Evaluation of worker productivity improvement criteria using interpretive structural modeling and Fuzzy Analytic Hierarchy Process

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Abstract: - In recent years, many printed circuit board (PCB) manufacturing firms have looked upon worker productivity improvement as the means by which they could improve their firm performance. This paper uses the critical factors and interpretive structural modeling (ISM) that determine the structure of analytical hierarchical process model in fuzzy environment. Fuzzy analytic hierarchy process (FAHP) based methodology be discussed to tackle the different decision criteria in a hierarchical structure in the improvement of worker productivity. The findings advocate that these manufacturing firms would thereby the hierarchical model to setup the priorities of the worker productivity improvement. The result finds that the best practice is most critical factor to overall objective.

Keywords: - worker productivity improvement, interpretive structural modeling, fuzzy analytical hierarchical process

1. Introduction

Improving worker productivity, thereby production process design and occupational health and safety (OHS) are major concerns of industry. Some of the common features of the industries are improper workplace design, ill-structured jobs, mismatch between worker abilities and job demands, poor team work and inappropriate management programs. This leads to poor worker health and in turn this reduces worker productivity and product quality and increases cost. Ergonomics or Human Factors application has been found to improve worker productivity, occupational health, safety and satisfaction. This has both direct and indirect effects on the over all performance of a company. It would, therefore, be extremely difficult to attain company objectives without giving proper consideration to ergonomics. And yet, the worker productivity is not only based on the ergonomics involved but also the process management, continuous improvement, team work and work design.

Effective application of ergonomics in work system design can achieve in both of physical working environment and psychological effect. This can enhance worker productivity, provide worker safety and physical and mental well-being, and job satisfaction. Many research studies have shown positive effects of applying ergonomic principles in workplaces, machine design, job design, environment and facilities design [1][2][3][4]. Studies in ergonomics have also produced data and guidelines for industrial applications. The features of ergonomic design of all physical working environment, psychological effect, workstation design, and facilities are well known [5][6][7]. Another point of view on improving worker productivity is through team work, continuous improvement and process management, they are mostly well known in total quality management principles [8][9][10][11].

However, there is still a need for acceptance and limited application in the industry. The main concern of process management is usually the improvement of inventory level, achieve of best practice and reduce product unit cost alone, continuous improvement is based on problem solving, track rework and rejects and modification of existing processes, team work considers as the voice of the working group and coordination, work design has to include comfortable with workstation design, clear instruction and components are reachable. Thus, the mentioned variables are given to the production system as a whole for worker productivity improvement. An ergonomically deficient workplace can cause physical and emotional stress, low productivity and poor quality of work [12]. It is believed production system deficiencies are the root causes of workplace health hazards, low level of safety and reduced worker productivity and quality.

The objective of this research is to model a hierarchical structure of worker productivity improvement through ISM and identify the priority weights of improvement of worker productivity through FAHP. This paper is organized as follows. Section 2 discusses the literature review. Section 3 addresses the research method while Section 4 presents the empirical results. Section 5 presents the discussion and conclusion of the paper.

2. Literature Review

The brief section on theoretical framework presents some core concepts related to process management, continuous improvement, team work, work design, OHS and worker productivity. Researchers have evaluated the internal control reform [13][14]. Internal control has proved to be successful in reducing occupational accidents and ergonomics improvement [15].

In Asia, employers tend to less aware of internal factors over which they have production control, including the organization of work in production system [16]. However, effective application of OHS in process management, continuous improvement, team work and work design is critical significant to improve worker productivity. The firms tend to use less elaborate and less effective control methods, focusing on individual behavior and individual protection [17]. Effective application of ergonomics in process management, continuous improvement, team work and work design can achieve a balance between worker characteristics and task demands. This enhance worker productivity, provide worker safety and physical and mental well being, and job satisfaction. Studies in ergonomics have produced data and guidelines for industrial applications. The features of ergonomic design of workstations, in job design, in facility design and in environment are well-known [18][19]. An ergonomically deficient workplace can cause physical and emotional stress, low productivity and poor quality of work.

There is a comparatively large amount of knowledge available regarding optimal design of workstations which including workstation design, training and feedback system. And concern with using manufacturing performance measures for operational control provides the capability to recognize when specific parts of the manufacturing process are moving out of control and signal a need for process adjustment and go to a cycle of continuous improvement by daily operations [20]. Moreover, the practices and techniques that help to achieve continuous improvement include process management and analysis. The effect of continuous improvement on worker productivity may be justified by organization strategic goal setting. However, improving OHS and worker productivity are major concerns of most industries. Always managers received workers' complains of fatigue, back pain, upper body and neck pain and hand or arm soreness.

