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Original Research

Improving Productivity Using Green Process Reengineering Technology

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Abstract

Improving productivity is one of the most important goals, pursued by economic units, in all the sectors and industries. The key objective is to increase revenues, enhance financial performance and maximize profitability. In general, the Iraqi economic units suffer from weakness and low productivity. Such problems can be overcome by implementing a variety of methods and techniques so that the productivity can be increased while the efficiency and quality can be maximum in the production processes. Several ways exist through which the economic units can become highly energy-efficient and mitigate its carbon emissions. In this background, the aim of the current study is to analyze the theoretical concept of productivity, the factors that affect productivity, its impact upon the overall performance of the economic units and to explore the best practices and methods that are available to improve the productivity in Iraqi industrial sector. The current study tested four hypotheses that focused on increasing productivity, reducing waste, improving profitability, adding competitive advantage to the organization and promoting environmental sustainability. From the study results, it can be concluded that the green process re-engineering is an effective tool to improve productivity and enhance the overall performance of the economic units, including the environmental performance. Further, this process makes use of modern technology, helps in the transition of using environment-friendly materials and the promotion of awareness and training.

Keywords: improving productivity, Green Process Re-engineering

Introduction

Improving productivity is a goal that is pursued by almost all the economic units in various types of industries. In other terms, improving productivity corresponds to increasing productivity, improving the quality and reducing the costs involved in the operations. However, majority of the industrial units face difficulty in achieving this goal. So, there are tools and techniques that can be used to achieve this goal and one of such tool is green process re-engineering. The application of Green Process Re-engineering (GPR) has become increasingly common in the recent years, as the companies strive to improve their productivity and

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reduce their environmental impact. GPR is a process in which the current processes are re-engineered so as to reduce their environmental impact and also increase the efficiency of the processes. The problems considered in this study are weak productivity issues in Iraqi economic units and the lack of compliance with the regulatory legislation on environmental protection. The study considered these problems in order to promote the reality of productivity and improve it in the Iraqi economic units. To achieve the objectives of this study, it is divided into four parts. The first part deals with the scientific methodology of the study, while the second part covers about the theoretical aspect of improving productivity, and Green Process Reengineering (GPR). The third part deals with practical application of the GPD process and the results achieved from the implementation of the model in the factory. The fourth part includes the conclusions reached and the recommendations which can help the study sample, achieve its objectives [1-3].

The significance of the current study stems from the importance of improving productivity using green process re-engineering technology. Thus, the aim of the current study is to enhance the efficiency of industrial processes in ways that comply with environmental standards and in parallel, improve the quality of the manufactured products. It also works to improve the consumption of natural resources, reduce the waste and emissions that are harmful to the environment and contribute to the preservation of the environment. In addition to these, the green process re-engineering technology is an effective means to achieve the sustainable development and accomplish the environmental, economic and social goals. This method helps in improving the positive image of the economic units and strengthen their position in the society. By improving productivity using green process reengineering technology, it is possible for the economic units to achieve competitive advantage and improve their overall performance in a sustainable manner [4-6].

Material and Methods

Productivity Improvement

Productivity is one of the most important criteria that determines the success and competitiveness of the economic units in a market. Therefore, it is important to pay attention to improve productivity since the organizations must work on to achieve their goals. This includes the improvement of efficiency of production processes and reduction of costs, thereby increasing productivity and the profits [7].

In literature, most of the researchers have dealt with improving productivity through the relationship of a product with techniques and methods that are used to achieve an increase in productivity or decrease in the costs, incurred upon the production processes. It always remains as a variable that is dependent on other techniques and procedures. Productivity is a relationship (which is usually a ratio or an indicator) between the outputs (goods and / or services) produced by a specific production system and the quantities of the inputs (resources) used by the system to produce this output [8].

The term ‘productivity’ is evaluated based on the achievement towards the specified goals, based on the relationships between the inputs and outputs of the industry [9].

The researchers observe that productivity is a measure in which a quantitative amount is determined to increase the production, reduce the costs or increase the quality of the production. Thus, improving productivity is linked with improving the overall performance of the economic unit. In other terms, improving productivity ratio is linked to improving the performance. In order to improve the performance, several diverse ways and methods are available and there are several concepts to improve the performance.

Performance Improvement

The concept of performance improvement has numerous important contents and dimensions in it as it encompasses the efforts required to support the methods of continuous improvement and measure the effectiveness of the economic units’ procedures [1]. It is a process through which the changes or adjustments are made that are appropriate to the actual performance so as to achieve the planned performance [10]. It is an integrated management process to understand and measure the performance levels, identify the variations and deviations and improve the performance of the workers by implementing corrective actions [11]. It includes a set of interlocking and integrated components that help in achieving the planned objectives with attention to find the solutions to the challenges and problems faced by the economic unit [12, 13].

