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Prediction of New Product Development (NPD) Performance in Research and Development (R&D) Company

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Abstract. NPD performance measures are crucial to R&D based organizations. A comprehensive review on NPD literature reveals that definitions of NPD performance measures proposed by prior researchers mainly focus on measurement taken post product launch, such as measurements of business financial gains and customer satisfaction. NPD Performance measures at pre product launch stage were rarely discussed. Hence, this research aims to propose a methodology for NPD performance measurement prior to product launch. The research adapts quantitative research tools and makes use of 98 survey data from a multi-location R&D company. NPD implementation effectiveness is calculated via descriptive analysis, and multiple regression technique is applied to predict NPD performance prior to product launch. Finding from the research suggested NPD constructs that presumed as important are not effectively implemented. The research also suggested that the strongest predictors for NPD performance within the scope of the company under study are NPD constructs "Concurrent Engineering (CE) Tools and Technique Application" and "Top-down CE approach."

Keywords: New Product Development, NPD Performance, Research and Development

1. Introduction

Studies of an organization's performance have been at the heart of organizational theory for many years. However, measurements of New Product Development (NPD) performance have been slow to converge to a standard or even an accepted operative framework[1]. Prior research has shown that NPD performance measurements or indicators can effectively distinguish between best practice and average Research and Development (R&D) firms[2]. However, many of the NPD performance variables focus on factors outside the R&D barrier[3]. Most of the NPD performance indicators concentrate on measurements of financial gains and market response of the new products, and lack of emphasis on indicators that measure the effectiveness of NPD process prior to product launch. An effective NPD process is the key impact factor in an organization's ability to develop and manage innovation[4]. Competitive and hostile business environments make an effective NPD process more important to business to ensure that the business stays ahead of present or potential competition[5]. Hence, this research reviews the types of NPD performance measurements as suggested by prior researchers, follows by proposal of methodology on NPD effectiveness measures and prediction of NPD performance prior to product launch.

2. Research background

This research focuses on a multi locations R&D company. The company under examination enjoys a high reputation for extensive research and development activities. As a multi-location R&D company, to remain competitive and continue with sustainable growth, effective management within the multi location R&D facilities is not the only challenge. Continuous improvement in NPD such as reduce product development lead time and reduce product costs is another concern. To address the aforementioned problems, two research questions are identified and formulated:

1. What is the level of NPD implementation effectiveness in the multi location R&D company?
2. How can NPD Performance in the multi location R&D company be best predicted?

3. Research scope

An ideal NPD process framework should be able to deal with incremental innovation in short term, and revolutionary innovation in longer term[6]. Therefore, to build up the organization capability to accommodate both incrementally and revolutionary innovation, in the formation of NPD process framework, organization should focus on framework that promotes incremental innovation and at the same time maintain a systematic process structure. The NPD process framework used by the company under study is a recursive based NPD framework that promotes concurrent engineering (CE) activities and multiple feedback loops across all NPD phases. CE promotes early involvement of a cross-functional team to simultaneously plan product, process and manufacturing[7] which will be manifested through concurrent work-flows, product development team and early involvement of constituents[8]. This research examines NPD effectiveness and performance of the company under study from the CE prespective. Seven main CE constructs[9] and 49 CE attributes were identified from comprehensive literature review of CE[10] which is summarized in Table 1.0.

