this step is done in two aspects: (Lan, 2011:8).

1. The emissions measurement for each green process is recorded on a regular basis to ensure that the reading is similar to the initial measurement after the green process redesign phase, this is to verify that the redesigned processes are being implemented according to specifications.

2. Evaluate and introduce new equipment and devices to achieve operations objectives while minimizing emissions.

A formal performance reporting mechanism should be established to maintain continuous improvement to reduce emissions from the operations carried out by the economic units (Ganesh, 2012:9).

The two phases of this framework are categorized under the “strategy” step of the Green Operations Framework, and all processes are taken into consideration for examination, Only the selected processes are moved forward to the third and fourth phases, which represent the 'design' and 'implementation' steps of the green process framework respectively, After all processes have been redesigned they are ready for implementation, and the performance is monitored in the fifth step which refers to the “operational” step of the green process reengineering framework (Lan, 2011:1).

The re-engineering of green operations reflects the environmental responsibility of the economic units, and that one of the effective methods to make the operations more environmentally friendly is the re-engineering of operations with a focus on the green perspective. Green Process Reengineering (GPRE) is a process that helps economic units to modernize their operations and meet environmental requirements to reduce harmful emissions from their operations, while ensuring the continuity of products for their customers, improving quality, reducing costs, and improving the speed and accuracy of operations. The concept of Green Process Reengineering (GPRE) works first by evaluating existing processes and their compliance with green process specifications and then using a variety of methods to improve the efficiency and effectiveness of operations in environmental aspects, and (GPRE) benefits the economic unit by reducing pollution, reducing waste, conserving energy, and reducing or eliminating wasteful and harmful practices.

4.2 Application of green process re-engineering technology in the research sample factory

The production process in the sulfuric acid plant requires a research sample with a set of stages that reflect the technological path of the production processes as follows:

The first stage: the melting unit. This unit specializes in dissolving sulfur as a raw material, which is supplied to the factory by the Iraqi Ministry of Oil (extracted from toxic gases associated with oil extraction in Iraqi fields), By using steam at a temperature of (100 -140) degrees Celsius, produced in the contact unit, and at the end of this stage, we get liquid sulfur whose chemical symbol is (S).

The second stage: the burning unit. This unit converts the liquid sulfur produced from the dissolution unit into a gas by adding oxygen (O₂) and at a temperature of (800) Celsius. generated in this unit to the dissolving unit.

Third stage: chemical contact unit. The contact unit is characterized by containing vanadium pentoxide (V₂O₅). As an auxiliary material that aids interaction and does not interfere with it, it is called by the employees of the production department (Al-fraash),

as it is spread in this unit, in this unit, sulfur dioxide (SO_2) is converted into sulfur trioxide (SO_3). Also, in this unit, the heat generated from the chemical reaction is transferred to the melting and burning units, and this contributes to reducing energy consumption and associated costs, thus reducing the environmental impact of these stages. But at this stage, sulfur dioxide (SO_2) is volatilized, which is a colorless toxic gas with a very pungent and unpleasant odor that is harmful to the environment. The product of the chemical reaction in this stage is converted to sulfur trioxide (SO_3) to the next stage, which is the absorption unit.

The fourth stage: the absorption unit. The task of this unit is to spray liquid sulfuric acid (H_2SO_4) with a concentration of (98%) by means of special sprayers on sulfur trioxide (SO_3), repeatedly to obtain fuming sulfuric acid (H_2SO_7), to be transferred to the neutralization unit.

The fifth stage: the equation unit. In this unit, water (H_2O) is added to reduce the concentration of sulfuric acid to (98%), which is the standard ratio for this concentrated sulfuric acid product (H_2SO_4). Here, a product is finished and sent to storage tanks and then sold.

The sixth stage: the filtration unit. From the previous operations, in the chemical contact unit, sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are volatilized into the atmosphere, which are toxic and polluting gases to the environment. For the purpose of disposal, it is drawn to the filter tower, where it is sprayed with a solution of sodium hydroxide (NaOH). Sodium hydroxide solution is a dissolving solution diluted with water. It is an alkaline solution, Sodium Hydroxide dissolves easily in water with intense heat, and concentrated Sodium Hydroxide (NaOH) solutions affect the skin in a very corrosive way, Likewise, dilute solutions of it affect the cornea of the eye severely, leading to blindness. It helps to corrode metals such as iron, as it is kept in clean glass bottles, covered with a rubber stopper, and then collected at the bottom of the filter towers in the form of sediment and then sent to the sediment treatment unit.