Therefore, performance improvement can be hypothesized as a process or a set of activities that examines the current performance systems and produces the results to find the deviations between planned or targeted performance and the actual outcomes so as to take corrective action and correct these deviations.

Strategic Performance Improvement Techniques

Cost and administrative accounting has been revolutionized by many accounting and administrative techniques since the early 1990s. These techniques are aimed at enhancing the performance of the economic units. Such improvement has moved away from traditional concepts that focus on the strategic dimensions, both inside and outside the unit [1, 14]. Hence, it can be understood that the external environment of an economic unit, in terms of technology

and automation, remains a catalyst for the development of administrative techniques. Such development aims at enhancing the performance including that of Total Quality Management (TQM), Sit, hexagonal diffraction, integrated computer manufacturing, process reengineering and other technologies [15, 16]. However, these technologies are unable to fulfil the needs of economic units in terms of performance improvement due to changing competition, its focus on preserving the environment and attempt to support the green products. From here, the strategic approach to cost management provides a technology that supports the process of improving the performance i.e., re-engineering of the green processes [17, 18].

Green Process Reengineering Concept (GPR)

In the recent years, there is an increasing awareness found among the economic units about the environment, thanks to the improved Business Process Management (BPM), a science that oversees how businesses perform in economic units to achieve consistent results and take advantage of the improvement opportunities [19]. At present, the researchers are advocating for scaling-up the BPM and integrating it with environmental sustainability dimension so as to find a new approach called 'Green BPM' [20]. Green BPM includes well-established industrial practices such as process modelling, re-engineering, process optimization, measurement, integration, and the cancellation of processes that do not have the characteristics of green processes [21]. Green BPM has a crucial element i.e., Green Process Reengineering (GPRE), a system that integrates the sustainability thinking process with business process management. Overall, the green BPM approaches the overall management of all the internal and external operations of the economic unit from a green perspective [17].

'Green Process Re-Engineering' (GPRE) is a new term that describes the application of Process Re-Engineering (P-RE) concept in addition to contemporary performance measure of the environmental impact [22]. Like all the restructuring efforts, the Green Re-Engineering Initiative (GPRE) challenges the core values and culture of an organizing by changing their operations. It fundamentally improves an economic unit's operations from the perspective of environment. Hence, the community and the natural environment that surrounds the economic unit become high-value categories [23]. It is an approach that is inclusive of an independent set of procedures to redesign the economic unit's operations, infrastructure and organization in a fundamental and comprehensive manner so as to create a clean and energy-saving ecosystem [24]. It can also be defined as the application of process re-engineering concepts taking into account the environmental impact, by redesigning and improving the manufacturing, packaging and distribution processes, to become highly sensitive to the natural environment [25, 26]. In other terms, it can also function as a system that provides appropriate concepts, methods and tools to support process modelling, implementation, monitoring and continuous change by taking the environmental impact of the economic unit operations into account [27, 28].

The concept of Green Process Re-Engineering (GPRE) has received attention in the recent years, as it provides a modern view of how the processes can be improved to increase the efficiency and effectiveness and it also helps in reducing the negative environmental impacts, while improving the performance. The goal of any economic unit should always be to maximize productivity, while reducing its environmental impact or becoming "green". Green Process Re-engineering (GPR) is a system or technology, through which the overall environmental impact of an economic unit can be improved by redesigning its processes. To be specific, the process helps to reduce the waste and pollution, achieve the optimal usage of energy and resources, and comply with government and regulatory requirements.

Advantages of Green Process Re-Engineering Technology

Economic units play an important role in influencing the environment through their day-to-day operations and activities. If such activities are one wrongly and repeatedly, it will not only be inefficient, but also produce high levels of pollution and consume excess amount of energy [29, 30].

Therefore, it is crucial for the economic units to take necessary steps and maintain their operations to be green enough, reduce pollution and determine the extent of emissions, produced during their operations [31]. This can be achieved through the application of the Green Process Reengineering (GPR) steps, which offer multiple advantages to economic units through which it is possible to

- Leverage the raw materials and energy
- Reduce pollution from the economic processes
- Increase the environmental sustainability of the economic unit

By adopting these steps, the economic units can achieve multiple benefits including improved efficiency, reduced costs, adherence to environmental legislation and regulations and increased awareness among the employees and the public about environmental conservation. Some of the steps involved in these processes (P-RE and GPR) are compared in Table 1.

