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A Fuzzy AHP for Identification and Ranking the Implementation Obstacles of TPM (Case Study: Gas Industry of Iran)

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Abstract

Total Productive Maintenance or TPM is a philosophy to enhance an organization's productivity and produce high quality goods by minimizing waste thereby reducing costs.

TPM is designed to maximize equipment efficiency by determining an extensive productive maintenance system covering the whole life of the equipment, extending across all equipment-related fields and with participation of all employees from the top management to the shop-floor workers, to advance productive maintenance through voluntary small group activities (Tsuchiya 1992). Most of the automotive manufacturing industries are focusing on strict quality standards in their production process and implementing a quality program called Total Productive Maintenance. With the fast development of the maintenance, it becomes critical to set up a TPM Evaluation criteria system. Fuzzy Analytic Hierarchy Process is a new multi-criteria evaluation method evolved from Saaty's AHP. So, this paper aimed to find out and rank the key factors and obstacles that affect success in TPM in Gas industry using fuzzy AHP approach, and give an evaluation method for TPM in order to help researches and managers to determine the drawbacks and opportunities.

Keywords: Obstacles, Total productive maintenance (TPM), Fuzzy sets, Fuzzy AHP (Analytical Hierarchy Process), Gas Industry of Iran

Introduction

Quality, considered a key strategic factor in achieving business success, is more than ever required for competing successfully in today's global market place (Dean et al., 1994) and it has become the key slogan as organizations strive for a competitive advantage in markets characterized by liberalization, globalization and knowledgeable customers (Jackson 2000). Following Millar's (1987) predication that there will be two kinds of company in the future–companies which have implemented total quality and companies which are out of business, companies worldwide, large and small, both in the manufacturing and service sectors, have adopted quality strategies, and made TPM (Total Productive Maintenance) a well-accepted part of almost every manager's 'tool kit'.

TPM is a unique Japanese philosophy, which has been developed based on the Productive Maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971 and was started by the Japanese in the sixties when they realized that increased demand necessitated more specialized machines which in turn required dedicated maintenance groups.

Total Productive Maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce (Bhadury, 2000).

To improve equipment reliability, the TPM strategy was implemented in which the regular daily maintenance was carried out by the operators while the mandate given to the maintenance crew was to carryout specialized maintenance, upgrades and modification jobs to minimize failures thereby increasing machine availability, reducing costs and improving profitability of the organization. The concept looks simple but the practical aspect of implementation is very complex involving various stages each of which requires focused attention else the TPM implementation process is bound to result in failure. Due to this very reason, industries in India and world over have struggled and failed in TPM implementation. TPM is not a quick-fix methodology resulting in instant results; it requires commitment, dedication and perseverance on part of the management and employees over the long run (in terms of years) to deliver noticeable visible results (Prasanth et al., 2013).

TPM is intended to bring both functions (production and maintenance) together by a combination of good working practice, team working, and continuous improvement (Chintan et al., 2014). Efficiency and effectiveness of equipment plays a dominant role in modern manufacturing industry to determine the performance of the organizational production function as well as the level of success achieved in the organization (McGraw-Hill.Ames 1996). The impact of equipment efficiency has become more and more critical as the widespread utilization and application of highly sophisticated and automated machines in the industry increases. The maintenance of these complicated equipment and machines thus became very crucial and costly to manufacturers. Many organizations began to realize that the continuity of this excellent performance must be supported by a strong backbone of efficient and effective equipment (Ahuja et al., 2009). Traditional maintenance technicians are regarded as passive and non-productive to the current production function. Hence, implementing Total Productive Maintenance (TPM) in the manufacturing industry has emerged as an important operational strategy to overcome the production losses due to equipment inefficiency. TPM is an innovative approach, which holds the potential for enhancing the efficiency and effectiveness of production equipment by taking advantages of abilities and skills of all individuals in the organization (Bangar et al., 2013). TPM focuses on maximizing the Overall Equipment Efficiency (OEE) with involvement of each and everyone in the organization. It will not only establish a complete maintenance system, but also aims to improve the maintenance skills and knowledge among the shop floor operators. Now, TPM and its implications received prestigious worldwide recognition in achieving the ultimate Zero Defects and Zero Breakdown targets (Fang 2000).

This study reveals the obstacles faced by Iranian industries whilst their attempt to implement TPM initiatives.