In an early study, [21] it was found that operators were unable to work in normal standing or sitting postures due to poorly designed and installed machines, poorly designed tasks, inappropriate work heights and lack of suitable work chairs. Musculoskeletal complaints are common among workers and may be associated with ergonomic as well as psychosocial factors at work [22][23]. Stress is another common problem in working life that is related to psychosocial factors and that may be associated with musculoskeletal complains [24]. Work-related upper extremity symptoms can include pain, tenderness, swelling, numbness, and loss of function in the fingers, hands, forearms, shoulders, upper back, and neck [25], and according to Piligan and colleagues [26], the most common approach to prevent the symptoms involves ergonomic interventions to (1) reduce awkward positions, (2) minimize the need to use excess force, (3) reduce highly repetitive movement, (4) reduce the period of time spent in one position, and (5) ensure sufficient rest/recovery periods.

It is evident that worker complaints received by managers could be attributed to ergonomic deficiencies. Poor ergonomic conditions in industry not only hinder productivity but also affect health and safety of workers and quality of work and products. Ergonomics has traditionally been used to decrease the number of occupational injuries by discovering those postures and tasks that crease significant musculoskeletal stress. However, the principles, which underlie ergonomics, can potentially be used to improve productivity as well [8]. In contrast, the study of Shikdar et al [3] were found the industries lack of skills in ergonomics and training, communication and resources are believed to be some of the factors contributing to the poor ergonomic conditions and consequent loss of worker productivity and reduced health and safety in the industries (metal, plastics, food, chemical, paper and packaging etc).

Nevertheless, Yeow and Nath Sen [27] studied an ergonomic improve on the workstations design for electronic firms resulted in many benefits, average saving in yearly rejection cost, reduction in rejection rate, increase in monthly revenue, improvements in productivity, quality, operator's working condition and OHS and enhance in customer satisfaction. The study of Ashraf and Naseem [28] resulted among productivity indicators and OHS attributes. Lack of skills in ergonomics and communication resources (feedback system) are, consequently, loss of worker productivity and failed in OHS. However, management must be knowledge and aware of the benefits of ergonomics and the prevention of injuries through ergonomic design of work system, ergonomics program must systematically approach to process management, team work and continuous improvement in order to improve worker productivity.

3. Methodology

The problem discussed here is concerned with PCB manufacturing firms, searching the study hierarchical model and to prioritize of the worker productivity improvement, the firms want to take into account all the important criteria which can affect the implementation prioritization. A decision-making group is formed which consists of the experts from each strategic decision area. A group of fifteen (15) experts consisting of PCB professionals are asked to make pair-wise comparisons for the main and sub-attributes. A questionnaire is provided to get the evaluations. However, since the group of experts came up with a consensus by the mentioned method, a single evaluation could be obtained to represent the expert's opinion. This research applies three (3) kinds of research methods that are Delphi method, ISM and FAHP

3.1 ISM

SM proposed by Warfield [29], Warfield [30] and Warfield [31] is a computer- assisted methodology to construct and understand the fundamental of the relationships of the elements in complex systems or situations. The theory of ISM is based on discrete mathematics, graph theory, social sciences, group decision-making, and computer assistance. The procedures of ISM are begun through individual or group mental models to calculate binary matrices, also called relation matrix, to present the relations of the elements. However, *Delphi method* is a technique to arrive at a group position regarding an issue under investigation, the Delphi method consists of a series of repeated interrogations, usually by means of questionnaires, of a group of individuals whose opinions or judgments are of interest. After the initial interrogation of each individual, each subsequent interrogation is accompanied by information regarding the preceding round of replies, usually presented anonymously. The individual is thus encouraged to reconsider and, if appropriate, to change his previous reply in light of the replies of other members of the group. After two or three rounds, the group position is determined by averaging. The method step is as following:

1. Provision for the inclusion of the scientific elements;
2. Means for exhibiting a complex set of relations;
3. Means for showing that complex set of relations which permit continuous observation, questioning and modification of the relations;
4. Congruence with the originators' perceptions and analytical processes;
5. Ease of learning by public (or, by inference, multidisciplinary) audience.

Graphical models or, more specifically, directed graphs (digraphs) appear to satisfy these requirements. In such a representation, the elements or components of a system are represented by the "points" of the graph and the existence of a particular relationship between elements is indicated by the presence of a directed line segment. It is this concept of relatedness in the context of a particular relationship which distinguishes a system from a mere aggregation of components.

A relation matrix can be formed by asking the question like "Does the feature e_i inflect the feature e_j"? If the answer is "Yes" then $d_{ij} = 1$, otherwise $d_{ij} = 0$. The general form of the relation matrix can be presented as follows:

$$D = \begin{array}{c} \\ e_1 \\ e_2 \\ . \\ . \\ e_n \end{array} \begin{pmatrix} e_1 & e_2 & \cdots & \cdots & e_n \\ 0 & d_{12} & \cdots & \cdots & d_{1n} \\ d_{12} & 0 & \cdots & \cdots & d_{2n} \\ \cdots & \cdots & \cdots & \cdots & . \\ \cdots & \cdots & \cdots & \cdots & . \\ d_{m1} & d_{m2} & \cdots & \cdots & 0 \end{pmatrix}$$

Where e_i is the i th element in the system, d_{ij} denotes the relation between i th and j th elements, $\boldsymbol{D}$ is the relation matrix.