The most important difference between (P-RE) and (GPRE) is that GPRE is committed to preserve the environment by following the procedures and steps that focus on the environmental perspective on one hand and the economic perspective on the other hand alike the P-RE. Thus, the GPRE is in line with the developments in global business legislation that seeks sustainability

Table 1. Comparison between Process Reengineering (P-RE) and Green Process Reengineering (GPRE).

Metric	(P-RE)	(GPRE)
Objectives	Achieve customer satisfaction, create process changes, reduce the costs and increase the productivity. [32]	Seek sustainable and energy-efficient growth by taking the regulatory aspects into account and reducing the emissions from operations [33].
Term	The concept is based on finding improvements and innovating new processes that are necessary and essential. [34]	The concept focuses on pro-active redesign and radical improvement of the manufacturing and distribution processes, driven by sensitivity towards the natural environment, [23]
Steps	The following steps are involved. 1. Define strategic vision and objectives. 2. Form a team with multiple tasks and functions. 3. Determine the requirements of the customers. 4. Determine the engineering characteristics.5. Planning and implementation [35]	Green Process Reengineering (GPRE) requires five steps as given below. 1.Inspect the operations with green process characteristics 2. Integration of the product-related processes with environmental dimensions 3.Re-engineering of the 'green' processes 4. Development of training programs and ensuring change management 5. Monitoring the performance and improving the processes [36]
Significance	The most important justifications are the needs of the customer and the requirements to outperform the competitors [16].	The most important justification for its application is the global trend to preserve the environment through green processes [37].

(Source: researcher numbers based on sources towards each)

and cleaner production and also adherence to the most important principles of Green Process re-engineering that are economical in production, implementation of the best methods and least resources to achieve the best possible productivity. The main benefit of GPRE is that it can help the economic units improve their productivity and reduce their environmental impact. By re-engineering the existing production processes and systems, it enables them to reduce the energy consumption, waste production and emissions. In addition to these, the GPRE can help save money by reducing the costs associated with energy use, waste disposal and emissions. Finally, it can help the companies become highly competitive by improving their production efficiency and reducing their environmental footprint.

Implementation Procedure for GPRE

In order to carry out the business within the economic unit, various practices are followed. These diverse practices stem from the literary surveys and the experiences of the researchers and business practitioners. Each practice is evaluated in terms of its impact on cost, flexibility, time, quality and the rest of the dimensions [38, 39]. Similar to traditional reengineering process, the success of the GPRE depends heavily on a step-based, performance-based approach that is applied to all the economic unit procedures and processes [21]. So, in order to successfully implement the GPRE) and achieve its goals, the following steps should be adhered to [36].

Inspect the Operations with Green Process Characteristics

This step focuses on the verification of the processes and their conformity to the basic green characteristics. Here, the whole set of the business processes are evaluated and validated in terms of five characteristics of the green processes namely, necessary, efficient, efficient, flexible, and measurable. In this step, all the processes are tested and those processes that meet the dimensions of the characteristics of green processes are alone converted to the next step. On the other hand, the processes that do not pass the test are then reported to the executive officer of the economic unit for further review [24, 40].

Integration of the Product-Related Processes with Environmental Dimensions

This step focuses on the integration of the economic unit operations with environmental requirements and dimensions. Being a complex stage, this step requires not only a comprehensive and an insightful understanding about the operations and how the economic units help in competing and achieving the business objectives, but also the involvement of the environmental dimensions in each activity of the operations. So, it becomes inevitable to develop and apply the most suitable methodology so as to understand the amount of pollution caused by the business activities. Further, it helps in identifying the issues and challenges so as to design the measures that reduce the emissions [41, 42]. This step includes two elements as given below [24].

First: Divide each process into different activities;

this is done by sequencing the workflows from the starting point of the process to the end point.

Second: Application of the environmental dimensions. The activities are carried out by developing a program that matches and aligns with the environmental specifications and dimensions.

Green Process Reengineering

Green Process Reengineering includes a comprehensive analysis of the processes in which the activities of each and every process are analyzed into smaller elements to determine its environmental impact, the energy density and the pollution caused by each activity, the importance of the activities and the extent to which it contributes towards achieving effectiveness in the process, with the possibility of modifying it to reach a low concentration of pollution, and developing alternative process designs [41, 43, 44]. The workflow of each process is also verified against the required resources and time. Then, the outputs of the analytical processes are used to develop the alternative 'green' processes, while reducing the emissions [21, 45, 46].

This step encounters a challenge i.e., there is a difficulty in redesigning or restructuring some of the processes due to their nature or due to other internal constraints. Further, it is also challenging to find an appropriate solution that can compensate the environmental impact without changing the process [33, 47].