Table 1.0 Concurrent Engineering Constructs and Attributes

1.0	**Top down concurrent engineering approach**
1.1	Top management commitment and involvement on CE
1.2	Company mission, strategies and policies which promote CE activities
1.3	Clear definition of NPD process flow, tracking method and NPD management system
1.4	NPD process which promotes identification of concurrent activities
1.5	Existent of driving force for new product development
1.6	Computer integrated information environment that allows automated configuration management and control
1.7	Effective communication and teamwork between different levels and departments throughout NPD process
1.8	A team approach (e.g., quality circles, cross-functional teams) in problem solving and continuous improvement
1.9	Team learning and knowledge sharing among employees
1.10	Management openness to change
2.0	**Interface with customers**
2.1	Understanding of the definition of customer (external and internal customer)
2.2	Involvement of customers at the early stage of NPD
2.3	Methods for translation of the "voice of the customers" into key product and process characteristics (e.g., QFD)
2.4	Integrates customer specification into product and process specification
2.5	Continuous feedback to the internal customer as the process evolves
3.0	**Formation of CE team**
3.1	Teams formed at the early stage of NPD phase
3.2	Optimum team size (number of team members)
3.3	Staffing of the team (team members from all disciplines – design, manufacturing, marketing and support)
3.4	Members participation in the team on full time basis
3.5	Team structure and reporting line (i.e., members report solely to team leader, and leader reports to management)
3.6	Team leader's skill and capability
3.7	Team members' skill and capability
3.8	Involvement of supplier in the team
3.9	Motivation of the team members
3.10	Training for members to improve soft skills (e.g., communication, effective meeting, empowerment and leadership)
3.11	Location/distance among members (Members are co-located within conversational distance of each other)
4.0	**Continuity of CE team**
4.1	Identify key team members
4.2	Key team members transit with the product (serve from beginning to the end of the project)
4.3	All team members serve from the beginning to the end of the project
4.4	Incentive scheme for team members who serve from beginning to the end of the project
4.5	Training provided for team members in transition (from 1 team to another; or from one location to another)
4.6	Organizational acceptance for team members in transition (from 1 team to another, or from 1 location to another)
4.7	Incentive scheme for team members in transition (from 1 team to another; or from 1 location to another)
5.0	**CE technique and tools application**
5.1	Application of Design for Manufacturing (DFM)
5.2	Use of Computer Aided Design (CAD) and Computer Aided Engineering (CAE)
5.3	Use of prototyping techniques on design benchmarking (Benchmarking of design options via prototyping models)
5.4	Use of Failure Mode and Effect Analysis (FMEA) for identifying high risk product and process characteristics
5.5	Validation and verification of critical components, parts and technologies at different stages of NPD

5.6	Consideration of produce ability and process capability in product design process (e.g., Cpk and Ppk studies)
5.7	Simulation of product manufacturing and support process (e.g., Engineering Build, Preproduction)
5.8	Use of Design of Experiments (DOE) for variability reduction procedures throughout the NPD process
5.9	Selection of optimization values for key product and process characteristics based on sensitivity analysis or DOE
6.0	**Early involvement of subcontractors and vendors**
6.1	Identify critical paths, schedules, and required concurrency of subcontractors and vendors activities
6.2	Top management peer acceptance of early subcontractor/vendor participation
6.3	Good communication channels with suppliers
6.4	Involvement of suppliers in product development process
7.0	**Corporate focus on continuous improvement and lessons learned**
7.1	Methods used for design tracking and feedback of lessons learned
7.2	Leaders assume active roles as facilitators of continuous improvement and creating conducive environment
7.3	Storage method or repository of lessons learned and accessibility to team members

4. Literature review

4.1. Definition of NPD Performance

NPD performance refers to the market reward for new products in terms of the products' contributions to company's sales and profits[11]. NPD performance can be also described as a measure of the time required to introduce a new product to the market[12], the level of product quality and the response from customers[13]. Examples of NPD performance measurements used by prior researcher to benchmark NPD performance of best practice R&D firms versus average R&D business are as following[14].

- Revenues and profits gained by the business from new products.
- Success and failure rates of new products.
- "On time" and "On budget".

4.2. NPD Performance Measurement from Holistic Viewpoint

In the research of identifying the most commonly used NPD performance measures, 17 NPD performance measures were identified and grouped into five NPD performance categories as summarized in Table 2.0[15].

Table 2.0: New Product Performance Measures

New Product Performance Measures	
Product Level Measure	Met Performance Specifications
	Met Quality Specifications
Customer Acceptance Measure	Customer Satisfaction
	Customer Acceptance
	Customer Competitive Advantage
	Number of Customers
Market Level Measure	Met Sales growth goals
	Met Revenue Goals
	Met Market Share goals
	Unit Volume goals
Financial Measure	Met Profitability goals
	Met Contribution goals
	Development cost
	Return of investment
Timing Measure	Launch on time
	Break-even time
	Time to market

5. Research Design

5.1. NPD Performance Measures Framework

The aforementioned literature review reveals that NPD performance measures suggested by previous researchers could be grouped into three main categories:

- Measurement of business financial performance.
- Measurement of customer satisfaction.
- Measurement of NPD process effectiveness.

In addition, NPD performance measures proposed by prior researchers tend to focus on measurement of activities or responses post product launch. There is a lack of NPD performance measurement tools for pre product launch activities (refer to Figure 1.0).

