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Evaluation and Improvement Sustainability in Manufacturing Organizations

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Abstract

Sustainability is the ability of businesses to utilize the resources found in nature in a manner that the environmental, economic, and social elements of industrial activities are minimized. Manufacturing firms are expected to include the three dimensions of sustainability in their activities and plans while maintaining a dynamic balance between them. Therefore, manufacturing organizations have to adopt several models for evaluating and measuring their degree of sustainability. This paper will present an outline for measuring the degree of sustainability in manufacturing businesses. Empirical work is carried out by using the proposed framework in an organization that manufactures plastic irrigation pipes to analyze the primary issues linked with sustainability dimensions and its indicators for identifying areas for development. Three major challenges have been identified that require adjustment in order to increase the organization's degree of sustainability. The first issue is reducing the wasted water used in plastic washing tanks by recycling water. The second issue is reducing human errors and risk by adding a safety shutdown mechanism for plastic shredding machines. The third issue is removing the bottlenecks from the production line by upgrading perforator and insertion machines. Re-assessment is carried out to monitor the achieved level of sustainability. The results showed that the implemented improvements greatly impact increasing the company's sustainability indices. The environmental sustainability index increased by 20.60%, social sustainability increased by 3.59%, and the economic sustainability index increased by 5.13%. The company's total sustainability index has increased by 5.95%.

Keywords

Sustainability; Sustainable Manufacturing; Measuring Model; Assessment Framework; Indicator.

1. Introduction

Sustainable manufacturing refers to the production of manufactured goods that are environmentally friendly, have a low environmental effect, conserve energy and natural resources, are safe for employees and communities, and are economically sound [1]. Sustainability is employed in the development of real tools for promoting and monitoring organizational accomplishments [2]. To meet the needs of various stakeholders, industries have been obliged to improve their environmental and social performance. As a result, the pursuit of sustainability includes the pursuit of increased economic performance [3]. Analyzing the sustainability and sustainable development index is one of the primary difficulties for manufacturing firms. Sustainability is measured by the performance of social, environmental, and economic elements [4]. While it is preferred to approach the three performances in a balanced manner, this is not always achievable. Businesses are focusing more on how to assess sustainability as its importance has grown in recent decades. A comparison of a program or project to current best practices is one method for establishing sustainability. The recommended practices for sustainability specified in invest go above and beyond the fundamental standards [5]. Using sustainability as a measure typically entails broadening the usual company reporting framework to include social and environmental performance as well as economic performance (the Triple Bottom Line). Most organizations are seeking about building specific measuring tools to assist them in achieving the optimal balance among the three principles. While achieving sustainability by balancing the triple bottom line principles is an ideal aim, it may assist guide decision making [6]. Most industrial firms have significant obstacles in modeling and analyzing sustainability and the sustainable development index. Assessing indices for sustainable development (S/SD) in the manufacturing is an essential aim since it is a novel and modern performance evaluation for determining the required for

these organizations to survive. Research on the adoption of sustainability in production firms must include a wide variety of training, such as sustainability identifications and challenges of applying sustainable training [7]. The aim of this work is to construct framework based on literature for assessing the social and environmental sustainability in manufacturing organizations. This model will apply in a manufacturing organization to evaluate its sustainability index. Then analyzing the collected data and results to recognize how they reflect on the feasibility of measuring methodology in industrial applications. Studying areas of improvement and proposing solutions in the factory to increase its sustainability. Reassessment the sustainability after implement the solutions are carried out.

2. Literature review

The process of achieving human development in a way that is inclusive, linked, equitable, sensible, and secure is referred to as sustainable development. The spirit of sustainable development, according to all definitions, indicates that development should consider both the protection of natural resources and the maintenance of environmental quality while meeting human needs [8]. According to these definitions, sustainability is a state obtained by sustainable development. To achieve sustainable development from industrial operations, the Triple Bottom Line (TBL) of economic prosperity, environmental protection, and societal development must be emphasized. [9]. When every TBL operate well, overall sustainability can be realized. TBL is difficult to achieve because increasing one feature may have a detrimental impact on the other. The problem to achieving sustainability is that all three aspects must be improved simultaneously. [10].

2.1 Assessing the sustainability in manufacturing organization

The return on investment and profits should be considered in the sustainability measuring methodology. The three dimensions of the sustainability measuring paradigm are economic, environmental, and social. This notion allowed for the creation of an index, which is an aggregate assessment of a company's sustainability performance as a dynamic balance of economic development, environmental improvement, and social equity [11]. [12] Established a proposed methodology to assess the sustainability of urban water systems, supposing five variables including financial, environmental, and social considerations. This model anticipated an aggregation based on percent scores for individual variable, which ended up establishing the amount of sustainability. Literature_studies recognized that the managers need specific tools to evaluate how they contribute to their respective companies' triple bottom line. [13] Proposed a methodology for improving the way of measuring sustainable manufacturing systems and analyzed its features. [14] Defines the indicators for sustainable production to measure the three pillars of sustainability. An analytical network process technique is used for variety of sustainable production indicators in order to analyze the sustainability of a manufacturing process. The production sustainability was measured using a radar graph with eighteen dimensions [15]. The performance in each dimension is then represented graphically. The resulting area of the graphic represents the manufacturing process's sustainability performance. [16] Takes a more thorough approach to developing a straightforward system for assessing the sustainability of individual industrial processes. The study contains a selection of sustainability metrics as well as various techniques of normalization. Although [16] provides a single metric for evaluating the sustainability of a manufacturing process by unifying the three characteristics of sustainability. Lowell Center for Sustainable Production [17] focuses on six key components of sustainable manufacturing: energy and resources consumption, the natural environment, social and community development, economic reactions, labor, and goods. It ensures that companies wish to address each of these six aspects in order to foster a better practicing of sustainable manufacturing among businesses, [17] developed five major guiding concepts that provide as the foundation for many of the current indicator systems, as indicated in Table 1.

2.2 Sustainability framework indicators

Sustainability frameworks are insufficient, and each one provides a unique perspective on what constitutes a thorough sustainability assessment framework, with no single one attaining consensus. Holistic composite sustainability metrics used inside a constructed framework are the most widely accepted and useful [18]. The analytic hierarchy process (AHP) proposed by [19] is one of the most

often used methods for weighing indices. A important element must be emphasized: adequate factor selection, rationale, and weighing are required for the index to be accurate in its assessment [20]. AHP enables firms to be rated and compared using trans-disciplinary indicators by prioritizing options based on multiple criteria. AHP additionally allows its users to calculate weights rather than assign them at random [21]. Based on the Lowell Center principles, [13] proposes a new technique for core and auxiliary indicators for improving company awareness and monitoring progress toward sustainable production systems. They proposed twenty-two indications, each with thorough implementation instructions. [21] Worked on the design of a model for calculating a composite sustainable development index in order to track the company's integrated economic, environmental, and social performance across time. Using the concept of (AHP), this was used by calculating the influence of specific indicators on the overall sustainability of an organization. [22] Developed a model for assessing environmental sustainability from the standpoint of the safeguarded by design scheme, leveraging pairwise comparison logic and the fuzzy group analytic hierarchy process approach. [23] Provided a performance assessment framework based on an intra-organizational collaborative decision-making (CDM) method, and within the CDM approach, a fuzzy analytic network process based green-balanced scorecard was applied. A network is formed by identifying and linking sub-constructs and sub-sub-constructs. [24] Established a new evaluation framework for assessing sustainability from the lowest levels, dimensions, and up to the level of sustainable development (manufacturing businesses and their towns and regional areas). The three pillars of sustainability are modeled, estimated, and merged into a concept known as the "general sustainable development index." Table 2 provides a summary comparison of the aforementioned measuring methodologies and frameworks [25].