In this research, in first we identified the application obstacles of TPM in Iranian industries and next have used the Fuzzy AHP approach for ranking the obstacles. The AHP was developed in the 1980s by Saaty. It is a systematic decision making method which includes both qualitative and quantitative techniques. It is being widely used in many fields for a long time. But one of the critical steps of AHP method is to set up the comparison matrixes. When the number of criteria's (or alternatives) in the hierarchy increases, more comparisons between criteria's (or alternatives) need to be made. This could easily cause confusion due to the excess of questions and hence the efficiency of the model. So a consistency check is required for the pair-wise comparison matrix. Therefore, whether the setting of the comparison matrix is scientific affects the correctness of AHP directly. When the comparison matrices are not consistent, we should adjust the elements in the matrixes and carry out a consistency test until they are consistent. Traditional AHP requires exact or crisp judgments (numbers). However, due to the complexity and uncertainty involved in real world decision problems, decision makers might be more reluctant to provide crisp judgments than fuzzy ones. In this paper, we will use a fuzzy AHP in which substitute membership scales for Saaty's 1-9scales to reduce adjusting times needed.

The rest of this paper is organized as follows: section 2, gives a literature review and concept of TPM, in section 3, The obstacles of TPM Implementation in Iranian Industrials is discussed and finally presents a conceptual model of research; Section 4, gives a brief review of AHP and Fuzzy AHP; Section 5, Presents the evaluation of the implementation obstacles of TPM in Gas industry; Finally in section 6, is the conclusion of this paper.

Literature review of TPM

TPM was initially started as a maintenance function which has now evolved into a management function. It as an equipment management program that involves all employees in the company in the maintenance and repair of the company's assets, whether a facility or plant (Terry Wireman, 1992). TPM seeks to maximize equipment effectiveness throughout the life time of the equipment and strives to maintain the equipment in optimum condition in order to prevent unexpected breakdown, speed losses and quality defects occurring from process activities (Ahuja and Khamba, 2008).

TPM is designed to maximize equipment efficiency by determining an extensive productive maintenance system covering the whole life of the equipment, extending across all equipment-related fields and with participation of all employees from the top management to the shop-floor workers, to advance productive maintenance through voluntary small group activities (Tsuchiya 1992). TPM can be specified as an approach to achieve rapid improvement of manufacturing procedures by involving and empowering production related employees and introducing a continuous procedure of quality improvement (Nakajima 1988). TPM performing has arisen from increased equipment efficiency, higher productivity, and better quality, less breakdowns, lower costs, and credible deliveries, motivating working environments, increased security and improved spirit of the employees (Ahuja and Khamba 2008b).

The TPM performing procedure has been charged with obstacles and risks. These obstacles or risk which make this performing a difficult task include: lack of management support, lack of participation of production associates, lack of resources, lack of term vision, no authorize person (Chan et al.2005).

Manufacturing organizations perceived and approbated that the equipment maintenance and its reliability are important strategies' that can significantly influence the organization's dexterity to compete efficiently. The maintenance processes can be streamlined to eliminate wastes thereby resulting an upswing of performance in areas valued by customers (Madu 2000). This has stimulated the manufacturing organizations to adapt Total Productive Maintenance (TPM) as a substantial process improvement and problem solving methodology for enhancing the organization's responsiveness to satiate customer needs and influencing cost optimization as part of management strategy to increase the market share and maximize profit. TPM has been acknowledged as the most propitious strategy for improving maintenance performance in order to succeed in an exceedingly demanding market arena (Hammer et al., 1993). The TPM implementation that has emerged as an operational strategy renders organizations with a guide to fundamentally transform their shop floor by integrating processes, culture, and technology (Nakajima 1998).

The manufacturing organizations in their quest of beating the global competition in demand-driven environments are progressively adapting strategies like Total Quality Management (TQM) and TPM to achieve accelerated, focused, and sustain-able results. The key focus of TQM is on employee empowerment for improving product quality, which aptly complements TPM that equivalently focuses on employee empowerment for enhancing production system availability, reliability, and capacity. TPM is an innovative approach to plant maintenance that is concomitant and works synergistically with TQM, just-in-time manufacturing (JIT), continuous performance improvement (CPI), Total Employee Involvement (TEI) and other world-class manufacturing strategies (Schonberger 1996; Ollila et al., 1999; Cua et al., 2001). Willmott (1994) reports that TPM aims to actively encourage a culture in which operators develop “ownership” of their ma-chines, learn more about them, and collaterally develop problem solving and diagnostic skills.

