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Identification and weighting factors influencing the establishment of a single minute exchange of dies in plastic injection industry using VIKOR and Shannon Entropy

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A B S T R A C T

Single minute exchange of dies (SMED) is one of the most important tools to achieve lean production system. The main idea of this system is to provide methods and to use creative and innovative solutions for continuous improvement. Due to the importance of this issue and its effect on reducing waste during the production process, this study presents a method to identify and to weight factors in the establishment of a single minute exchange of dies in 14 plastic injection factories. In this study, fourteen factories in injection industry were chosen and the factors influencing the implementation of single minute exchange of dies were identified. Following data collection, decision matrix was formed and the weight of each factor was determined by using Shannon Entropy. Then, in order to determine the readiness of factories, VIKOR method was used to rank companies. The results indicate priorities of the following factors in establishing SMED that include: Senior management support, technical capabilities, technical knowledge of staff and consultants, knowledge of mold design, manufacturing infrastructure, team work, combination of the project team work, benchmarking, training, clear understanding of project objectives, rewards and motivation, proper management expectation, project management, teamwork and organizational culture. Practical implications: Due to the factors, Top manager can make the best decision for implementing of SMED technique. This study develops factors influencing on SMED implementation based on Shannon and VIKOR methods for ranking parameters and plants.

1. Introduction

Recently, due to widespread of production systems, it is necessary to implement efficient and effective methods to control and to benefit from all the features of these systems. On the other hand, in recent decades, industrial organizations have been changed and production issues have faced particular complexity through application of innovative technologies in the industry. Hence, in terms of the comprehensiveness, the just in time production systems, as production planning system and inventory control, has been at the top of the pyramid of innovative systems of planning and control

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(Chu et al., 2007). Therefore, the high startup time is considered as a serious problem in achieving the primary goals of the system. Single minute exchange of dies (SMED) is associated with preparation work in less than 10 minutes. In other words, when we switch from production of a piece to another one, this must be accomplished in the shortest possible time. Although, we may think it is not always possible, but in most cases, it is achievable.

The primary concern in most developing countries is that not only manufacturers have insufficient resources but also the proper use of the existing resources may not happen due to unavailability of the required technical knowledge. Iran is not an exception, and there is a need in producing and using innovative productive methods to achieve international standards. Perhaps some think that preparation is the only small aspect of production while reducing preparation time is the primary solution to resolve bottlenecks, to reduce cost and to improve the quality of products and it is the great step towards future technologies that are robotic and automation (Codruta et al., 2010).

Studies in many Injection Industries in Iran indicate that in this industry, production methods and equipment, as well as many machines are old and due to the increasing application of this industry in Iran and increased necessity for constant power with foreign manufacturers, it is necessary to use innovative productive methods and revise on traditional methods.

Thus, in this study, additionally it is attempted to identify the factors influencing the successful implementation of single minute exchange of dies in plastic injection industry using the team decision making techniques, these factors are weighted and also readiness of studied factories in the establishment of the system are investigated. In other words, it can be said that this research aims to respond to following questions: what are the factors influencing SMED in injection industry and how much does each factor weight and also how do factories in industry prepare to establish SMEDs?

2. Material and methods

Single Minute Exchange of Dies (SMEDs) is a process based on the principle of innovation introduced in the mid-80s, including separation and conversion of internal to external startup operations. Experience has indicated that by emphasizing the procedural attitudes and implementing SMEDs, the company was able to eliminate wastes, non-value added activities and it has been saved through the amount of nearly 360,000 Euros, about 2% of the sales volume of the company (Hwang & Yoon, 1981).

SMED is one of the most important tools of lean production in order to decrease waste and improve flexibility in production process to reduce the manufacturing categories and flow improvement. SMED reduce the non-productive time by standardizing operations and reducing the using tools and applications. However, the most conducted studies do not offer certain suggestions to implement these tools. To resolve this defect, in order to develop implementation outcomes of SMED, common statistical and engineering tools can be applied, seamlessly. Proposed approach of SMED is tested for injection machinery in Auto industry that this implementation through re-engineering and using of internal resources and without requiring significant investment causes a decrease timing and organization startup.