After constructing the relation matrix, we can calculate the reachability matrix using Eqs. (1) and (2) as follows

$$M = D + I \quad (1)$$

$$M^* = M^k = M^{k+1} \quad k>1 \quad (2)$$

Next we can calculate the reachability set and the priority set based on Eqs. (3) and (4), respectively, as the following equations

$$A\ (t\ i) = \{\ t_j \quad |\ m'_{ij} = 1\} \quad (3)$$

$$R\ (t\ i) = \{\ t_j \quad |\ m'_{ij} = 1\} \quad (4)$$

where m_{ij} denotes the value of the ith row and the jth column. Then, according to Equation (5), the levels and relationships between the elements can be determined and the structure of the elements' relationships can also be expressed using the graph.

$$R\ (ti) \cap A\ (ti) = R\ (ti) \quad (5)$$

Ultimately, this research follows the ISM computational method and result the research model for the further analyzing in FAHP.

3.2 FAHP

AHP has been widely used to address the multi-criteria decision making problems. It has been generally criticized because of the use of a discrete scale of one to nine which cannot handle the uncertainty and ambiguity present in deciding the priorities of different attributes (See Table 1). The hierarchy of the decision variables is the subject of a pair wise comparison of the AHP. Traditionally, the pair wise comparison is established using a nine-point scale which converts the human preferences between available alternatives as equal importance, weak importance, strongly importance, demonstrated importance and absolute importance. Even though the discrete scale of AHP has the advantages of simplicity and ease of use, it is not sufficient to take into account the uncertainty associated with the mapping of one's perception to a number [32]. The linguistic assessment of human feelings and judgments are vague and it is not reasonable to represent it in terms of precise numbers. It feels more confident to give interval judgments than fixed value judgments. Hence, triangular fuzzy numbers are used to decide the priority of one decision variable over other. Synthetic extent analysis method is used to decide the final priority weights based on triangular fuzzy numbers.

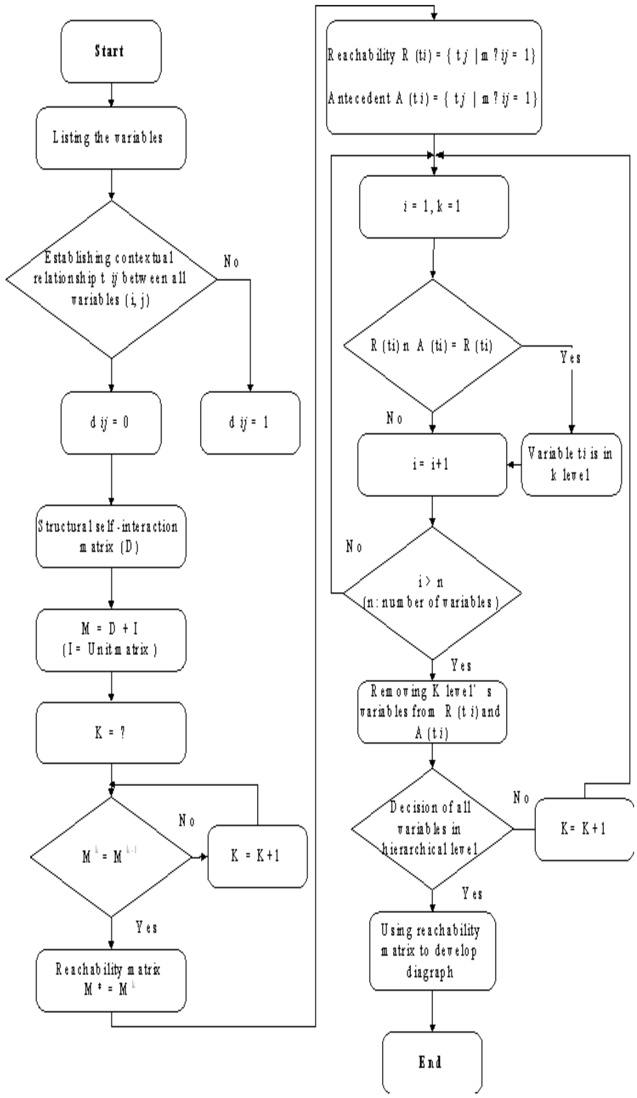

Figure 1 . ISM computational flowchart

Fuzzy set theory has proven advantages within vague, imprecise and uncertain contexts and it resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It was specially designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many decision problems. Fuzzy set theory implements classes and grouping of data with boundaries that are not sharply defined (i.e. fuzzy). Fuzzy set theory includes the fuzzy logic, fuzzy arithmetic, fuzzy mathematical programming, fuzzy graph theory and fuzzy data analysis, usually the term fuzzy logic is used to describe all of these. The FAHP is the fuzzy extension of AHP to efficiently handle the fuzziness of the data involved in the decision of best worker productivity improvement. It is easier to understand and it can effectively handle both qualitative and quantitative data in the multi-attribute decision making problems. In this approach triangular fuzzy numbers are used for the preferences of one criterion over another and then by using the extent analysis method, the synthetic extent value of the pair wise comparison is calculated. Based on this approach, the weight vectors are decided and normalized, thus the normalized weight vectors will be determined. As a result, based on the different weights of criteria and attributes the final priority weights are decided.