Table 1 Fundamental of sustainable production [17]

No	Principles of sustainable production	
1.	Products and services are designed and developed to be:	
	A.	Safe and environmentally friendly throughout their entire cycle**.**
	B.	Made, packaged, and delivered with the least amount of material and energy.
	C.	As appropriate, durable, repairable, readily recyclable, compostable, or easily biodegradable.
2.	Processes are developed and run in such a way that:	
	A.	Energy and materials are used within sustainable limitations, with a preference for renewable forms
	B.	Chemicals, physical agents, technologies, and circumstances that endanger for health or the environment must be decreased or removed.
	C.	Working environments are designed to reduce or eliminate chemical, biological, and physical dangers.
	D.	Wastes and byproducts that are harmful to the environment are minimized or eliminated.
3.	Workers are valued and:	
	A.	They are encouraged and assisted in developing their skills and abilities.
	B.	Their work is designed to maximize their efficiency and inventiveness while also encouraging decision-making participation.
	C.	Their safety and well-being are paramount.
4.	Communities associated with any stage of the product lifetime (from raw material production through product creation and disposal) are valued and improved economically, socially, and physically.	
5.	Economic performance is improved by:	
	A.	Providing customers with high-quality products and services that meet societal demands.
	B.	Encouraging stakeholder participation in decision-making.
	C.	Fostering creativity.

3. Proposed conceptual framework for sustainability in manufacturing

Sustainable manufacturing enterprise design is critical in organizational development. More work, expense, and time must be expended in establishing the dimensions, characteristics, and indicators for the sustainability model in order to boost manufacturing enterprise sustainability. The framework for sustainability in manufacturing is developed based on studying a numerous number of papers in the

literature and analysis which suitable for manufacturing. Finally the proposed framework is based on [24] with some modifications in the dimensions indicators. The dimensions of sustainability consist of three pillars such as economic, social and environmental sustainability as shown in figure 1. Indicators are often used to give essential information about a social, economic, or environmental system. They enable for the examination of patterns and cause-and-effect correlations in primary data. Several concepts are employed in the social component of sustainability to build socially rooted institutions that create values. The generation of socially sustainable value is depends on the interaction of the economy, society, and environment. Manufacturing companies are being encouraged to boost their good social contributions while decreasing their adverse effects. The societal issues are usually classified into several broad categories, including work management, human rights, societal commitment, customer issues, and company practices. These components and the indicators that go with them must reflect social interactions with individuals, stakeholders, and society as a whole. Manufacturing organizations are employing lean production practices to reduce waste and promote sustainability to improve environmental challenges. In order to attain these notions of environmental sustainability, then production input and output must be minimized, while ecological effectiveness must be improved. The third factor of sustainability is environmental sustainability, which has various dimensions. These aspects are also mentioned vocally, such as environmental management, resource utilization, pollution, danger, and natural environment. In the case of business performance, management wants to determine whether a company is meeting its set goals and objectives. Manufacturing, non-manufacturing, social, and environmental components of sustainability are classified into issues, with indicators highlighting the most important subjects associated to this issue [24].

Table 2 Comparison between the most commonly applied sustainabilitymeasuring systems [25]

Reference	Advantages	Disadvantages
Veleva and Ellenbecker (2001)	- Detailed list of indicators. - Encourages ongoing improvement through the indicator development process.	- Rather than comparing multiple ones, the framework in question has a tight boundary. - There is no explicit guidance on how to develop and calculate additional indicators.
Krajnc and Glavic (2005)	- Indicator listed in detail. - Compare the different indices over time to track the rate and direction of change.	- The interdependence of diverse sectors is not addressed. - The framework has a narrow boundary in question rather than comparing several ones. - There is no emphasis on risk assessment.
Larimiana, Zarabadia, and Sadeghib(2013)	The fuzzy-based technique is used to address the inherent uncertainty in assigning precise values for the indicators.	- The interdependence of the many sectors is not addressed. - There is no emphasis on risk assessment.
Bhattacharyaet al. (2014)	A more thorough approach to analyzing a company's sustainability initiatives in a changing environment.	- Rather than comparing various questions, the framework has a tight boundary in questions. - There is no special emphasis on risk assessment. - Complicated for broad application. - Due to its tremendous complexity, it is neither practical nor useful for company comparisons.
Garbie (2014)	- Comprehensive indicators. - Indicators calculations and mathematical model are simple and easily comprehended.	- Rather than comparing multiple ones, the framework in question has a tight boundary. - The economic sector's manufacturing indicators have collapsed.

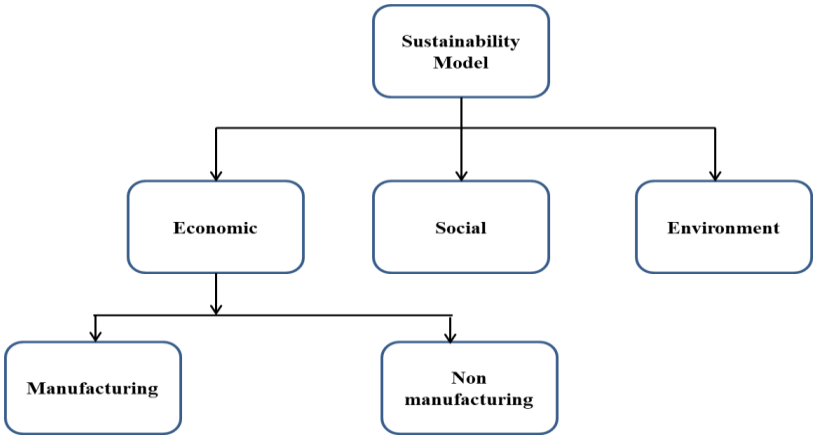

Fig. 1 Dimensions of sustainability [24]

3.1 Social Sustainability

Because discussions about sustainable development often focus on the environmental or economic aspects of sustainability, social sustainability is sometimes overlooked. To get the most sustainable conclusion, all three sustainability aspects must be addressed. Social sustainability occurs when official and informal processes, organizations, structures, and connections actively encourage current and future generations' abilities to construct healthy and livable communities. According to the Western Australia Council of Social Services (WACOSS), Communities that are socially sustainable are egalitarian, diverse, connected, and democratic, and they provide a good quality of life. Social sustainability is the process of creating long-term, effective environments that promote well-being by understanding what people need from the places where they live and work. Social sustainability combines physical realm and social world infrastructure design to support social and cultural life, social amenities, citizen participation mechanisms, and space for people and places to evolve. From a business standpoint, social sustainability is about understanding how corporations affect people and society. Social sustainability is seen as a significant pillar of sustainability in manufacturing firms. Table 3 shows these challenges/aspects: work management (S1), human rights (S2), social commitment (S3), customer issues (S4), and commercial practices (S5). Each issue/aspect will be presented in conjunction with its accompanying sustainability indicators, and each issue will be evaluated separately.