Obstacles of TPM Implementation in Iranian Industrials

A methodical identification of these obstacles can serve as a platform to foster organizations to develop and establish an extensive TPM implementation program that successfully overcome the obstacles for TPM implementation in Iranian manufacturing organizations. This study reveals the obstacles faced by Iranian manufacturing industries whilst their attempt to implement TPM initiatives. The responses of the questionnaire survey, detailed interviews and informal conversation have been analyzed to determine the obstacles hampering effective TPM implementation. These obstacles have been broadly categorized as behavioral, organizational, cultural, techno-logical, departmental, operational and financial obstacles (Murugadoss et al., 2012).

According to the literature review, the following conceptual research model was suggested as figure 1:

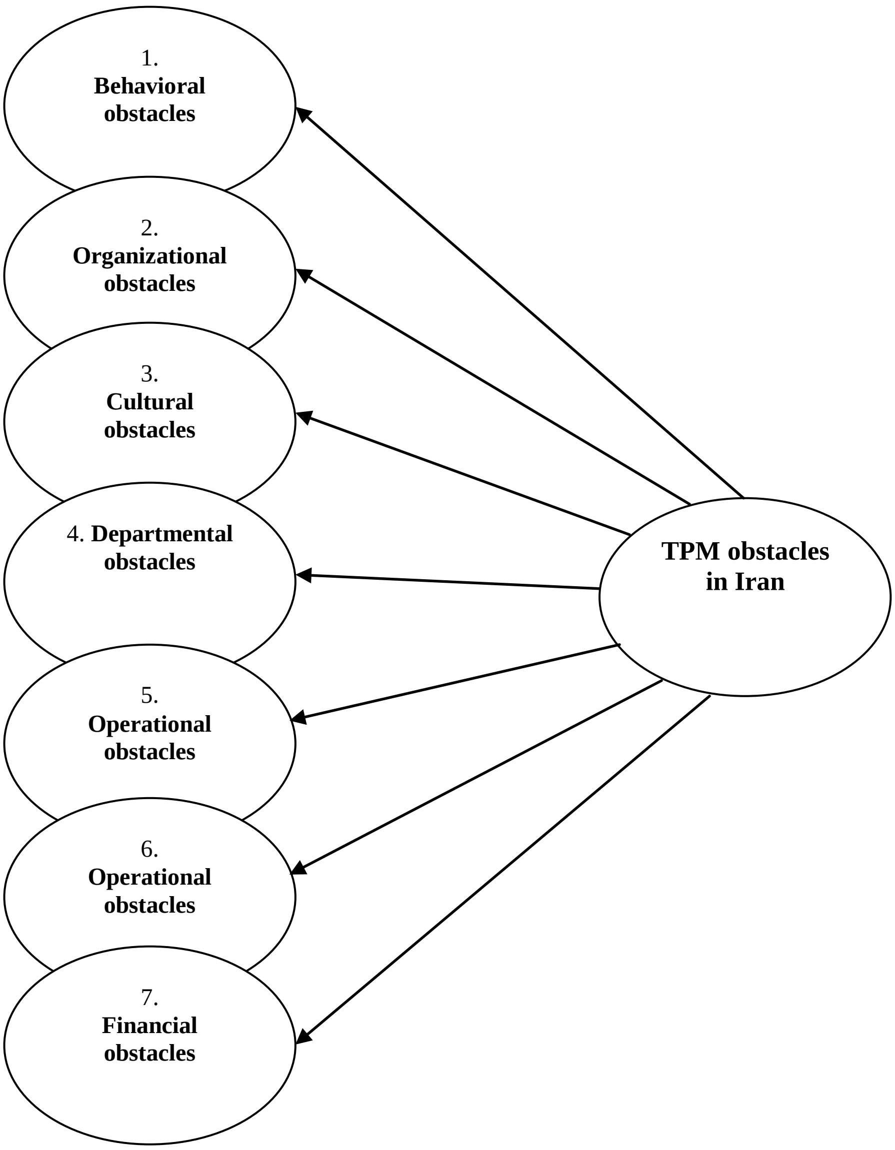

Figure1.The conceptual model of TPM obstacles in Iranian Industries

A brief review of FAHP

Analytic hierarchy process (AHP) is developed by Saaty (1982, 1988, 1995) that is probably the best known and most widely used MCA approach. (Cathy et al. 2004).