Table 1. Saaty's nine-point scale [33]

Intensity of importance	Definition	Explanations
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over other	Experience and judgment slightly favor one activity over another
5	Essential or strong important	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j* then *j* has the reciprocal value when compared with *i*	A reasonable assumption

In following, the outlines of analysis method on fuzzy AHP are given $X = \{x1, x2, ..., xn\}$ be an object set, and $U = \{u1, u2, ...um\}$ be a goal set. According to Saaty [33], each object is taken and extent analysis for each goal, g_i , is performed, respectively. Thus, m extent analysis values for each object can be obtained, with following signs:

$$M_{gi}^1, M_{gi}^2, ...M_{gi}^m, \qquad I = 1,2,.....,n$$
(6)

Where all the M_{gi}^j (j = 1,2,…,*m*) are triangular fuzzy numbers (TFNS) whose parameters are *a*, *b*, and *c*. They are least possible value, respectively. A TFN is represented as (*a*,*b*,*c*). The steps of Chang's extent analysis can be given as in following

Step 1. The value of fuzzy synthetic extent with respect to the i^{th} object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1}$$
(7)

To obtain $\sum_{j=i}^{m} M_{gi}^j$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} aj, \sum_{j=1}^{m} bj, \sum_{j=1}^{m} cj \right), i = 1, 2, ..., n$$
(8)

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1}$, perform the fuzzy addition operation of $M_{gi}^j (j = 1, 2, ...m)$ values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = \left(\sum_{i=1}^{n} ai, \sum_{i=1}^{n} bi, \sum_{i=1}^{n} ci \right)$$
(9)

And then compute the inverse of the vector in equation (4) such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} ci}, \frac{1}{\sum_{i=1}^{n} bi}, \frac{1}{\sum_{i=1}^{n} ai} \right)$$
(10)

Step2. The degree of possibility of $M_2 = (a_2, b_2, c_2) \geq M_1 = (a_1, b_1, c_1)$ is defined as

$$V(M2 \geq M1) = \sup_{y \geq x} \left[\min \left(\mu_{m1}(x), \mu_{m2}(y) \right) \right]$$
(11)

And can be equivalently expressed as follows:

$$V(M_2 \geq M_1)=hgt(M_1 \cap M_2)=\mu_{M2}(d)=\begin{cases} 1, & \text{if } b_2 \geq b_1 \\ 0, & \text{if } a_1 \geq a_2 \\ \dfrac{a_1-c_2}{(b_2-c_2)-(b_1-a_1)}, & \text{otherwise} \end{cases}$$

(12)

Where, d is the ordinate of the highest intersection point D between μ_{m1} and μ_{m2}, to compare M_1 and M_2, we need both values of V ($M_1 \geq M_2$) and V ($M_2 \geq M_1$) (See Figure 2).

Step 3. The degree of possible for a convex fuzzy number to be greater than k convey fuzzy number M_i (i = 1,2, …,k) can be defined by V ($M \geq M_1$, M_2,…M_k) =

$$V\left[(M \geq M_1) and (M \geq M_2) and ......and (M \geq M_k)\right] = \min V(M \geq M_1),$$

i= 1,2,3,….k. (13)

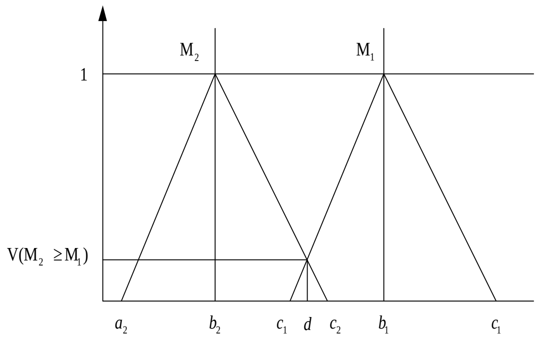

Figure 2. The intersection between M_1 and M_2

Table 2. Triangular fuzzy conversion scale

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Equally important	(1/2,1,3/2)	(2/3,1,2)
Weakly important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

Assume that

$$d'(A_i) = \min \ V \ (Si \geq S_k)$$

(14)

For k=1,2,…..,n; $k \neq i$. Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), ...d'(A_n)\right)^T$$

(15)

Where A_i (i=1,2,…n) are n elements.

Step 4. Via normalization, the normalized weight vectors are

$$W = \left(d(A_1), d(A_2), ...d(A_n)\right)^T$$

(16)

Where, W is a non-fuzzy number. The triangular fuzzy conversion scale given in Table 2 is used in the evaluation model of this paper.