Seventh stage: sediment treatment unit. In this unit, the sediment transferred from the filtration unit is treated, where the light material in this unit is added to the sediment to neutralize it, and then it is disposed of, by throwing it into the sewers.

4.3 Requirements for the implementation of comprehensive production maintenance in the sulfuric acid plant

The sulfuric acid plant provides the necessary requirements to achieve the objectives of (TPM) and its eight pillars, which aim to maintain production equipment and machinery in good condition and sustain their work. Although the factory is more than forty years old, and in order to reach the maximum level of effectiveness and efficiency, and along the life cycle of machines with an impact on productivity and quality and within the material and human energies available in the research sample factory, Table (4) shows the human energy of the relevant departments and divisions in the implementation of total productive maintenance.

Table 3 Human capacity to implement (TPM)

No.	Maintenance Type	number of engineers	Number of employees	total summation
1	mechanical	1	12	13
2	electrical	1	6	7
3	workshops	1	12	13
Total		3	30	33

The percentage of maintenance workers represents (25.4%) of the total workers in the factory, which are (130 workers). As for the tasks performed by the workers in the production department and the maintenance department, and for the purpose of fulfilling the maintenance requirements in the production department, and through interviews and field coexistence with workers and engineers in the concentrated sulfuric acid production department, we found that the sulfuric acid factory, the research sample, is in constant and almost daily war with corrosion, as the equipment The machines work in an acidic medium, and their production is sulfuric acid, which is known to dissolve the hardest and hardest metals.

And that the production workers mobilize their efforts and devise ways to maintain and sustain their production equipment. We found that the workers use stone bricks and change them constantly to reduce the effect of acid on the equipment and to extend its productive life to the maximum possible period. In addition to the use of metals for nuts and bolts in the equipment by the Maintenance Division, which reduces the effect of acid on the equipment and reduces its corrosion. These materials are metal (stainless steel 316), stainless steel, and cast iron with certain specifications (alloy 20).

As for the maintenance department, and to fulfill the requirements of comprehensive production maintenance, it performs the following procedures:

1. Preparing and implementing plans for maintenance operations, and carrying out oversight procedures on these plans, to verify the effectiveness of maintenance operations in terms of the use of human, financial and time resources, and to maintain the continuity of the production process and production flow.
2. Supervising the electrical and mechanical contracts concluded with internal and external parties, monitoring the implementation of those contracts and conducting technical checks during and after implementation.
3. Develop periodic plans to manage maintenance operations, and provide studies and proposals that aim to achieve smooth flow of product without interruption or breakdowns.

4. Preparing and developing training and educational programs, in coordination with the training department in the company, to improve the ability of workers to carry out production and maintenance operations, which contributes to making workers multi-skilled and experienced, and this reflects positively on the effectiveness of all operations and tasks assigned to them.

Accordingly, we find that the sulfuric acid plant, the research sample, provides the requirements for implementing total production maintenance (TPM), and that it is implemented, but in an informal and non-comprehensive manner, as the procedures were taken by workers in the maintenance and production departments and their handling of problems that may limit the factory’s ability to continue production without stopping equipment, Improving the overall efficiency and effectiveness of the equipment, reducing breakdowns and accidents, reducing downtime for maintenance, reducing maintenance costs, and maintaining the level of production capacity.

4.4 Green process reengineering steps to improve performance

Implementation of green process re-engineering steps on the processes or the technological path of production processes in the sulfuric acid plant, the research sample, to improve the overall performance of the research sample, and assist it in meeting the legislative and legal requirements for protecting the environment from pollutants. Increasing the efficiency and effectiveness of performing total production maintenance and contributing to achieving its objectives. We can apply the steps of Green Process Reengineering (GPR) to the research sample operations as follows:

4.4.1 Examination of processes with green process characteristics

In this step, we examine the processes of the research sample factory and verify their validity and compliance with the characteristics of the five green processes (Necessary, efficient, effective, agile and measurable) and we convert those that do not have the characteristics of green operations only to the next step, And it is reported to the executives in the research sample factory for the purpose of reviewing it, and table (5) shows the results of testing the technological path processes for production in the research sample factory in terms of their conformity with the specifications of green operations.

