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ORIGINAL PAPER

Development of decision support system for sustainability evaluation: a case study

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Abstract The industries have created threat to the present environment through their manufacturing methods. Moreover, the excessive utilization of natural resources have led to scarcity and triggered danger for the future generations. So there exists a vital need for the modern companies to renovate their manufacturing technologies. Thus, a new concept of manufacturing process known as sustainable manufacturing has been introduced and it gained great importance in the present scenario. Sustainable manufacturing means the production of goods in such a way that it utilizes minimum natural resources and produces safer, cleaner, and environment-friendly products at an affordable cost. The purpose of this article is to assess the sustainability level of a manufacturing organization taking into consideration various factors needed for insuring sustainability. During the course of this research, a sustainability model was developed using fuzzy logic and the sustainability index was calculated. Manual calculation of sustainability index consumes more time and it is mistake prone. So, in order to avoid such inadequacies, a computer-based decision support system was developed designated as fuzzy-logic-based sustainability evaluation decision support system. The system calculates the fuzzy logic sustainability index, Euclidean distance, and fuzzy performance importance index. This model will help the companies to analyze various aspects of sustainability within their organization and work toward further improvement of it.

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Introduction

The modern manufacturing organizations are forced to adopt sustainable manufacturing principles due to regulations enforced by Government policies. As a sequel to it, the need for developing environmentally friendlier products arises. Sustainability includes environmental, economic, and social dimensions. Hence, the assessment of sustainability must be a comprehensive and holistic approach. Due to the drawbacks associated with traditional methods, the usage of fuzzy methods gains importance. Hence, the requirement for fuzzy-based sustainability evaluation was realized. Due to the complexity associated with fuzzy-based sustainability evaluation, fuzzy-logic-based sustainability evaluation decision support system (FLBSE-DSS) was designed and deployed in our study. The novelty of the study reported in this article is the development of exclusive DSS for sustainability evaluation in a fuzzy environment. Also, the practical feasibility of the developed DSS was test implemented in a real time manufacturing environment. The conceptual features and working mechanism of FLBSE-DSS will be presented in this article.

Literature review

The literature has been reviewed from the perspectives of sustainability evaluation, fuzzy logic, and DSS applications in sustainability.

Literature review on sustainability evaluation

Now-a-days, sustainability assessment has become a household term for the modern industries. As the companies are compelled to reduce cost and insure environmental safety of products, evaluation of sustainability has become very important for them. Several aspects of sustainability have undergone research in this regard and different scholars have applied this concept in their respective fields of manufacturing. Afghan et al. (1999) performed sustainability assessment of desalination plants for water production on the basis of environment, resources, and ecological factors. Robert (2000) presented the concepts of sustainable development using metrics like life cycle analysis, ecological footprinting, and Factor-X. Calderon (2000) assessed the sustainability of urban pilot projects requesting financial support. Also, Ravetz (2000) portrayed an integrated assessment for sustainability appraisal in cities and regions. Noble (2002) suggested an assessment practice related to environmental sustainability which can contribute to designing more sustainable policies. In 2003, a multi-criterion framework was presented by Munda (2003) for assessing sustainability. In 2004, an initiative was taken by Pope et al. (2004) to achieve triple bottom line by an integrated assessment process laying emphasis on minimizing unsustainability. Brunner and Starkl (2004) demonstrated the importance of a decision aid system in estimating sustainability. For evaluating sustainability in city regions, Weik and Binder (2005) presented a method of creating sustainability solution spaces which enables the user to make decisions. Ugwua and Haupt (2007) found important performance indicators for infrastructure delivery and technical processes for evaluating sustainability. Ticehurst et al. (2007) introduced a Bayesian network approach for calculating sustainability of coastal lakes in New Southwales (Australia). Lee and Huang (2007) presented the idea of sustainability index in Taipei. The results showed that social and environmental factors are progressing towards sustainability development in areas where institutional and economical elements are comparatively poor. Pulselli et al. (2007) demonstrated the engineering analysis of a building regarding its manufacturing and maintenance for the calculation of housing sustainability. Lozano (2008) presented sustainability in three dimensions using Venn diagrams, planning hexagon, and three concentric circles which illustrate the striking equilibrium existing between social, economic, and environmental factors both in short and long-term perspectives. Chen et al. (2009) showed a method concerning energy and resource limitations depending on reasons such as energy yield ratio, energy sustainability index, energy load ratio, net economic benefit index while evaluating local sustainability of a constructed wetland in Beijing. Tseng et al. (2009) presented a procedure for evaluating the indicators of a firms' sustainability in an unknown environment. Amekudzi et al. (2009) presented sustainability concept and sustainability assessment model of other infrastructure system for regional sustainable improvement. Benedetto and Klemes (2009) demonstrated "Environmental Performance Strategy Map" which analyzes economic and environmental aspects with a broader perspective. This graphical representation enables the grouping of environmental factors with a "Sustainability Environmental Performance Indicator" so that strategic decision-making facilities can be entertained.

Literature review on fuzzy logic applications

The definition of fuzzy is "not clear or precise." It is a system of data appropriate for expressing notions that cannot be defined distinctly but are influenced by their context. Here, data is not expressed in exact numbers but it varies over a considerable range. It originated in ancient Greece with Plato and Aristotle and finally Zadeh, a Professor in University of Berkeley in California was the first person to print ideas on fuzzy logic in 1965.

Fuzzy logic is similar to human reasoning. It permits approximate data and inferences in addition to any vague or inadequate data in contrast to the traditional logic which allows only specific data. Fuzzy logic in the form of fuzzy numbers can also be used to express linguistic variables. The linguistic variables facilitate the intake of several values from one extreme to the other using fuzzy numbers. It provides an alternative way to characterize linguistic and subjective features of today's world of computer technology.