The AHP method is based on three principles: (1) construction of a hierarchy, (2) priority setting and (3) logical consistency (Macharis et al., 2004). First, a hierarchy is used to decompose the complex system into its constituent elements. A hierarchy has at least three levels: the overall objective or focus at the top, the (sub-) objectives (criteria) at the intermediate levels and the considered alternatives at the bottom (Macharis et al., 2004; Dagdeviren, 2008). Second, the relative priorities of each element in the hierarchy are determined by comparing all the elements of the lower level against the criteria, with which a causal relationship exists. The multiple pair-wise comparisons are based on a standardized comparison scale of 9 levels; see Table 1 (Saaty, 2008). The result of the pair-wise comparisons is summarized in the pair-wise comparison matrix Table 2, where its standard element $P_c(a_i, a_l)$ indicates the intensity of the preference of the row element (a_l) over the column element (al) in terms of their contribution to a specific criterion C. Lastly, the consistency of decision makers as well as the hierarchy can be evaluated by means of the consistency ratio (Wang and Yang, 2007). This procedure is explained in detail in Saaty (1988).

Table 1: The Saaty scale for pair-wise comparison (Saaty, 2008)

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Higher importance
7	Much higher importance
9	Complete dominance
2,4,6,8	Intermediate values
$\frac{1}{2}, \frac{1}{3}, \frac{3}{4}, \dots, \frac{1}{9}$	Reciprocals

Table 2: Pair-wise comparison of elements in AHP

C	a_1	...	a_l	...	
a_1	1				
...		[1]			
a_i			$P_c(a_i, a_l)$		
...				[1]	
a_n					1

AHP is widely used for multi-criteria decision making and has successfully been applied to many practical problems (Saaty, 1980). In spite of its popularity, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the DM's perceptions to exact numbers (M.-F. Chen et al. 2008). A number of methods have been developed to handle fuzzy AHP. Decision making expert systems are often complex and multifaceted. In recent years, tools for modeling decision making have improved significantly, and multi-criteria decision making (MCDM) models are widely considered to be very useful in resolving conflicts related to the decision making process.

In the literature, several approaches to fuzzy AHP have been proposed by various authors. The first method was proposed by Van Laarhoven and et al. (1983). In this method, elements in the reciprocal matrix were expressed by triangular fuzzy numbers. In contrast, Buckley (1985) used trapezoidal numbers to determine fuzzy comparison ratios. He criticized Laarhoven and Pedrycz's method since linear equations do not always yield a unique solution, and this method is only valid for triangular fuzzy numbers. Bounder et al. (1989), pointed out an error in the method of Laarhoven and Pedrycz, and showed how it can be corrected. Mohanty and Singh (1994), introduced a procedure for solving an AHP problem in a fuzzy environment. (Ruoning et al. 1992), discussed the extensions of AHP to fuzzy environments and presented a procedure for constructing the fuzzy judgment matrix. Their subsequent paper, continues the discussion and goes further into the problem of extracting the fuzzy weights from the fuzzy judgment matrix by the logarithmic least squares method, which is one of the main ranking methods in AHP(Ruoning et al. 1996). Chang (1996), proposed a method that uses triangular fuzzy numbers for the pair-wise comparison scale of fuzzy AHP and extent analysis for the synthetic extent values of pair-wise comparisons. Gogus and Boucher (Gogus et al. 1997) presented some results and extensions of the use of fuzzy pair-wise comparisons in multi-criteria decision analysis. In another paper, Gogus et al. 1998, defined strong transitivity and weak monotonicity for fuzzy pair-wise comparison matrices. Deng (1999), presented a simple and straightforward fuzzy approach to qualitative multi-criteria analysis problems. Zhu et al. (1999), proved the basic theory of triangular fuzzy numbers and improved the criteria for comparing the sizes of triangular fuzzy numbers. Ruoning (2000), dealt with the question of estimating the weights of factors by least squares from a fuzzy judgment matrix. Mikhailov (2000), proposed a new Fuzzy Programming Method, based on a geometrical representation of the prioritization process. Csutoraet al. (2001), presented a new method of finding the fuzzy weights in fuzzy hierarchical analysis, which is the direct fuzzification of the kmax method. Buckley et al. (2001), presented a new method of finding the fuzzy weights. By applying the properties of goal programming (GP) to treat a fuzzy AHP problem, Yu (2001), incorporated an absolute term linearization technique and a fuzzy rating expression into a GP–AHP model for solving fuzzy AHP problems in group decision-making. Mikhailov (2003), proposed a new approach to deriving priorities from fuzzy pair-wise comparison judgments, based on an a-cuts decomposition of the fuzzy judgments into a series of interval comparisons. Eneaet al. (2004), presented an approach based upon a fuzzy extension of the AHP. This paper focuses on the constraints that have to be considered within fuzzy AHP in order to take into account all the available information. This study demonstrates that more certain and reliable results can be achieved by considering all the information derived from the constraints. Kulak et al. (2005), dealt with a multi-attribute transportation company selection for effective supply chain using both fuzzy multi-attribute axiomatic design and fuzzy AHP. Erensal et al. (2006), used the fuzzy AHP to analyze the links between competitive advantages, competitive priorities and competencies of a firm in the context of technology management. Göleçet al. (2007), presented a comparative study to establish complex fuzzy methodologies in evaluating the performance of a manufacturing system and showed that fuzzy AHP leads to the best result.