4. RESULTS

4.1 ISM Result

Table 3. The study criteria of measurement

No.	Criteria of measurement	No.	Criteria of measurement
1	Worker productivity improvement	11	Cost of quality process reduction
2	Process management	12	Employees suggest to modify to existing processes
3	Continuous improvement	13	Employees achieve their department's goals
4	Team work	14	Employees, make suggestions to any of the activities of production process
5	Work design	15	Components are reachable
6	Occupational health and safety	16	Clear with all assembly line instructions.
7	Reduce inventory	17	Workstation design
8	Best Practice	18	Physical working environment
9	Reduce product unit cost	19	Psychological effect
10	Problem solving bases on systematic analysis		

After constructing the relation matrix, we can calculate the reachability matrix using Eqs. (1) and (2) as follows

After constructing the relation matrix, we can calculate the Reachability set and antecedent set using Eqs. (3) and (4). Then, according to Equation (5), the levels and relationships between the elements can be determined and the structure of the elements' relationships can also be expressed using the graph.

This research has result the structural hierarchical level
Level 1= {1}
Level 2= {2,3,4,5,6}
Level 3= {7,8,9,10,11,12,13,14,15,16,17,18,19}

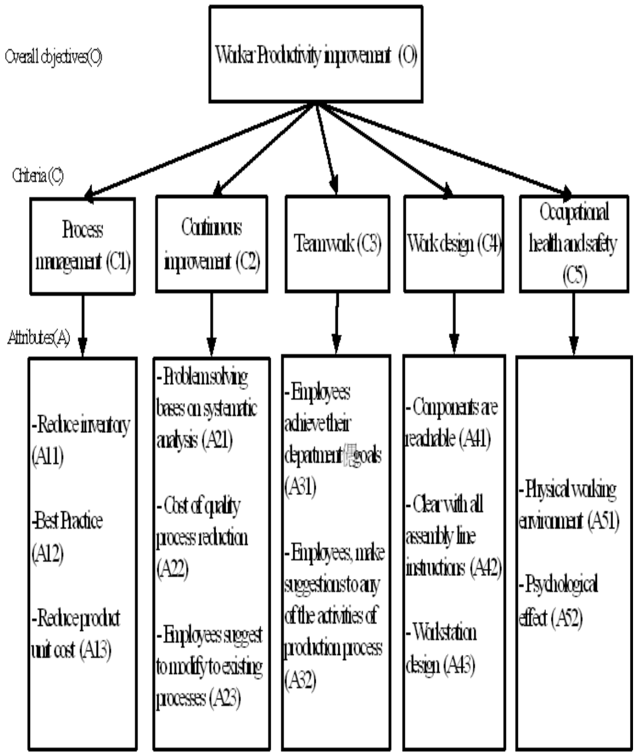

Figure 3. Result of ISM for FAHP

4.2 FAHP result

The whole hierarchy of the worker productivity can be easily visualized from Figure 3. After the construction of the hierarchy the different priority weights of each criteria and attributes are calculated using the FAHP approach. The comparison of the importance or preference of one criteria or attribute over another can be done with the help of the questionnaire. The preference of one measure over another is decided by the available research, the current business scenario and by the experience of the experts. The method of calculating priority weights of the different decision criteria using FAHP is discussed below.

The different values of fuzzy synthetic extend [Eq. (10)] with respect to the four different criteria are noted by M_1, M_2, M_3, M_4 and M_5

$M_1 = (23.85, 16.76, 17.84) \otimes (1/36.73, 1/34.17, 1/60.71) = (0.678, 0.515, 0.301)$
$M_2 = (13.32, 6.99, 7.49) \otimes (1/36.73, 1/34.17, 1/60.71) = (0.379, 0.215, 0.127)$
$M_3 = (8.33, 1.55, 1.55) \otimes (1/36.73, 1/34.17, 1/60.71) = (0.237, 0.048, 0.026)$
$M_4 = (13.65, 7.27, 8.25) \otimes (1/36.73, 1/34.17, 1/60.71) = (0.389, 0.223, 0.139)$
$M_5 = (1.56, 1.6, 1.6) \otimes (1/36.73, 1/34.17, 1/60.71) = (0.044, 0.049, 0.027)$

The degree of possible of Mi over Mj ($i \neq j$) can be determined by Eq. (12) (13)
$V(M_1 \geq M_2) = 1$，$V(M_1 \geq M_3) = 1$，$V(M_1 \geq M_4) = 1$，$V(M_1 \geq M_5) = 1$
$V(M_2 \geq M_1) = 0.219$，$V(M_2 \geq M_3) = 0.039$，$V(M_2 \geq M_4) = 0.1$，$V(M_2 \geq M_5) = 1$
$V(M_3 \geq M_1) = 0.352$，$V(M_3 \geq M_2) = 0.189$，$V(M_3 \geq M_4) = 0.194$，$V(M_3 \geq M_5) = 0.11$
$V(M_4 \geq M_1) = 0.217$，$V(M_4 \geq M_2) = 1$，$V(M_4 \geq M_3) = 0.357$，$V(M_4 \geq M_5) = 1$
$V(M_5 \geq M_1) = 0.349$，$V(M_5 \geq M_2) = 0.189$，$V(M_5 \geq M_3) = 1$，$V(M_5 \geq M_4) = 0.193$