Andriantiatsaholiniaina and Phillis (2003) developed a sustainability assessment by fuzzy evaluation (SAFE) model for performing sensitivity analysis to identify the most important factors contributing to sustainable development. It uses fuzzy logic reasoning and basic indicators of environmental integrity, economic efficiency, and social welfare. Kuswandari (2004) measured the sustainability of forest management (SFM) using fuzzy analytical hierarchy process (AHP) and rule-based fuzzy reasoning method. The cognitive mapping technique was used to show the causal relationship between verifiers and indicators and to determine the order of importance in attaining SFM. Baumgartner (2005) presented the concept of integrated sustainability assessment using fuzzy logic. Here the ecological, social, and economic assessments were integrated with fuzzy logic to consider the specific conditions of the decision situation while the preferences of decision makers were modeled with case-specific fuzzy sets. Prato (2007) assessed ecosystem sustainability and management using fuzzy logic. The author compared the stochastic and nonstochastic methods with the fuzzy logic assessment methods, evaluated fuzzy propositions about ecosystem sustainability and identified a group-preferred management alternative. Conner et al. (2009) used fuzzy logic to extensively evaluate the sustainability of an entity based on a number of basic indicators (air, land, economy, health, etc.). Phillis and Davis (2009) assessed corporate sustainability using multi-staged fuzzy reasoning model. Sensitivity analysis of the model reveals the most important indicators affecting corporate sustainability by identifying the areas which managers and executives need to pay special attention. Phillis and Kouikoglou (2009) in his book "Fuzzy Measurement of Sustainability" developed mathematical model which uses fuzzy logic for assessing sustainability of various aspects of a society on a scale from 0 to 1. Reliable data existing for all the nations of the world are then ranked according to their sustainability as measured by the model. Liu and Huang (2009) developed a fuzzy-logic-based Triple-A template that can be used to conduct more effective sustainability studies in three consecutive steps: assessment, analysis, and action. Piluso et al. (2010) introduced a fuzzy-logic-based assessment framework, which can be implemented to handle the aforementioned uncertainties and allow for a sound short- to mid-term assessment of sustainability. Kommadath et al. (2011) used a fuzzy-logic-based approach along with the weak sustainability criteria and context-dependent sustainability indicators to assess sustainable development of the mining and minerals sector. Pislaru and Trandabat (2012) assessed the environmental impact of a company using fuzzy logic taking into account four factors of ecological environment namely air, water, land, and biodiversity.

Literature review on decision support system applications

DSS is a computer-based program application that helps the user in corporate business and organizational decision-making activities. Its history dates back to 1965 when there arrived a necessity for building large scale information systems. The first developments in this section were that of IBM System 360 and other mainframe systems which paved the way for making cost-effective management information systems (MIS) in large companies. In late 1960's, from the combination of studies on organizational decision-making carried out at Carnegie Institute of Technology and the practical work on interactive computer system done at Massachusetts Institute of Technology, Peter Keen and Charles Stabell introduced a new type of information system-a model oriented DSS. Several journals on DSS were published in the later years.

From the application point of view, Nagarur and Kaewplang (1999) developed a DSS involving maintenance management. Lefroy et al. (2000) developed a framework evaluating sustainable land management (FESLM) and undertook three case studies to assess the sustainability of different land management systems practiced by farmers on sloping lands of Indonesia, Thailand, and Vietnam. The data were used to develop a group of SLM indicators which have been included in a prototype DSS with related thresholds. For real time control of manufacturing process, Swanepoel (2004) developed a DSS. In order to incorporate real data from a machine tool sales organization Gopalakrishnan et al. (2004) developed a DSS. Arslan et al. (2004) formulated a DSS that not only directs a machine tool but also helps the user to resolve those particular problems. Šliogeriene et al. (2006) developed a DSS for sustainability assessment of power generation technologies. Tian et al. (2007) conducted a study as how the research and development of DSS in China is progressing. The authors analyzed the direction and area of their research. Vinodh et al. (2008) developed a decision support system named Decision Support System for Quantifying Agile Criteria (DESSAC) for analyzing the agility level of a company. For the synthesis of production control of an assembly line packaging of semi-conductors, Mok (2009) used evolutionary optimization methods. The author equated both DSS, the one developed by him and the one originally used by the manufacturer and found that there is much scope for improving productivity. Caricato and Grieco (2009) provided a DSS involving mathematical programing centered on customer service and its scientific problems. They supported their model comprising of production allocation and complementary problems with an effective case study. Lacquaniti and Sala (2009) presented a DSS for assessing the sustainability of using local biomasses as an energetic source. Manos et al. (2009) presented a DSS for sustainable development and environmental protection of agricultural regions. They tried to optimize the production plan of an agricultural region considering various factors like available resources, environmental parameters and vulnerability map of the region. Sala and Castelani (2011) used a multi-disciplinary DSS to define guidelines for sustainability assessment of technologies using forest biomass for energy production, detecting critical issues, and areas for improvement. They performed a case study in an Italian mountain community in northern Italy to assess environmental, economic, and social sustainability of a plant producing electricity powered by syngas which comes from gasification of woody forest biomass. Gameda et al. (2012) developed a DSS for sustainable land management of farming systems.

Based on the literature review, it was found that although many researchers have conducted studies on sustainability assessment but none of them have been accompanied or supported by a DSS linked with fuzzy logic. In this paper, a research study has been attempted on this topic in detail.

Methodology

The methodology followed for sustainability assessment is shown in Fig. 1.

As seen from the above diagram, literature review on sustainability assessment was first performed. Then it was followed by literature review on the conceptual model needed to compute the sustainability index and fuzzy logic approach was used to formulate and construct the DSS. Thus, the FLBSE-DSS was developed. Then a suitable organization was identified and a case study was conducted for implementing the software and analyzing the sustainability assessment of the organization. After that the inputs of various ratings and weights differing from 0 to 1 were taken from the decision makers. It was followed by calculation of fuzzy sustainability index, Euclidean distance, and fuzzy performance importance index for the company using the given input data. The results were compared with the prevailing atmosphere in the organization. Finally, the management threshold was fixed and the weaker sections were discovered.

