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Full Length Research Paper

Effective factors on sustainability of manufacturing processes, overcoming shrinkage in improved processes

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Although process owners, theorists and scholars have various viewpoints about effective ways of improvement of processes, they have consensus on two important subjects. First, process improvement activities have an extraordinary effect on increasing efficiency and second, there are barriers against consistency and maintenance of current level of improved processes. In enterprise level, it is easier to talk about problems of sustainability of processes than suggesting a formula including related factors. In this article, an abstract is presented about findings of a broad study on companies executing process improvement plans. The study aims to recognize and analyze effective factors on sustainability of improved processes, using discriminate regression and a model for sustainable improved processes. To do this, using multi criteria decision making (MCDM) and experts' viewpoints, effective factors on sustainability of process improvement activities are determined. Then, a sixteen-factor model resulted from experts' viewpoints is applied in the form of questionnaires to gather the related data from 75 manufacturing processes in some major Iranian companies. In this analysis, the criteria include trends and percentage of improvements. Among the sustainability factors, a formal system for recording problems has the highest effect on discrimination of sustained processes (with a high ranking level from the experts' viewpoints). In addition, documentation and standardization of processes are in the second level from both academic and industrial professionals' viewpoints. In sustainability of manufacturing processes in the aforementioned companies, a clear picture about necessity of improvement is in the third level (albeit, from experts' viewpoint, it's in the fifth level). As a result, some factors such as a list of daily problems of processes, clear perception of the necessity of improvement, process monitoring and standardization are selected as independent or predictive variables with a significant effect on discrimination of two sustainability groups (as dependent variables).

Key words: Sustainability of improved processes, multi criteria decision making (MCDM), discriminate analysis, factors of sustainable improvement.

INTRODUCTION

Today, there are a lot of articles and studies about process improvement activities, but the related questions on their sustainability are unanswered (Batman, 2002). Process improvement tools can be considered on a spectrum, with an incremental and continuous change on one extreme and rapid and radical changes (known as process reengineering) on the other (Salegna, 1995). There is no doubt that process improvement tools, irrespective to their type, have extraordinary and tangible positive effects on performances and results of processes. But the main problem is in the later levels in which, in a short period of time, they return to the initial

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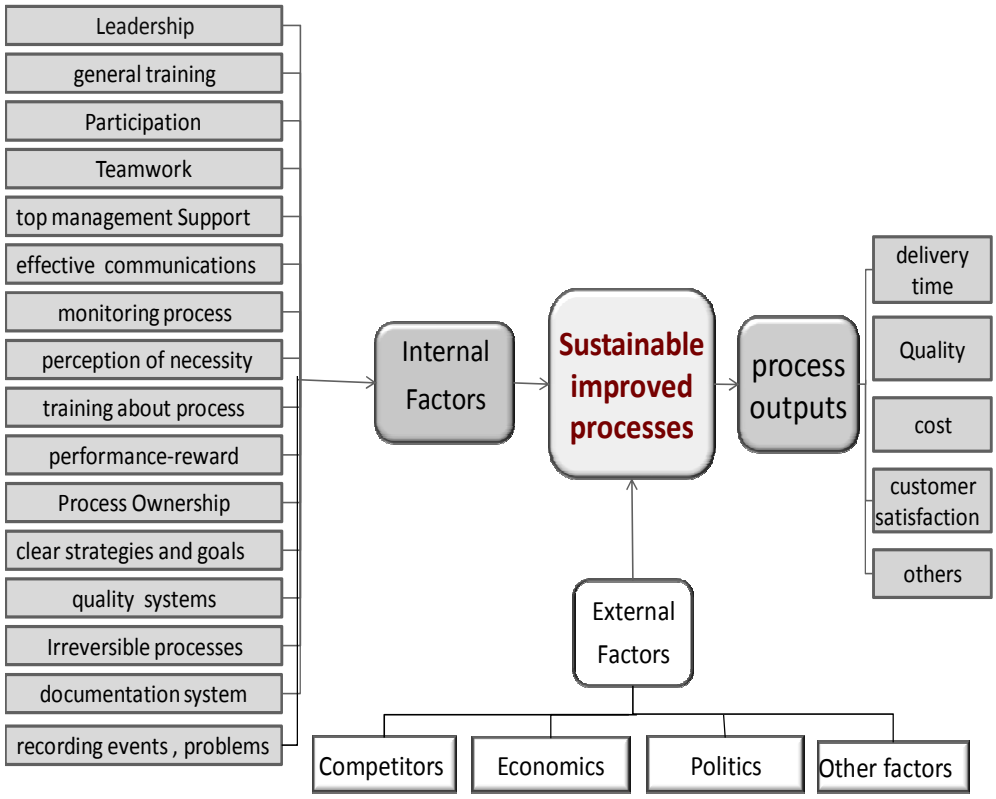