With the help of eq. (14), the minimum degree of possibility can be stated as below:
$m(C1) = \min V(M_1 \geq M_2, M_3, M_4) = \min(1,1) = 1$, Similarly, m(C2) = 0.1, m(C3) = 0.11, m(C4) =0.217, m(C5) =0.189. The weight vector is given as Wo = $(1, 0.1, 0.11, 0.217, 0.189)^T$ [Eqs (15)] and after the normalization process, the weight vector of overall objective with respect to decision criteria C1, C2, C3 and C4 can be presented as follows Eqs (16): Wo = (0.62, 0.06, 0.07, 0.13, 0.12).

Now the different attributes are compared under each of the criteria separately by following the same procedure as discussed above. The matrix eigen value must be normalized and then do the same process to find the weight vector of each attribute. The fuzzy evaluation matrices of attributes and the weight vectors of each attribute are shown and the fuzzy evaluation matrices of decision alternatives and corresponding weight vector of each alternative with respect to corresponding attributes are determined. Finally the priority weights of each worker productivity improvement can be calculated by weights of the corresponding criterion. The completed results are shown in Table 4, Table 5, Table 6, Table 7, Table 8 and Table 9.

The worker productivity improvement requires thorough production site analysis, the priority weights of criteria in overall objective are as process management (C1- 0.619), continuous improvement (C2- 0.062), team work (C3- 0.068), work design (C4- 0.134) and OHS (C3- 0.117). Base from these results, the case firm is care more on process management.

Table 4. The fuzzy evaluation of the attributes with respect to criteriaC1

C1	A11	A12	A13	W_{C1}
A11	(1, 1 , 1)	(7/9, 3/4, 5/6)	(2/3, 2/3, 3/4)	0.036
A12	(6/5, 4/3, 9/7)	(1, 1, 1)	(6, 6, 7)	0.849
A13	(4/3, 3/2, 3/2)	(1/7, 1/6, 1/6)	(1, 1, 1)	0.115

Table 5. The fuzzy evaluation of the attributes with respect to criteria C2

C2	A21	A22	A23	W_{C2}
A21	(1, 1, 1)	(5, 5, 6)	(2/3, 2/3, 3/4)	0.032
A22	(1/6, 1/5, 1/5)	(1, 1, 1)	(7, 6, 6)	0.818
A23	(4/3, 3/2, 3/2)	(1/7, 1/6, 1/6)	(1, 1, 1)	0.15

Table 6. The fuzzy evaluation of the attributes with respect to criteria C3

C3	A31	A32	W_{C3}
A31	(1, 1, 1)	(1/5, 2/9, 1/4)	0.23
A32	(4 , 9/2, 5)	(1, 1, 1)	0.77

Table 7. The fuzzy evaluation of the attributes with respect to criteria C4

C4	A41	A42	A43	W_{C4}
A41	(1, 1, 1)	(1/4, 1/4, 1/3)	(5, 5, 6)	0.45
A42	(4, 4, 3)	(1, 1, 1)	(6, 6, 6)	0.52
A43	(1/6, 1/5, 1/5)	(1/6, 1/6, 1/6)	(1, 1, 1)	0.03

Table 8. The fuzzy evaluation of the attributes with respect to criteria C5

C5	A51	A52	W_{C5}
A51	(1, 1, 1)	(5, 5, 6)	0.85
A52	(1/6, 1/5, 1/5)	(1, 1, 1)	0.15

Effective of worker productivity improvement requires from the study empirical result from case firm, the global priority weights are as 1. best practice (A12- 0.525), 2. Physical working environment (A51- 0.1), 3. Reduce product unit cost (A13- 0.071), 4. Clear with all assembly line instructions (A42- 0.07), and 5. Components are reachable (A41- 0.061) are top five most important attributes to overall objective for worker improvement in this study.

Table 9. Integrated the priority weights of criteria and attributes to acquire global priority

Criteria		Attributes		Global priority	Ranking
C1	0.619	A11	0.036	0.022	8
		A12	0.849	0.525	1
		A13	0.115	0.071	3
C2	0.062	A21	0.032	0.002	13
		A22	0.818	0.051	7
		A23	0.150	0.009	11
C3	0.068	A31	0.231	0.016	10
		A32	0.769	0.052	6
C4	0.134	A41	0.452	0.061	5
		A42	0.521	0.070	4
		A43	0.027	0.004	12
C5	0.117	A51	0.851	0.100	2
		A52	0.149	0.017	9

5. CONCLUSION

ISM developed in this paper acts as a tool for top management to understand the variables of worker productivity improvement. Though ISM is developed on the basis of perception of the experts of worker productivity improvement, the results are quite generic and helpful for the top management to drive the efforts towards the roots of the worker productivity improvement problem. ISM approach leads us to the variables where fruitful results in terms of worker productivity improvement can be achieved. ISM developed in this paper is not specific to any sector and specific model for any other sector may differ slightly from the model.