In 1969, in the original factory of Toyota Motors, the necessary time for the preparation of the Press 1,000-ton during preparation work for had been about 4 hours and it was reduced to three minutes relying on the separation of internal and external preparation operation for 9 months. Starlight researchers after establishing improvement team, using the investigations results of Toyota and Mitsubishi, they reduced the startup time from 180 to 70 minutes using SMED to achieve single-minute time (Moxham & Greatbanks, 2001). Other factors introduced as key factor in implementing SMED include clear goals and adjectives, maintenance of top management of organization, project world-beater, and consultant acquisition (Alves & Tenera, 2009). In a joined study accomplished on efficiency increase through reducing startup time, some factors such as structural and cultural changes lead to significant changes in organizational structure and influence the way of doing things and people interaction. Training all managers and staff, top management support, clear understanding of objectives and consultant acquisition are influential, significantly (Fawaz, 2003). King (2009), in their study about development on how to decrease the startup time in factories, stated that strong management of project, training at all levels, communication and collaboration between units and process reengineering were influential (Sousa et al., 2009). Perinić et al. (2009) performed an investigation, which led to implementation of SMED in casting factories of Die Cast reducing the startup time (Ulutas, 2011). In 2006, a study conducted based on using lean production methods for the improvement of startup time and it was indicated that such factors like clear understanding of project objectives, consultant acquisition, intersectional coordination, training all managers and staff were effective to incorporate project teamwork and process reengineering in SMED implementation (McIntosh, et al, 2001).

In many investigations, SMED, as a tool or a technique, is a considered as a primary key factor in the maintenance, total preventive maintenance, the process of continuous improvement to achieve lean production (Opricovic & Tzeng, 2002). In 2001, an investigation about startup time implementation introduced SMED and explained its application and stated that such factors including leaders capabilities and top managers in change management, managers training, team personnel and staff of strong project management, project world beater, organizational culture, available adequate and proper information in organization and allocation of responsibilities appropriated by authority were effective in its implementation. A survey conducted in 2001 SMED could be implemented in enterprise area and startup time was decreased dramatically (Nyhuis et al., 2010). According to the results of the survey in 2001 about lean production and its tools, one of the most important factors to achieve lean production that was done the die exchange in less than 10 minutes.

The purpose of this study is to answer the following questions:

- What are the effective factors in establishing SMED in plastic injection industry?
- How much do the factors weight?
- According to factors, what is the priority of studied factories in industry about establishment of this system?

To find out more about the implementation of SMED technique, it is necessary that industry executives get acquainted with factors so that considering them leads to accelerate SMED implementation and its success or not considering them causes to fail attempts of this system establishment.

2.1. Methodology

Since this study aimed on weighing and prioritization of recognized factors, thus Shannon entropy method was used to weight and VIKOR method was done in order to prioritize.

2.2. Shannon entropy

Entropy is the concept of physics, social sciences and information theory, as it represents the provided uncertainty level of the expected information content of a message. In other words, entropy in information theory is a criterion for expressed uncertainty level through a discrete probability distribution as if this uncertainty were more discrete distribution than lower frequency distribution (Asgharpour, 2005).

2.3. VIKOR

VIKOR method is a new one in multi scale decision developed and presented to solve problems with improper and opposing scales (Different measurement units) (King , 2011). This method is used multi scale optimization of complicated system (Huang et al., 2009). It also concentrates on grouping method and selecting from a set of items and determines compatible answers for a problem with opposing scales where compatible answer is the closest valid answer to ideal answer (Perinić, et al. , 2009). It should be noted that the proposed model considers a multi-scale ranking index based on approaching to the ideal answer (Oprpcovic & Tzeng, 2004).

The weighting factors has been recognized, and also statistical population compromises professionals, experts and practitioners of injection industry, moreover 14 main factories in this area has been used to prioritize the factors. In present study, first we used library methods and studied literature associated with the topic. We also performed as interview with experts to recognize and to extract effective factors on SMED implementation and establishment. 19 factors has been identified which were presented to industry experts personally to confirm and to determine more effective factors; finally, 14 factors were taken plant experts in order to be weighted using the Shannon entropy method.

