The impact of organizational design and management (ODAM) factors (macroergonomics) on resilience engineering: The Case of large Gas Refinery

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Abstract

Safety problem and decreasing human errors are absolutely critical in gas refinery. two ways that can reduce human errors are implementing macroergonomics and resilience engineering (RE). Macroergonomics is a top-down sociotechnical system approach to the design of work systems and the application of the overall work-system design of the human–job, human–machine, and human–software interfaces. Macro ergonomics technology is named "interface technology of human- organization – environment-machine. Researches shows that there is a strong need to integrate organizational design and management (ODAM) factors. Resilience engineering is a paradigm for safety management that focuses on how to help people to cope with complexity under pressure to achieve success. RE includes top-level commitment, reporting culture, learning, awareness, preparedness, flexibility, self-organization, teamwork, redundancy and fault-tolerant. This study evaluates the impact of macroergonomics (ODAM factors) on each items of RE and efficiency in a gas refinery through the obtained data from questionnaires and data envelopment analysis (DEA) approach and solved by matlab software. Also, the impacts of each item of RE from ODAM factors are compared with each other by L. The results show that commitment and self-organization have the greatest impact from macroergonomics factors. This study is amongst the first ones that examine the behavior of macroergonomics on resilience engineering through DEA.

Keywords: Macro ergonomic; Integrated resilience engineering; Data envelopment analysis(DEA); Technical efficiency; ODAM; organization; management.

1. Introduction and literature view

1.1. Macroergonomics

In the 1950s, the ergonomics field began in response to human–machine mismatches, especially in aviation (Chapanis, 1965). The 21st century is evidenced by unprecedented technology and complexity and in part this has produced renewed work system design challenges. For example, in healthcare, nurses and other staff are routinely working 12 h shifts. Healthcare organizational structures have changed, mismatches exist between human staff and medical technology and the drive to reduce cost has created efficiencies at the expense of effectiveness and human personnel wellbeing. Thus, medical errors and the associated human and financial costs are of great concern in this industry. In the military, ‘‘friendly fire’’ incidents are making the headlines. Manufacturing has been rapidly migrating to such countries as China. Aviation is also challenged by reduced demand and the need to reduce costs. In the US construction industry, workers are experiencing safety and health incidents at an alarming rate. It is not yet clear why other countries have lower incidence rates, nor why in the US certain ethnic sub-groups experience more incidents than others.

However, as recognized in Europe, it is suspected that a combination of managerial, design and cultural factors will be implicated (Haslam et al., 2005). The service sector is plagued by work design issues and human–computer interaction needs are extensive. Virtually, every industry is challenged and these needs go beyond the human–machine interface level of solution.

These examples and others suggest the need for a large system approach as offered by macro ergonomics (Kleiner, 2005). Macro- ergonomics is concerned with the analysis, design, and evaluation of work systems. The term work is used herein to refer to any form of human effort or activity, including recreation and leisure pursuits. As used herein, system refers to sociotechnical systems. These systems may be as simple as a single individual using a hand tool or as complex as a multinational organization. A work system consists of two or more persons interacting with some form of (1) job design, (2) hardware and/or software, (3) internal environment, (4) external environment, and (5) an organizational design (i.e., the work system's structure and processes). Job design includes work modules, tasks, knowledge and skill requirements, and such factors as the degree of autonomy, identity, variety, meaningfulness, feedback, and opportunity for social interaction. The hardware typically consists of machines or tools (Hendrick & Kleiner, 2001).

Coupled with the need to attend to the larger system is the need to yield significant results. In this context, it appears that ergonomists like others need to cost-justify their interventions (Beevis and Slade, 2005).

Macro ergonomics may be a way to aid this pursuit Macro ergonomics is concerned with the analysis, design, and evaluation of work systems. The term work is used herein to refer to any form of human effort or activity, including recreation and leisure pursuits (Hendrick & Kleiner, 2002).

A macro-ergonomics strategy, aiming at optimizing the sociotechnical system and studying the effect of organizational structures on human behavior and on safety. Macro-ergonomics are derived from the Total Quality Management principles (Carayon, 2003), which focus on the conditions required to improve a system as a whole, by acting mainly on (i) the number, training and satisfaction of staff members, (ii) equipment quality and equipment maintenance, (iii) improvement of the physical environment, (iv) quality of work processes, and (v) economic production that is sufficient in quantity and quality. This is not only an analysis method, but also an approach of the design of socio-technical systems

(Carayon, 2006; Clegg, 2000), presenting the characteristic of being systemic (treating jointly the technical and organizational aspects), participative, and ongoing.