Development of Training and Change Management Programs

This step focuses on development and implementation of the training programs for workers and is aimed at change management process. Once the processes are redesigned to suit the green specifications, the economic unit should start dealing with the change and prepare the employees with training programs [17]. The green training programs provide development for the workers and nurture them with skills to access the necessary knowledge so as to redesign the green processes. The participants acquire basic skills and knowledge in green processes and continue to implement the same from their training program [48, 49].

According to [36], some of the supportive processes include the communication from the core processes of skills development, knowledge transfer and organizational improvement [50]. It forms the crux of the organizational change management process for an effective management [51, 52].

Another key element to be considered, during the change management phase, is to measure the effectiveness of the communications and encourage the knowledge sharing culture within the economic unit. Effective communication provides a common platform for all the stakeholders to exchange information and knowledge whereas it also enables highly-efficient and effective cooperation among the departments of the economic unit [52, 53].

Performance Monitoring and Process Improvement

This step emphasizes the monitoring of the performance and continuous improvement of the operations via the modernization of the related services and the facilities [27]. This step is carried out in two aspects as briefed herewith [17].

First: The measurement of the emissions, for each green process, is recorded on a regular basis. This is done in order to ensure that there exists a similar reading to the initial measurement after the redesign phase of the green process gets completed. Further, it is also required to verify the implementation of the redesigned processes, according to the specifications.

Second: Evaluation of the new equipment and devices and its introduction to achieve the objectives of operations, while at the same time, minimizing the emissions.

A formal performance reporting mechanism should be established to maintain a continuous improvement so as to reduce the emissions from the operations carried out at the economic units [41].

The two phases of this framework are classified within the 'strategy' step of the Green Processes Framework. All the processes are taken into consideration for examination whereas only a few selected processes are moved forward to third and fourth phases. These phases correspond to 'design' and 'implementation' steps of the Green Processes Framework respectively. Once all the processes are redesigned and ready for implementation, the performance is monitored in the fifth step that indicates the 'operational' step of the Green Processes Reengineering Framework [17, 54, 55].

Study Hypotheses

First Hypothesis: Improving production processes using green process re-engineering technology will lead to increased productivity.

Second Hypothesis: the use of green process re-engineering technology in production will reduce waste and pollution resulting from production processes, which will lead to reduced costs and improved profitability.

Third Hypothesis: Green process reengineering technology will help improve product quality and save energy and resources, which will lead to an increase in the company's competitiveness in the market.

Fourth Hypothesis: Applying green process re-engineering technology in production processes will help promote environmental sustainability and preserve the environment and natural resources for future generations.

Study Sample Description

For the application aspect, the current study was conducted in the sulfuric acid factory named "Euphrates General Company for Chemical Industries and Pesticides". The current research paper discusses the application of green process reengineering steps in the chosen factor to improve its productivity.

The current study utilized the theoretical approach to analyze the concept of productivity and its impact factors, the concept of green process re-engineering and the steps taken to implement it. A practical approach was used in this study to analyze the factory research sample and apply the steps of green process re-engineering to improve productivity. The information about the study factory and relevant data were collected through factory records, direct monitoring of the production processes and interviews with the factory workers.

Results and Discussion

This section of the study details about the technological processes involved in the factory's production work, the environmental damage caused by the current processes, analysis of the weaknesses, application of green process re-engineering, results and the implementation of the process.

Technological Path of Production Processes in the Factory

This section explains how sulfuric acid is manufactured through a set of stages:

Stage 1: Melting unit. This unit is concerned with dissolving sulfur as a raw material. The factory obtains the sulfur from the Iraqi Ministry of Oil, and use steam at a temperature of (100-140°C). Thus, it results from the contact unit and the sulfur is dissolved. Finally, liquid sulfur is obtained while its chemical code is (S).

Stage 2: Incineration Unit. This unit converts the liquid sulfur, a resultant product from the melting unit, into gas by adding oxygen (O_2) at a temperature of (800ºC). The heat is obtained from the contact unit to produce sulfur dioxide (SO_2) from this stage, knowing that the heat generated at this stage is used in the first stage.

Stage 3: Chemical catalyst unit. The catalyst unit is characterized with the presence of vanadium pentoxide (V_2O_5) as an auxiliary material i.e., it helps the reaction while it does not take part in the reaction. The production department staff call this process as bedding, where it is brushed in this unit to convert the sulfur dioxide (SO_2) to sulfur trioxide (SO_3). The heat generated in this unit, from the chemical reaction, is consumed at the melting and burning units. Thus, the energy consumption is reduced and accordingly the cost too. In this stage, the sulfur dioxide (SO_2) becomes volatile. Being a toxic gas, it has no color yet has a very pungent, foul smell and is harmful to the environment. The product of the chemical reaction in this phase is converted into sulphur trioxide (SO_3) and sent to the subsequent phase of the absorption unit.