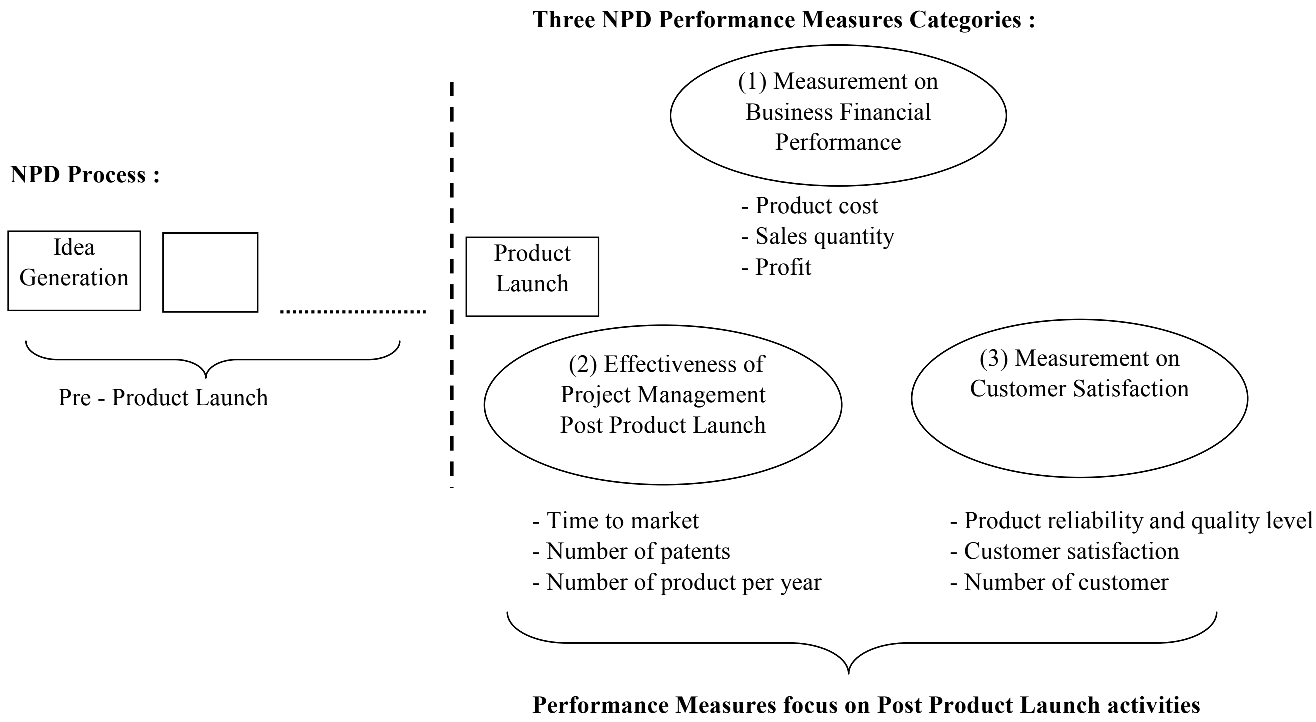

Fig 1: Summary of NPD Performance measures from prior researchers

5.2. Factor model for NPD Performance

The NPD performance measures employed in this research comprise the three main category of NPD performance measurement, including effectiveness of project management (on Time-to-market), measurement of business performance on financial aspects (on cost); and assessment of product achievement via performance target and quality specification (on reliability target). The seven CE construct (from Table 1.0) were integrated with NPD performance to form a framework using the factor approach (Figure 2.0).

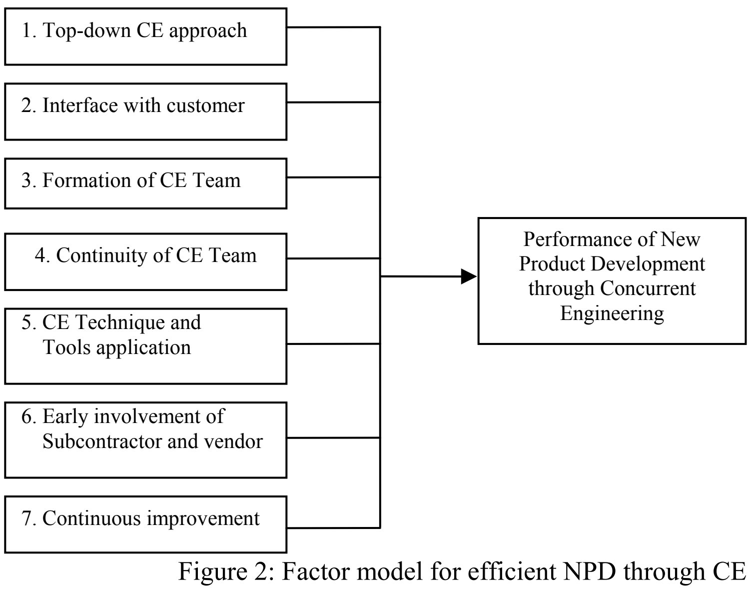

Figure 2: Factor model for efficient NPD through CE process

The factor approach is favoured over the process approach so as to better understanding the relationship between causes and effects. Within the context of this study, the causes are the seven main CE construct, while the effect is efficient NPD through CE process. In factor theories, these constructs are usually conceptualized as variables, i.e., entities which can take on a range of values[16].