In macro ergonomics technology that is named “interface technology of human-organization – environment-machine”, all four components of technical-social systems is considered, however the main focus is relationship between organizational design with technology used in the system in order to optimizing system - human function. Macro ergonomics is a top-down sociotechnical system approach to the design of work systems and the application of the overall work-system design of the human-job, human-machine, and human-software interfaces (Hendrick & Kliener, 2001).

Although various ergonomists had written about the importance of a true systems approach and considering organizational and management factors in ergonomics, the formal beginning of macroergonomics as an identifiable subdiscipline had its roots in the work of the Human Factors Society's Select Committee on Human Factors Futures, 1980-2000(Hendrick& Kliener, 2001).

For the human factors/ergonomic discipline to be truly effective, and responsive to the foreseeable requirements of the next two decades and beyond, there was a strong need to integrate organizational design and management (ODAM) factors into research and practice. In 1988, ODAM was one of the five major themes of the 10th IEA Triennial Congress in Sidney, Australia, For the 12th and 13th Congresses, more paper proposals were received on macroergonomics and ODAM than on any other topic, and it was one of the three largest topics in terms of papers presented at the 14th Congress (Hendrick,1986).

In 1998, in response to the considerable methodology, research findings, and practice experience that had developed internationally during the 1980s and 1990s, the Human Factors and Ergonomics Society ODAM Technical Group changed its name to the "Macroergonomics Technical Group" (ME TG)(Hendrick,2001).

1.2. Resilience engineering

Incidents and accidents reporting and error analyzing, in itself, cannot improve safety to a higher level in complex systems and hazardous environments (Huber et al., 2009). Resilience engineering (RE) is a new method that can control incidents and limit their consequences. (Azadeh et al., 2013). Resilience engineering (RE) is an emerging safety management paradigm concerned with normal work, rather than emphasizing learning from incidents (Saurin and Junior, 2011).

In recent years, resilience engineering (RE) has attracted widespread interest from industry as well as academia because it presents a new way of thinking about safety and accident (Steen and Aven, 2011).

Some studies have been conducted in the context of RE whose aim was often the improvement of safety system such as oil distribution plant (Abech et al., 2006); refining plant(Tazi and Amalberti, 2006); aviation (Zimmermann et al., 2011);aviation (Dekker et al., 2008); health and safety management systems (Costella et al., 2009); high-risk process environments(Huber et al., 2009); oil and gas exploration (Storseth et al.,2009); electricity distributor (Saurin and Carim Junior, 2011);chemical plant (Shirali et al., 2012); industrial processes (Dinhet al., 2012).

The six indexes in a resilient system or organization are as follows (Wreathall, 2006):

- Management commitment: This item emphasizes that safety is a core organizational value rather than a temporary priority (Costella et al., 2009).
- Reporting culture: it supports the reporting of problems and issues up through the organization or system, yet not tolerating culpable behaviors.

  - Learning: RE emphasizes learning from the analysis of nor-mal work, while it does not ignore learning from accidents, incidents and other events (Wreathall, 2006).
  - Awareness: Management understands the quality of human performance by data gathering at the plant. Also, personnel should be aware of the current status of defenses in the system (Wreathall, 2006).
  - Preparedness: The organization or system actively anticipates the problems of human performance inhuman–machine systems and prepares to cope with them(Wreathall, 2006).
- Flexibility: It is the ability of the system or organization to adapt the complex or new problems so that it maximizes the ability of the system to solve the problems without disrupting overall functionality. Hence, flexibility is often a key factor to cope with the problems in the system (Wreathall,2006).

In addition to the items of RE framework, according to the conditions of complex systems and hazardous environments, the integrated resilience engineering items(RIE) are for improving the performance of safety and human resources. These are as follows:

- Self-organization: The applications of which are generally made of multiple independent entities with a knowledge limited to their environment and that locally interact (directly or indirectly) to generate a result. Independent entities usually work in a decentralized manner (Serugendo,2009). In self-organization systems, order comes from the actions of interdependent agents who exchange information, take actions, and continuously adapt to feedback about others' actions rather than from the imposition of an overall plan by a central authority (Plowman et al., 2007). Self-organization systems usually overcome an extensive range of changes/faults (Serugendo, 2009).
- Teamwork: Recent investigations highlight the role of teamwork in different areas of healthcare. Other high-risk industries, such as aviation and the nuclear industry, have long

recognized the importance of teamwork to improve safety (Burtscher andManser, 2012). The core components of teamwork are leadership, communication, mutual support, and situation monitoring (Battles and King, 2010).