Methodology of fuzzy-logic-based sustainability evaluation

Calculation of FLSI

(a) At first, the ratings for the attributes and weights for the enablers, criteria, and attributes are taken. In sustainability assessment, there exists a lot of ambiguity in the data. So, for this purpose the use of triangular or trapezoidal numbers are recommended. Here, triangular fuzzy numbers have been used to specify the linguistic variables. These ratings and weights in the form of linguistic variables are then replaced by their corresponding triangular fuzzy numbers.

The ratings of the attributes are given on a scale of 0–10 while the weightage of the enablers, criterion, and attributes are given on a scale of 0–1 both in sets of triangular fuzzy numbers. Each set of triangular fuzzy numbers is represented by a corresponding linguistic variable. The following linguistic variables are used to represent the sustainability performance (Table 1).

The fuzzy numbers associated with the linguistic ratings and weights are also shown in the above table. The linguistic variables which are used to signify the nature of the organization along with their fuzzy numbers are as follows (Table 2):

(b) The fuzzy numbers of the ratings of the attributes undergo element to element multiplication with the fuzzy numbers of the weights of those attributes i.e., the left fuzzy number of rating is multiplied with the left fuzzy number of weight, middle with the middle and so on. This is done for all the attributes within a particular criterion.

(c) Then this resultant set of fuzzy numbers i.e., all the sets of fuzzy numbers obtained by multiplication of ratings with corresponding weights are added column-

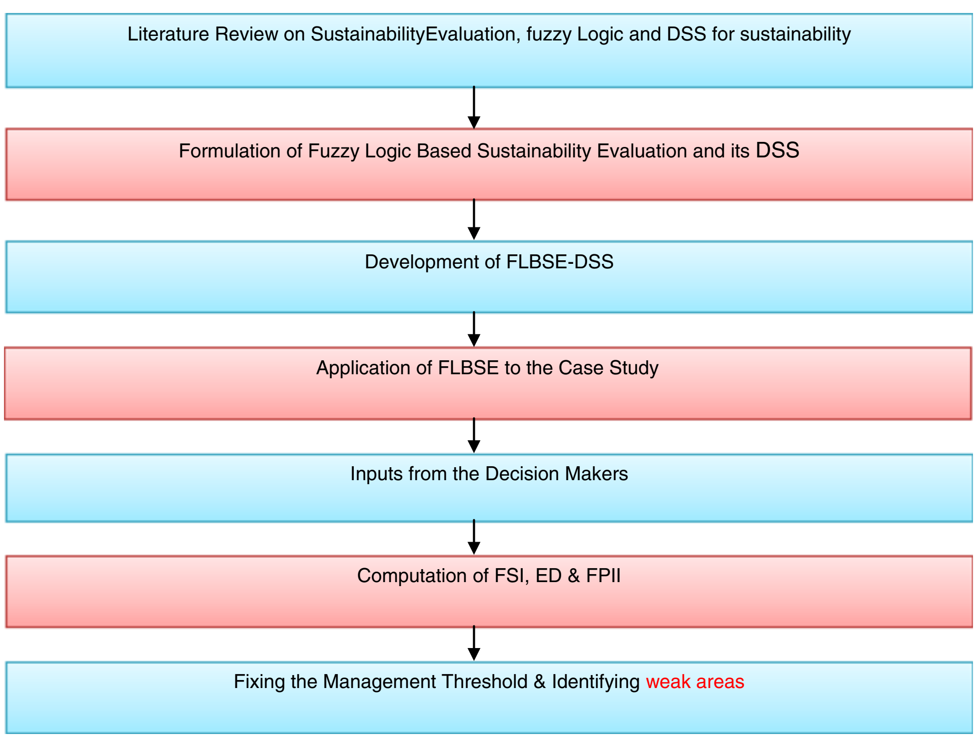


Fig. 1 Methodology

Table 1 Linguistic variables and their related fuzzy numbers

For weights		For ratings	
Linguistic variable	Fuzzy number	Linguistic variable	Fuzzy number
Very high (VH)	(0, 0.05, 0.15)	Excellent (E)	(0, 0.5, 1.5)
High (H)	(0.1, 0.2, 0.3)	Very good (VG)	(1, 2, 3)
Fairly high (FH)	(0.2, 0.35, 0.5)	Good (G)	(2, 3.5, 5)
Medium (M)	(0.3, 0.5, 0.7)	Fair (F)	(3, 5, 7)
Fairly low (FL)	(0.5, 0.65, 0.8)	Poor (P)	(5, 6.5, 8)
Low (L)	(0.7, 0.8, 0.9)	Very poor (VP)	(7, 8, 9)
Very low (VL)	(0.85, 0.95, 1)	Worst (W)	(8.5, 9.5, 10)

Table 2 Fuzzy numbers pertaining to the nature of organization

Linguistic variable	Symbol	Fuzzy numbers
Extremely sustainable	(ES)	(7, 8.5, 10)
Very sustainable	(VS)	(5.5, 7, 8.5)
Sustainable	(S)	(3.5, 5, 6.5)
Fairly sustainable	(FS)	(1.5, 3, 4.5)
Slowly sustainable	(SS)	(0, 1.5, 3)

wise. Thus, the resultant of so many fuzzy triangular numbers is converted to a single triangular fuzzy number.

(d) Also the set of fuzzy numbers representing the weights of the ratings are added column-wise in a similar way as done in the previous step for the multiplied set of fuzzy numbers. The index thus found is for 3rd grade sustainable capability which can be formulated as $\sum_{k=1}^{N} R_{ijk} \otimes W_{ijk}$ (Vinodh 2010) (where R is the rating, W is the weight, N is the no. of attributes, i, j, k are the subscripts for enabler, criteria, and attribute, respectively). Similarly 1st and 2nd grade sustainable capabilities can also be calculated.