5.3. Research tool

This research applies quantitative survey to assess importance level and implementation level of CE in the multi location Research and Development (R&D) company. Data is collected based on a survey questionnaire which incorporates the seven CE constructs, the 49 attributes and the 3 NPD performances measures derived from the literature review. In the questionnaire, the respondents were asked to rate the importance level of CE in NPD process by rating each of the 49 statements on a five point scale ranging from (1) not important to (5) extremely important, followed by rating of the implementation level of each of the 49 attributes on a five point scale ranging from (1) no implementation to (5) full implementation. In additional, the respondents were also asked to rate the level of NPD performance by rating the 3 performance measures from (1) Very low to (5) Very high. The perception of the importance level and implementation level of the 49 CE attributes were used to identify the implementation effectiveness of the CE in NPD and subsequently to predict NPD performance.

5.4. Sampling Design

The total population for this research is 159 respondents (consists of personnel involved in the NPD activities in the form of design engineers, technical development engineers, test engineer, tooling engineers, quality engineers and commercial executives). A random sampling technique group was deployed of which 98 personnel was identified

5.5. Analysis tools

5.5.1. Terrell Transformation Technique

Ordinal data collected from quantitative survey questionnaire is converted to interval data by Terrell Transformation Technique[17] prior to further basic statistic analysis[18]. Raw data from Likert-scale is categorized as ordinal data, which does not give any indication of the magnitude of the differences among the rank. The scores from the five point Likert-scaled data are transformed into interval data through Terrell Transformation technique using the following formula:

$$\text{Transformed Score} = \frac{(\text{Actual Raw Score-Lowest Possible Raw Score})}{(\text{Possible Raw Score Range})} \times 100\%$$

- **Actual Raw score** for *Y* = Average score of *X*

  $$= \sum_{i=1}^{n} (X\text{i})/\text{n}$$

  Where, *Y* = construct; *X* =attributes for construct *Y*; *n* = number of attributes (X) for construct *Y*
- **Lowest Possible Score**
  For Likert scale of 1 to 5, the lowest score for individual attribute is "1", therefore,
  Lowest Possible Raw score = (Number of attributes per construct) X 1 = *n*
- **Possible Raw Score Range -** for Likert scale of 1 to 5, Possible raw score range is 4.

The transformed score of the implementation level will be divided by the transformed score of the important level to generate an index of NPD implementation effectiveness.

5.5.2. Regression analysis

Multiple Regression technique is used to predict the level of NPD performance. The technique is also applied to assess how strongly each critical construct (independent variables) influences NPD performance by measuring Standard Regression Coefficients (Beta). In addition, the correlation between the observed NPD efficiency and the predicted value of NPD efficiency, i.e. adjusted R square, will also be measured through Multiple Regression analysis tool.

6. Result and discussion

6.1. Reliability test

The reliability of quantitative data from survey questionnaire is evaluated through Cronbach Alpha reliability test as shown in Table 3.0. The Cronbach Alpha reliability coefficients in the range of 0.8447 to 0.9484 imply that the quantitative data is statistically significant as Cronbach Alpha reliability coefficients greater than 0.7 are suggested to be adequate for testing the reliability of factors[19].

Table 3.0 Reliability Analysis

Constructs	Detail	Alpha
1	Top down CE approach	0.8447
2	Interface with customer	0.8871
3	Formation of CE team	0.9484
4	Continuity of CE team	0.8916
5	CE technique and tools application	0.8777
6	Early involvement of subcontractor and vendor	0.8972
7	Continuous improvement	0.8978

6.2. Level of NPD effectiveness

NPD effectiveness in this research refers to the percentage of NPD implementation level versus importance level where the implementation and importance levels used in the analysis were transformed into indices through Terrell Transformation Technique. A low effectiveness number means that the importance placed by the companies or viewed by the employees has not been translated into practice successfully. However, an effectiveness level higher than 100% can be presumed to indicate over-focus. From the result of survey, Table 4.0 summarizes the important level, implementation level and effectiveness of the seven main constructs.