Stage 4: Absorption unit. The task of this unit is to spray the liquid sulfuric acid (H_2SO_4) using special sprays upon the sulfur trioxide gas (SO_3) repeatedly to obtain the fuming sulfuric acid (H_2SO_7), which is then transferred to the dilution unit.

Stage 5: Dilution unit. In this unit, water (H_2O) is added to reduce the concentration of the sulfuric acid to (98%), which remains the standard percentage of this product i.e., concentrated sulfuric acid (H_2SO_4). Here, the product is completed, stored in storage tanks and then sold.

Stage 6: Percolation Unit. From the previous processes in the chemical catalyst unit, both sulfur dioxide gas (SO_2) and sulfur trioxide gas (SO_3) are toxic in nature and pollute the environment. Both the gases are flushed into the atmosphere to get disposed. They are withdrawn to the filter and if it is sprayed with the alkaline solution i.e., sodium hydroxide solution (NaOH+water) it has a severe impact on the workers in terms of contact. So, it is stored with clean glass bottles, covered with a rubber seal, and then collected under the Percolation towers in the form of sediments. Afterward, it is transferred to the sediment treatment unit.

Stage 7: Sediment Treatment Unit. At this unit, the transferred sediment gets processed at the percolation unit, where the inflorescence material in this unit is added to the sediment to equalize it. Then, it is disposed of, by subtracting it from the trocars (sewers).

The factory operates by shift system i.e., three shifts a day of 24 hours and eight workers per shift as shown in Table 2.

The design capacity of the sulfuric acid plant in the research sample is (40 tons per day) (13200/330 working days) by work (20 hours per day). Thus, the optimal time to produce one ton, according to the production capacity, is 30 minutes per ton or 50% of the hour to produce one ton of sulfuric acid.

Table 2. Shift pattern and the division of the factory workers at the production department.

Foreman	Production; worker-	Maintenance worker	Bulldozer driver	Total
1	3	3	1	8

(Source: Preparation of the researcher based on the information of the production department in the factory research sample)

Pollutants and the Damage Caused by Sulfuric Acid Plant

Chemical industry, especially sulfuric acid plant, is one of the most polluting and dangerous industries. According to the reports from the Directorate of Environment, Babylon province, the production processes of the plant have many effects on society since it pollutes the environment and also the buffer zone nearby the areas. This is because the gaseous and liquid pollutants get transmitted to the neighboring areas by air, running water or groundwater. These pollutants are briefed herewith.

1. Gaseous pollution: Sulfuric plant operations result in the emission of many gases that pollute the environment such as sulfur dioxide gas (SO_2) and sulfur trioxide gas (SO_3). These gases cause damage to the society and the environment. The gases released by these plants as waste from the production processes are first-class toxins. Being colorless gases, it poses serious threat to the human health. When such gases are inhaled, it increases the risk of exposure and causes multiple health problems including stroke, heart disease, respiratory diseases, and early death.
2. Liquid pollution: The diluted and concentrated sulfuric acid are the liquid residues of the production processes followed in the sulfuric acid plant. These are collected in the special treatment basins and tests are constantly conducted to equalize the basement. Then, the solutions are put to the water of the trocars and this process is carried out in the central processing unit of the factory. This unit is characterized by the simplicity of its work site. When comparing the seriousness of the issue, it is treated with local materials that act as an alternative to the original materials required for processing. The testing devices too are very old and worn out, which results in frequent failure of water treatment tests. In addition to these, the poor quality of the industrial water and sewage drainage networks result in serious environmental damage, including:
   - Damage to the agricultural areas, livestock and fisheries as well.
   - Unpleasant smells are emitted that change the color and taste of water due to inaccurate treatment of the toxic substances
3. Solid pollution: The production processes of the sulfuric acid plant are subtracted as mercury residues by the electrolysis unit to produce chlorine. Here, the titanium anode is placed on top of the mercury cathode and sodium chloride solution is placed between them. When the electric current is passed through the unit, chlorine is released at the titanium anode whereas the sodium gets dissolved at the mercury cathode. Here, the residues are formed in the form of small clusters, which are left over from the damage of mercury cells. On the contrary, there are no effective and efficient treatment units as well. These substances are dangerous pollutants and can affect the nearby areas as well as the factory workers.