Fuzzy AHP of group decision making are used for the justification of worker productivity improvement. The basic concepts of fuzzy multi-attribute decision making (MADM) methods are derived mainly from classical MADM methods. The size of a MADM problem is characterized by the number of attributes and the number of alternatives. The existing FAHP methods are complex and difficult to apply to most large size real-world problems. A good and simple method which is conceptually easy to understand and practically capable of solving real-world problems is desirable. Decisions are made today in increasingly complex environments. In more and more cases the use of experts in various fields is necessary, different value systems are to be taken into account, etc. In many of such decision-making settings the theory of group decision making can be of use. Fuzzy group decision making can overcome this difficulty. In general, many concepts, tool and techniques of artificial intelligence, in particular in the field of knowledge representation and reasoning, can be used to improve human consistency and implement ability of numerous models and tools in broadly perceived decision making and operations research.

Because traditional worker productivity models do not take care of the inherent strategic benefits of OHS involved, a multi-attribute decisions-making method should be used to justify them. Since humans are unsuccessful in making quantitative predictions, where they are comparatively efficient in qualitative forecasting, fuzzy set theory is an excellent tool to handle qualitative assessments about worker productivity improvement systems. In the last two decades, few fuzzy multi-attribute models in the justification of worker productivity improvement were developed. These qualitative assessments may be on process management, continuous improvement, team work, work design and OHS.

The highest ranking of Best practice is a management idea which asserts that there is a technique, method, process, activity, incentive or reward that is more effective at delivering a particular outcome than any other technique, method, process, etc. The idea is that with proper processes, checks, and testing, a desired outcome can be delivered with fewer problems and unforeseen complications. In the business vernacular, "best practices" are not subject to peer review or standards-development process, so no one in particular is charged with determining of the best practice in a particular domain. Therefore, best practice is the spirit of process management practice, maybe we should go further to the flexibility topic research for this case firm in order to find out the key point of best practice.

Lastly, we emphasis the contribution of this research contributes to build up the theoretical model of worker productivity improvement. This study takes a step in that direction of setting priorities of clarifying, organizing and integrating terms and concepts relevant to worker productivity improvement in the firm process.

Limitation of research and future study

In the present work only nineteen variables are identified for modeling the worker productivity improvement. More number of variables affecting worker productivity improvement can be identified to develop ISM. The experts' help have been sought to analyze driving and dependence power of the variables [34]. Here the framework developed depends upon the opinion of few production experts and has some element of bias. Through ISM, a relationship model among worker productivity improvement variables has been developed. This model has not been statistically validated. LISREL software can be used to examine the relationships derived from this model. Structural equation modeling (SEM), also commonly known as linear structural relationship approach has the capability of testing the validity and reliability of such hypothetical model [35]. Thus, it may be applied in the future research to test the validity of this model.

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References:

[1] Rayan, J.P. A study of selected ergonomic factors in occupational safety. In: A. Mital, Editor, *Advances in industrial ergonomics and safety I*, Taylor and Francis, London, 1989, pp.359–364.

[2] Das, B. and Sengupta, A. Industrial workstation design: A systematic ergonomic approach. *Applied Ergonomics*, 27(3), 1996, pp.157–163.

[3] Shikdar, A.A. and Das, B. A field study of worker productivity improvements. *Applied ergonomics*, 26(1), 1995, pp.21–27.

[4] Das, B. and Shikdar, A. Participative versus assigned production standard setting in a repetitive industrial task: A strategy for improving worker productivity. *International journal of occupational oafety and orgonomics*, 5(3), 1999, pp.417–430.

[5] Grandjean, E. *Fitting the task to the man: an ergonomic approach*, Taylor and Francis, London, 1998.

[6] Sanders, M.S. and McCormick, E.J. *Human factors in engineering and design* (7th ed.), McGraw-Hill, New York, 1992.

[7] Konz, S. *Work design: Industrial ergonomics* (5th ed.), Grid Columbus, Ohio. 1995.

[8] Dean Jr., J.W. and Bowen, D.E. Managing theory and total quality: improving research and practice through theory development. *Academy of management review*, 19(3), 1994, pp.392–418.

[9] Black, S.A. and Porter, L.J. Identification hand/wrist? a review of the epidemiological literature. *American Journal of Industrial Medicine*, 41, 1996, pp.315–42.