Fuzzy AHP stepwise procedure

Fuzzy AHP uses fuzzy set theory to express the uncertain comparison judgments as a fuzzy numbers. The main steps of fuzzy AHP are as follows:

Step1: Structuring decision hierarchy, Similar to conventional AHP, the first step is to break down the complex decision making problem into a hierarchical structure.

Step2: Determination of Fuzzy Pair-wise Matrix as below:

	C_1	C_2	...	C_n
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$
$\vdots$			$\vdots$	$\vdots$
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)

That: $(a_{ij}^l, a_{ij}^m, a_{ij}^u) = (\frac{1}{a_{ji}^u}, \frac{1}{a_{ji}^m}, \frac{1}{a_{ji}^l})$

Consider a prioritization problem at a level with n elements, where pair-wise comparison judgments are represented by fuzzy triangular numbers $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$. As in the conventionalAHP, each set of comparisons for a level requires $\frac{n(n-1)}{2}$ judgments, which are further used to construct a positive fuzzy reciprocal comparison matrix$\tilde{A} = \tilde{a}_{ij}$such that:

$$\begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

Step3: Determination of composed Fuzzy column Matrix as:

	C_1	C_2	...	C_n	$\tilde{s}_i$
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$
⋮			⋮	⋮	⋮
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)	$\tilde{s}_m = (s_m^l, s_m^m, s_m^u)$

That: $\tilde{s}_1 = \left(s_1^l, s_1^m, s_1^u\right) = \left(\frac{a_{11}^l + a_{12+\cdots+}^l a_{1n}^l}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^u}, \frac{a_{11}^m + a_{12+\cdots+}^m a_{1n}^m}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^m}, \frac{a_{11}^u + a_{12+\cdots+}^u a_{1n}^u}{\sum_{i=1}^n \sum_{j=1}^n a_{ij}^m}\right)$ (1)

Step4: Determination of composed Crisp column Matrix based on value degree as:

	C_1	C_2	...	C_n	$\tilde{s}_i$	s_i
C_1	(1,1,1)	$(a_{12}^l, a_{12}^m, a_{12}^u)$	...	$(a_{1n}^l, a_{1n}^m, a_{1n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$	s_1
C_2	$(a_{21}^l, a_{21}^m, a_{21}^u)$	(1,1,1)	...	$(a_{2n}^l, a_{2n}^m, a_{2n}^u)$	$\tilde{s}_1 = (s_1^l, s_1^m, s_1^u)$	s_2
⋮			⋮	⋮	⋮	...
C_m	$(a_{m1}^l, a_{m1}^m, a_{m1}^u)$	$(a_{m2}^l, a_{m2}^m, a_{m2}^u)$	...	(1,1,1)	$\tilde{s}_m = (s_m^l, s_m^m, s_m^u)$	s_m