(e) After that the single triangular number obtained in Step-D is divided element to element by the single triangular number obtained in Step-E. Such resultant triangular fuzzy numbers are obtained for each particular criterion. This operation can be expressed as (Vinodh and Balaji 2011) :

$$\text{Rating for SV}_{ij} = \sum_{k=1}^{N} R_{ijk} \otimes W_{ijk} / \sum_{k=1}^{N} W_{ijk} \tag{1}$$

(f) Then similar operations are done on the different criterion as done in all the previous steps as each criterion has now a single triangular fuzzy number and with it a corresponding weight. This is done for each enabler.

(g) After doing such calculations a single triangular number is obtained for each enabler. Now the same operations are again done on all the different enablers as done with criterion and attributes to get a final triangular number. This number obtained is required the fuzzy logic sustainability index of the given manufacturing organization.

Euclidean distance

Euclidean distance is calculated to find out which set of fuzzy numbers corresponding to a particular linguistic variable fits best with the resultant fuzzy logic sustainability index. To do this, at first all triangular fuzzy numbers corresponding to the linguistic variables are plotted on an x–y axis. Along with them the triangular fuzzy number of resultant FLSI is also plotted in the same graph. Then, the centroids of all the respective triangles are calculated using the formula: $(a + b + c)/3$ (where a, b, and c are the left, middle, and right fuzzy numbers, respectively) where the x-coordinate and the y-coordinate is constant i.e., 1/3 (as 2 of the vertices lie on the x-axis and the third at a height of 1 from the middle fuzzy number). After finding all the centroids, the distance of the centroid of the FLSI triangle from each of the remaining triangles is calculated using distance formula between two points

$$\left(\sqrt{\{(x_1 - x_2)^2 + (y_1 - y_2)^2\}},\ \text{where } x_1, x_2 \text{ are the } x - \text{coordinates and } y_1, y_2 \text{ are the } y - \text{coordinates}\right) \tag{2}$$

Then when all these distances are found, the least among them is selected as the Euclidean distance. The corresponding triangle with which this least distance is found is the one which almost matches the FLSI triangle. This triangular fuzzy number has its own conforming linguistic variable. The result is thus displayed on the screen in the form of that linguistic variable corresponding to that particular fuzzy number.

Calculation of FPII

Fuzzy performance importance index (FPII) (Lin et al. 2006) is obtained by the combination of performance ratings and importance weights of each sustainability element capability. It contributes to the sustainability assessment of an organization. The degree of contribution for a factor is directly proportional to the FPII of that factor. Thus, FPII helps in identifying the principal obstacles. The fuzzy performance importance index can be calculated as $\mathrm{FPII}_{ijk} = W'_{ijk} \otimes R_{ijk}$ where W'_{ijk} is (1,1,1) $\ominus W_{ijk}$ and W_{ijk} is the fuzzy importance weight of sustainability element capability *ijk*.

Thus the formula used is $\{(1,1,1) \ominus W_{ijk}\} \otimes R_{ijk}$ (3)

All the FPIIs must be ranked as fuzzy numbers do not always yield a totally ordered set like real numbers. The ranking of the fuzzy numbers here is based on Chen and Hwang (1992) left-and-right fuzzy-ranking method because of two advantages. First, it preserves the ranking order and second, it also considers the absolute location of each fuzzy number.

Case study

The case study was conducted in a machinery and automobile parts manufacturing company situated in Tiruchirappalli, Tamil Nadu, India (referred hereafter as XYZ Pvt. Limited). The organization has already implemented several sustainability concepts such as 3R-based (Reduce, Reuse, Recycle) Green Manufacturing and Air Quality Control. The first author was responsible for the implementation of sustainability concepts within the organization. The ratings and weights were taken from five experts whose knowledge about the company and the linguistic terms involved in evaluation were very high. They were experienced members of the case organization holding very important positions of responsibility and have assisted the author in applying the sustainability concepts. There existed a need for the organization to assess the sustainability level so as to enhance the competitive position.

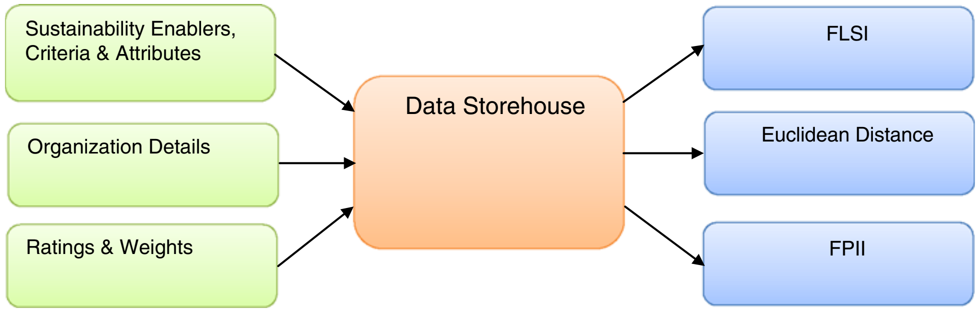
Conceptual model

The conceptual model for sustainability evaluation is based on three sustainability enablers, 15 criteria and 50 attributes. The sustainability enablers used are economic sustainability, environmental sustainability, and social sustainability. The linear variables that are used to signify the enabler is SV_i, where SV means sustainability variable and 'i' is a subscript which takes values starting from 1. Similarly SV_{ij} is used to represent the criteria with 'j' being a similar subscript as 'i' taking values from 1. Also SV_{ijk} symbolizes the corresponding attributes and 'k' behaves the same as 'i' and 'j'. This means a symbol like SV_{123} is a sustainability variable representing third attribute of the second criteria pertaining to the first enabler. The attributes are based on environmental, economic, and social enablers consisting of five criteria each. An excerpt of the conceptual model is shown in Table 3.