Table 4 Testing factory operations for compliance with green process specifications

	Necessary	efficient	effective	agile	measurable	test result
dissolution process	✓	✓	✓	✓	✓	Matching
burn unit	✓	✓	✓	✓	✓	Matching
chemical contact unit	✓	✓	✓	x	x	not matching

absorption unit	✓	✓	✓	✓	✓	Matching
equation unit	✓	✓	✓	✓	✓	Matching
Filtration unit	✗	✗	✗	✗	✗	not matching
Sediment treatment unit	✗	✗	✗	✗	✗	not matching

Where the technological path of the production processes in the factory includes the research sample from a group of stages and processes, namely:

4.4.1.1 Dissolving unit

This unit performs the process of melting the sulfur received from the company's warehouses in a solid form and converting it into liquid sulfur and it is symbolized by the chemical symbol (S). This process is one of the necessary and basic processes in the manufacture of sulfuric acid, and this process is one of the highly effective and efficient processes where water vapor is used to generate energy in order to dissolve solid sulfur and convert it into liquid, and that this process is graceful and measurable, and through this process, no production Any substances harmful to the environment, whether liquid, solid or gaseous, so it can be considered that this process is characterized by the characteristics of green processes.

4.4.1.2 Burn unit

In this unit, the process of burning the liquid sulfur received by the dissolution unit and converting it into gaseous sulfur with the chemical symbol (SO_2) takes place. Where it is formed according to the chemical equation ($\text{S} + \text{O}_2 = \text{SO}_2$), in this process oxygen (O_2) is combined with liquid sulfur (S) to produce sulfur dioxide gas and with the help of heat coming from water vapor coming from the chemical contact unit, This process is one of the necessary processes in the manufacture of sulfuric acid, and this process is one of the highly effective and efficient processes, as water vapor is used to generate energy in order to burn liquid sulfur and convert it into gas. And that this process is measurable and agile, and through this process, there is no leakage of sulfur dioxide (SO_2) gas, as it consists of the union of oxygen with liquid sulfur without any other additions, excess or excess, and it is transported through a conveyor tube to the chemical contact unit, and accordingly it can Consider this process to have the characteristics of a green process.

4.4.1.3 Chemical contact unit

In this unit, the process of converting sulfur dioxide (SO_2) gas received from the combustion unit into sulfur trioxide, which bears the chemical symbol (SO_3), takes place. This process is carried out using vanadium pentoxide (V_2O_5) as a catalyst for converting sulfur dioxide (SO_2) into sulfur trioxide (SO_3). And that (V_2O_5) helps in the conversion

process and is not included in the gas produced from this process, and that this process is essential, necessary and important for the manufacture of sulfuric acid, and that this process is very effective and efficient. And that this reaction is a heat-emitting reaction that is used to generate energy in the rest of the technological path stages of the operations, and that this process is not measurable and is not characterized by grace, and in this process a leak of sulfur dioxide gas (SO_2) occurs, This is due to the inefficiency of the catalyst vanadium five oxide (V_2O_5) and the corrosion that occurs to the internal parts of the production equipment, which causes volatilization of sulfur dioxide gas (SO_2), which is a colorless toxic gas but has a very pungent and unpleasant odor and is very harmful to the environment. Accordingly, this process is not in conformity with the specifications of green processes and is not characterized by its characteristics, and it is required to take measures to re-engineer it by converting it to the second step of applying green process re-engineering, and informing factory officials of the search sample for them to take the necessary measures in this regard.

4.4.1.4 Absorption unit

The process of this unit is to spray liquid sulfuric acid ($\text{H}_2\text{S}_2\text{O}_4$) through special sprayers, repeatedly and not continuously. This process results in fuming sulfuric acid ($\text{H}_2\text{S}_2\text{O}_7$). It is converted into an equation unit to complete the process of making sulfuric acid. It is agile and measurable, and no environmentally harmful materials are produced because this process takes place in special ovens prepared for this purpose. And that workers in production use certain means and methods to maintain this unit, so it can be considered that this process is characterized by the characteristics of green operations.

4.4.1.5 Equation unit

The process of neutralizing millet sulfuric acid coming from the absorption unit takes place in this unit through the use of water (H_2O) to reduce the concentration of fuming sulfuric acid to a percentage of (98%). This process results in a concentrated sulfuric acid product ($\text{H}_2\text{S}_2\text{O}_4$), and the product is sent to storage tanks and then sold. This process is essential to neutralize the fuming sulfuric acid and turn it into a product that can be stored, sold and used by customers. It is characterized by effectiveness and efficiency, as only water is used in this process, and this process is agile and measurable, and through this process, no substances harmful to the environment are produced, so it can be considered that this process is a green process.