Figure 1. Conceptual model for the first level of experts.

and even a lower level, because of shrinkage of improved processes (Dale, 1997). To remove the instability of improvement activities, certain studies are made in developed countries to identify and provide boosting and preventing factors of industries to stabilize the improved processes. Initial observations and interviews show a lot of failures of manufacturing companies in continuing their evolutionary process by using continuous improvement methods and philosophies. Moreover, an analysis of the literature shows a huge waste of resources indicating importance of the problem.

Studies made by Griffith in Perkins Company are the first studies referring to shrinkage and non-sustainability of the improvement activities. With respect to success of Perkins' engineers reaching a 41% process improvement level and their failure in sustaining it, Griffith contends that sustaining the improved processes is more difficult than their execution (Griffith, 1996). So, it is necessary to identify effective factors on sustainability to provide related courses of actions to reach a sustainable improvement. The main question is what are the effective factors on sustainability of the improvement activities? This article contains results of a study to answer the question. Here, a conceptual model and the related research steps are provided to study processes after improvement activities, and identify the most effective sustainability factors to provide a sustainable improvement model.

RESEARCH METHODS

Conceptual model

The study is based on a theoretical framework and a conceptual model which the researcher applies to relate effective factors to each other. Till now, lots of factors are provided by authors and scholars about process improvement but they seem incomplete because each of them has seen the problem from a different point of view. In this thesis, using a comparative approach, all effective factors on sustainability are studied and a comprehensive model is developed. By applying results of previous studies, and the Delphi technique, the conceptual model is provided based on the experts' opinions. Figure 1, presents a conceptual model for the first level of experts using a Delphi method with respect to numerous effective factors on sustainability, the study only analyzes internal factors but by applying a holistic viewpoint, role of internal factors is considered in the total system (Figure 1).

In literature review studies and books published in the field of change management and sustainability have been investigated. With respect to numerous endless effective factors on sustainability, the study only analyzes internal factors but by applying a holistic viewpoint. So role of internal factors is considered in the total system. All effective internal factors are elicited using a content analysis of literature and interview with experts, and summarized in Table 1.

Study process

In the study, after analyzing theoretical foundations, a new conceptual model is developed, showing relationship among sustainability factors. From a data gathering viewpoint, this study is descriptive (non-experimental) and correlation. It is a descriptive

Table 1. Identifying sustainability factors.

Factors	References
Charismatic leadership	Bessant, 1994; Jones and David, 2004
General training of management	Experts
Participation of employees in decision making	Dale, 1997; Upton, 1996
Teamwork	Bateman et al., 2004
Support and commitment of top management to improvement	Experts, Found et al., 2005; Jones and David, 2004; Bessant, 1994; Bateman, 2004
Effective communications	Experts, Dale, 1997
Monitoring process	Experts, Found et al., 2005; Jones and David, 2004; Bessant, 1994
A clear perception of necessity of improvement	Upton,1996; Found et al., 2005
Specialized training about process	Experts, Upton, 1996; Dale, 1997
Performance-based reward	Experts
Process ownership	Upton, 1996; Found et al., 2005
Clear strategies and goals	Experts
Quality management systems	Experts, Bessant, 1994; Found et al., 2005; Griffiths et al., 2004
Design of a non-shrinkable (Irreversible) structure for the process	Experts
Process standardization	Found et al., 2005; Bateman, 2004
Formal reporting system (recording events and problems)	Experts, Found et al., 2005; Jones and David, 2004

study because the researcher has explored the current variables of the study and has not manipulated them. In addition, it is a correlation study because the researcher has provided a cause and effect model to indicate relationship among the variables. Figure 2 shows the study process, including initial study, finding the resources, interview with practitioners and scholars, analyses, conclusions and suggestions. In the study, a multi criteria decision making (MCDM) technique is used as a systematic tool to structure ideas and factors.