With
VL:(0,0.5,2); L:(1,2,3); ML:(2,3.5,4); M:(4,5,6); MH (5,6.5,8); H:(7,8,9); VH (8,9.5,10)

$$V(\tilde{A} > \tilde{B}) = \begin{cases} 1 & ; \quad a_m \geq b_m \\ \frac{b_l - a_u}{(a_m - a_u) - (b_m - b_l)} & ; els \end{cases} \quad (2)$$

$$V(\tilde{A} > \tilde{B}, \tilde{C}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{A} > \tilde{B}), V(\tilde{A} > \tilde{C}), V(\tilde{A} > \tilde{D}), \ldots\} = \alpha$$
$$V(\tilde{B} > \tilde{A}, \tilde{C}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{B} > \tilde{A}), V(\tilde{B} > \tilde{C}), V(\tilde{B} > \tilde{D}), \ldots\} = \beta$$
$$V(\tilde{C} > \tilde{A}, \tilde{B}, \tilde{D}, \ldots) = \text{Min}\{V(\tilde{C} > \tilde{A}), V(\tilde{C} > \tilde{B}), V(\tilde{C} > \tilde{D}), \ldots\} = \gamma$$
$$V(\tilde{D} > \tilde{A}, \tilde{B}, \tilde{C}, \ldots) = \text{Min}\{V(\tilde{D} > \tilde{A}), V(\tilde{D} > \tilde{B}), V(\tilde{D} > \tilde{C}), \ldots\} = \lambda$$

That: $s_1 = s_A = \frac{\alpha}{\alpha+\beta+\gamma+\lambda}$, $s_2 = s_B = \frac{\beta}{\alpha+\beta+\gamma+\lambda}$, $s_3 = s_C = \frac{\gamma}{\alpha+\beta+\gamma+\lambda}$, $s_4 = s_D = \frac{\lambda}{\alpha+\beta+\gamma+\lambda}$
(3)

Step5: Consistency check and deriving priorities and Weighting & Ranking. This step checks for consistency and extracts the priorities from the pair-wise comparison matrices. In existing fuzzy AHP methods, only a few past studies have addressed the issue of checking for inconsistencies in pair-wise comparison matrices. According to Buckley (1985), a fuzzy comparison matrix $\tilde{A} = \tilde{a}_{ij}$isconsistent if$\tilde{a}_{ik} \otimes \tilde{a}_{kj} \approx \tilde{a}_{ij}$ wherei, ji, k = 1,2, … , n and⊗isfuzzy multiplication, and ≈ denotes fuzzy equal to. Oncethe pair-wise comparison matrix,$\tilde{A}$, passes the consistencycheck, fuzzy priorities $\tilde{w}_i$can be calculated with conventional fuzzy AHP methods. Then, the priority vector$(w_1, w_2, \ldots, w_n)^T$can be obtained from the comparisonmatrix by applying a prioritization method. Briefly, stages of Consistency check is as below:

Stage1: deviation the fuzzy triangular matrix to tow matrix as;

1. Interval numbers of triangular judgments: $A^m = [a_{ijm}]$
2. Geometric average of upper and low limits of triangular numbers: $A^g = \sqrt{a_{iju} a_{ijl}}$

Stage2: Calculating of weight vector for each matrix using saaty's method as below:

$W_i^m = \frac{1}{n} \sum_{j=1}^n \frac{a_{ijm}}{\sum_{i=1}^n a_{ijm}}$; $\quad W^m = [W_i^m]$ (4)

$W_i^g = \frac{1}{n} \sum_{j=1}^n \frac{\sqrt{a_{iju} a_{ijl}}}{\sum_{i=1}^n \sqrt{a_{iju} a_{ijl}}}$; $\quad W^g = [W_i^g]$ (5)

Stage3: Calculating the biggest of specific amount for each matrix as below:

$\lambda_{max}^m = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^n a_{ijm} \left(\frac{W_j^m}{W_i^m}\right)$, (6)

$\lambda_{max}^g = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^n \sqrt{a_{iju} a_{ijl}} \left(\frac{W_j^g}{W_i^g}\right)$ (7)

Stage4: Calculating of consistency index using the relations:

$CI^m = \frac{(\lambda_{max}^m - n)}{n-1}$, $CI^g = \frac{(\lambda_{max}^g - n)}{n-1}$ (8)

Stage5: Calculating of consistency rate using the relations:

$CR^m = \frac{CI^m}{RI^m}$, $CR^g = \frac{CI^g}{RI^g}$ (9)

If both of indexes were less of 0.10, Then fuzzy matrix is consistent, and if they were most of 0.10, then decision makers should revise the prioritization, and if one of these indexes were most of 0.10, then decision makers should revise the interval amounts of triangular judgments (Buckly, 1985).