[10] Fuentes-Fuents, M.M.; Albacete-Sae, C.A.; Llorens-Montes, F.J. The impact of environmental characteristics on TQM principles and organizational performance, *The international journal of management science*, 32, 2004, pp.425-442
[11] Jung, J.Y. and Wang, Y.J. Relationship between total quality management (TQM) and continuous improvement of international project management (CIIPM), *Technovation*, 26(5-6), 2006, pp.716-722
[12] Tseng, ML., Wu, WW., Lin, YH., and Liao, CH. An exploration of relationships between environmental practice and manufacturing performance using the PLS path modeling. WSEAS transactions on environment and development 4(6), 2008, pp.487-502
[13] Torp, S. and Moen BE. The effects of occupational health and safety management on work environment and health: a prospective study. *Applied Ergonomics* , Article in press 2005
[14] Saksvik, PO., Torvatn, H., Nytro, K. Systematic occupational health and safety work in Norway: a decade of implementation. *Safety science*, 41, 2003, pp.721-38
[15] Hovden, J. The ambiguity of contents andresults in Norwegian internal control of safety health and environment reform. *Reliability Engineering system safety* , 60, 1998, pp.133-141
[16] Noish. Work-related musculoskeletal disorders and psychosocial factors. In: Bernard, B. (Ed.), Musculoskeletal Disorders (MSDs) and Workplace Factors. National Institute for Occupational Safety and Health, Cincinnati., 1997.
[17] Bongers, PM., Kremer, AM. and Ter Laak, J. Are psychosocial factors risk factors for symptoms and signs of the shoulder, elbow or of the critical factors of TQM. *Decision sciences*, 27(1), 2002, pp.1–21
[18] Pransky, G., Robertson, MM. and Moon, SD. Stress and work-related upper extremity disorders: implications for prevention and management. American *Journal of Industrial Medicine*, 41, 2002, pp.443–455.
[19] Resnick, ML. and Zanotti, A. Using ergonomics to target productivity improvements. *Computers industrial engineering*, 33(1-2), 1997, pp.185-88.
[20] Lin, Z.P., Wang R., and Tseng, M.L. Determination of a cause and effect service quality model for leisure farms in Taiwan: an aspect from Beijing tourists. *WSEAS* transactions on business and economics 6(2), 73-86.
[21] Shikdar, A.A., Carlopio, J., Cross J., Stanley P. and Gardner D. Mechanical equipment injuries in small businesses. *In: Ergonomics in a Changing WorldProceedings of the Ergonomics Association of Australia*, Perth, Australia. 1993, pp. 199–205 .
[22] Pfau, LD. Total Quality Management gives companies a way to enhance position in global marketplace. *Industrial Engineering*, 21(4), 1989, pp.17–21.
[23] Borcherding, JD. and Alarcon, LF. Quantitative effects on construction productivity. *The Construction Lawyer* , 11, 1991, pp.1–48.
[24] Dieterle R., DeStephanis A. Use of productivity factors in construction claims. *AACE Transactions*, 1(1), 1992, pp.1–7.
[25] Hanna, A.S. and Donald, H.G. Factors affecting construction productivity: Newfoundland versus rest of Canada. *Canadian Journal of Civil Engineering* , 21, 1994, pp.663–73.
[26] Piligan,G.; Herbert, R.; Hearns, M.; Dropkin, J.; Landsbergis P. and Cherniack, M. Evaluation and management of chronic work-related musculoskeletal disorders of the distal upper extremity. *American Journal of Industrial Medicine*, 37, 2000, pp.75–93.
[27] Yeow, PHP., and Nath Sen, R. Quality, productivity, occupational health and safety and cost effectiveness of ergonomics improvements in the test workstation of an electronic factory. *Journal of operations management*, 32, 2003, pp.147-163
[28] Ashraf, AS. and Naseem, M.S. Worker productivity and occupational health and safety issues in selected industries, *Computer & Industrial Engineering*, 45, 2003, pp.563-72
[29] Warfield, J.N. Toward interpretation of complex structural modeling, *IEEE Trans. Systems man cybernet*, 4(5), 1974a, pp.405–417
[30] Warfield, J.N. Developing interconnection matrices in structural modeling, *IEEE Trans. Systems man cybernet*, 4(1), 1974b, pp.81–87.
[31] Warfield, J.N. *Societal systems: planning, policy, and complexity*, Wiley Interscience, *New York*. 1976.
[32] Kwong, C.K. and Bai, H. A fuzzy AHP approach to the determination of importance weights of customer requirements in quality function development. *Journal of Intelligent Manufacturing*, 13, 2002, pp.367-377.
[33] Saaty, T.L. *The analytic hierarchy process*, McGraw-Hill Book Co, New York. 1980.

[34] Tseng, M.Ml., Wu, W.W., Lee, Y.T. and Liao, C.H. An explorative model of customers' service quality perceptions for leisure fars in Taiwan. *WSEAS transactions on business and economics*. 5(12), pp.507-523

[35] Byrne, B.M. *Structural Equation Modeling with LISREL, PRELIS and SIMPLIS: Basic concepts, application and programming*. Lawrence Erlbaum, Mahwah, NJ. 1998.