Thus, in addition to understanding experts' viewpoints, its conformity or nonconformity with theoretical foundations is cleared. Then, some samples of the processes are selected to measure sustainability and role of factors among manufacturing and operational processes of some top Iranian companies to gather the required data and provide a sustainability model. Therefore, in the first and main step, by using Delphi technique's stages, some variables and their relationships are identified and in a conceptual model, suitable means of analysis are provided. Finally, by applying a discriminate analysis, the most important sustainability factors (and the answer of the current study's question) are recognized. Population of the study includes some experts such as managers, process owners and experts of 12 manufacturing companies of top Iranian companies which, by providing their assessment about the manufacturing and production processes and process improvement activities during 2005 to 2007, have participated in the study. Since each company has had one to three manufacturing processes, and can have more than one process owner, the population includes at most 150 processes. By using a limited sampling formula, 120 questionnaires are prepared and distributed. Among 89 returned questionnaires, 14 were useless and 75 were analyzed.

RESULTS AND DISCUSSION

Demographic characteristics

A summary of the demographic characteristics in Tables 2 and 3 show some aspects of the 75 samples of manufacturing processes.

Data analysis

When dependent variable is nominal and independent variable is quantitative, discriminate analysis is used to forecast dependent variable based on independent one (Hair, 1998). Discriminate analysis is useful when the researcher tries to design and prepare an estimating group membership model based on the observed characteristics of each subject. The main advantage of the technique is deployment of a discriminate function from a set of linear combinations of independent variables with the most discrimination power among groups. The process used in discriminate analysis can be summarized in three steps:

Step 1: Selection of variables based on theoretical and conceptual considerations, prior knowledge of researcher and an initial analysis.
Step 2: One method of discriminate analysis is a simultaneous regression analysis of all predicting variables showing a significant two-variable correlation with each other. Another method is step-by-step regression analysis for all predicting variables known as Wilk's method. In this study, based on the step-by-step analysis, the variables are entered into the model, based on their discriminating power and the other less-powerful ones would leave it. In other words, the most discriminating variables enter the model and the weakest ones leave it (variables with the highest correlation with the dependent variable remain and the others leave it).