4.4.1.6 Filtration unit

The task of this unit is to carry out the process of withdrawing gases (sulfur dioxide (SO_2) and sulfur trioxide (SO_3)) from the chemical contact unit and disposing of them. It is one of the toxic and polluting gases of the environment, and after it is withdrawn, it is sprayed with a special solution, sodium hydroxide (NaOH), to form deposits from the withdrawn gases, which are collected at the bottom of the filter towers and then transferred to the sediment treatment unit. And the results of this process do not indicate its effectiveness or efficiency, as electrical energy is used to withdraw these

gases, as well as the cost of the precipitating substance sodium hydroxide solution (NaOH), In addition to its health disadvantages to the safety of workers, as well as its environmental damage, its help in corroding iron, and work stoppages for the purpose of performing maintenance, The high maintenance costs spent on this unit without any economic or return that meets the requirements of environmental protection. Accordingly, the filtering unit process cannot be considered a green process and should be re-engineered, and those responsible should be informed to take necessary action.

4.4.1.7 Sediment treatment unit

In this unit, the process of disposing of the sediment coming from the filtration unit takes place, by adding a light substance to the sediment for the purpose of neutralizing its acidity, and then these sediments that have been neutralized are routed to the drains (sewers) to complete the disposal process. This process is considered one of the unnecessary processes that do not add any value to the product, as it is unnecessary in addition to its environmental damage to the soil and groundwater. Therefore, this process is not characterized by the specifications of green processes and should be re-engineered, and the executives in the research sample should be informed of the results of this process.

4.4.2 Integration of non-conforming processes with environmental dimensions:

At this stage, the processes that do not conform to the specifications of the green processes are divided into their constituent activities, to be integrated with the environmental dimensions, and the non-conforming processes are integrated through the preparation of a program that adheres to the necessary environmental determinants and dimensions, and then working on the implementation of this program. And that the processes that do not conform to the specifications of green processes within the technological path of production processes in the sulfuric acid plant, the research sample is the chemical contact unit, The filtration unit, the sediment treatment unit, as these operations need to link their activities with the environmental dimensions, and through coexistence with the production department of the research sample factory, the non-conforming operations consist of a group of activities, As for the environmental dimensions of these operations, all green operations seek to achieve dimensions represented by reducing emissions, reducing consumption of unclean energy, and disposing of process waste in an environmentally friendly manner by recycling it or using landfills properly. Table (6) shows the processes and activities that make it up, as well as the environmental dimensions that these activities should meet or match, as follows:

Table 5 Operations activities that do not comply with green specifications and environmental dimensions

operations	activities	environmental dimensions
chemical	Vanadium pentoxide (V_2O_5)	Reducing emissions and leakage of

contact unit	Gas pullers	gases.
	Gas Disposal	Reducing the emitted heat that causes corrosion of equipment.
	Gas withdrawal	Reduce energy consumption.
Filtration unit	Add sedimentation solution	Reducing resource consumption without environmental or economic return or feasibility.
	Subtraction of sediment	
Sediment treatment unit	Sediment withdrawal	Disposal of sediments by recycling or environmentally friendly methods that do not cause any harm to the environment, whether soil, water or groundwater
	Add the light material	
	Getting rid of deposits with trowels	

After defining the activities related to the environmental processes and dimensions required of these activities, the next step is to move to the step of re-engineering the green processes to achieve the required dimensions of these processes and activities related to the technological path of the production processes in the research sample factory.

4.4.3 Re-engineering green processes

In this step, the environmental impacts of the activities that make up the operations are determined, as well as the importance of each activity of the operations and the contribution of this activity to the production processes as a whole. For the purpose of modifying the non-conforming activity or replacing it with another activity by following methods and procedures that lead to the implementation of environmental dimensions and thus lead to the conformity of operations with the specifications of green operations, i.e., re-engineering of this activity to be less harmful to the environment, As well as providing the required resources and budget for these alternative activities, and thus the processes are developed to obtain alternative green processes that are not harmful to the environment.