Table 3 the main aspect of sustainability

Issue/Aspect	Indicator	Symbol
Social sustainability	Work management	S1
	Human rights	S2
	Societal commitment	S3
	Customer issues	S4
	Business practices	S5

A. Work management issues (S1)

Work management is defined by Gartner, the world's largest information technology research and advisory firm, Communities that are socially sustainable are egalitarian, diverse, connected, and democratic, and they provide a good quality of life. Social sustainability is the process of creating long-term, effective environments that promote well-being by understanding what people need from the places where they live and work. Social sustainability combines physical realm and social world infrastructure design to support social and cultural life, social amenities, citizen participation mechanisms, and space for people and places to evolve. Work management encompasses a wide range of sub-issues. Employment (S11), work conditions (S12), social dialogue (S13), social security (S14), and human resource development (S15) are the issues represented. Table 4 displays the indicators connected to work management difficulties as well as the performance metrics that are used.

Table 4 Sustainability index regarding the work management issues

Issue/Aspect	Indicator	Performance measure
Work Management Issues (S1)	Employment (S11)	The number of new employees hired each year.
	Work conditions (S12)	The number of accidents caused by working conditions.
	Social dialogue (S13)	Percentage of stakeholders conversing.
	Social security (S14)	Percentage of social safety precaution benefits.
	Human resources development (S15)	The number of practicing hours per employee.

B. Human rights (S2)

Human rights are the basic rights and liberties to which all people are known, and are commonly understood to include the right to life and liberty, freedom of opinion and expression, and equality before the law. People are more likely to contribute to sustainable communities when they have full access to natural resources, a clean environment, jobs, education, and social services. When basic human needs and fundamental human rights are not met, individuals' ability to engage in social, economic, and environmental systems that promote sustainability is compromised. Human rights (S2) are a fetal aspect of social sustainability and social expectations. It consists of a percentage of child labor (S21). S22 represents freedom of association as a percentage of founding an association. Discrimination (S23) is depicted as a relative relation of benefits among employees. Table 5 lists human rights indicators and their performance measurements.

Table 5 Sustainability index regarding the human rights

Issue	Indicator	Performance metrics
Human Rights (S2)	Child labor (S21)	Children hiring percent
	Freedom of association (S22)	Percentage of new associations formed
	Discrimination (S23)	Discrimination as a percentage

C. Societal commitment (S3)

Lord Holme defined corporate societal commitment/responsibility in a World Business Council for Sustainable Development publication as "business's continual commitment to act ethically and contribute to economic success while improving the quality of life of its personnel and their families, as well as the local community and society at large." Corporate social responsibility is a relatively new management technique in which corporations aim to make a positive impact on society while conducting business. Evidence demonstrates that when firms take on societal commitment freely, it is far more effective than when it is required by governments. Companies should have a plan to enhance both qualitatively (people and process management) and quantitatively (societal effect). The second is just as important as the first, and stakeholders in every firm are more interested in "the outer circle"; the company's operations and how they affect the environment and society. Several sub-issues indicate social responsibility, which are measured using sustainability metrics. Level of involvement in local community (S31) is expressed as a percentage of total community involvement. The degree of education is used to assess the significance of education (S32). A percentage of health services offered to employees is used to assess the level of healthcare (S33).

The number of offering jobs every year is used to measure job creation (S34). How much societal investment (S35) is evaluated is a percentage of yearly budget to societal investment. S36 measures culture and technological development as a percentage of what technology and culture provide to society. Budget for societal investment (S36) measures culture and technological development as a percentage of what technology and culture provide to society. Table 6 shows societal commitment indicators and how to measure company’s performance regarding each indicator.

Table 6 Sustainability index regarding the societal commitment

Issue/Aspect	Indicator	Performance measure
Societal Commitment (S3)	Community involvement (S31)	Percentage of employees involved in the local community Average education level per total employees.
	Education (S32)	Percentage of total health-care spending or budget.
	Healthcare (S33)	The number of new employment created per local community.
	Job creation (S34)	Investment in society as a percentage of annual budget
	Societal investment (S35)	Technology and culture as a percentage of society
	Culture development (S36)	Percentage of employees involved in the community Average education level.

D. Customer issues (S4)

The consumer is the foundation of any business's success. Identifying and addressing consumer expectations should be one of the primary goals of every business plan. Consideration of the client at all stages of the process helps the organization achieve its long-term goal of recurring business by assuring enhanced customer satisfaction. Consideration of consumer desires during product development and advertising is not the only way to emphasize client needs. Customer service and interaction with the consumer after the product has been sold also contribute to the development of strong bonds with the consumer and supply enterprises with critical information that will help them retain their customers' loyalty. One of the most important issues is poor customer service. Customer happiness is critical since it. Customer challenges in terms of social sustainability include marketing and information (S41), private life protection (S42), and service quality (S43). Table 7 explains how to assess a company's success in terms of customer service KPIs.

Table 7 Sustainability index regarding the customer issues

Issue/Aspect	Indicator	Performance measure
Customer Issues (S4)	Marketing and information (S41)	Percentage of honestmarketing
	Private life protection (S42)	Percentage of customer’s private lifeprotection
	Quality of services (S43)	Percentage of customers satisfaction from services

E. Business practices (S5)

A good company that is motivated to create and keep business will have strong ethical business practices. Building excellent corporate practices begins with setting an ethical example and developing policies and procedures that control staff activity. The importance of good ethical business practices can be discovered in a company's reputation and brand. Customers must trust the company brand in order to make recurring purchases. This is due to the fact that they can typically obtain a comparable product or service from a competitor. Business ethics assist the organization in staying ahead of competitors who use less ethical business practices. When it comes to sustainability, corporate practices are mostly concerned with understanding corruption and fair trade. They must be employed in order to decrease bias. These practices are divided into two categories; combating corruption (S51), and fair commerce (S52). Table 8 displays indicators of the business practices component and their accompanying performance metrics.

Table 8 Sustainability index regarding the business practices

Issue/Aspect	Indicator	Performance measure
Business practices (S5)	Fight against corruption (S51)	Number of corruption inside enterprise per year
	Fair-trading (S52)	Degree or percentage of company’s fair-trading

3.2 Environmental Sustainability

Environmental sustainability has been studied as the effects of a specific set of uses on manufacturing enterprises, such as waste reduction, recycling, and pollution control. Furthermore, some economic sustainability, such as supply chain management, has a corresponding effect on environmental sustainability. Environmental expenditures are incurred when environmental management procedures are monitored in order to reduce waste and pollution as a means of advancing

sustainability. Certain environmental manufacturing techniques, such as minimizing raw material consumption, recycling solid waste, and re-configuring goods, are more environmentally sustainable. The last pillar characteristic of global production sustainability is environmental sustainability. Environmental sustainability has five important components: environmental management (N1), resource utilization (N2), pollution (N3), hazard (N4), and natural environment (N5) as shown in table 9. Each issue will be debated with its oriented sub-issues and the sustainable model including for the five environmental concerns.