- Redundancy: Also, redundancy is the existence of alternative pathways from the sources to demand or surplus capacity in normal conditions, for use when components become unavailable (Kalungi and Tanyimboh, 2003). Redundancy exists in a human–machine system when two or more operators (people) are concerned with the completion of a required function and have access to information related to that function.
- Fault-tolerant: Fault-tolerant system is one of the most promising methods of increasing system safety and reliability. The main purpose of fault-tolerant system is to maintain the specified performance of a system in the presence of errors (Ling and Duan, 2010).

1.3. Problem definition

This study survey the impacts of organizational design and management (ODAM) factors (macroergonomics) on some items of resilience engineering by DEA method, in case of gas refinery. This is the first study that considers the interaction of macroergonomics with resilience engineering by DEA method.

Data envelopment analysis (DEA) is a method for for estimating efficiency scores of departments. It is measured efficiency of decision making units (or DMUs). DEA has many applications in engineering case studies such as data mining, measuring performance of electric power generations, location optimization of wind plants and … .

The other contribution of this paper would be the finding which item of resilience engineering has the greatest influence from macroergonomics.

This paper includes the following structure: Section 2 defines the relationship between macroergonomics and resilience engineering, section 3 explain the methodology (questionnaire design and DEA method). In next Section (4), the raw data of this study is presented. After that, in Section 5, the computational results of this study are showed and final section has the conclusion of this study.

2. Relationship between macroergonomics and resilience engineering

In complex systems such as process plants, petrochemical and chemical industries and refineries**,** human operator plays an important and critical role (Azadeh et al., 2000).

After creating macroergonomics viewpoint, scientific knowledge about human capabilities, limitations, and other characteristics was developed and applied to the design of operator controls, displays, tools, workspace arrangements, and physical environments to enhance health, safety, comfort, and productivity, and to minimize human and organizational error via design.(Hendrick & Kleiner, 2001).

At organization level, poor management, training, education, communication, regulation and team-work as well as work environment injurious factors could cause human error and safety issues which consequently would result in environmental risks (Bertolini, 2007; Toriizuka, 2001).

Effective application of ergonomics in work system design can achieve a balance between human characteristics and task demands. This can enhance human productivity, reduce human error, provide improved safety (physical and mental) and job satisfaction (S.Asadzadeh et al., 2013).

According to the above subjects ; base on the impact of macroergonomics on reducing human and organizational error and also the impact of more factors of resilience engineering in the creation of errors in human and organizational levels, relationship between these two items (macro ergonomics and resilience engineering) can be showed by considering human and organizational errors concept. Also, macroergonomics surveys the impact of organizational design and management (ODAM) factors and it is clear that organization and management have a good impact on resilience engineering. For example, in the organizational level, when the workload of system is high, teamwork can decrease the pressures of individual and organizational with mutual support and they can assist each other. Thus, identifying the organization with macorergonomics view can help to efficient use of teamwork factor (the factor of IRE) for improving organization and decreasing the human errors.

3. Methodology

Azadeh,(2005) had a study for optimizing operations and increasing capacity of gas refineries by considering macroergonomics. They evaluate this company on four elements of macroergnomics viewpoint for achieving objectives such as reducing human errors. They gathered the data from questionnaires. Now, in continuation of previous work, the impact of organizational design and management (ODAM) factors is evaluated on each items of resilienc engineering and efficiency of system is calculated in this paper.

3.1. Questionnaire design

Two kinds of structured questionnaire was developed for personnel based on the topics and indexes of some RE items and macroergonimcs factor(ODAM) (Azadeh, 2005). Because the some questions are five options and the others are three options, for evaluating the result, the total data are been scaled from 1 to 9 score.

3.1.1. Resilience engineering questionnaire

1. Top level commitment (e.g. Do your managers and supervisors valorize for teamwork?)
2. Learning (e.g. Is there a specialized training in relation to your work?)

3. Awareness (e.g. Are the existing regulations and instructions clear? (in normal and emergency condition))
4. Flexibility (e.g. Do you have a problem with using the written regulations and instructions in emergency situations?)
5. Self- organization (e.g. Do you have this feeling that you are interdependent for making your decisions in work (without any need to managers and supervisors)?)
6. Redundancy (e.g. Is there a answerable for replacing and substituting safety accessories?)

3.1.2. Macroergonomics questionnaire

For this purpose, the questions divided into two groups, the first group are depend on managers and the second groups are depend on organization. Two examples questions are as follows:

1. Managers (e.g. Are you watched with managers and supervisors?)
2. Organization (e.g. Do you need for memorizing regulation and instructions?)