Table 3 Excerpt of sustainability assessment model

Enabler	Criteria	Attributes
Environmental sustainability (SV_2)	Air resources (SV_{21})	1. Air quality effects (SV_{211})
		2. Global warming (SV_{212})
		3. Stratospheric ozone depletion (SV_{213})
	Water resources (SV_{22})	1. Water usage (SV_{221})
		2. Release of water effluents and pollutants (SV_{222})
	Land resources (SV_{23})	1. Land usage and transformation (SV_{231})
		2. Direct and indirect releases of soil pollutants (SV_{232})
		3. Product innovativeness (SV_{233})
	Mineral and energy resources (SV_{24})	1. Contribution to depletion of non-renewable energy resources (SV_{241})
		2. Contribution to depletion of energy resources (SV_{242})
		3. Green manufacturing (SV_{243})
	End of disposal policy (SV_{25})	1. Clean development mechanism (CDM)
		2. Practice (SV_{251})
		3. Carbon foot-print (SV_{252})
		4. 6R concepts (SV_{253})

Fig. 2 DSS architecture



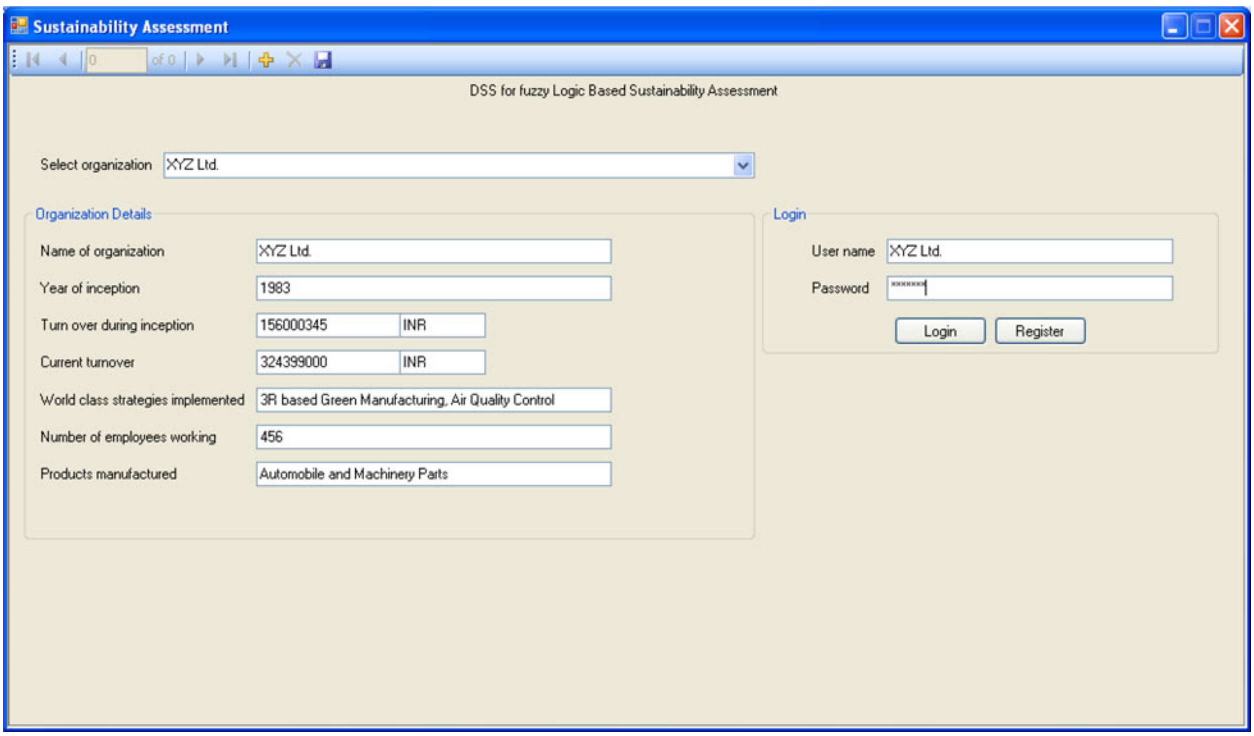


Fig. 3 Registration details of organization with user login and password

DSS architecture

The software structure of FLBSE-DSS has been constructed using Microsoft Access as the back end and Microsoft Visual Studio as the front end. The architecture of FLBSE-DSS is shown in Fig. 2. Figure 2 shows sustainability enablers, criteria, and attributes, weights and ratings and the organization details as the inputs. All the inputs are saved in the data storehouse which serves as a database. These input data are used in generating the outputs.

The data for ratings and weights are entered in the form of linguistic variables for the corresponding enablers, criteria, and attributes. The linguistic variables correspond to a set of three fuzzy numbers which undergo appropriate computations and the output is generated. Euclidean distance method compares the generated output with standard sustainability ratings. The least distance obtained among them from a particular rating is the required Euclidean distance and the rating from which it is least distant represents the current sustainability level. FPII for all sustainability attributes were calculated which enables the identification of weaker areas.