Table 9 the main aspect of sustainability

Issue/Aspect	Indicator	Symbol
Environmental sustainability	Environmental management	N1
	Use of resources	N2
	Pollution	N3
	Dangerousness	N4
	Natural environment	N5

A. Environmental management (N1)

Environmental sustainability has been studied as the effects of a specific set of uses on manufacturing enterprises, such as waste reduction, recycling, and pollution control. Furthermore, some economic sustainability An environmental management system is the detailed, methodical, planned, and recorded management of an organization's environmental programs. It includes the organizational structure, strategy, and resources for developing, implementing, and sustaining environmental policy. Environmental management systems (EMSs), such as ISO 14001, provide a framework for businesses looking to effectively manage their environmental problems. Putting in place an ISO 14001-compliant EMS can help firms incorporate environmental concepts into their operations. Environmental management begins with the creation of a product and continues through disposal and discarding. Many key concerns confront environmental management (N1), it has many major aspects including environmental budget (N11), environmental certification (N12), environmental concerns and compliance (N13), and workers implications (N14). Table 10 illustrates the sustainability indicators of environmental management with performance metrics of each indicator.

Table 10 Sustainability index regarding the environmental management

Issue/Aspect	**Indicator**	**Performance measure**
Environmental Management (N1)	Environmental budget (N11)	Percentage of budget paid for environmental issues
	Environmental certification (N12)	Percentage of conformity with ISO14001
	Environmental concerns and compliance (N13)	Percentage of environmentalimpact assessment
	Workers implications (N14)	Number of environmental accidents per year

B. Use of resources (N2)

Sustainable environmental management is required to conserve natural resources for future generations. Alternative resources could be created to alleviate the burden on limited resources. Alternative resources, on the other hand, can be costly and time-consuming to produce. Existing resources could be used more efficiently to avoid depleting finite resources so quickly. As a result, sustainable resource usage is becoming increasingly important for the long-term development of present economies and the preservation of a clean environment. The use of resources (N2) has become one of the most critical aspects of environmental challenges. Resources must be set aside as an investment in environmental capital. This capital resource is made up of renewable energy (N21), recycled water (N22), and recycled solid wastes (N23). Table 11 shows the sustainability indicators of use of resources aspect with performance measures.

Table 11 Sustainability index regarding the use of resources

Issue/Aspect	Indicator	Performance measure
Resources (N2)	Renewable energy (N21)	Energy using percent from renewable resources
	Recycled water (N22)	Percentage of using recycled water
	Recyclable solid waste (N23)	Percentage of using recyclablesolid wastes

C. Pollution (N3)

Pollution is a very frequent idea in everyday survives. It is an essential and important aspect to examine pollution in the country as a whole, and also in industrial estates and manufacturing firms as a specific source of pollution. There are three types of pollution depend on these issues: air pollution, water pollution, and land contamination. Pollution (N3) will take into account three separate indicators: air pollution (N31), water pollution (N32), and land pollution (N33). Table 12 depicts the pollutant sustainability indicators, together with performance metrics for each indicator.

Table 12 Sustainability measures regarding to pollution

Issue	Indicator	Performance metrics
Pollution (N3)	Air pollution (N31)	Total amount emission ofgasses produced from the facility in (kg).
	Water Pollution (N32)	Total of pollutants particles in (mg) concentrated at the water
	Land pollution (N33)	Total Land-filled waste produced from the facility in (kg).

D. Dangerousness (N4)

Although risk is seen as one of the fetal issues affecting environmental sustainability, resolving the difficulties that result from it is difficult and time-consuming. Dangerousness is classified into three categories: dangerous input, dangerous output, and dangerous wastes. Dangerousness (N4) is comprised of three indicators: hazardous intake (N41), hazardous output (N42), and hazardous wastes (N43). Table 13 depicts the dangerousness sustainability indicators, along with performance measures for each indicator.

Table 13 Sustainability measures regarding to dangerousness

Issue	Indicator	Performance metrics
Dangerousness (N4)	Dangerous input (N41)	Total Kilograms per cubic meterof dangerous input material
	Dangerous output (N42)	Total Kilograms per cubic meterof dangerous output
	Dangerous wastes (N43)	Total Kilograms per cubic meter of dangerous wastes

E. Natural environmental (N5)

The term "natural environment" refers to all objects including landscapes, oceans, water, atmosphere, biodiversity, and rural areas. Human activity affects the natural environment, which allows for human life. The natural environment must be preserved in its natural state, which is reflected by concerns such as eco-system services, biodiversity, pure land use, and rural development. Natural environmental (N5) issues are represented by the following issues: eco-system services (N51), biodiversity (N52), pure land use (N53), and rural development (N54). Table 14 depicts the natural environmental sustainability indicators, together with performance metrics for each indicator.

Table 14 Sustainability index regarding to natural environmental

Issue/Aspect	Indicator	Performance measure
Natural environmental (N5)	Eco-system services (N51)	Percentage level of carbondioxide in the atmospheric
	Biodiversity (N52)	Number of animal and plant species in the biotic community
	Usage pure land (N53)	Meter square of pure land consumed for the plant
	Development rural areas (N54)	Percentage of yearly budget for charity rural area

3.3 Sustainability/Sustainable Development (S/SD) Assessment

A. Assessing S/SD indices in production enterprises is an essential goal since it is a novel and developed performance evaluation to calculate the component requirements for these enterprises to survive. The primary goal of this part is to discover how to examine each significant issue individually and collectively address the sustainability dimensions.

B. Assessment of major issues/aspects

The final model to evaluate the sustainability depends on each main issue of sustainability components which is presented in equation (1), which can be regarded to estimate the sustainability index [24].

$$E(SD_i) = \prod_{j=1}^{n_{ij}} (I_{ij})^{Y_{ij}} = \left(\frac{T_{i1}}{E_{i1}}\right)^{Y_{i1}} . \left(\frac{T_{i2}}{E_{i2}}\right)^{Y_{i2}} \dots \left(\frac{T_{n_{ij}}}{E_{n_{ij}}}\right)^{Y_{n_{ij}}} \quad \text{Eq. (1)}$$

Where:

$E(SDi)$	Index of effort to sustainable development (SD) of major issue *i.*
J	Considered the sub-issues in every major issue or facet of the sustainability model for each dimension, $j = 1; 2; \dots n_{ij}$. Where: nij = each main issue has a number of indicators (performance metrics). i. Performance metric for sub-problem j in major issue i represents the percent of the target upon sustainability (T) to the existing (E).
I_{ij}	Performance measures of sub-issue j in major aspect i representing the percent between the target towards the sustainability (T) and the current sustainability (E). $Iij = Tij/Eij$ …… If $Tij > Eij$ $\quad$ $Iij = Eij/Tij$ …… If $Tij < Eij$
Tij	Value of issue j in major issue i for the sustainability target (T).
Eij	The value of facet j in significant aspect i in relation to the existing (E) status.
Yij	The exponent of the shift for the sustainability target (T) for sub-problem j in main issue i represents the absolute value of the difference between the current state (E) and the target (T). $Y_{ij} = \log\|d_{ij}\|$
Dij	Value of the difference between target value and current value for sub issue j in major issue i.

C. Measurement of sustainability dimensions/pillars

Equation (2), which is based on Equation (1), presents the sustainable mathematical model of the sustainability (e.g., economic, social, and environmental) in manufacturing firms. Equation (2) is used to calculate the sustainability/sustainable development (S/SD) index of every sustainability major individual based on the percent weights of sustainability issues.

$$S/SD_K = \sum_{i=1}^{n_i} w_{iK} . S/SD_{iK} \quad \text{Eq. (2)}$$

Where:

S/SD_K	Sustainability of major dimension/pillar.
W_{iK}	Relative importance or weight regarding issues i of pillar K.
S/SD_{iK}	Sustainability of main issue i in major pillar K**.**

3.4 Sustainability Indicator Model

[13] Created a model for establishing and monitoring a company's sustainability performance consists of eight steps, which is depicted in Figure 2.

