Development of hierarchy of flexible manufacture with factor analysis and cluster analysis approaches (Case study: Ilam Cement production factory)

Mohammad Bandari

Department industrial management, Payam Noor University, PO Box 19395-3697, Tehran, Iran

Mohammad Bandari; Development of hierarchy of flexible manufacture with factor analysis and cluster analysis approaches (Case study: Ilam Cement production factory)

ABSTRACT

Flexibility in production receives attention because application of flexibility is usually the most suitable and effective mechanism in responding to global competition, ever-changing technology and reduction in product life cycle. The present study aims to develop and test flexibility model with emphasis on new product performance in production organizations (Ilam cement factory) and identify flexibility dimensions in relation to new product performance and within the framework of hierarchy structure. The main problem is: what are the factors of flexible manufacture hierarchy and what factors are placed in each level in cluster analysis? Measurement criteria for flexibility provide managers with an instrument to evaluate environmental threats in production field.

Key words: Flexible manufacture system, Product development

Introduction

Today, production and manufacture flexibility is considered as an important factor in achieving competitive advantage. This concept refers to a number of general variables and not one single variable. Many industries are confronted with customers' demands for various products and with rapid production speed and delivery time. Competition among industries in satisfying such needs requires them to use flexible systems instead of traditional systems. For example, use of automatic machinery, automatic traffic systems, industrial automation and … are among the characteristics of such systems [12]. Companies act globally in preparation of necessary resources and also distribution of products. Customers prefer to receive service and products as soon and reliable as possible, even their necessary product is produced in another country [2]. The present study aims to increase understanding towards production flexibility role in new product development. Dimensions were collected from previous studies in terms of relationship with NPD activities.

Statement of the problem:

Production companies are faced with global competition and uncertainty and development of high-quality and low-cost products is no longer a guarantee for success. Therefore, production companies must develop new products based on market demand and in a cost-effective, on-time and effective manner. Companies' capabilities and rapid responding to market changes through development of new products need flexibility. Relationship between production flexibility and organizational performance has not yet been clarified in NPD field. The present research tries to develop and test flexibility model with emphasis on NPD in an industrial production company. Identification of flexible dimensions in relation to NPD and in hierarchy structure of these dimensions are provided in the present study. The main problem of this research is to find flexible manufacture hierarchy factors and to find factors in each level in cluster analysis.

The main goals of the present study are as follows:

1. identification of flexibility dimensions which are related to NPD and formulation of a hierarchy for these dimensions.
2. provision of empirical support for new product as a mediating factor between flexibility and performance.
3. after determination of dimensions of flexibility, organizations can select the best dimensions for their products development.

Review of research literature:

1. flexible manufacture system (F.M.S)
Flexibility, is the ability of a production organization for arrangement and effective handling of resources in order to respond to change conditions. [13].

2. product development
NPD is carried out using a number of product quality goals, cost and timing [11],

Research hypotheses:
1. what are the flexible dimensions in Ilam cement factory?
2. what are the levels (hierarchy) of flexible manufacture in Ilam cement factory?
3. what are the clusters related to each of the dimensions of flexible manufacture levels in Ilam cement factory?

Research methodology:
The present study is a theoretical and development-application research. It is also a survey study from data gathering point of view. Research questions were tested by means of field study and interview with experts in cement industry. Data was gathered and then, flexible manufacture hierarchy technique dimensions were investigated using scientific methods. Factor and cluster analyses were conducted after that.

Statistical sample and population:
According to research nature, Ilam cement factory was selected as population of the research. Respondents were individuals familiar with NPD activities and production. Job positions of the individuals included: managing director, installations manager, operation manager, production manager, manufacturing engineer and other employees of manufacturing part. Sample included 150 people. Because population number was limited, all population members (150) people were selected as sample size. 150 questionnaires were distributed and all of them were collected.

Data analysis method:
Questionnaire was used as data gathering tool which included 31 questions. All questions were designed based on 5-point Likert scale. Point 5 has the most and point 1 has the least importance.