3.2. Data envelopment analysis(DEA)

Efficiency is a key concept for large organizations and, hence, DEA is utilized in the integrated approach. DEA is a multi-factor analysis tool that measures the relative efficiency of a given set of DMUs. The benefits of DEA approach are clearly understood. It effectively considers multiple input and output factors in computing the efficiency scores. As efficiency scores vary on different selections of inputs and outputs, it is needed to utilize an accurate DEA specification for each particular case (Serrano Cinca et al., 2002). DEA is a methodology based on a linear programming model for evaluating relative efficiencies of DMUs with common inputs and outputs. It is used for ranking and analyzing DMUs such as industries, universities, schools, hospitals, cities, facilities layouts, banks,etc. Azadeh and Ebrahimipour (2002, 2004), Azadeh and Jalal(2001), Azadeh et al. (2008) and Zhu (1998).

Furthermore, DEAis a non-parametric approach that uses linear programming to calculate the efficiency in a given set of DMUs. DEA models can be input- or output-oriented and can be specified as constant returns to scale (CRS) or variable returns to scale (VRS)(Azadeh et al., 2012).In this paper, DEA approach which is a well known deterministic approach is used for DMUs performance assessment in the petrochemical plant.

In this paper, DEA approach which is a well -known deterministic approach is used for DMUs performance assessment in the gas refinery and evaluating the impact of macroergonomics on resilience engineering.

3.3. Applied model

Finding the efficiency of different departments is of interest and the data are inputted to the DEA model to obtain the ranking of DMUs. The original fractional CCR model (1) evaluates the relative efficiencies of n DMUs $j=1,...,n$ that each DMU includes m inputs and s outputs; and is denoted by $x_{1j}, x_{2j}, ..., \mathrm{x}_{mj}$ and $y_{1j}, y_{2j}, ..., y_{mj}$, respectively (Charnes et al., 1978). This is done by maximizing the ratio of weighted sum of output to the weighted sum of inputs:

$$
\begin{aligned}
&\max\ \theta = \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{r=1}^{m} v_i x_{ip}} \\
&\text{s.t.} \\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{r=1}^{m} v_i x_{ij}} \quad j= 1,...,\mathrm{n}\ ,\ r=1,...,s, \qquad (1) \\
&\theta x_{ip} \geq \sum_{j=1}^{n} \tau_j x_{ij} \quad \forall i=1,...,4\ , \\
&u_r, v_i \geq 0, \quad i=1,..,m, \quad r=1,..,\mathrm{s}.
\end{aligned}
$$

In model (1), the efficiency of DMU_p is θ_p and u_r and v_i are the factor weights. However, for computational convenience, the fractional programming model (1) is modified in linear programming form as follows:

$$\begin{aligned}
&\max\ \theta = \sum_{r=1}^{s} u_r y_{rp} \\
&\text{s.t.} \\
&\sum_{r=1}^{s} u_r y_{rp} - \sum_{r=1}^{m} v_i x_{ij} \le 0 \quad j = 1,\ldots,\mathrm{n} \\
&\sum_{r=1}^{m} v_i x_{ip} = 1 \\
&u_r, v_i \ge \varepsilon, \quad i = 1,..,m, \quad r = 1,..,\mathrm{s}
\end{aligned} \tag{2}$$

In model (2), ε is introduced to ensure that all the factor weights will have positive values in the solution. The model (3) evaluates the relative efficiencies of n DMUs ($j = 1,\ldots,n$), respectively by Maximizing outputs while inputs are constant. The output-oriented CCR model is as follows:

$$\begin{aligned}
&\max\ \theta \\
&\text{s.t.} \\
&x_{ip} \ge \sum_{j=1}^{n} \lambda_j x_{ij}, \quad i = 1,\ldots,\mathrm{m} \\
&\theta y_{rp} \ge \sum_{j=1}^{n} \lambda_j x_{rj} \quad r = 1,\ldots,s \\
&\lambda_j \ge 0
\end{aligned} \tag{3}$$

However, the linear programming model (3) does not allow for the ranking of efficient units as it assigns a common index of one to all the efficient DMUs in the data set. Therefore, model (3) is modified by Andersen and Petersen (1993) for DEA-based ranking purposes, as follows:

$$
\begin{aligned}
&\max\ \theta = \sum_{r=1}^{s} u_r y_{rp} \\
&\text{s.t.} \\
&x_{ip} \geq \sum_{j=1}^{n} \lambda_j x_{ij}, \quad i = 1,\ldots,\text{m} \\
&\theta y_{rp} \geq \sum_{j=1}^{n} \lambda_j x_{rj}, \quad r = 1,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \geq 0
\end{aligned}
\tag{4}
$$

4. Experiment

The gas refinery is located in southern province of Hormozgan, Iran. The questionnaires were distributed to exploitation units and 41 departments were selected for the purpose of this study. Every section was named a DMU. Also, raw data related to DMUs are shown in Table 1.