The homepage shows the registration details of the organization. It is shown in Fig. 3. It contains the name of organization, year of inception, turnover during inception, current turnover, world class strategies implemented, number of employees working, and products manufactured as the details. There is also provision for modifying or deleting the information whenever required. The right hand side of the page contains the login with username and password. For a new organization which has not registered, it can register its information by clicking on the register tab. After doing so, an organization can simply select the

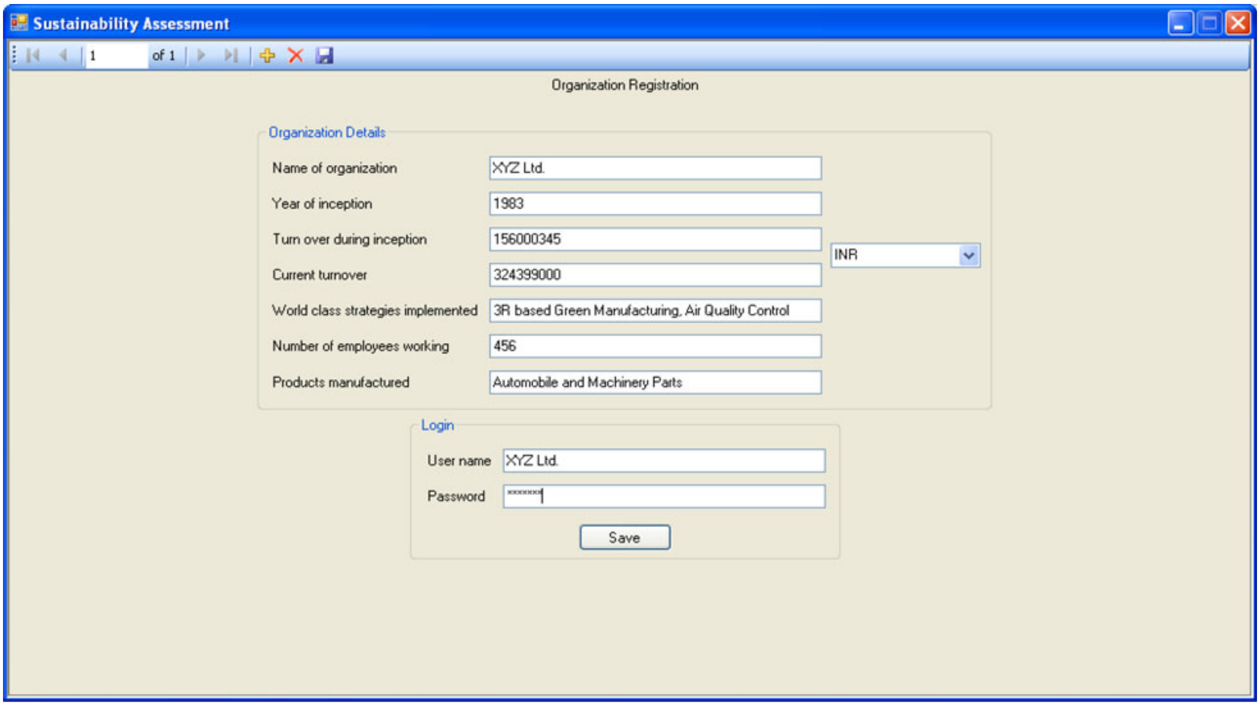


Fig. 4 Window for new organization registration

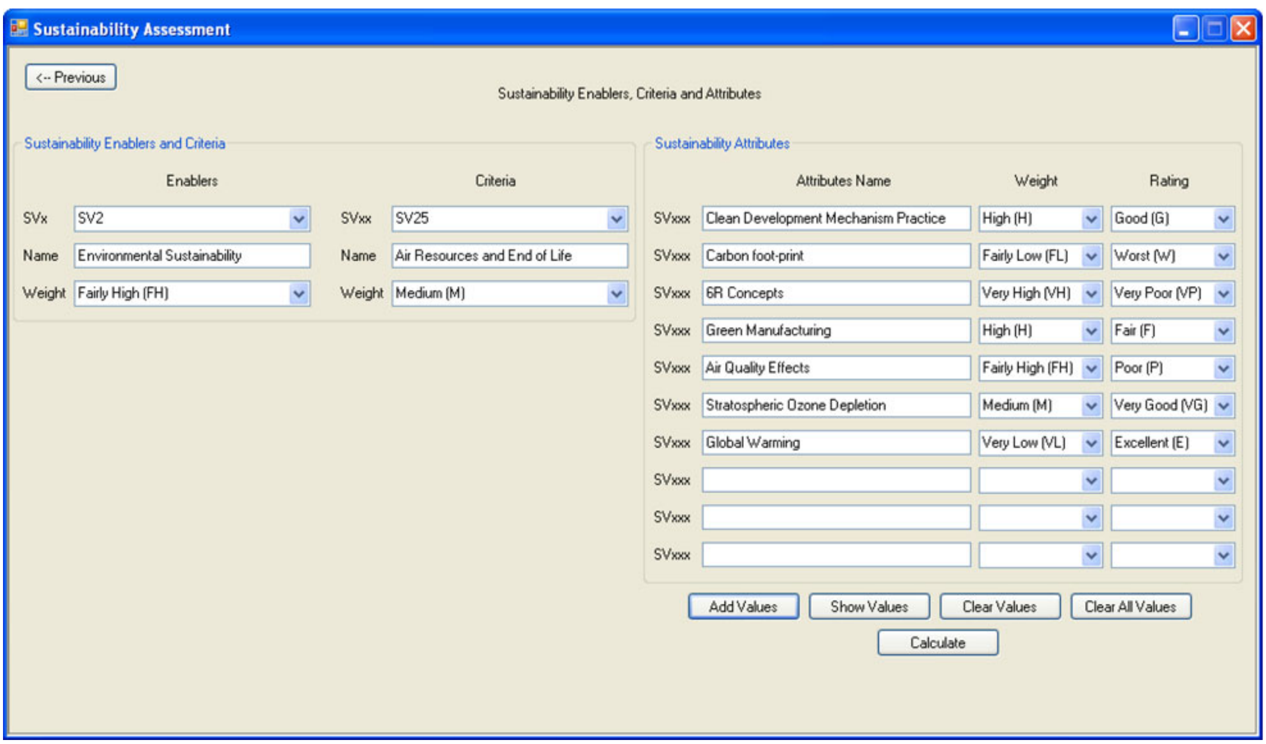


Fig. 5 Window depicting definition of enablers, criteria, and attributes

name of organization, enter the username and password and proceed with its evaluation. The page for new user registration is shown in Fig. 4. One can enter all data related to the organization on the registration page. FLBSE-DSS enables the user to add the enablers, criterion, and attributes for the organization by defining them by names. Also the user is expected to provide ratings and weights for these enablers, criterion, and attributes. The