Statistical methods used in different studies comprise the most important part of research metrology. In this research, the following tests were used to analyze data: factor analysis and cluster analysis. The main goal of factor analysis is to study the structure and order in multi-variable data, i.e., to determine the number and nature of common factors and their influence on superficial characteristics. Factor analysis was conducted in order to make sure that whether survey items are related to only one dimension of flexibility or not. Exploratory factor analysis was conducted to determine new factors like flexibility dimensions in data structure and also to specify which items are placed in each dimension [5].

Six methods of clustering are used for evaluation of the presence of hierarchy structure in flexibility dimensions. In this study, the method complete linkage-correlation was used. In the present study, Chronbach's alpha was used to measure reliability of the questionnaire. The results of Chronbach's alpha are summarized as follows:

<table>
<thead>
<tr>
<th>Questions</th>
<th>Number of questions</th>
<th>alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 4</td>
<td>4</td>
<td>0.893</td>
</tr>
<tr>
<td>5 to 7</td>
<td>3</td>
<td>0.822</td>
</tr>
<tr>
<td>8 to 14</td>
<td>7</td>
<td>0.682</td>
</tr>
<tr>
<td>15 to 17</td>
<td>3</td>
<td>0.693</td>
</tr>
<tr>
<td>18 to 20</td>
<td>3</td>
<td>0.775</td>
</tr>
<tr>
<td>21 to 23</td>
<td>3</td>
<td>0.769</td>
</tr>
<tr>
<td>24 to 26</td>
<td>3</td>
<td>0.770</td>
</tr>
<tr>
<td>27 to 31</td>
<td>5</td>
<td>0.742</td>
</tr>
<tr>
<td>All questions</td>
<td>31</td>
<td>0.768</td>
</tr>
</tbody>
</table>

Cronbach's alpha for all questions is 0.768 which is indicative of good reliability of the questionnaire.

Flexible manufacture hierarchy model:
In this model, there are three levels for flexible manufacture hierarchy. In the lowest level, 3 operational flexible dimensions were specified (machine, work, material displacement). Flexibility dimensions specified for the middle level of this hierarchy help determine general flexibility of the factory [8].

These dimensions are OPF, ROF and VOF. Two other dimensions of flexibility (new product and correction) belong to the first level or strategic level of hierarchy. Hierarchy model is provided in figure 1.
In this model, it is assumed that there is direct relationship between each of the eight dimensions of flexibility and NPD based on the criteria of internal and external performance measurement and also it is assumed that product development type is the mediator of this relationship. 5 items of flexibility include (work, machine, material displacement, correction, new product) were extracted from Coste studies and the three other items were extracted from Coste and Malhotra approach for flexibility (operation, routing and volume) [9].

**Determination of factors number:**

One of the most important steps in factor analysis is determination of the number of factors which can explain the observed correlations among the observed variables in a logical and satisfactory method. In factor analysis, the following methods are used to extract factors numbers. Some of the important methods are referred to in the following sentences:

**First table in output analysis:**

The first table from output analysis is Kaiser-Mayer-Olkin measure of sampling adequacy and Bartlett test of approximate chi-square. As it can be observed in table 2, Kaiser-Mayer-Olkin value is equal to 0.823 and is suitable. Bartlett test investigates whether observed correlations matrix belongs to a society with non-correlated variables. If this hypothesis is rejected, data is suitable for factor analysis and otherwise, factor analysis must not be conducted. As it can be seen, sig value is less than 0.05 (sig=0.000) and therefore, variables correlation is rejected.

**Second table in output analysis:**

The second table in output analysis is the number of factors present in the questionnaire. Based on the Cattle Pebble diagram, a graph is sketched based on the number of factors and eigen values and it can be used to determine the number of factors whose values are greater than 1. In this graph, eigen values are graphed according to their importance from the largest to smallest.