4.1. Input and output variables

Choosing the input–output variables is an important step in DEA approach (Azadeh et al., 2009). According to the nature of the DMUs under evaluation − where the change in output is not a function of direct change in input values− an output-oriented DEA model with a Variable Returns to Scale (VRS) frontier type is selected. This study run DEA model for each factor of resilience engineering separately. Every time, DEA uses one of the resilience engineering variables (commitment management, learning, awareness, flexibility, self-organization and redundancy) as an output variable and organizational design and management (ODAM) factors use as input variables .

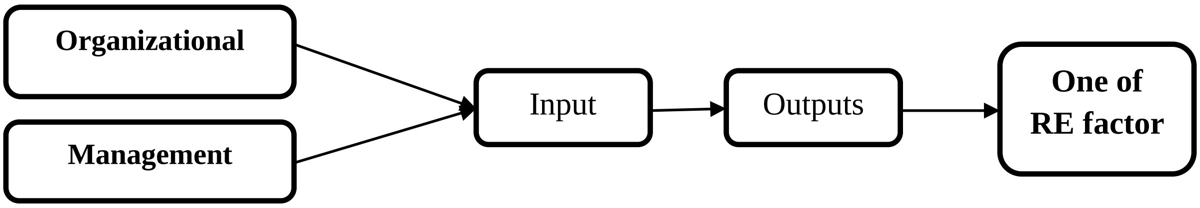

Figure 1:input and output variables

Table 1:Raw data for 41 DMUs of the gas refinery.

DMU no.	Resilience Engineering						Macro Ergonomy	
	commitment	learning	awareness	flexibility	self-organization	redundancy	organization	management
DMU1	1	8.5	3.33	5	1	8.00	5.43	4.88
DMU2	2	8.5	6.67	7	5	5.00	4.86	7.13
DMU3	2	1.5	4.33	5	2	5.00	5.57	5.63
DMU4	8	8.5	7.33	3	7	7.00	5.14	5.50
DMU5	3	8	7.33	6.5	1	6.50	6.71	6.50
DMU6	3	4	5.33	8.5	1	6.00	6.43	6.50
DMU7	1	7	5.33	8	7	8.00	7.57	7.00
DMU8	1	8	6.00	8	9	7.50	6.14	5.63
DMU9	2	7.5	6.00	7.5	3	8.50	5.57	6.13
DMU10	8	8.5	6.00	7	3	7.50	5.00	7.00
DMU11	9	4.5	6.00	7	3	6.50	6.00	5.38
DMU12	2	5	6.33	8	5	1.00	4.57	4.75
DMU13	1	9	6.33	5	8	5.00	4.29	4.75
DMU14	2	8.5	4.00	5	5	7.00	4.71	3.38
DMU15	5	8.5	6.00	2.5	5	6.00	6.14	7.00
DMU16	7	1	6.00	5	9	6.00	5.86	4.00
DMU17	5	8.5	6.67	5	1	6.50	4.57	6.00
DMU18	5	2	4.33	7.5	5	5.00	5.71	7.38
DMU19	7	5	4.00	8.5	5	5.00	6.14	6.75
DMU20	5	2	4.33	8.5	2	6.50	5.14	4.63
DMU21	5	2	4.00	8	1	3.00	5.00	6.00
DMU22	5	4.5	4.33	7.5	2	6.00	5.29	7.25
DMU23	1	4.5	3.67	7.5	3	7.00	2.43	3.00
DMU24	1	5	6.67	5	1	6.50	6.29	5.75

DMU25	9	5.5	7.33	5.5	5	4.50	4.71	4.88
DMU26	9	5	6.00	6	2	7.00	4.86	6.75
DMU27	1	5.5	8.00	7.5	8	3.00	5.14	7.25
DMU28	5	7.5	4.67	6.5	5	5.00	5.29	5.75
DMU29	2	8	5.33	3	2	5.00	5.71	4.63
DMU30	2	7.5	6.00	2	9	5.00	5.14	6.00
DMU31	3	7	5.67	8.5	8	7.00	4.14	7.13
DMU32	2	4	5.00	4	1	8.50	5.43	4.13
DMU33	8	4	5.33	2	9	6.00	5.29	5.63
DMU34	9	9	8.33	8	5	7.50	6.29	8.13
DMU35	3	4.5	4.67	5	5	4.00	5.29	4.88
DMU36	2	1.5	5.00	5	5	1.50	4.43	4.50
DMU37	2	6	5.00	5	5	3.00	5.29	4.75
DMU38	1	5	4.33	5	5	3.50	6.29	5.38
DMU39	1	2	5.00	8	3	1.50	6.29	2.38
DMU40	2	4	2.00	2	2	1.00	1.86	4.25
DMU41	5	8	5.00	3.5	3	2.50	6.29	6.25
Mean	3.829268293	5.529412	5.43902439	5.902439	4.292682927	5.40243902	5.324041812	5.62195122

