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# A NEW PRODUCT DEVELOPMENT FRAMEWORK: COMBINING ANALYTIC HIERARCHY PROCESS & STRUCTURAL EQUATION MODELING APPROACH

**Sudeshna Roy[*1], Nipu Modak[1] and Pranab K Dan[2]**
**[*1, 1]Mechanical Engineering Department, Jadavpur University, Kolkata, India**
**[2]Rajendra Mishhra School of Engineering Entrepreneurship, Indian Institute of Technology Kharagpur, India**

## Abstract

Identification of factors contributing to product development success in Indian manufacturing firms becomes essential for every organization to sustain in the competitive and volatile market environment which in turn reflects the ultimate achievement of the company. This study concerns about the identification of success factors and as well as success measures of new product development (NPD) in Indian manufacturing firms. Previous researches proves the importance of management related factors such as market analysis (MA), top management support (TMS), cross functional team (CFT), planning (P), human resource management (HRM), strategic management (SM) for successful product design and development. Accordingly, various aspects of success measures has been identified and segmented by experts in six different groups based on their characteristics such as measures related to time (C1), cost (C2), quality (C3), customer (C4), technological improvements (C5) and additional features (C6). Weights of clustered success measures have been calculated using Analytic Hierarchy Process (AHP). As the weight of the quality related measures is higher than others, so this has been used as success measure for this study. The manifests of the quality related measures are meet quality guidelines, achieved product performance goal and achievement of design goals. This empirical study is based on the data collected from 29 engineering manufacturing industries in India, involved in product design and development activities. The reliability of the data has been tested by applying Cronbach's Alpha reliability test using IBM SPSS software. The main objective of this study is to develop a framework using structural equation modeling approach (SEM) to analyse the effects of the all six management related constructs on product development success which can be expressed by quality related constructs. The model is structured using IBM SPSS AMOS 22.0 software for analysis purpose. The hypothesis testing performed by using SEM approach proves that each factor has positive impact on product development success.

**Keywords**: Critical success factors, success measures, AHP, Structural Equation Modeling

## 1. INTRODUCTION

Several constituents affecting firm's performance and plays a vital role for their success and survival is termed as critical success factors in previous literatures. New product development (NPD) activity has become essential for betterment of firm's performance for sustaining in the volatile and competitive market environment in the global perspective ([1]Buyukozkan and Arsenyan, 2012). According to empirical study of previous researchers NPD success can be influenced by various management related factors such as market analysis ([2]Medeiros,

 

Ribeiro and Cortimiglia, 2013; [3]Sadeghi, Azar and Rad, 2012), top management support (Felekoglu and Moultrie, 2014; Yeh, Pai and Liao, 2012), cross functional team (Yeh, Pai and Liao, 2012; Lau, 2011), planning (Sadeghi, Azar and Rad, 2012; Tsai, 2012), HR management (Medeiros, Ribeiro and Cortimiglia, 2013; Sadeghi, Azar and Rad, 2012; Tsai, 2012), strategic management (Medeiros, Ribeiro and Cortimiglia, 2013; Buyukozkan and Arsenyan, 2012). Same as the various success factors numerous measures of product development success indexed in previous literatures (Kazerouni et al., 2014; Huang, Soutar and Brown, 2004; Lipovetsky et al. 1997) is essential for complete SEM framework development. Segmentation of previously identified success measures such as measures related to time, cost, quality, customer, technology and additional features as per experts' opinion of various manufacturing industries adds novelty to this research.

The objective of this study is to calculate the weights of the segmented success measures based on the experts' opinion involved in product design and development from manufacturing industries using AHP technique. The SEM has been applied to develop a model depicting the impact of six management related factors on product development success which again expressed by the quality related success measures.

## 2. METHODOLOGY

The Analytic Hierarchy Process (AHP) is a general theory of measurement using pairwise comparisons for both discrete and continuous depending upon the experts' judgements to derive priority scales. The scale that measure intangibles in relative terms is known as Saaty's scale followed by the name of the originator of the method Thomas L. Saaty in 1980. In practical field, the comparisons have been done using this scale signifies the importance of one element over another with respect to a given attribute (Saaty 1987, Saaty 2008).