The first step is defining the goals and objectives of sustainable production. Attempt to define all critical parts of an organization's operations and stimulate all interested party participation in making all the decision.

Step 2 is identifying the prospective indicators that will identify a company's goals and targets for sustain the production. This step is challenging for small businesses with a scarcity of resources.

Step 3: Determine which indicators will be used for implementation. Businesses are urged to think of additional, production-specific metrics. This procedure must include all staff.

Step 4 is target setting by all the managerial stuff, after consulting with all interested party, establishes defined objectives. This phase is critical because it Ensures managerial trust and encourages responsibility.

Step 5 is the implementation of the chosen indicators, which includes collection of data, and interpretation of outcomes. This step consumes the most of time and necessitates widespread sharing from an organization's personnel, especially middle management.

Step 6 is to monitor and communicate the outcomes. For continuous improvement, a business must discuss and assess the outcomes of the chosen indicator on a regular basis.

Step 7 Acting on results is an important phase in the indicator analysis process. Management implements corrective actions and indicates that indicators are a continual process of improving all dimensions in the organizational sustainable performance.

Step 8: Review all metrics, policies, and objectives. This is an important phase because it establishes the groundwork for establishing new goals, objectives, and indicators.

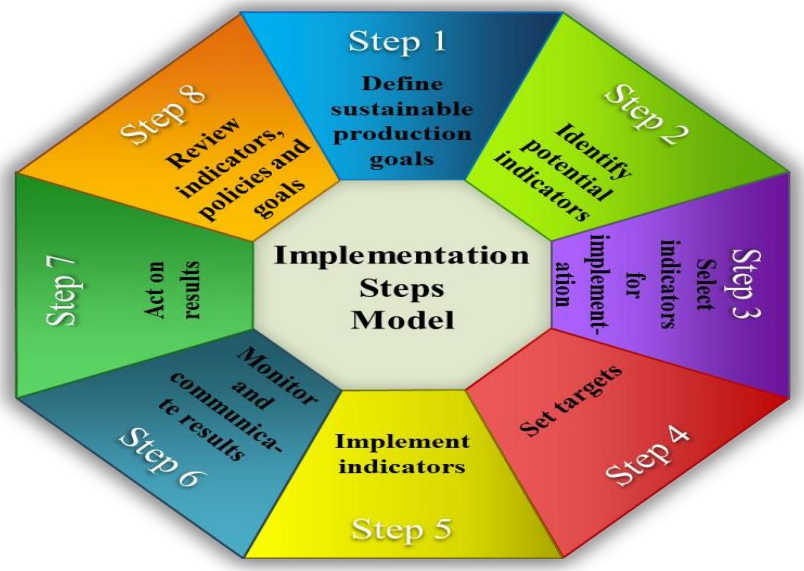

Fig. 2 Model for establishing and monitoring enterprise sustainability performance [13]

4. Empirical testing of framework in plastic irrigation pipes manufacturing

Data is collected from plastic irrigation pipes manufacturing company specializes in producing drip irrigation hoses with different diameters. A survey of sustainability indicators was done to estimate the gape between the current and planned performance of the company. Some values were obtained directly from the company staff when they were already available, while other values were obtained through benchmarks or scientific analysis. Moreover, the percentage of existing sustainability of the company is measured through the percentage achieved in each aspect and dimension. The collected data from the company are used to measure the sustainability aspects in each separate dimension of sustainability.

4.1 Measuring the social Sustainability

There are five major aspects that will be measured under the social sustainability; work management (S1), human rights (S2), societal commitment (S3), customer issues (S4), and business practices (S5).

A. Work management issues (S1)

The aspect of work management issues can be measured through several indicators that includes; employment (S11), work conditions (S12), social dialogue (S13), social security (S14), and human resources development (S15). The collected data for the first aspect work management (S1) is summarized in table 15 which includes; the indicators, the existing and target values with additional required actions.

Table 15 Information about employment

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
S11	9.76%	11.64%	1.88	19.26	Increase employees by 19.26%.
S12	3.36	0.96	-2.4	71.43	Decrease accidents rate by 71.43%.
S13	1	3	2	200	Increase in dialogue by 200 %.
S14	53.17%	93.66%	40.49	76.15	Increase security by 76.15%.
S15	4.4 hr.	14 hr.	9.6	218.18	Increase training by 218.18%.

B. Human rights (S2)

The aspect of human rights issues can be measured through several indicators which includes; (S21) is child labor, (S22) is freedom of association, and (S23) is discrimination. The collected data for human rights (S2) is summarized in table 16.

Table 16 Information about human rights

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
S21	1.37%	0.34%	-1.03	75.18%	Decrease hiring children by 75.18%
S22	0%	0%	0	-	No actions in creating association.
S23	4.5%	1%	-3.5	77.78%	Decrease discrimination by 77.78%

C. Societal commitment (S3)

The aspect of societal commitment can be measured through several indicators which includes; (S31) is involvement in community, (S32) is education, (S33) is healthcare, (S34) is job creation, (S35) is societal investment, and (S36) is culture development. Table 17 summarizes the collected data related to societal commitment (S3) issues.

Table 17 Information about work management

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
S31	50%	83.33%	33.33	66.66	Increase local community by 66.66%.
S32	14.36%	20%	5.64	39.28	Increase education by 39.28%.
S33	53.17%	93.66%	40.49	76.15	Increase health service level by 76.15%.
S34	5	8	3	60	Increase in number of new jobs by 60%.
S35	5%	5%	0	-	No action in annual budget.
S36	0.25%	1%	0.75	300	Increase culture society by 300%

D. Customer issues (S4)

The aspect of customer issues can be measured through several indicators that includes; (S41) is marketing and information, (S42) is private life protection, and (S43) is quality of services. Table 18 summarizes the collected data related to customer (S4) issues.

Table 18 Data collected for customer issues

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
S41	99%	99%	0	-	No action in delivering honest marketing
S42	57.14%	85.71%	28.57	50	Increase customers life protection by 50%
S43	72.5%	82%	9.5	13.1	Increase customers satisfaction by 13.1%

E. Business practices (S5)

The aspect of business practices can be measured through several indicators which include; fight against corruption (S51) and fair-trading (S52). Table 19 summarizes the collected data related to business practices (S5) issues.

Table 19 Data collected related to business practices issues

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
S51	0.4	0.2	-0.2	50	Decrease corruption by 50%.
S52	70%	85%	15	21.43	Increase fair-trading by 21.43%.

F. Sustainability index for Social Sustainability

Equation 1 is used to determine the sustainability index for each of the five primary dimensions of social sustainability. The achieved results show that 1820% more effort toward sustainability is needed in work management, particularly in social security and human resource development, and 230.8% more effort toward sustainability is needed in human rights, particularly in child labor. As shown in table 20, 730% more effort is required for sustainability compared to the existing in terms of societal commitment, particularly in community involvement and healthcare, 204% more effort is required for sustainability compared to the existing in terms of customers, particularly in private life protection, and 77.4% more effort is required for sustainability compared to the existing in terms of business practices, particularly in fair-trading as shown in table 20.