Evaluation of the implementation obstacles of TPM

Step1: Now we use fuzzy AHP to evaluate the implementation obstacles of TPM in Iran. We will use a numerical illustration to show our method. First, set up the analytic hierarchy model of TPM evaluation as figure2:

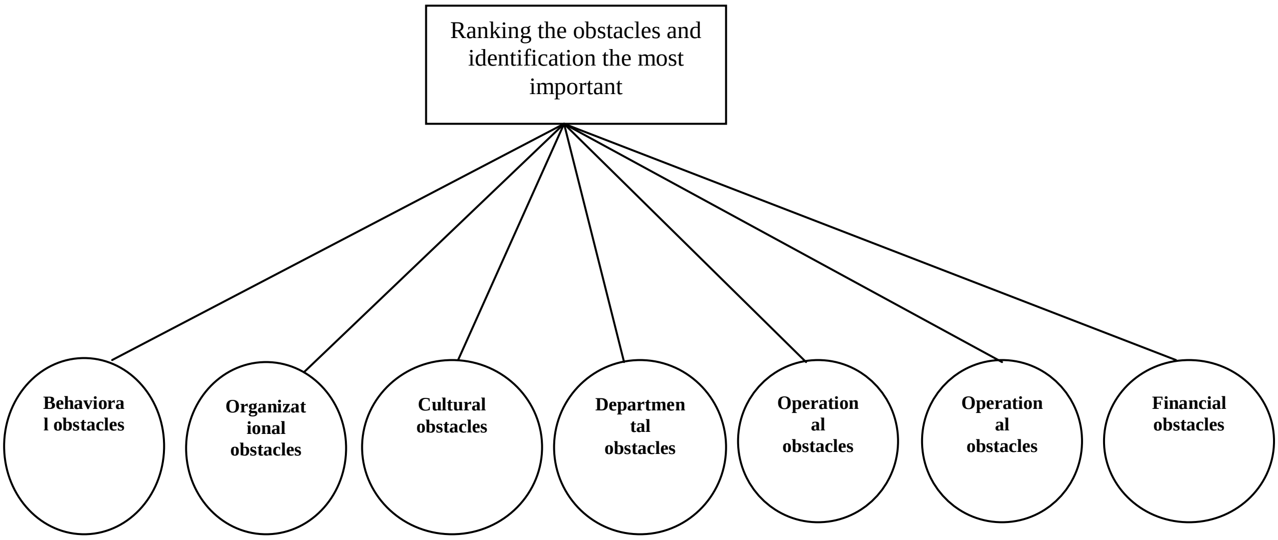

Figure2. The hierarchy model of the evaluation of TPM

Step2: Next, we give the geometric Fuzzy Pair-wise Matrix for TPM evaluation. On the other hand, in this step, a questionnaire prepared and ten experts in TPM completed it with linguistic variables. To convert the fuzzy linguistic variables to fuzzy number can use the table3:

Table 3: Linguistic variables for paired comparison criteria

VL (Very low)	0	0.5	2
L (Low)	1	2	3
ML (Medium Low)	2	3.5	4
M (Medium)	4	5	6
MH (Medium High)	5	6.5	8
H (High)	7	8	9
VH (Very High)	8	9.5	10

Finally, the geometric fuzzy pair-wise matrix is implemented calculated as figure3.

Fuzzy Pair-wise Matrix	C1			C2			C3			C4			C5			C6			C7		
C1	1.00	1.00	1.00	1.00	2.00	3.00	4.00	5.00	6.00	0.00	0.50	2.00	7.00	8.00	9.00	5.00	6.50	8.00	8.00	9.50	10.00
C2	0.33	0.50	1.00	1.00	1.00	1.00	7.00	8.00	9.00	2.00	3.50	4.00	8.00	9.50	10.00	8.00	9.50	10.00	8.00	9.50	10.00
C3	0.17	0.20	0.25	0.11	0.13	0.14	1.00	1.00	1.00	0.00	0.50	2.00	7.00	8.00	9.00	5.00	6.00	8.00	8.00	9.50	10.00
C4	0.50	2.00	1000.00	0.25	0.29	0.50	0.50	2.00	1000.00	1.00	1.00	1.00	8.00	9.50	10.00	8.00	9.50	10.00	8.00	9.50	10.00
C5	0.11	0.13	0.14	0.10	0.11	0.13	0.11	0.13	0.14	0.10	0.11	0.13	1.00	1.00	1.00	2.00	3.50	4.00	5.00	6.50	8.00
C6	0.13	0.15	0.20	0.10	0.11	0.13	0.13	0.17	0.20	0.10	0.11	0.13	0.25	0.29	0.50	1.00	1.00	1.00	7.00	8.00	9.00