Structural equation modelling (SEM) is a comprehensive, multivariate statistical approach which is used to build a relationship among multiple variables to test hypotheses (Hoyle 1995). It examines the structure of interrelationships expressed in a series of equations which represents the relationships among constructs. It is the combination of both confirmatory factor analysis and multiple regressions with various extensions to test interdependencies of measured variables and latent constructs as well as between several latent constructs also known as unobserved variables. Latent variables are indicated by manifest or measured variables which are obtained from responses of questions or some type of observations from questionnaire survey (Hair et al. 2010). In present era SEM is highly popular statistical model among the researchers of various fields like marketing research, supply chain management and operation management, due to its flexibility and robustness.

This work involves formulation of six hypotheses which are tested using Structural Equation Modelling (SEM) on primary data set obtained from survey. These Hypotheses are mentioned below.

H1: Market Analysis (MA) has a positive impact on Quality measures.

H2: Top Management Support (TMS) positively influences the Quality measures.

H3: Cross Functional Team (CFT) has a positive impact on Quality measures.

H4: Planning (P) is positively related with Quality measures.

H5: Human Resource Management (HRM) has a positive effect on Quality measures.

H6: Strategic Management (SM) positively related with Quality measures.

 

# 3. RESULTS

## 3.1 WEIGHT CALCULATION USING ANALYTIC HIERARCHY PROCESS

Various measures of the product development success have been identified in the previous literatures. In this empirical study, these success measures have been clustered into six groups based on experts' opinion of Indian manufacturing industries. These are measures related to time (C1), cost (C2), quality (C3), customer (C4), technology (C5) and additional features (C6). The weights of these measures have been calculated using AHP technique based on Saaty's 9 point scale shown in Table 1. Calculation of weights adds the novelty in this research. The responses of product design and development managers and personnel from Indian manufacturing industries have been collected for weight calculation through questionnaire survey. The calculated weights of success measures have been listed in Table 2.

Table 1 Saaty's 9 Point Scale

| Scale points | Definition of Scale points | Explanation |
|---|---|---|
| 1 | Equally Important | Two attributes are equally important |
| 3 | Somewhat more important | One attribute is slightly more important than other |
| 5 | Much more important | One is moderately more important than other |
| 7 | Very much Important | One is strongly preferred over other |
| 9 | Strongly Important | One attribute is extremely more important over the other |
| 2,4,6,8 | Intermediate Values | |

Table 2 Weightage calculation of success measures (as per experts' opinion)

| | C1 | C2 | C3 | C4 | C5 | C6 | $n^{th}$ root of product values | Eigen Vector |
|---|---|---|---|---|---|---|---|---|
| C1 | 1 | 1/5 | 1/7 | 1/3 | 5 | 3 | 0.732 | 0.087 |
| C2 | | 1 | 1 | 1 | 5 | 5 | 2.236 | 0.269 |
| C3 | | | 1 | 1 | 5 | 7 | 2.501 | 0.301 |
| C4 | | | | 1 | 5 | 7 | 2.172 | 0.261 |
| C5 | | | | | 1 | 3 | 0.411 | 0.049 |
| C6 | | | | | | 1 | 0.277 | 0.033 |
| Total | | | | | | | 8.320 | 1.00 |

The eigenvector of the relative importance of C1, C2, C3, C4, C5 and C6 is (0.087, 0.269, 0.301, 0.261, 0.049, 0.033). Thus, C3 i.e. quality related success measures is the most important for product development success measurement followed by C2 and C4, which are roughly equal and then C1, C5 and C6 respectively.