5. Result and discussion

In this study, DEA is used as an effective method for ranking the DMUs and analyzing the data. ODAM factors and each factor of RE are inserted to DEA model in order to determine the relationship between them. In other word, the impact of ODAM factors(macroergonomics) are evaluated on each RE items separately. Table 2 shows DEA results that is solved by matlab software for all DMUs and RE factors by model (1).

In this paper, the most efficient factor would be determined. Tables 2 shows efficiency and ranking obtained from the impact of ODAM factors on each items of RE; commitment, learning, awareness, flexibility, self-organization, redundancy.

Also, the mean efficiency obtained from ODAM influences in each RE items is shown. As you see in this table, ODAM factors will have the most influence on commitment and self- organization items. Next section deals with researching and comparing ODAM influences on different factors of IRE on average technical efficiency by using LSD test and SPSS software.

5.1. Comparison results with LSD test

The first pairwise comparison technique was developed by Fisher in 1935 and is called the least significant difference (LSD) test. This technique can be used only if the ANOVA F omnibus is significant. The main idea of the LSD is to compute the smallest significant difference (i.e., the LSD) between two means as if these means had been the only means to be compared (i.e., with a t test) and to declare significant any difference larger than the LSD.

In this paper, the pairwise comparisons are used for comparing which RE item has the greatest influence from ODAM factors (macroergonomics) by LSD test and SPSS software. The SPSS results are shown in table 3. Also, the mean plot is shown in figure 2. By analyzing LSD results, it is showed that commitment and self-organization have the greatest influences from ODAM factor, and after it, learning, flexibility, redundancy and awareness have more impact from ODAM factor, respectively.

Table 2: DEA results for 41 DMUs in impact ODAM on each items of RE

Unit name	**Commitment**		**Learning**		**Awareness**		**flexibility**		**Self-organization**		**Redundancy**	
	TE	Rank	TE	Rank	TE	Rank	TE	Rank	TE	Rank	TE	Rank
DMU1	9.00	1	1.06	33	2.20	1	1.70	8	8.91	2	1.06	36
DMU2	4.50	7	1.06	33	1.13	28	1.21	23	1.25	27	1.64	17
DMU3	4.50	7	6.00	4	1.75	5	1.70	11	1.80	20	1.70	13
DMU4	1.13	29	1.06	31	1.03	33	2.83	4	2.95	11	1.19	27
DMU5	3.00	15	1.13	27	1.07	30	1.31	20	1.38	24	1.31	22
DMU6	3.00	15	2.25	10	1.47	11	1.00	32	1.06	29	1.42	18
DMU7	9.00	1	9.00	1	1.50	10	1.06	27	1.12	27	1.06	31
DMU8	9.00	1	9.00	1	1.26	22	1.06	27	1.12	27	1.13	27
DMU9	4.50	5	4.50	4	1.29	19	1.13	25	1.20	24	1.00	30
DMU10	1.13	24	1.12	24	1.30	18	1.21	21	2.95	11	1.10	28
DMU11	1.00	25	2.00	10	1.25	20	1.21	20	3.00	9	1.31	22
DMU12	4.23	7	1.80	14	1.12	22	1.04	25	1.64	20	8.07	1
DMU13	7.90	4	1.00	28	1.05	24	1.65	14	1.00	27	1.59	15
DMU14	1.94	12	1.00	29	1.35	13	1.61	15	1.18	21	1.07	25
DMU15	1.80	12	1.06	23	1.33	15	3.40	3	1.80	11	1.42	15
DMU16	1.00	21	8.73	1	1.08	20	1.67	11	1.00	27	1.39	17
DMU17	1.73	17	1.06	22	1.07	20	1.70	10	8.39	4	1.24	19
DMU18	1.80	12	2.08	7	1.87	3	1.13	17	1.80	13	1.70	11
DMU19	1.29	17	1.80	9	1.98	1	1.00	22	1.80	10	1.70	10
DMU20	1.69	16	4.48	3	1.64	4	1.00	21	4.31	7	1.29	16
DMU21	1.80	12	4.50	2	1.91	1	1.06	17	8.85	2	2.76	5
DMU22	1.80	12	2.00	5	1.85	1	1.13	16	4.50	3	1.41	12
DMU23	1.00	15	1.00	18	1.00	19	1.00	19	1.00	19	1.00	20
DMU24	9.00	1	1.80	6	1.14	13	1.70	8	9.00	1	1.31	13
DMU25	1.00	14	1.64	8	1.00	18	1.53	11	1.67	11	1.81	7
DMU26	1.00	14	1.80	7	1.26	12	1.42	11	4.36	3	1.17	12
DMU27	9.00	1	1.64	7	1.00	13	1.13	12	1.12	11	2.78	4
DMU28	1.80	10	1.20	9	1.63	2	1.31	11	1.80	7	1.69	8
DMU29	4.22	4	1.12	11	1.33	8	2.83	3	4.50	2	1.70	7
DMU30	4.50	2	1.20	9	1.28	9	4.25	2	1.00	13	1.67	7
DMU31	2.53	7	1.24	8	1.13	9	1.00	10	1.00	9	1.12	9
DMU32	3.55	4	2.19	4	1.33	8	2.10	3	8.62	1	1.00	11
DMU33	1.13	7	2.25	3	1.42	5	4.25	1	1.00	8	1.40	7
DMU34	1.00	7	1.00	8	1.00	9	1.06	7	1.80	4	1.13	7
DMU35	3.00	5	1.93	3	1.57	2	1.70	2	1.76	4	2.11	5
DMU36	3.76	3	5.94	1	1.34	5	1.65	4	1.56	5	5.33	1
DMU37	4.35	2	1.50	3	1.44	3	1.70	2	1.75	4	2.81	2
DMU38	9.00	1	1.80	2	1.73	1	1.70	2	1.80	3	2.43	2
DMU39	1.00	3	1.00	3	1.00	4	1.00	4	1.00	4	1.00	3
DMU40	1.00	3	1.00	3	1.00	3	1.00	3	1.00	3	1.00	3
DMU41	1.80	2	1.13	2	1.55	1	2.43	1	3.00	1	3.40	1
Mean	3.42		2.44		1.36		1.62		2.73		1.79	