C7	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.10	0.11	0.13	0.13	0.15	0.20	0.11	0.13	0.14	1.00	1.00	1.00

Figure3. The geometric Fuzzy Pair-wise Matrix

Step3: Then we calculate the composed Fuzzy column Matrix in excel software as figure4:

	$\tilde{s}_i$		
C_1	0.01	0.21	0.31
C_2	0.02	0.27	0.36
C_3	0.01	0.16	0.24
C_4	0.01	0.22	16.04
C_5	0.00	0.07	0.11
C_6	0.00	0.06	0.09
C_7	0.00	0.01	0.01

Figure4. The composed Fuzzy column Matrix

Step4: In this step, we determinate the composed Crisp column Matrix based on value degree as figure5:

composed Crisp column Matrix	C1	C2	C3	C4	C5	C6	C7	
C1	1	1	0.832252	1	0.413239	0.343653	0.012933	
C2	0.835192	1	0.68392	0.996926	0.321269	0.262514	-0.00493	
C3	1	1	1	1	0.522265	0.440623	0.030484	
C4	0.972918	1	0.807887	1	0.398645	0.330993	0.011877	
C5	1	1	1	1	1	0.888809	0.145843	
C6	1	1	1	1	1	1	0.168651	
C7	1	1	1	1	1	1	1	
V(Ci>C1,C2,C3,C4,C5,C6,C7)	0.835192	1	0.68392	0.996926	0.321269	0.262514	-0.00493	-0.00493
Revised: V(Ci>C1,C2,C3,C4,C5,C6,C7)	0.840119	1.004927	0.688847	1.001853	0.326196	0.267441	0	

Figure5. The composed Crisp column Matrix based on value degree

Step5: Consistency check and deriving priorities and Weighting & Ranking as figure6:
In this paper, Fuzzy AHP is implemented in the software Excel. Calculated consistency ratio by software is 0.04 and 0.05 for tow indexes, so that represents the relative consistency of decision makers' judgments.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Weight	0.205162	0.24541	0.168221	0.244659	0.079659	0.065311	0.0001
Rank	3	1	4	2	5	6	7

Figure6. The Weighting & Ranking of TPM obstacles in Iran

6. Conclusion

Total Productive Maintenance (TPM) has been recognized as one of the significant operation strategy to regain the production losses due to equipment inefficiency. Many organizations have implemented TPM to improve their equipment efficiency and to obtain the competitive advantage in the global market in terms of cost and quality. As said earlier, TPM implementation is not easy. But its payoff is huge. Management has to invest in time, money and resources for a successful implementation. The organization as a whole should be dedicated and committed to TPM. This requires transformation of work culture from ―It's not my job but yours‖ to ―It's our job (Prasanth et al., 2013). Since this is the age of globalization, therefore it is necessary for the manufacturing industries to move towards modern trend development in all sectors of industries including maintenance department. So-that it is observed; TPM is one of the best tools for making manufacturing industries competitive and effective, in the field of maintenance (Kapil et al., 2012).
In this study, first the application obstacles of TPM are identified in Iranian industries with presentation a conceptual model. In finally, the TPM obstacles are ranked using Fuzzy AHP as figure7:

Obstacles	C_1 **Behavioral obstacles**	C_2 **Organizational obstacles**	C_3 **Cultural obstacles**	C_4 **Departmental obstacles**	C_5 **Operational obstacles**	C_6 **Operational obstacles**	C_7 **Financial obstacles**
Weight	0.205162	0.24541	0.168221	0.244659	0.079659	0.065311	0.0001
Rank	3	1	4	2	5	6	7

Figure7. Ranking of TPM obstacles in Iranian industries using FAHP

So this paper gives an evaluation method for TPM in order to help researches and managers to determine the drawbacks and opportunities.

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