Improving the Performance Based on Green Process Re-Engineering

The technological path of the traditional production processes in the sulfuric acid plant, considered for the study, is reformulated to improve the overall performance of the plant. This way, it is possible to meet the legislative and legal requirements for environmental protection against contaminants using the Green Process Reengineering (GPR) steps:

Inspection of the Operations for Green Process Characteristics

In this step, the processes involved in the sulfuric acid plan were evaluated, validated and matched against the characteristics of five green processes i.e., necessary, efficient, efficient, agile, and measurable. The processes that do not possess the characteristics of green processes only are converted to the next step and are reported to the factory executives for their review.

Table 3. Analysis of the sulfuric acid plant's operations and their compliance with the specifications of green processes.

Specifications / Operations	Significant	Effective	Efficient	Agile	And measurable.	Test Result
Melting unit	**P**	**P**	**P**	**P**	**P**	Complied
Incineration Unit	**P**	**P**	**P**	**P**	**P**	Complied
Chemical catalyst unit	**P**	**P**	**P**	**O**	**O**	Non-complied
Unit of absorption	**P**	**P**	**P**	**P**	**P**	Complied
Unit of Dilution	**P**	**P**	**P**	**P**	**P**	Complied
Percolation Unit	**O**	**O**	**O**	**O**	**O**	Non-complied
Sediment treatment	**O**	**O**	**O**	**O**	**O**	Non-complied

(Source: Prepared by the researcher using the information of the production department)

Table 3 shows the evaluation results regarding the processes of the technological path of production in the factory, in terms of compliance with the specifications of green processes.

It includes the technological path of the production processes in the factory, from a set of stages and processes as briefed herewith.

1. Melting unit:

This unit is one of the necessary units and executes the basic process in manufacturing sulfuric acid. Further, this process also has high effectiveness and efficiency, where water vapor is used to generate the energy in order to dissolve the solid sulfur and turn it into liquid. This process is agile and measurable. Further, this process does not emit any materials that are harmful to the environment, whether liquid, solid or gas. So, this process can be counted as a green process.

2. Incineration unit:

Incineration unit is one of the necessary processes to be followed when manufacturing the sulfuric acid. This unit is also characterized by high efficiency and effectiveness in which the water vapor is used to generate energy in order to burn liquid sulfur and convert it into gas. This process is measurable and agile. It does not leak sulfur dioxide gas (SO_2) as it has a union of oxygen and sulfur liquid without any other additives, surplus or excess. The gas is then transferred through a pipeline to the chemical catalyst unit and thus this process can be counted as characterized by the green processes.

3. Chemical catalyst unit:

This unit is essential and important for the manufacturing of the sulfuric acid. Being an effective and efficient unit, this phase reactions are heat-emitting ones and are used in the generation of energy. The generated energy is used for the rest of the stages involved in the production processes. This process is not measurable and is not characterized by agility. Further, the sulfur dioxide gas (SO_2) gets released due to the inefficiency of the co-factor vanadium pentoxide (V_2O_5) and the corrosion of the internal parts of the production equipment. Thus, the step makes the sulfur dioxide gas (SO_2) to be volatile. Therefore, this process is not in conformity with the specifications of green processes and does not have their characteristics. So, action must be taken to re-engineer the process and convert it as the second application step for the green process re-engineering. This step must be informed to the factory for taking the necessary action.

4. Absorbtion unit:

This process is one of the basic and necessary processes in this industry. It is effective, efficient, agile and measurable. Further, this step produces no harmful materials to the environment. Because this process is carried out in the special ovens that are intended for this purpose alone. Further, the production workers use certain means and methods to maintain this unit. So, this process can be counted as a green process.

5. Unit of Dilution:

It is a necessary and a basic process to equate the fuming sulfuric acid and turn it into a product that can be stored, sold and used by the customers. This phase is characterized by effectiveness and efficiency, as only water is used in this process. Further, this process is agile and measurable, and through this process, no environmentally-harmful substances are produced. So, this process can be considered a green process.

6. Percolation unit:

The results of this unit do not indicate its effectiveness or efficiency, as electrical energy is used to withdraw these gases. Further, the cost of the sodium hydroxide solution (NaOH), health disadvantages brought by this step upon the safety of workers, environmental damage, heating the iron, work stops for the purpose of maintenance, and high maintenance costs spent upon this unit without economic return or environmental returns altogether make the percolation unit process as a non- green process. Therefore, the process should be reengineered and those responsible for it should be informed to take the necessary measures.

7. Sediment treatment unit:

This process is an unnecessary process that does not add any value to the product. It is unnecessary and also causes environmental damage. Therefore, this process is not characterized as per the specifications of green processes and should be reengineered. Finally, the factory executives are to be informed about the results of this process.

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 as follows; component activities, activities that are to be integrated with the environmental dimensions, and non-conforming processes that need to be integrated by preparing a program that adheres to the necessary environmental determinants and dimensions and then implement it.