Table 3: LSD test for comparison between impacts on RE factors

Multiple Comparisons

Dependent Variable: RE

LSD

(I) DMU	(J) DMU	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
commitment	learning	.98340*	.41667	.019	.1626	1.8042
	awareness	2.06692*	.41667	.000	1.2461	2.8877
	flexibility	1.79903*	.41667	.000	.9782	2.6198
	selforganization	.69722	.41667	.096	-.1236	1.5180
	redundancy	1.63257*	.41667	.000	.8118	2.4534
learning	commitment	-.98340*	.41667	.019	-1.8042	-.1626
	awareness	1.08352*	.41667	.010	.2627	1.9043
	flexibility	.81563	.41667	.051	-.0052	1.6364
	selforganization	-.28618	.41667	.493	-1.1070	.5346
	redundancy	.64917	.41667	.121	-.1716	1.4700
awareness	commitment	-2.06692*	.41667	.000	-2.8877	-1.2461
	learning	-1.08352*	.41667	.010	-1.9043	-.2627
	flexibility	-.26789	.41667	.521	-1.0887	.5529
	selforganization	-1.36970*	.41667	.001	-2.1905	-.5489
	redundancy	-.43435	.41667	.298	-1.2551	.3864
flexibility	commitment	-1.79903*	.41667	.000	-2.6198	-.9782
	learning	-.81563	.41667	.051	-1.6364	.0052
	awareness	.26789	.41667	.521	-.5529	1.0887
	selforganization	-1.10181*	.41667	.009	-1.9226	-.2810
	redundancy	-.16646	.41667	.690	-.9873	.6543
selforganization	commitment	-.69722	.41667	.096	-1.5180	.1236
	learning	.28618	.41667	.493	-.5346	1.1070
	awareness	1.36970*	.41667	.001	.5489	2.1905
	flexibility	1.10181*	.41667	.009	.2810	1.9226
	redundancy	.93535*	.41667	.026	.1146	1.7561
redundancy	commitment	-1.63257*	.41667	.000	-2.4534	-.8118
	learning	-.64917	.41667	.121	-1.4700	.1716
	awareness	.43435	.41667	.298	-.3864	1.2551
	flexibility	.16646	.41667	.690	-.6543	.9873
	selforganization	-.93535*	.41667	.026	-1.7561	-.1146

*. The mean difference is significant at the 0.05 level.