2.4. Validity and Reliability

Validity indicates to what extent measuring tools measures variable or stable features can be tested (Agustin & Santiago, 1996). In order to obtain test validity in this study, test questions were investigated by experts and masters' opinions and tips and they eliminated uncertainty that indicates acceptable content validity of test. Validity means, during a short time if we present measuring tools to one group of individuals for several times then results are close together. Therefore, an index called "reliability coefficient" has been applied to measure reliability (Sarmad et al., 1998). Thus, the capability coefficient is involved in a range of 0 (non-relationship) to 0.01 (full-relationship). Reliability indicates to what extent measuring tools measures stable features can be tested or variable and temporal features (Agustin & Santiago, 1996). One way to test the internal reliability of the questionnaire is Cronbach's Alpha. Questionnaire credibility was obtained 0.890 by SPSS software. Therefore, the high validity of the questionnaire was confirmed.

3. Results

Following the opinion of experts, 14 factors were confirmed as the most important factors. Then the entropy method was applied to calculate the weight and the importance of each factor was determined according to the experts' opinion. These factors includes top management support, technologic capabilities, technical knowledge staff and consultants, knowledge of die design, production infrastructure, combination of SMED project work teams, modeling, training at all levels, a clear understanding of the project objectives, rewarding and motivating staff, proper management of expectation, project management, teamwork and organizational culture.

4. Discussion

4.1. Calculation of factors weight through Shannon entropy

Following validity and stability, questionnaires were distributed in factories (before distribution, arrangement of presence in factories, interview, legislation of the research topic and completing the questionnaires were made). In addition, fulfillment of each questionnaire was accomplished as interview, explanation and description of SMED concept and benefits and capabilities. Then a decision matrix was made and after that normalized.

After normalizing, entropy or uncertainty index (E_j) and deviation degree to each criterion (D_j) were calculated (Table 1).

$$D_j=1-E_j,\ k=\frac{1}{Ln\ m},\ Ej=-k\sum_{i=1}^{m}\left[p_{ij}.LnP_{ij}\right] \quad (1)$$

By normalizing deviation degree, the weight of each criterion is obtained by using the time approach $W_j=\frac{d_j}{\sum_{j=1}^{n} d_j}$ as following:

Table 1
Entropy, deviation degree and weight of each criterion

Criterion		W_j	E_j	D_j
X_1	Top management support	0.07059	6.78524	-5.7852
X_2	Technological capabilities	0.07103	6.82129	-5.8213
X_3	Technical knowledge of staff and	0.0709	6.80897	-5.809
X_4	Die design knowledge	0.07076	6.79864	-5.7986
X_5	Production infrastructure	0.0722	6.91596	-5.916
X_6	work teams Combination of SMED	0.071	6.81706	-5.8171
X_7	Modeling	0.0706	6.78428	-5.7843
X_8	Training at all levels	0.0716	6.87122	-5.8712
X_9	Clear understanding of project	0.0716	6.86671	-5.8667
X_{10}	Staff rewarding and motivating	0.0716	6.91219	-5.9122
X_{11}	Proper management of expectations	0.0721	6.91219	-5.9122
X_{12}	Project management	0.0721	6.91044	5.9104-
X_{13}	Team work	0.07185	6.88854	-5.8885
X_{14}	Organizational culture	0.072	6.90118	-5.9012

4.2. Plastic injection industry ranking using VIKOR method

In this step, 14 studied factories according to 14 criteria have been investigated and selected item must have superior percentage. In this method the best and the least index value is considered the first and the last selected item, respectively. VIKOR methods include the following steps:

4.3. VIKOR ranking steps

In the first step, decision matrix is made according to the number of criteria, the number of items and also evaluation of them for different criteria that indicates value of each item for each index; and each matrix row shows the status of each of the items. In second step, matrix will be non-scale by Euclidean software that is shown by n_d :

$$n_{ij}=\frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \quad (2)$$

4.4. Weighted normalized matrix

Weighted normalized matrix is obtained by multiplication of normalized matrix (n_d) in the diagonal matrix of indexes' weight ($w_{n.n}$), where indexes' weight is used by Shannon entropy, which is shown by $V= n_d.w_{n.n}$.