The processes that do not conform to the specifications of the green processes within the technological path of the production processes involved in the sulfuric acid plant are chemical catalyst unit, percolation unit, and the sediment treatment unit. These processes need to link their activities with the environmental dimensions. By coexisting with the factory's production department, the non-conforming processes consist of a set of activities. With regards to the environmental dimensions of these processes, all the green processes seek to achieve the dimensions of reducing the emissions, reducing unclean energy consumption and disposing off the process residues in an environment-friendly manner by recycling them or using landfills properly. Table 4 shows the processes, their component activities and the

Table 4. Activities of the chemical plant operations that do not conform to green specifications and environmental dimensions.

Operations	Activities	Environmental dimensions
Chemical catalyst unit (Chem.)	Vanadium pentoxide diffusion (V_2O_5)	Reduce emissions and gas leakage. Reduce the emission of heat that causes the equipment to corrode.
	Gas puller (Eng.)	
	Disposal of gas	
Percolation Unit	Intake of gases	Reduce power. Reduce the resource consumption without environmental or economic return or benefit.
	Addition of sediment solution	
	Subtraction of sediment	
Sludge treatment	Sediment withdrawal (Geol.)	Disposal of the sediment by recycling or environment-friendly methods that do not cause any harm to the environment, whether it is soil, water or groundwater
	Add inflorescence material	
	Disposal of plaque in the trocars	

(Source: Prepared by the researcher using the information of the production department)

environmental dimensions that these activities should meet or match.

After identifying the activities related to the processes and the environmental dimensions required for these activities, the next step is to re-engineer the green processes so as to achieve the required dimensions of these processes and the activities related to the technological path of the production processes followed in the sulfuric acid plant.

Green Process Reengineering

In this step, the environmental effects of the activities that make up the industrial units' processes, the importance of each activity of the processes and the amount of contribution of every activity to the production processes as a whole are determined. This was done to modify the non-conforming activity or replace it with another activity by following a few methods and procedures that result in the implementation of environmental dimensions. Thus, it becomes possible for the processes to align with the specifications of green processes, to cause less harm to the environment, while at the same time, provide the resources required for alternative activities. Thus, the processes are developed to obtain alternative green processes.

The activity of vanadium pentoxide (V_2O_5) remains a non-conforming process activity. According to the production department official, this activity acts as the basis for sulfuric acid production process. Though this activity is basic and important, it causes negative environmental effects due to the heat of the chemical reaction. This heat, in turn, makes the toxic sulfur dioxide gas (SO_2) volatile and erodes the internal parts of the production furnaces. The scenario leads to the cessation of the production process and increases the maintenance periods and costs. Table 5 shows the activities, its importance and contribution of each activity to the processes as a whole and the associated environmental impacts:

Table 5. Environmental impacts of the operations' activities and the amount of their contribution.

Activities	His Relevance:	Environmental effects of the activity
Vanadium pentoxide diffusion (V_2O_5)	Very important.	Gas volatilization and equipment corrosion
Gas puller (Eng.)	Very important.	SO_2 Gas Volatility
Disposal of gas	Very important.	SO_2 Gas Volatility
Intake of gases	Very important	SO_2 Gas Volatility
Addition of sediment solution	Important	Production of toxic substances and gas volatilization
Subtraction of sediment	Important	Environmental pollution and equipment erosion
Sediment withdrawal (Geol.)	Important	Pollution of the environment by acidic substances
Add inflorescence material	Important	Pollution of the environment by acidic substances
Disposal of plaque in the dumpsters	Important	Soil and groundwater contamination with acidic substances

(Source: Prepared by the researcher using the information of the Directorate of Environment of Babil Governorate)

Table 5 shows that all the activities are essential and are necessary to complete the production process to reach the final product (i.e., sulfuric acid). But, they have a significant and negative impact on the internal and external environment of the factory. Through field coexistence in the factory, there is an urgent need to add an additional unit that purely aims at achieving the environmental-friendly production processes and what is known as green process. The double absorption tower method is the additional unit to be installed in the plant. In this process, the gases produced at the contact unit i.e., SO_2 and SO_3 are passed twice to the contact unit to produce more contact and convert from sulfur dioxide to sulfur trioxide. It produces more amount of high-quality sulfur gas, which in turn helps to achieving high conversion efficiency of SO_2 and produce the high concentrations of SO_3.

The results obtained from the implementation of Green Process re-engineering upon the research sample factory are discussed below. The addition of a dual absorption unit helped in achieving a set of advantages and the most important are as follows.