The activities related to non-conforming operations are represented by the activity of vanadium pentoxide (V_2O_5), According to the opinion of the production department official, this activity is the basis of the sulfuric acid production process. This activity is very basic and important, but it causes environmental effects resulting from the heat of the chemical reaction, causing the volatilization of toxic sulfur dioxide (SO_2). As well as corrosion of the internal parts of the production furnaces, which causes a halt in production, as well as an increase in maintenance periods and an increase in its costs. As well as the rest of the activities, as table (7) shows the activities and the importance and contribution of each activity to the operations as a whole and the environmental impacts associated with them, as follows:

Table 7 the importance of operations activities that do not conform to green operations

activities	its importance	environmental effects of the activity
Vanadium Pentoxide (V_2O_5) brushes	Very basic and important	Gas volatilization and corrosion of equipment
Gas pullers	very important	Gas volatilization
Gas disposal	very important	Gas volatilization
Gas withdrawal	very important	Gas volatilization
Add sedimentation solution	Important	Production of toxic substances and gas volatilization
Subtraction of sediment	Important	Environmental pollution and corrosion of equipment
Sediment withdrawal	Important	Environmental Pollution
Add the light material	Important	Environmental Pollution
Getting rid of deposits with trowels	Important	Soil and groundwater pollution

Therefore, it is necessary to re-engineer these activities in order to improve the factory operations to match the specifications of green operations, and according to our knowledge of modern production methods for the production of sulfuric acid through the Internet sites, as well as what was confirmed by the director of the production department in the factory, there is a method that can reduce the environmental impacts of the factory, which is the Double Absorption Tower method. In this process, the gases that resulted from the contact unit are passed twice in the absorption unit to produce more absorption to convert (SO_3) into concentrated sulfuric acid (H_2SO_4).

The double absorption method increases yields and decreases the release of unconverted (SO_2). Recently, government regulations in most developed countries set the maximum allowable release in sulfuric acid plants. This requires all modern factories to use the double absorption method, in addition to adhering to regulatory legislation. There are benefits to be realized from the implementation of the double absorption method, including:

1. Reducing two stages of the technological path of the current operations in the factory, the research sample, helps to shorten the production cycle, increase the speed of production and processing, and reduce downtime for maintenance and the cost of maintenance. Reducing environmental pollutants and thus improving the overall performance of the factory. The research sample and units are:

- Filters unit: the operations and activities it includes and its use of expensive sodium hydroxide (NaOH), which causes harm to workers and the environment by producing solid residues harmful to the environment.
 - Sediment treatment unit: what it includes of operations and activities and what it uses of the light material, as well as its disposal of waste in the drains (sewage), which causes pollution of the environment through soil and groundwater.
2. An increase in energy generation, as we will have (2) contact units that, through their own chemical reaction, will lead to an increase in the generated energy, which may exceed the need of the factory and the company as a whole, and supply the national grid with surplus electricity.
 3. Increasing the design capacity of the research sample factory to reach (24,750 tons annually), after it was (13,200 tons).

And through our discussions with production officials in the research sample factory, to find out the expected cost of implementing the double absorption method, the cost of implementing this method is (800) million dinars, Table (7) shows the details of the required parts, their numbers, and their costs for the implementation of the double absorption method, as follows:

Table 7 Details of the parts required and their cost to implement the double absorption method

required part	Number	cost
pullers	2	150 million
New absorption furnace cost	1	450 million
Production pipelines and equipment		200 million
Total		800 million

4.4.4 Develop training programs and change management.

For the purpose of continuous and comprehensive development and investment of efforts and amounts spent, and to sustain the benefits achieved by the steps of re-engineering green operations, as well as obtaining the best economic and environmental returns from the amounts spent on re-engineering operations in the research sample factory, additional measures should be taken such as preparing a training program for re-engineering Process engineering to manage and sustain green operations, and to provide employees with the knowledge needed to re-engineer green operations.

And that the research sample factory is continuing to hold technical and administrative courses at an escalating pace, as a number of courses have been planned and implemented at the company's site and at the ministry's site. And from the information

of the Planning Department in the research sample, the percentage of implemented courses was 113% for the year 2021 and 160% for the year 2022 of what is planned for the courses. This is an indication of the ability and willingness of the research sample factory to benefit from and sustain the steps taken to re-engineer green operations through its continuation in holding technical and administrative courses.

4.4.5 Performance monitoring and continuous improvement of operations

To follow a system for monitoring performance, and to make continuous improvements to operations by updating the services and equipment used in order to ensure the continuity of operations conforming to the specifications of green operations, Performance monitoring should focus on the two most important aspects of GPR implementation, namely:

The first: Measuring the emissions and pollutants from the new processes on a regular basis, in order to ensure that these processes perform the purpose for which they were designed and that they meet the legislative requirements for environmental protection and their compliance with the sulfuric acid industry's determinants within the permissible limits.