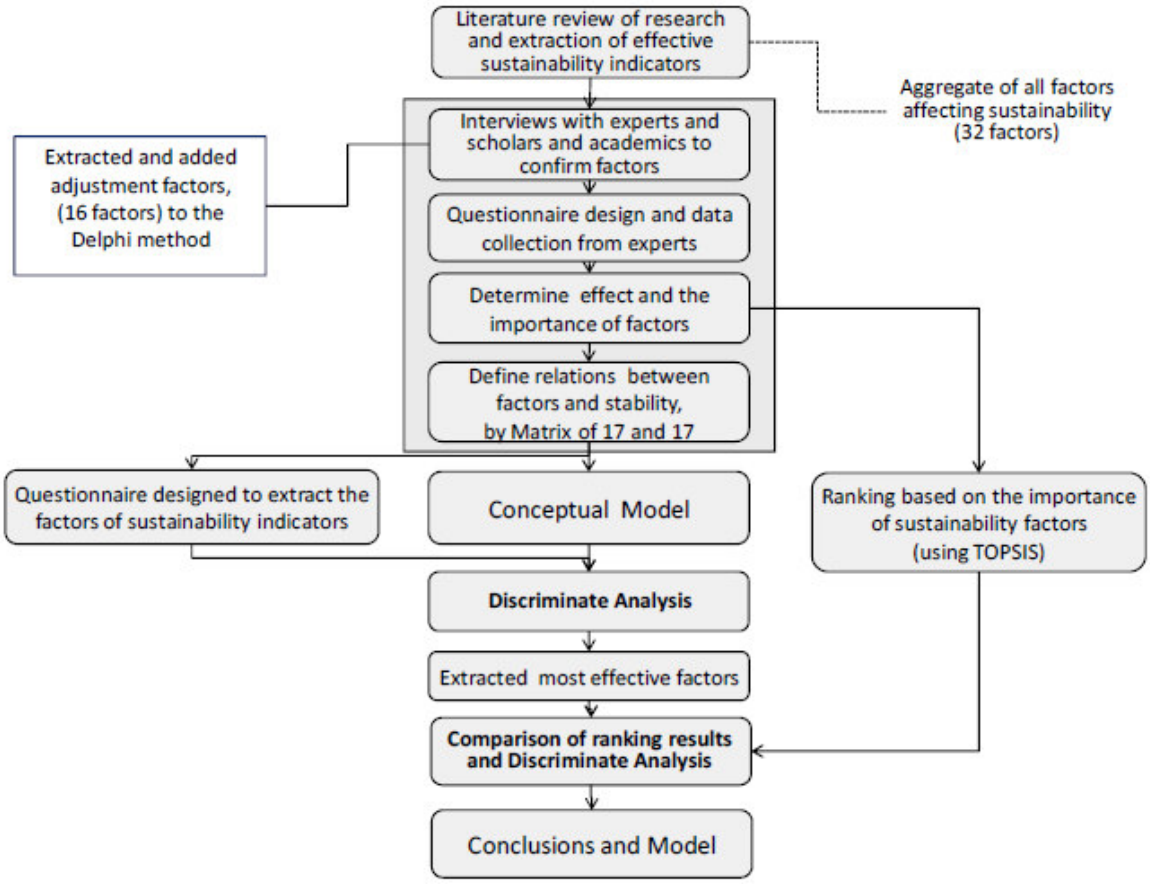

Figure 2. Study process.

Table 2. Nature of processes from automation viewpoint.

Nature of processes	Frequency	Percentage
Full automation	45	60
Man-controlled	24	32
Manual	6	8
Total	75	100

Table 3. Type and frequency of improvement tools.

Technique	Frequency	Percentage
Pareto	21	28
PDCA	17	22.7
5S	13	17.3
7Waste	10	13.3
SMED	10	12
SPC	5	6.7
Total	75	100

The step-by-step process would be used when the researcher has a lot of potential independent variables and tries to select the most discriminating ones.

Step 3: Interpretation of the results is made by the Wilks' step-by-step method. Standard discriminating function is one of the most common methods to analyze the with the

Table 4. Discriminate analysis group statistics.

Factor		Mean	Std. Deviation	Valid N (leastwise)	
				Unweighted	Weighted
Unsustainable	X_1	2.7222	0.66911	18	18.000
	X_2	1.9444	0.80237	18	18.000
	X_3	2.7778	0.73208	18	18.000
	X_4	1.7222	0.66911	18	18.000
	X_5	2.3333	0.76696	18	18.000
	X_6	1.8889	0.67640	18	18.000
	X_7	3.2778	0.82644	18	18.000
	X_8	2.3889	0.69780	18	18.000
	X_9	1.6667	0.84017	18	18.000
	X_{10}	1.8889	0.83235	18	18.000
	X_{11}	2.3333	0.90749	18	18.000
	X_{12}	2.2222	0.54832	18	18.000
	X_{13}	1.7222	0.57451	18	18.000
	X_{14}	1.9444	0.41618	18	18.000
	X_{15}	2.2222	0.94281	18	18.000
	X_{16}	2.1111	0.67640	18	18.000
Sustainable	X_1	4.2456	0.63473	57	57.000
	X_2	4.0702	0.70355	57	57.000
	X_3	3.8947	0.67306	57	57.000
	X_4	4.1930	0.63916	57	57.000
	X_5	3.7368	0.81342	57	57.000
	X_6	3.7544	0.98707	57	57.000
	X_7	2.5614	0.84552	57	57.000
	X_8	1.9825	0.91595	57	57.000
	X_9	1.9474	0.69233	57	57.000
	X_{10}	2.2807	0.83995	57	57.000
	X_{11}	1.8947	0.74843	57	57.000
	X_{12}	2.0877	0.57572	57	57.000
	X_{13}	1.8772	0.84664	57	57.000
	X_{14}	1.6316	0.69774	57	57.000
	X_{15}	1.6842	0.71108	57	57.000
	X_{16}	1.2982	0.46155	57	57.000

with the highest discrimination power among the related groups, used to predict the group membership in future (Hooman, 2002). Here, after entering the process data in the SPSS software, the variables would be gradually refined in five steps. The results are as follows:

First, mean and standard deviation of the variables is calculated for the two groups separately. The difference between group means is one of the initial analyses which is a sign of discriminating power of groups. So, by comparing the difference among group means, those variables with the highest difference have higher contributions to discriminate the groups. For example, mean of factor 1 (X_1), that is support and commitment of top management, is 4.25 and 2.75 for the stable and unstable and groups, respectively. In the next step, if the difference is significant, the related variable plays a role in discriminating among the groups (Table 4).

Test of equality of group means

This table is used to test the significant difference among the means of the groups. As noted earlier, only those variables with the highest significant difference between their means can have a contribution in the discrimination process.

Spearman test

As a whole, the aim of a statistical hypothesis is determining the acceptance or rejection of the hunch about an aspect

Table 5. Spearman coefficients of correlation.

Paired relationships	No.	Spearman coefficient	Significance level	Error level	Result
Support and sustainability	75	0.678	0	0.05	H_0 Reject
Support and performance appraisal and reward system	75	0.519	0	0.05	H_0 Reject
Support and participation in management	75	-0.381	0.100	0.05	H_0 Reject
Support and general training	75	-0.144	0.218	0.05	H_0 Accept
Standardization and problem recording system	75	0.668	0	0.05	H_0 Reject
Standardization and sustainability	75	0.726	0	0.05	H_0 Reject
Monitoring and problem recording system	75	0.314	0.006	0.05	H_0 Reject
problem recording system and perception of necessity of improvement	75	0.315	0.006	0.05	H_0 Reject
Problem recording system and sustainability	75	0.676	0	0.05	H_0 Reject
A clear perception of necessity of improvement and sustainability	75	0.600	0	0.05	H_0 Reject
A clear perception of necessity of improvement and process ownership	75	0.071	0.545	0.05	H_0 Accept
Performance appraisal system and sustainability	75	0.650	0	0.05	H_0 Reject
Specialized training and problem recording system	75	-0.287	0.013	0.05	H_0 Reject
Specialized training and problem appraising system	75	-0.220	0.580	0.05	H_0 Accept
Quality control and strategy	75	-0.114	0.331	0.05	H_0 Accept
Team-working and effective communications	75	0.320	0.005	0.05	H_0 Reject
Team-working and charismatic leadership	75	0.214	0.065	0.05	H_0 Reject
Team-working and general training	75	0.141	0.228	0.05	H_0 Accept
Team-working and sustainability	75	0.206	0.076	0.05	H_0 Accept
Non-shrinkable structure and sustainability	75	-0.100	0.394	0.05	H_0 Accept

of the population based on the gathered data. Because the hypothesis may be right or wrong, two complementary hypotheses emerge in the mind. If (H_0) or null hypothesis cannot be rejected, it shows that there is not any relationship. If the H_0 hypothesis is rejected, the counter hypothesis (H_1) would be accepted, showing a relationship between the two variables. By observing the coefficient of correlation table, relationship between the paired factors can be tested to analyze their indirect effects.

Table 5 shows some relationships between factors suggested by academic experts, tested by industrial data and Spearman test in the 95% significance level. Among the tests, the study can refer to the relationship between standardization of process and problem recording system and between problem recording system and necessity of improvement which have significant relationships with each other. Also, there is a significant relationship between monitoring process and formal problem recording system but the relationship between team-working and general training and sustainability is not significant. Moreover, it does not show any significant relationship between ownership of process and sustainability and also design of a non-shrinkable structure.

Conclusion

Sustainability factors of manufacturing processes in industrial organizations

With respect to importance of determining a sustainability model for improved processes and necessity of analyzing the relationship among the aforementioned factors and sustainability, an audit analysis via discriminate regression (by dividing processes into stable and unstable ones), determines effect of each factor on sustainability and achieves the study's goal to provide a stable improvement model. Thus, the required analyses were made based on information gathered from 75 processes. Then, 16 sustainability factors were selected as independent or predicting variables that have a significant effect on discriminating two groups of stable processes. Hence, the study's results include answering to the question that, which factors lead to sustainability of processes? Here, referring to sustainability factors and determining their importance and effect on sustainability of improved processes in the manufacturing field, it is tried to determine the relationship among the aforementioned factors and sustainability.