Table 20 sustainability index for Social Sustainability

Code of Indicator	Existing sustainability (%)	Sustainability Index (%)	Recommended action
S1	5.21	1820	More effort is needed in work Management by 1820 %.
S2	30.23	230.8	More effort is needed in human rights by 230.8 %.
S3	12.05	740	More effort is needed in societal commitment by 740 %
S4	32.89	204	More effort is needed in customers by 204 %
S5	56.37	77.4	More effort is needed in business practices by 77.4 %

4.2 Measuring the Environmental Sustainability

There are five major aspects that will be measured under the environmental sustainability; (N1) is environmental management, (N2) is the use of resources, (N3) is the pollution, (N4) is dangerousness, and (N5) is natural environment.

A. Environmental management (N1)

The aspect of environmental management can be measured through several indicators that include; (N11) is environmental budget, (N12) is environmental certification, (N13) is environmental compliance, and (N14) is workers implications. Table 21 illustrates the sustainability assessment of each indicator of environmental management with its target, and the recommended actions.

Table 21 Information about environmental management

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
N11	1%	1.1%	0.1	10	Increase environmental budget by 10%
N12	0%	100%	100	100	Increase certification by 100%
N13	93%	100%	7	7.52	Increase compliance by 7.52%
N14	1.2	0.4	-0.8	66.67	Decrease workers implication by 66.67%

B. Use of resources (N2)

The aspect of use of resources can be measured through several indicators that include; (N21) is renewable energy, (N22) is recycled water, and (N23) is recyclable wastes. Table 22 illustrates the sustainability assessment of each indicator of use of resources with its target, and the recommended actions.

Table 22 Information about the use of resources

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
N21	0	25%	25	-	Increase target by 25%
N22	20%	92%	72	360	Increase recycled water by 360%
N23	100%	100%	0	0	No action in recyclable waste

C. Pollution (N3)

The aspect of pollution can be measured through several indicators that include; (N31) is air pollution, (N32) is water pollution, and (N33) is land pollution. Table 23 illustrate the sustainability assessment of each indicator of pollution with its target, and recommended actions.

Table 23 Information about use of resources

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
N31	2.414	2.10	-0.314	13.01	Decrease air pollution by 13.01%.
N32	9	7	-2	22.22	Decrease water pollution by 22.22%.
N33	0%	0%	0%	-	No action in land pollution.

D. Dangerousness (N4)

The aspect of dangerousness can be measured through several indicators that include; (N41) is dangerous input, (N42) is dangerous output, and (N43) is dangerous wastes. Table 24 illustrate the sustainability assessment of each indicator of dangerousness with its existing, and target.

Table 24 Information about dangerousness

Code of Indicator	Existing value (E)	Target value (S)	Required change (s) %	Percent of change (%)	Recommended action
N41	0%	0%	0%	-	No efforts needed.
N42	0%	0%	0%	-	No efforts needed.
N43	0%	0%	0%	-	No efforts needed.

E. Natural environment (N5)

The aspect of natural environment can be measured through several indicators that include; (N51) is eco-system services, (N52) is biodiversity, (N53) is land use, and (N54) is development of rural areas. Table 25 illustrate the sustainability assessment of each indicator of natural environment with its target, and recommended actions.

Table 25 Information about natural environment

Code of Indicator	Existing (E)	Target (S)	Value of change %	Percentage of change (%)	Recommended action
N51	$14.44x10^6$	$12.56x10^6$	$-1.88x10^6$	13.01	Decrease eco system services by 13.01%
N52	22000	22660	660	3	There is an increase in biodiversity of 3%
N53	5200	4675	-525	10.09	decrease usage pure land of 10.09%
N54	3%	3.6%	0.6	20	Increase rural areas by 20%

F. Sustainability index for environmental sustainability

The sustainability index for each five major aspects for social environmental is calculated based on Equation 1. The obtained results revealed that; 86.9% more effort is required for sustainability compared to the existing for environmental management issues, 1701.1% more effort is required for sustainability compared to the existing for resource use, 100.5% more effort is required for

sustainability compared to the existing for pollution, and no effort is required for sustainability compared to the existing for dangerousness, 144.7 % more effort is required for sustainability compared with the existing is needed regarding natural environmental issues as shown in table 26.

Table 26 sustainability index for environmental sustainability

Indicator code	Existing sustainability (%)	Sustainability index (%)	Action required
N1	53.5	86.9	More effort in environmental Management by 86.9 %.
N2	5.56	1701.1	More effort in the use of resources by 1701.1 %.
N3	33.28	100.5	More effort in pollution by 100.5 %
N5	100	0	No effort is required in dangerousness.
N5	40.87	144.7	More effort in natural environmental issues by 144.7 %

4.3 Sustainability index for economic sustainability

The existence sustainability index for each seven major aspects for economic sustainability is calculated as; reconfiguration process (E1) is 39.5%, competitive manufacturing (E2) is 42%, performance evaluation (E3) is 35.75%, globalization issues (E4) is 31.10, emerging issues (E5) is 5.41%, innovation products (E6) is 31.83, Flexible organization management (E7) is 28.67.

4.4. Assessment of Enterprise Sustainability

The overall index of sustainability can be determined by calculating the relative weight of each aspect and dimension with respect to others in the same level in the hierarchy of sustainability model. These weights are obtained through the use of (AHP) technique.

A. Assessment of social sustainability

Weights of each aspect in the dimension of social sustainability is determined by the manager of the company and showed in this matrix:

	S1	**S2**	**S3**	**S4**	**S5**
S1	1	5	2	1/3	1/3
S2	1/5	1	1/4	1/8	1/7
S3	1/2	4	1	1/4	1/4
S4	3	8	4	1	2
S5	3	7	4	1/2	1

The achieved results showed that the weights of each social sustainability aspects are presented; (S1) is 0.1496, (S2) is 0.0366, (S3) is 0.0988, (S4) is 0.4109 and (S5) is 0.3041. Index of social sustainability (S/SDS) in the factory is calculated based on Equation (2) with 33.73%.

B. Assessment of environmental sustainability

Weights of each aspect in the dimension of environmental sustainability is determined by the manager of the company and presented in this matrix:

	N1	**N2**	**N3**	**N4**	**N5**
N1	1	1/2	3	7	4
N2	2	1	4	8	5
N3	1/3	1/4	1	4	3
N4	1/7	1/8	1/4	1	1/3
N5	1/4	1/5	1/3	3	1

The achieved results showed that the weights of each environmental sustainability aspects are presented; (N1) is 0.2926, (N2) is 0.4415, (N3) is 0.1451, (N4) is 0.0393, and (N5) is 0.0815. Index of environmental sustainability (S/SDN) in the factory is calculated based on Equation (2) with 30.20%.

C. Assessment of economic sustainability

Index of environmental sustainability (S/SD) in the factory is calculated based on Equation (2) with 34.25%.

D. Assessment of total sustainability

Weights of each dimension of sustainability is determined by manager of the company and presented in matrix:

	E	**S**	**N**
E	1	3	7
S	1/3	1	4
N	1/7	1/4	1

The achieved results showed that the weights of each sustainability dimensions are presented; economic sustainability (E): 0.6555, social sustainability (S): 0.2648, and environmental sustainability (N): 0.0797.