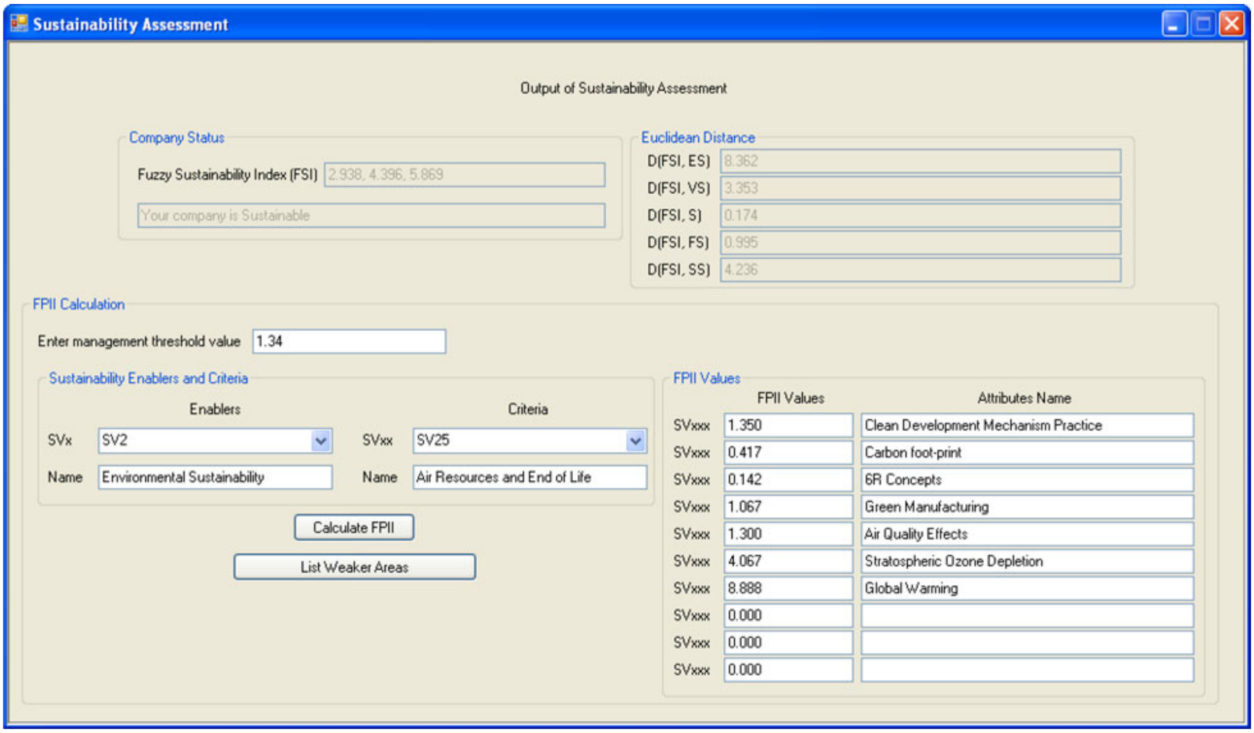


Fig. 6 Window showing the generation of FSI and FPII values

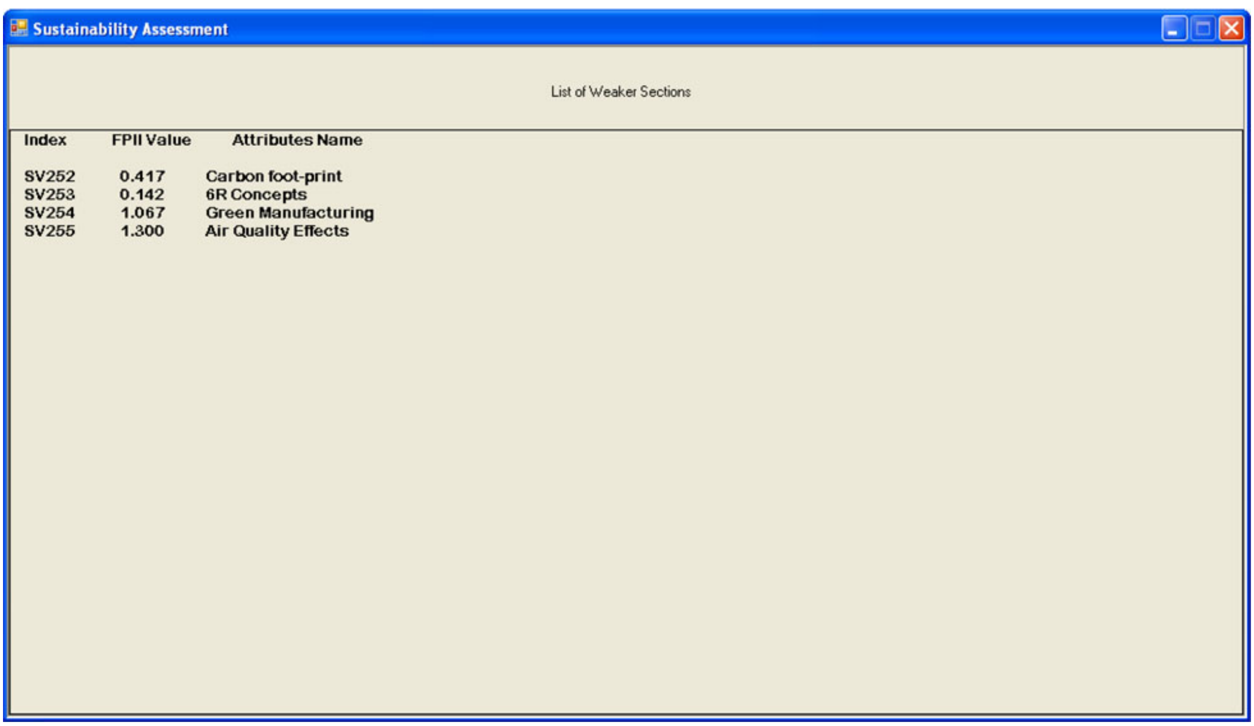


Fig. 7 Window showing list of weaker areas

snapshot of this task is shown in Fig. 5. After that the calculations are done and the result i.e., the FLSI is displayed as shown in Fig. 6. The Euclidean distance calculations are also done by matching FSI with standard linguistic expressions and the result is shown on the same page regarding the status of the organization. Also on that