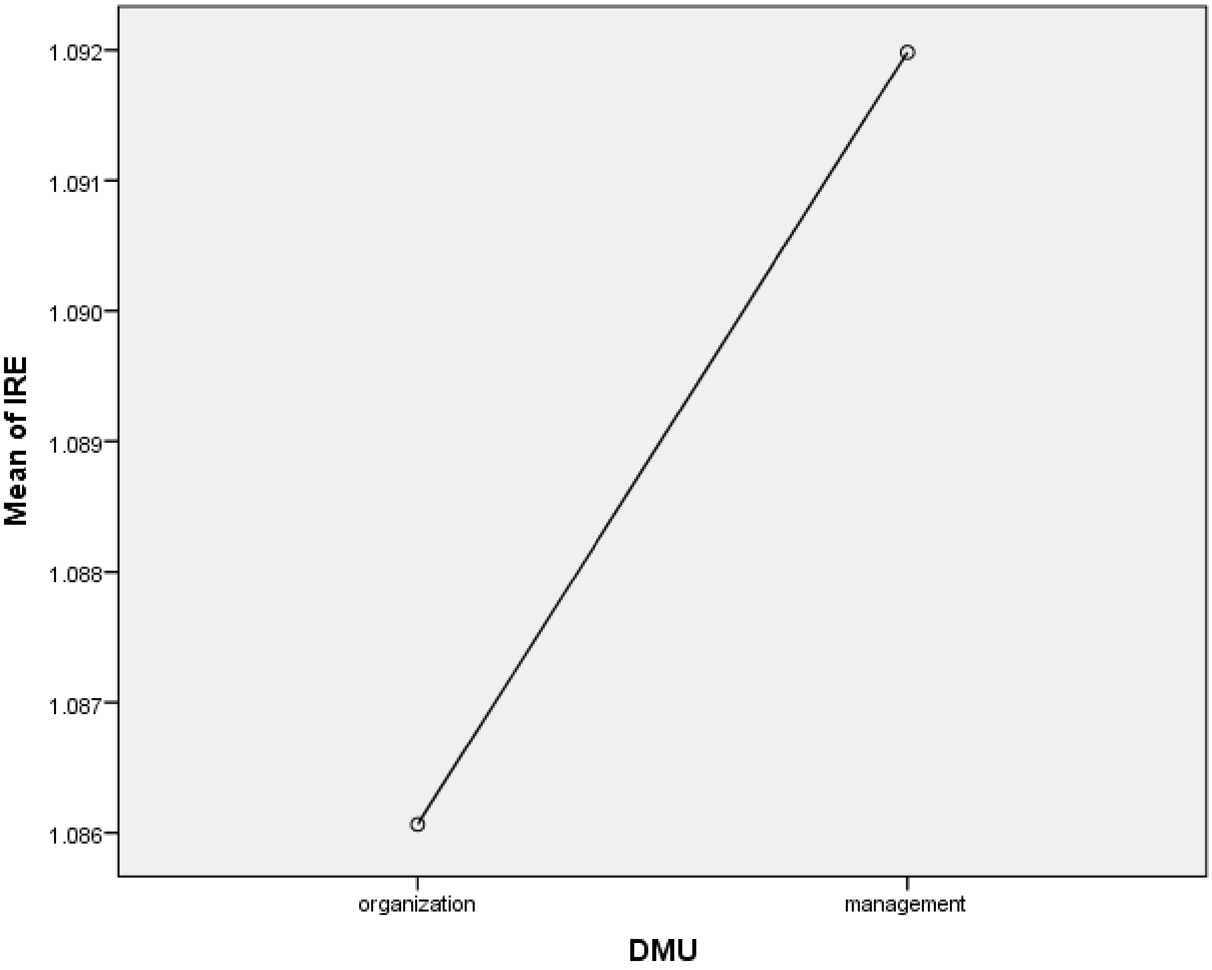

Figure 2: the mean plot of ODAM- RE

Figure 2 shows that there is a direct relationship between ODAM factors and RE items and RE items have large impacts from macroergonomics.

6. Conclusion

The main aim of this study was to find the impact of macroergnomics on RE items by DEA method in case of gas refinery. First, the concept of macroergonomics and RE were stated; then two questionnaires were prepared based on macroergnomics (ODAM factors) and RE items. Cronbach's alpha was calculated and its value was 90%. In the next section, suitable models for this system were presented and after that the impact of ODAM variables on each items of RE were evaluated one by one by DEA methodology. This is the first study that examines the impacts of macroergonomics on resilience engineering by DEA approach. The results of DEA model (1), showed that commitment and self-organization variables have the greatest influence from macroergonomics. The pairwise comparisons between the impact of macroergonomics on each items of RE were done by SPSS software (by using LSD test) and it is showed that commitment and self-organization have the greatest influences from ODAM factor, and after it, learning, flexibility, redundancy and awareness have more impact from ODAM factor, respectively.

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