## 3.2 ANALYSIS OF MEASUREMENT VALIDITY

To accomplish research objectives, another questionnaire consisting of manifests of six latent variables listed in Table 3 has been developed to survey the implementation of aforesaid management related success factors from same experts as mentioned before. The 7 point likert scale has been used to rate all measures where 1 denotes very low and 7 denotes very high. The reliability of the survey data for each construct has been computed using Cronbach's Alpha (α) reliability test and its values have been enlisted in Table 4 which show that survey data are reliable as $\alpha \geq 0.8$ (Ong, Lai and Wang 2004). After that, SEM approach is applied to examine the impacts of success factors on quality measures by hypotheses testing using IBM AMOS 22 software.

 

Table 3 List of manifest variables of latent constructs

| Latent Variables | Manifest Variables |
|---|---|
| 1. Market Analysis (MA) | Market testing (MA1), Identification of target market (MA2), Emphasis on customer satisfaction (MA3); |
| 2. Top Management Support (TMS) | Delegation of Top Management (TMS1), Leadership by example (TMS2), Willingness of Management in taking risk on NPD (TMS3); |
| 3. Cross Functional Team (CFT) | Level of communication of team members for NPD (CFT1), Sharing of information among different departments (CFT2), Degree of exchanging complete and accurate information for problem-solving (CFT3); |
| 4. Planning (P) | Planning of the entire NPD process in your company (P1), Organized strategic planning for coordinating NPD projects (P2), Planning of the space distribution for components and body structure (P3); |
| 5. Human Resource Management (HRM) | Tradition of working as a team (HRM1), Effective use of manufacturing engineering skills (HRM2), Effective use of resources within your company (HRM3); |
| 6. Strategic Management (SM) | Long term planning (SM1), Effort to reduce product development cost (SM2), Correct forecasting of technology trend (SM3); |
| 7. Quality (Q) | meet quality guidelines (Quality1), achieved product performance goal (Quality2) and achievement of design goals (Quality3); |