Table 6. Canonical discriminate function coefficients.

Factor	Function
	1
X_2 Standardization	0.627
X_3 Monitoring	0.745
X_4 List of daily problems	0.987
X_5 Clear perception	0.470
X_7 Training	-0.534
(Constant)	-8.629

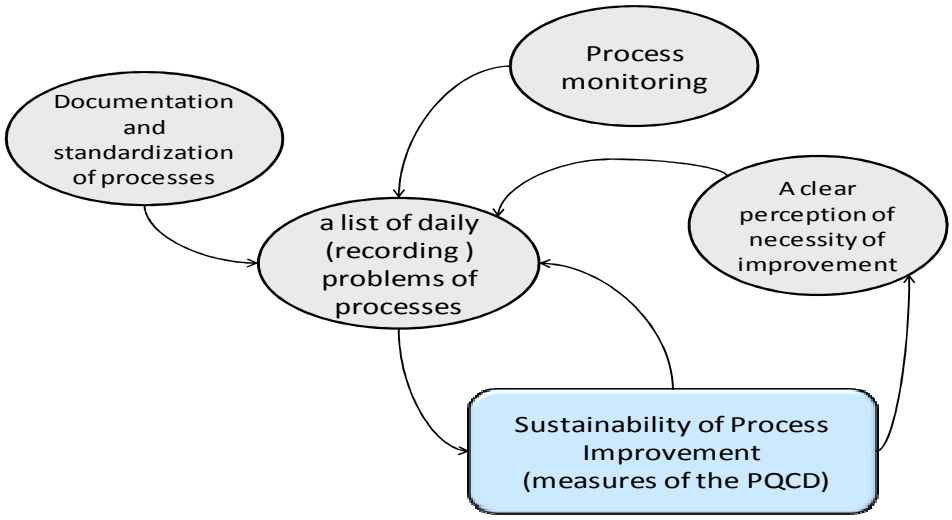

Figure 3. A stable improvement model.

Analyzing the data related to 75 improved processes in the top manufacturing companies shows that, among the sustainability factors, a formal recording system for problems, has the highest effectiveness in discriminating among stable processes (although it has been in the fourth rank from experts' viewpoint). Moreover, documentation and standardization of process, from both academic and industrial experts' viewpoints, is in the second rank. In sustainability of top Iranian industries, a clear perception of necessity of improvement has the third effect (it has been in the fifth level from experts' viewpoint). Process monitoring and performance and reward appraisal system in the discriminate analysis are in the fourth and fifth levels (third and sixth levels from experts' viewpoints). As a result, some factors such as daily recording of problems of the processes, a clear perception of necessity of improvement, process monitoring and standardization of process were selected as independent or predicting variables with significant effects on discriminating two stable groups selected as dependent variables. As presented in Table 6, based on a canonical discriminate function coefficient, the discriminate function is as follows:

$$z_1 = -8.629 + 0.987x_1 + 0.745x_2 + 0.627x_3 + 0.470x_4$$

Which:

X_1= formal recording system for problems
X_2= documentation and the standardization of process
X_3= clear perception of necessity of improvement
X_4= process monitoring

Although the training factor has a significant coefficient, it is excluded from the function because it is negative. Results of the analysis show that, fairly unstable processes have devoted more time and resources for specialized trainings. It should be noted that the fix parameter in the function is negative, implying if the related factors are zero (that is, the companies do not try for sustainability), they are predisposed for shrinkage and deterioration of improved processes.

Sustain improvement model

To answer the final question of the study based on the

findings and by determining the most effective factors on sustainability of improved processes and their significance, a model containing effective activities on sustainability was derived (Figure 3), which after execution of each improvement activity, can lead to sustainability. Therefore, after execution of the improvements, process monitoring and a formal recording system for problems lead to sustainability. Moreover, clear perception of necessity of improvement and documentation of process has the highest effect on preparation of a list of problems and sustainability of processes.

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