1. Reduction of two stages involved in the technological path of the current processes in the factory. This helps to shorten the production cycle and increases the speed of production and processing. Further, the downtime period for maintenance and the environmental pollution are also reduced. This in turn enhanced the overall performance of the plant and units.
– Filter Unit: The processes and the activities that cause harm to the workers and the environment by producing solid residues that are harmful to the environment are prevented.
– Sediment treatment unit: what is included in the disposal of the waste in the trocars (sewers) polluted the environment through soil and groundwater.

2. Increasing the available capacity of the factory up to 24,750 tons per year from 13,200 tons.

Develop Training and Change Management Programs

Additional measures should be taken such as the training programs to the workers upon Green Process reengineering to manage and maintain the operations, and provide them with necessary knowledge to reengineer the green processes. This is to be done for the purpose of continuous and comprehensive development, to gain the investment of the efforts and cost, to sustain the benefits achieved by the implementation of Green Process reengineering and finally obtain the best economic and environmental returns from the amounts spent on re-engineering operations in the factory.

Performance Monitoring and Continuous Process Improvement

By following a performance monitoring system, continuous improvement of the processes by updating the services and equipment used to ensure the continuous compliance of the processes in alignment the specifications of green processes, it is possible to increase the performance. Further, the performance monitoring should focus on the two most important aspects of implementing the green process reengineering, namely:

First: Measuring the emissions and pollutants from new processes on a regular basis. This has to be done with an aim to ensure that these processes are performing the purpose for which they were designed to. Further, it should also be ensured that they meet the environmental requirements, while adhering to the determinants of the sulfuric acid industry within the permissible limits.

With regards to follow-up on the adherence to environmental determinants, the onus lies on the competence of Directorate of Environment, Babylon province. Through interviews with factory officials and employees of the Directorate of Environment in Babylon, the current study found that:
– The Directorate of Environment in Babylon did not set limits for this industry, but rather builds and bases its opinion on the fact, that the factory is environmentally contrary, due to the expansion of urban housing on the land near the factory.
– The lack of modern sensors or measurements that determine the extent of the factory's commitment to environmental determinants, through which it is possible to determine the amount of sulfur dioxide gas emitted by the factory and the rest of the pollutants, as it is based on laboratory studies only in determining the amount of pollution and at annual intervals or more than about a year.

Second: Performance evaluation of the newly-used equipment is to be conducted for the application of green process re-engineering. In the factory, the performance evaluation of the dual absorption unit should be conducted and ensured that it meets the objectives of green process re-engineering. Further, it should also reduce the emissions up to the limit allowed within the international and local determinants.

To complete the implementation and application of all the steps of green process re-engineering, there is a requirement to conduct the performance audit and a reporting information system to achieve continuous improvement in terms of reducing the emissions from the sulphuric acid production processes. This task remains the responsibility of the Chemical Security Division, Information Department of the Euphrates Chemicals and Pesticides Company.

Conclusions

Green process re-engineering is an effective tool to improve productivity and the overall performance of the economic units. This is inclusive of the environmental performance which can make a significant difference

in the production efficiency as well as environmental performance. The authors observed that this phenomenon worked with the increased available capacity of the factory from 13,200 tons per year to 24,750 tons per year.

Green Process re-engineering is one of the modern methods that help the economic units to increase its productivity and improve the efficiency effectively. Green Process re-engineering means redesigning and improving various processes involved in the economic unit so as to ensure the reduction of waste and pollution and improved usage of the resources.

Alike this method, the authors suggest to review some of the methods that can be used to improve productivity using Green Process Re-engineering:

1. Recruitment of experts in green processes: Economic units can hire experts in green processes to evaluate different processes and identify the areas that need improvement. When green process experts are hired, they can develop customized solutions and provide process improvement recommendations in an environment-friendly manner.
2. Modern software and systems can be used to improve productivity and re-engineer the green processes altogether. For example, intelligent control systems can be used to improve the process efficiency and save energy.
3. Switch to eco-friendly materials: Companies and organizations can improve productivity by using eco-friendly materials. When eco-friendly materials are used in different processes, it reduces their environmental impact and improve the efficiency at the same time.
4. Attention to recycling: Economic units can improve productivity by recycling the waste and used materials. When recycled properly, it saves the natural resources and reduces the production costs.
5. Applying sustainability in all the aspects of business: Economic units can improve productivity by using green process reengineering and by applying sustainability principles in all the aspects of business. When sustainability principles are applied in production and manufacturing processes, the environmental impact gets reduced and efficiency gets improved.
6. Promoting awareness and training: Economic units can improve productivity by using green process reengineering through awareness creation and training programs. When workers are aware how important the green process reengineering and environment-friendly measures are, they can participate in improving the processes and enhancing the efficiency.

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Conflict of Interest

The authors declare no conflicts of interest.

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