Index of sustainability (S/SD) in the factory is calculated based on Equation (2) with 33.79%. Table 27 presents the sustainability dimensions and the total sustainability of the company. This sustainability index is compared with the average and best index in this field of industry as shown in figure 3. The achieved results from data collection are revealed that the company has a low sustainability index compared with the competitive industries including the three dimensions of sustainability and need many areas of improve.

Table 27 the measured sustainability indices of the company

Sustainability dimensions	Sustainability index %
Social sustainability	33.73
Environmental sustainability	30.20
Economic sustainability	34.25
Total factory sustainability (S/SD)	33.79

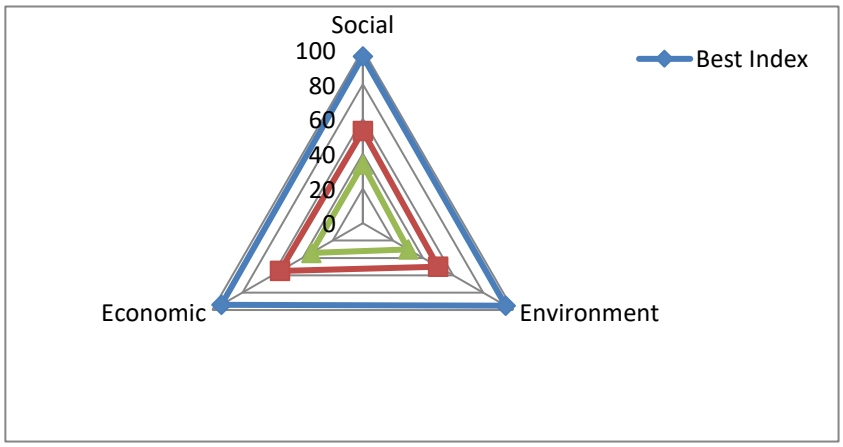

Fig. 3 Performance of the company against leaders in the industry

4.5 Recommended areas for improving the performance

After analysis all the processes in the production line for improvement. Many upgrades are required to increase productivity and have greater business value. The main problems in the production line are assessed such as; bottleneck in the production line caused by perforating and insertion machines, high water consumption in the production line, low efficiency of ventilation system in the plant.

A. Ventilation system

Employers must ensure that their workers work in a safe and healthy environment. This contributes to better yield from workers, employee retention, and substantially improves social sustainability of the enterprise. Several areas were tackled in order to raise the level of safety inside the plant. First is designing a ventilation system for one of the departments of the factory. Second solution is an automatic shutdown mechanism of plastic shredding machine is implemented to avoid related injuries. Third solution is putting up instructional posters containing general health and safety precautions for supervisors and workers to take into consideration while operating machines and dealing with different tasks inside the facility.

B. Water consumption

The plant's high water use is regarded as a critical issue. Water reuse is an increasingly appealing economic solution to this problem; with good management, all water can be utilized to the greatest extent possible before disposal, resulting in less demand from the original source. The plant's high water use is regarded as a critical issue. Water reuse is an increasingly appealing economic solution to this problem; with good management, all water can be utilized to the greatest extent possible before disposal, resulting in less demand from the original source. After studying and investigation of different types of filtration systems, it is found that automatic self-cleaning filter is the most applicable one for this case compared to the other ones. After installation of the automatic self-cleaning filter in the production line of the plastic recycling, it was noted that there is not any modification needed concerned with the pipes of waste water in terms of the inlet and exist of filter. This solution has positive impact on environmental and economic sustainability.

C. Bottleneck in the production line

The bottleneck has a great impact on decreasing the productivity of the production line. Upgrading perforating and insertion machines can improve the overall production flow and efficiency of the production line with higher investment but more promising income in the future. Mechanisms and features of the existing perforating and insertion machines are analyzed and compared with a new proposed machine that are researched as a replacement to increase productivity output of the factory. This area of improve will positively impact on sustainability dimensions.

5. Results of reassessment the sustainability

After implementing the proposed solutions for the three areas of improvement, re-evaluation of sustainability are achieved to determine the changes in the different sub-issues of sustainability dimensions. Moreover, total sustainability indices of environmental, social, and economical dimensions are calculated. Overall sustainability of the enterprise is calculated and compared to previous measurement.

5.1 Environmental sustainability

The total index of environmental sustainability can be deduced through multiplying the new values by the obtained respective weights of each aspect. The resulted environmental index of the company is found to be 50.80%. Figure 4 shows the environmental sustainability aspects before and after improvement.

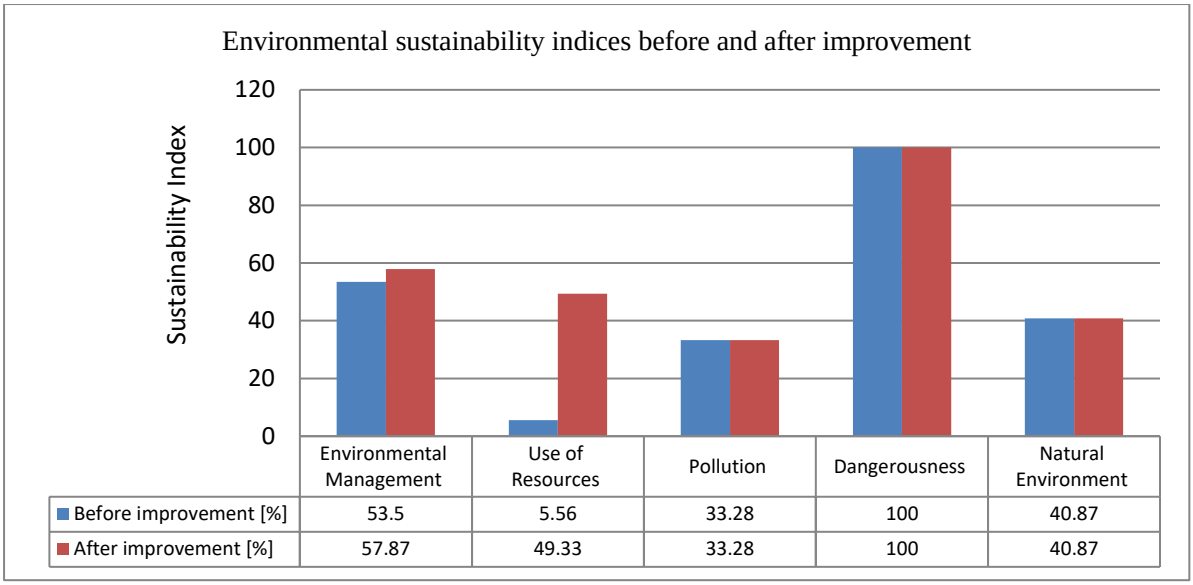

Fig. 4 Environmental sustainability indices before and after improvement

5.2 Social sustainability

The total index of social sustainability can be deduced through multiplying the new values by the obtained respective weights of each aspect. The obtained results showed that the company increased its social dimension of sustainability index from 33.73% to 37.32%. Figure 5 shows the social sustainability aspects before and after improvement.