As it was mentioned before, each question is attached to the highest correlation in a row by means of a rotated matrix, and the results are summarized in table 3 which shows that what factor is connected to each question.
In order to answer the first question of the research which tries to determine the dimensions of flexibility in Ilam cement factory, we can say that flexibility has 8 dimensions as follows: labor flexibility, machine flexibility, material handling flexibility, improved flexibility, new product flexibility, operational flexibility, routing flexibility, and the last dimension of flexibility is volume flexibility. Before conducting cluster factor analysis for answering the second question which tries to investigate hierarchy correlation among flexibility dimensions, we use bivariate correlation test and its results are summarized in the following table. Presence of hierarchy correlation among the 8 dimensions of flexibility is verified. Consequently, the second question is also answered.

**Fig. 2:** Presence of hierarchy correlation.

**Cluster analysis:**

In order to answer the third question which tries to determine dimensions clusters of each of flexible manufacture levels in Ilam cement factory, we use cluster analysis. This kind of analysis can be used to determine the natural structure of relationships. Youhanson and Vikren believe that cluster analysis is done by means of different methods so that results match is verified. These methods include inter-group communications, nearest neighbor, the result of cluster analysis is a Dendo-gram graph which is used for identification of clusters' interconnection and provides necessary information for determination of suitable number of clusters. Clustering method was used to evaluate the presence of hierarchy structure for 8 dimensions of flexibility. Complete linkage-correlation method was also used. ROF and MOF were grouped in the furthest clusters. Dendo-gram for cluster analysis using complete linkage-correlation method
According to the results of statistical analyses, the following conclusions can be drawn for research questions:

First question:
What are the flexible dimensions in Ilam cement factory? After evaluation of all criteria for measuring production flexibility in terms of being one-dimensional, all set of items selected for the 8 flexibility dimensions were tested in order to evaluate their difference validity. Factor analysis was conducted for all 31 items of survey and it was assured that the items are placed only in one dimension and are not used in other dimensions. We also concluded that flexibility has 8 dimensions as follows: labor flexibility, machine flexibility, material handling flexibility, improved flexibility, new product flexibility, operational flexibility, routing flexibility, and the last dimension of flexibility is volume flexibility which is obtained from literature review and exploratory factor analysis also verified it.

Second question of the research:
What are the levels of (hierarchy) flexible manufacture in Ilam cement factory? The present study aims to investigate hierarchy correlation among the dimensions of flexibility in which we used bivariate correlation test. According to table 2, presence of hierarchical correlation among the 8 dimensions of flexibility is verified. Improved flexibility and routing flexibility are placed at the top level (strategic level) of manufacture and in the next level (workshop level), labor flexibility and machine flexibility and volume flexibility are placed. In the in the lowest level, operation flexibility, new product flexibility and Material handling flexibility are placed.

Third question of the research:
What are the clusters of dimensions of each of the levels of flexible manufacture in Ilam cement factory? Cluster analysis was used to answer this question. This analysis was conducted by means of complete linkage-correlation method. Cluster method was conducted to evaluate the presence of hierarchical structure among the 8 dimensions. ROF showed the closest relationship with VOF, while MOF had the most relationship with MAF.

Research results:

The present product showed the complexity of relationship between flexible manufacture and NPD. Previous studies showed that this relationship is very complex even when they focus on one domain like supply chain management or strategic resourcing. This study showed that when new product development type is important, important relationships are formed between flexibility and performance.

Flexible manufacture system does not provide the producer with productivity increase but also it changes all company's strategy like purchase and material order to distribution and marketing. Moreover, flexible manufacture system provides an unprecedented opportunity for breaking products price. Reduction in inventories is the key advantage of this system.

Flexible manufacture may lead to a set of goals like reduction in operational costs, manufacture management improvement and other advantages.
Recommendations:

In the present research, data was gathered from Ilam cement factory in Iran and the results of this research cannot be generalized to other industries, so many other studies are necessary to explain the relationship between NPD and flexible manufacture. Moreover, more complex models are necessary for explanation of relationship between NPD and flexible manufacture dimensions. New methods like DEA can be used to calculate the best performance for a new product development based on the performance of other new products and many inputs and outputs are considered in that.

Recommendations for next studies:

Conduction of this research in other industries like electronic, petrochemical and …. Conduction of the present research in organizations with small, average and large organizations. Use of more flexible mathematical models with larger data sets.

References