Following up on compliance with environmental determinants is the responsibility of the Environment Directorate in Babil Governorate, and through our experience in the factory and interviews with officials in the factory, the research sample, as well as employees of the Environment Directorate in Babil, we note:

- The Directorate of Environment in Babylon did not set specifics for this industry, but based its opinion on the fact that the factory is in violation of the environment due to the expansion of urban housing on lands close to the factory.
- The absence of modern sensors or measurement devices that determine the extent to which the factory, the research sample, adheres to the environmental determinants, that is, determining the amount of sulfur dioxide gas emitted from the factory and the rest of the pollutants from the factory, as it is based on laboratory studies only in determining the amount of pollution and at intervals annually or more than a year Approximately.

The second: is a performance evaluation of the newly used equipment for the application of green process reengineering and in the research sample factory. The performance evaluation of the double absorption unit that will be adopted, and ensure that it achieves the objectives of re-engineering green operations and reducing emissions to the extent permitted within international and local limits. To complete the implementation and application of all green process reengineering steps, it is required to establish a formal performance reporting mechanism to maintain continuous improvement to reduce emissions from the operations of the sulfuric acid plant, the research sample, and this task falls to the Chemical Security Division in the Information

Department of the Al Furat Chemicals and Pesticides Company, the research community.

As well as to preserve the gains of re-engineering green operations and to achieve continuous improvement of these operations, it is to continue implementing the pillars of Total production maintenance (TPM), in an official manner, and to find an official department to follow up on their implementation, as well as to achieve effectiveness and efficiency from its pillars and pillars.

5. Conclusion

We reached several conclusions, which can be listed as follows:

1. TPM is a strategy through which machines, equipment, workers, and supporting processes are integrated to maintain the quality of production and the integrity of systems to maximize the overall effectiveness of machines and equipment to achieve the optimum cost.
2. (TPM) aims to improve and develop the performance of economic units in all respects by reducing maintenance costs and reducing time costs, thus achieving the highest return, maintaining equipment, improving its effectiveness, and involving maintenance personnel.
3. That the implementation of (TPM) depends on a set of basic pillars that should be provided, and that the implementation and the level of success varies from one economic unit to another.
4. Successful implementation (TPM) requires following certain methods and procedures to improve the performance of its activities in particular, and the general performance of the economic unit in general, coupled with this improvement by adhering to regulatory legislation for environmental protection and preservation.
5. The research sample sulfuric acid plant provides implementation requirements (TPM), and it is implemented, but informally and not comprehensively.
6. Green Process Reengineering (GPRE) is a system or technology by which the overall environmental impact of an economic unit can be improved by redesigning its operations, more specifically to reduce waste and pollution, achieve optimal use of energy and resources, and achieve compliance with governmental and regulatory requirements for environmental protection.
7. The (GPRE) concept works by first evaluating existing processes and their compliance with green process specifications, and then using a variety of methods to improve the efficiency and effectiveness of processes in environmental aspects.

8. The application of (GPPE) leads to improving the performance of economic units in general and the performance of (TPM) in particular, which leads to reducing costs and complying with the requirements of environmental protection.
9. The double absorption method increases yields and decreases the release of unconverted (SO_2). As well as reducing two stages of the current production stages, and increasing the design capacity of the research sample factory to reach (24750 tons annually).
10. The Directorate of Environment in Babylon did not set restrictions for this industry but based its opinion on the fact that the factory is in violation of the environment due to the expansion of urban housing on lands close to the factory. And the absence of modern sensors or measuring devices that determine the extent of the factory's commitment to the environmental determinants.

As for the most important steps that we recommend to the factory in order for it to be relied upon, it is that the management of the research sample factory must adopt an administrative unit for the implementation of (TPM) in an official and comprehensive manner for all its pillars. As well as following the steps of applying the (GPPE) technology by evaluating the current processes and their conformity with the specifications of the green processes, and then using a variety of methods to improve the efficiency and effectiveness of operations in environmental aspects, in addition, the management of the research sample factory is required to provide the necessary amounts to equip the factory with the double absorption unit. It is necessary to work in a double-absorption method in order to take advantage of the benefits that accrue from it, as well as keeping pace with global developments and adhering to environmental protection legislation. The Environment Directorate in Babylon must set parameters for this industry, and provide modern sensors or measurement devices that determine the extent to which the factory, the research sample, adheres to environmental parameters.

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