## 3.3 HYPOTHESES TESTING

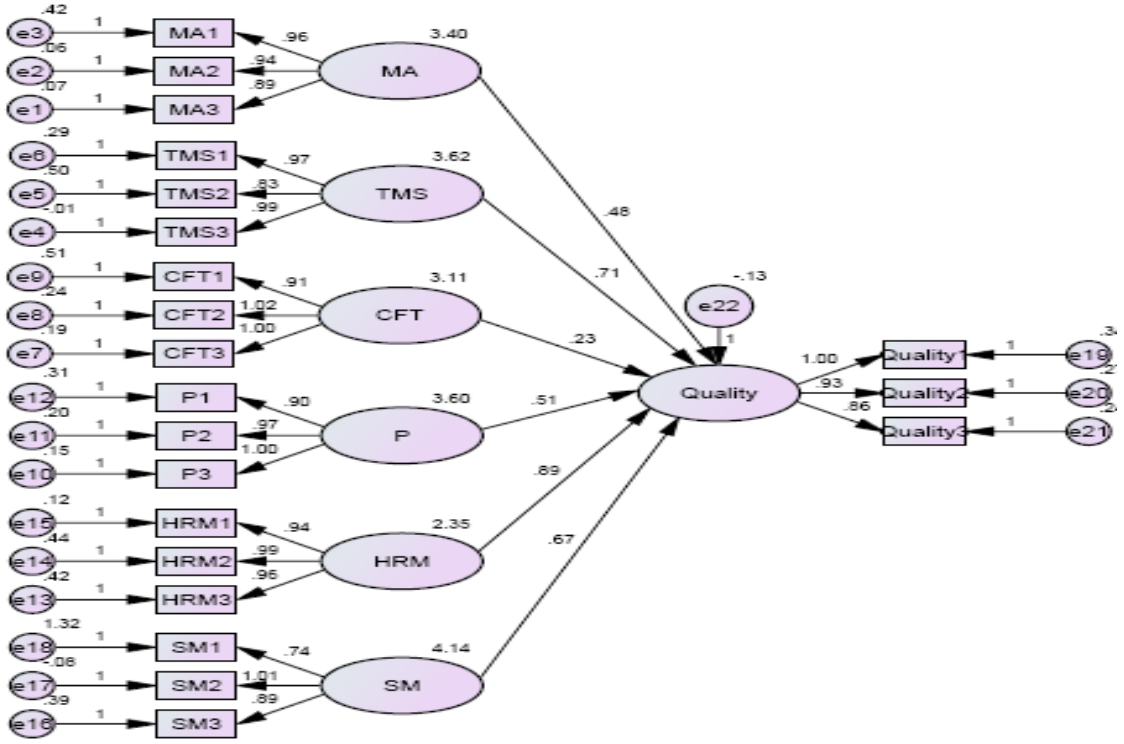


Fig. 1 Structural Equation Modeling (SEM) model after execution

Fig. 1 shows the path diagram developed by AMOS which demonstrates the hypothesized relationships among latent constructs. The values over the arrows indicate the associated standardized regression weights obtained after execution of SEM analysis. The statistics of path estimates have been listed in Table 4 which shows all the six hypotheses considered are proven right because all path estimates are positive and >0.4 which is quite acceptable. The inferences drawn here are on the basis of the path estimate values. Validation of the model

 

has been conducted by various fitness measures. Standard values of fit indices (Byrne, 2010) and values obtained from the test have been listed in Table 5 and Table 6 respectively.

Table 4 Statistics of path estimates

| Description | Path | Hypothesis | Cronbach's Alpha (α) | Estimate |
|---|---|---|---|---|
| 1. Market Analysis & Quality | MA–Q | H1 | 0.89 | 0.48 |
| 2. Top Management Support & Quality | TMS – Q | H2 | 0.86 | 0.71 |
| 3. Cross Functional Team & Quality | CFT – Q | H3 | 0.94 | 0.23 |
| 4. Planning & Quality | P–Q | H4 | 0.88 | 0.51 |
| 5. Human Resource Management & Quality | HRM-Q | H5 | 0.81 | 0.89 |
| 6. Strategic Management & Quality | SM-Q | H6 | 0.93 | 0.67 |

Table 5 Fitting indices (adopted from (Byrne, 2010))

| Fit Indices | Desired Range |
|---|---|
| $\chi^2$ /degrees of freedom | ≤ 2.00 |
| RMSEA(Root Mean Square Error of Approximation) | Values less than 0.05 show good fit<br>Values as high as 0.08 represent reasonable fit<br>Values from 0.08 to 0.10 show mediocre fit<br>Values > 1.0 show poor fit |
| Goodness-of-fit index (GFI) | ≥ .90 |
| Average Goodness-of-fit index (AGFI) | ≥ .90 |

Table 6 Model Fitting Parameters

| Chi-Square($\chi^2$) | Df | $\chi^2$/df | GFI | AGFI | RMSEA |
|---|---|---|---|---|---|
| 148.76 | 80 | 1.859 | 0.904 | 0.879 | 0.0448 |

As per Table 6, both the fit indices GFI and AGFI are within the desired range i.e. 0.904 and 0.879 respectively. The Chi-square value is also satisfactory and the value of $\chi^2$/df is also considerable and RMSEA value is quite small as it should be. As the values of all fitness parameter indices are well within permissible range it can be stated that all these six factors play a vital role in successful product development in Indian industries.

## 4. CONCLUSIONS

This study explores the impact of management related six factors on product development success in Indian manufacturing industries. The segmentation of success measures according to the opinion of design and development experts from Indian manufacturing industries adds novelty to this work. Based on the questionnaire survey, weights of the success measures such as measures related to time, cot, quality, customer, technology and additional features have been calculated using AHP. The result depicts the highest weight of the quality measure relative to others. The SEM model, established by using six management related success factors and most weighted success measure i.e. quality, portray the relationships of latent constructs. In the real world scenario, it has been observed that all the success factors are positively related with product development success which can be improved by implementing and controlling these success factors as well. In this way, this study helps the management of India manufacturing industries to consider the important success factors as well as measures and to implement them for better achievements in near future.

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