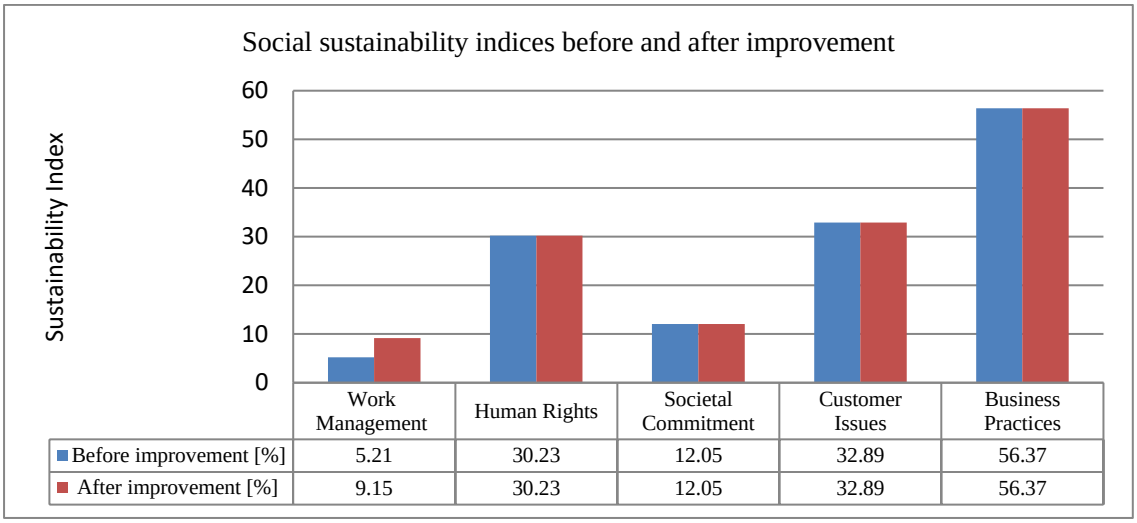

Fig. 5 Social sustainability indices before and after improvement

5.3 Economic sustainability

The total index of economic sustainability can be deduced through multiplying the new values by the obtained respective weights of each aspect. The obtained results showed that the company increased its economic dimension of sustainability index from 34.25% to 39.38%. Figure 6 shows the economic sustainability aspects before and after improvement.

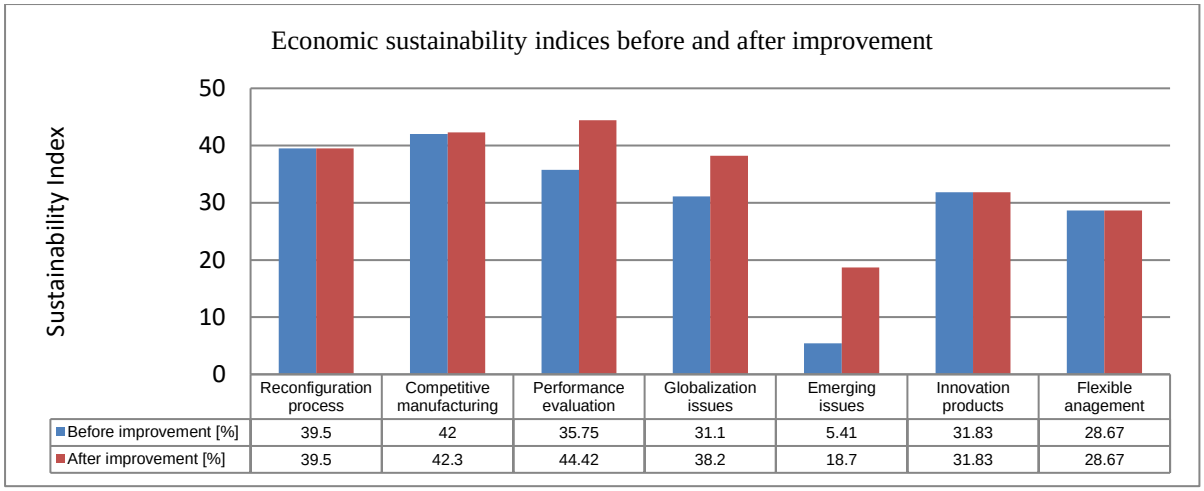

Fig. 6 Social sustainability indices before and after improvement

5.4 Total sustainability of the company

The social sustainability index increased from (33.73 to 37.32) %, the environmental sustainability index increased from (30.20 to 50.80) %, and the economic sustainability index increased from (34.25 to 39.38)%. Figure 7 shows the sustainability dimensions before and after improvement. The overall sustainability of the company is calculated through Equation 2, and found to be increased from (33.79 to 39.74)% as a result of implementation of the proposed solutions.

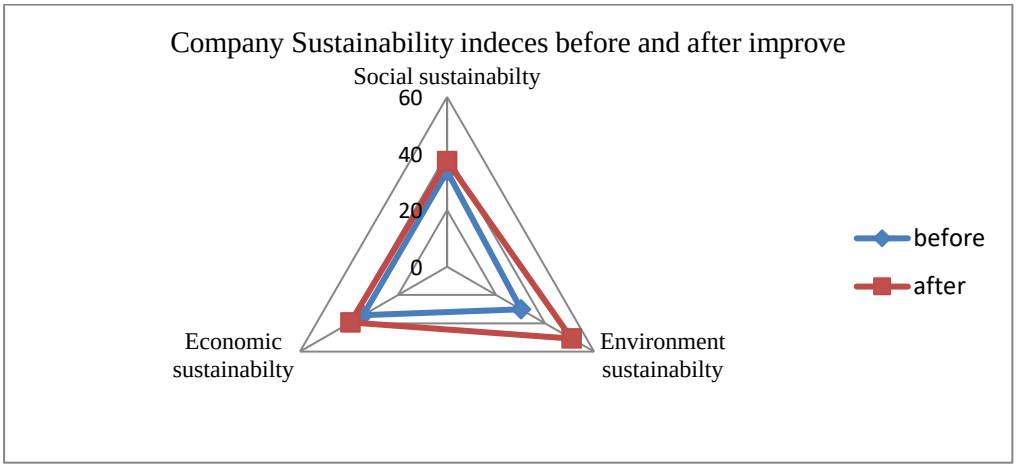

Fig. 7 Sustainability dimensions indices before and after improvement

6. Conclusion

For manufacturing companies, sustainable production is becoming increasingly crucial. Some companies have recently begun to implement a sustainability assessment in order to understand and supervise the actual performance of products and operations in terms of sustainable manufacturing. Based on a survey of the literature, this research article focuses on sustainable manufacturing and presents a framework and indicators of sustainable manufacturing. Managers and practitioners can choose or exclude framework and indicator items based on manufacturing suitability. This framework can be used as strategic indicators to analyze the company's sustainability level and as a tool to promote increased sustainability awareness, measurement, and reporting. An eight-step guide for implementation of the model was followed in the process of measuring index of sustainability inside the selected company. The suggested framework also allows decision makers to create their own indicators based on the company's and stakeholders' mindset. The findings of measuring sustainability show that three areas of improvement in the organization are underperforming in terms of sustainable manufacturing. Following the implementation of the offered solutions in the organization, the indices of sustainability dimensions are re-assessed. The results showed that the applied solutions had a

significant influence on boosting the sustainability indexes. The measured environmental sustainability increased by 20.60%, the index of social sustainability increased by 3.59%, and the index of economic sustainability increased by 5.13%. The total sustainability index of the enterprise is increased by 5.95%.

Abbreviations

TBL	Triple Bottom Line
S/SD	Sustainable development
AHP	Analytic hierarchy process
CDM	Collaborative decision-making
WACOSS	Western Australia Council of Social Services

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