We determine the highest and lowest values of the normalized weighted matrix value

$$f_i^{-}=\min_j f_{ij} \qquad f_i^{*}=\max_j f_{ij}$$

where f_i * is the best value and f_i is the worst value of i th among all items.
Next, we determine the utility index (S) and dissatisfaction index (R) where R and S values are calculated according as follows,

$$S_j = \sum_{i=1}^{n} w_i \frac{\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)} \tag{3}$$

$$R_j = \max_j \left[w_i \frac{\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)} \right] \tag{4}$$

The calculation and items ranking is as follows,

$$Q_j = v\frac{\left(S_j - S^-\right)}{\left(S^* - S^-\right)} + (1-v)\frac{\left(R_j - R^-\right)}{\left(R^* - R^-\right)} \qquad R^* = \min R_j \quad , \quad R^- = \max R_j \qquad S^* = \min S_j \quad , \quad S^- = \max S_j \tag{5}$$

V is selected due to the level of group agreement of decision makers, if there is a high agreement, in agreement with the majority of votes, and the low agreement, the value will be >0.5 , = 0.5 and <0.5, respectively.

Finally, we sort the items based on reduced values of *R, S* and *Q*. An item will be selected as the preferred item that known as the best item among 3 groups. Placement order of these items is considered due to the reduction of *R, S* and *Q* values.

4.5. Selection of the best item

The best item (with the least Q) will be achieved under the condition that the following two conditions are established (Mahmodi, 2002).

$$Q(A_2) - Q(A_1) \geq DQ, DQ = \frac{1}{m-1} \tag{6}$$

Table 2 shows details of the ranking for various factories.

Table 2
The summary of ranking of various factories

Items	S_j	rank	R_j	Rank	Qi	Rank
1	0.855	6	0.473	5	0.0411	10
2	0..089	14	0.024	14	1.00	1
3	1.084	3	0.479	3	0.332	12
4	0.908	4	0.475	4	0.393	11
5	0.831	7	0.240	10	0.591	7
6	0.704	10	0.248	8	0.635	5
7	0.764	8	0.245	9	0.614	6
8	0.238	13	0.053	13	0.928	2
9	0.652	11	0.230	11	0.652	4
10	0.328	12	0.072	12	0.885	3
11	1.551	1	0.719	1	000	14
12	0.742	9	0.470	6	0.499	9
13	0.887	5	0.250	7	0.572	8
14	1.104	2	0.480	2	0.325	13

5. Conclusion

In present study, following comprehensive investigation as well as according to identified nature of factories and application of internal and external conducted researches and studies about the identification of effective factors on successful implementation of SMED, effective factors and criteria were identified and after doing poll of experts, 14 of them were confirmed. Scale weighting was calculated by Shannon entropy and VIKOR algorithm that was done due to final obtained weights.

Certainly, we can identify many factors as effective factors in SMED implementation in industry, but the most important factors are ones which can benefit from other factors and have them (if we prepare them). Therefore, 14 factors determined as the most important are effective in successful establishment and implementation of SMED in injection industry according to experts and professionals' opinions.

According to indices weight calculation, top management support is in a relative high importance and some factors such as technological capabilities and technical knowledge of consultants and staff, die design knowledge and production infrastructures in second level, then and in the lowest significant level there is organizational factor (Table 1). Results show that factories in high level of top management support and technological capabilities are in the head of ranking.

According to final prioritization of factories shown in Table 2, Cruise (that is located in higher level) has more relative significance than other factors in terms of top management support and technological capabilities. Compared with Silver (that is located in lower level), it is more prepared to implement SMED successfully. With regard to presented results, it is suggested that during SMED implementation, managers should consider all listed factors, because these influence on managers' decision-making to set up these systems. Due to final calculated weights, we can observe that top management support and technological capabilities are the most influential and they are in a proper training program or high support for successful implementation of SMED to decrease implementation failure risk. Also, managers should evaluate organizational condition for this system implementation accurately. This causes to increase certainty in successful implementation of this system by identification of improvement and revision opportunities.

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