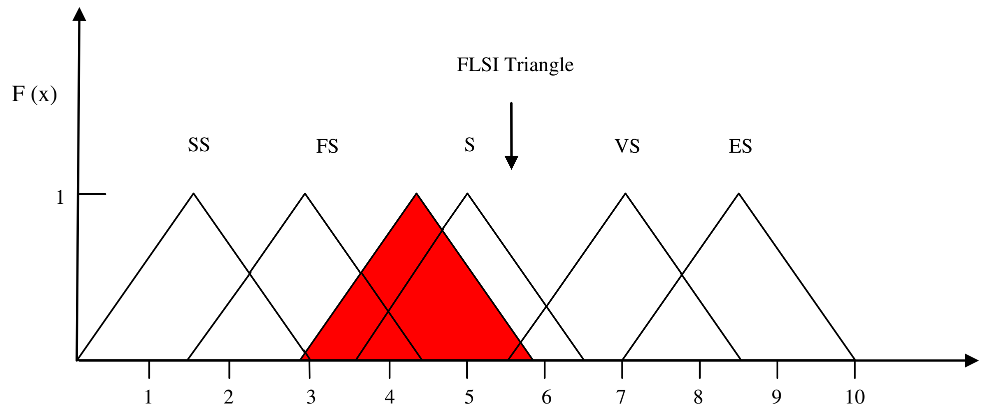


Fig. 8 Method of calculating ED by representing triangular fuzzy numbers

Table 4 Excerpt of generated FPII values

Attribute no.	Attribute name	Linear variables	FPII output
1st attribute	Clean development mechanism practice	SV_{251}	1.350
2nd attribute	Carbon foot-print	SV_{252}	0.417*
3rd attribute	6R concepts	SV_{253}	0.142*
4th attribute	Green manufacturing	SV_{254}	1.067*
5th attribute	Air quality control	SV_{255}	1.300*
6th attribute	Stratospheric ozone depletion	SV_{256}	4.067
7th attribute	Global warming	SV_{257}	8.888

* Weaker attributes

screen itself, the user can enter the name of an enabler, criterion, and obtain the FPII values of the attributes for that particular set of enabler and criterion. The list of weaker sections along with their index number and FPII, determined after fixing the management threshold is shown in Fig. 7.

Results and discussions

According to Eq. 1, FLSI of the case organization is found to be (2.938, 4.396, 5.869). In order to determine the current sustainability level, Euclidean distance calculations were done using Eq. 2. The results are as follows: D (FLSI, ES) $= 8.362$, D (FLSI, VS) $= 3.353$, D (FLSI, S) $= 0.174$, D (FLSI, FS) $= 0.995$ and D (FLSI, SS) $= 4.236$.

Euclidean distance was found to be lesser for third case which indicates that the company is sustainable. The FLSI triangle corresponding to the above sustainability index calculation is shown in Fig. 8. The results coincided with the environment prevailing within the company. But scope still exists for development and achieving further sustainability to make it a more developed sustainable organization.

In order to attain such a higher level of sustainability for this company XYZ Ltd., the weaker sections must be detected. FLBSE-DSS helps the company to achieve it by computing the fuzzy logic sustainability index (FLSI) and the fuzzy performance importance index (FPII) for different combinations of enablers and criteria. The FPII of all attributes within a particular criterion in a specific attribute was calculated using Eq. 3. Thus, the resultant FPII from the above calculations according to Chen and Hwang (1992) left-and-right fuzzy-ranking method are presented in Table 4. The management threshold is fixed as 1.34. Those attributes whose FPII values lesser than management threshold are found to be weaker.

When this software was test implemented in the case organization after demonstrating it practically, they found it an effective tool for evaluating the sustainability of the organization. Such a kit can be used to continuously evaluate the sustainability of other similar organizations also. In the modern world of technology, with industries facing stiff competition among each other, such software can be very handy in analyzing the performance of the system.

Practical implications

There were several weaker areas found within the manufacturing organization which restricted its sustainability level. The actions taken are narrated as follows.

Appropriate environmental impact assessment (EIA) methods were initiated in the case organization to determine air quality effects. Efforts were taken in the case organization toward the implementation of green manufacturing techniques like design for environment (DFE), life cycle assessment (LCA), and quality function deployment for environment (QFDE). Initiatives were being taken to analyze the environmental impact and to minimize the carbon foot-print. Actions were initiated toward the implementation of 6R (Reduce, Reuse, Recycle, Repair, Remanufacture, and Recover) concepts in the organization.

Conclusions

Sustainable development insures sustainable, long-term, and competitive benefits for manufacturing organizations. In this context, the evaluation of sustainability is very much needed. In order to systematically compute and analyze sustainability of the case organization, FLBSE-DSS was developed. The developed FLBSE-DSS computes the sustainability index of the organization and generates FPII for various sustainability attributes. In this present study, FLSI of the organization was found to be (2.938, 4.396, 5.869). Using Euclidean distance approach, the organization was found to be sustainable. Besides determining sustainability index and Euclidean distance, DSS also identifies weaker sustainability attributes like air quality effects, 6R concepts, green manufacturing, and carbon foot-print as weaker areas. After mitigating the weaker areas, suitable initiatives were derived and subjected to implementation in the case organization.

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