Table 4.0 Summary of Analysis result for RQ1

Constructs	Detail	TTT Important Index (a)	Important Level Ranking	TTT Implementation Index (b)	Effectiveness (b/a)	Effectiveness Level Ranking
1	Top down Concurrent Engineering Approach	76.79%	2	57.04%	74.29%	4
2	Interface with customer	72.45%	4	53.93%	74.44%	3
3	Forming of CE teams	71.87%	5	47.70%	66.38%	6
4	Continuity of CE teams	71.65%	6	41.87%	58.44%	7
5	CE technique and tools application	81.24%	1	61.08%	75.19%	2
6	Early involvement of subcontractors and vendors	70.60%	7	53.32%	75.52%	1
7	Corporate focus on continuous improvement and lesson learned	74.15%	3	54.08%	72.94%	5

An analysis of the results as shown in Table 4.0 suggest that NPD implementation effectiveness across all the 7 CE constructs are above average however, none of the constructs have been fully implemented. Comparison of implementation effectiveness ranking and importance ranking are made to evaluate management focus level. An efficient NPD process requires additional focus on high importance factors. In another words, the avoidance of under focus or over focus circumstances.

Summary of Table 4.0 reveals that construct 6 "Early involvement of subcontractor and vendors" is ranked as the most effectively implemented construct with the effectiveness at 77.52%. However, it is ranked as the least important construct with TTT important index of 70.60%. This suggests that implementation of CE activities in the NPD process might have led to an over focus on less important construct. Perhaps geographical factors are the main dispute behind the scenes. As example, as a multi located R&D organizations, R&D facilities in Malaysia are apart from the other of global functional departments. However, the Malaysia R&D facilities are closer to contractors and vendors as the majority of them are located in the South East Asia region.

Constructs 1 and 7,"Top down CE approach" and "Corporate focus on continuous improvement and lesson learned" are placed fourth and fifth in the implementation effectiveness ranking with an effectiveness of 74% and 73% respectively. However, both constructs are suggested as second and third important constructs by respondents. This reveals that in the NPD process of the company under study, there is insufficient focus on these two important constructs. Whereas, comparison between effectiveness level and important level for constructs 2, 3, 4 and 5 suggest that they are implemented at a level that is relatively in-line with their respective importance level.

The interpretation of the findings is that the perceived implementation level of CE constructs in the company is not relatively in line with the perceived level of importance. Two generic issues are observed: over-focus and under focus. Measurements of effectiveness are crucial to ensure implementation is focused on the right area based on importance level. The analysis tool used has been proven proficient in identify areas of improvement for an effective NPD implementation.

6.3. Prediction of NPD Performance Prior to Product Launch

The analysis embodied into this research question is multiple regression analysis with SPSS (Statistic Process for Social Science) version software. With reference to the factor model of Figure 2.0, a multiple regression analysis is performed between the effect, i.e. respondent's perception on NPD performance as dependent variable and the seven causes or CE constructs as independent variables. Table 5.0 summarizes the type of variables entered or removed from Regression analysis as well as the method of analysis. In the case of this study, a "Stepwise" method is used. From Table 5.0, two variables, Construct 5 and Construct 1, were entered, and none of the variables were removed. Hence, two models could be developed from the analysis.

Table 5.0: Regression analysis - Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	Construct 5	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Construct 1	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

6.4. Analysis of R Square

Table 6.0 is an illustrative analysis of the output from SPSS software. "R" is a measure of the correlation between the observed value and the predicted value of the dependent variable. In this study, this would be the correlation between NPD Performance as suggested by the participants and the levels predicted by the independent variables. R square, or "Coefficient of determination", is the square of this measure of correlation (R), and is a measure of how strong a prediction of CE efficiency can be made by knowing the independent variables.

Table 6.0: Regression Analysis - Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1 [(a)]	0.776	0.602	0.598	0.3751	0.602	145.09	1	96	0
2 [(b)]	0.805	0.648	0.64	0.3546	0.046	12.427	1	95	0.001

a - Predictors: (Constant), CEMC5

b - Predictors: (Constant), CEMC5, CEMC1

From Table 6.0, Model 2 produces a higher value for R Square (R^2 = 0.648) than Model 1 (R^2 = 0.602). Therefore, Model 2 is superior due to its higher R square. This implies that 64.8% of the variation in

NPD Performance can be explained by construct 5, "CE Tool and Technique application" and construct 1, "Top-down CE approach".

6.5. Developing the regression equation

Table 7: Regression Analysis - Coefficients

Model 2	Coefficients
(Constant)	8.10E-02
Construct 5	0.53
Construct 1	0.392

From Table 7, based on the coefficients of model 2, the regression equation that could best predict NPD performance for the company under study is as follows:

NPD Performance = 0.0081 + 0.53(Construct 5) + 0.392(Construct 1)

The analysis reveals that Construct 5 "CE Tools and Techniques application" and Construct 1 "Top down CE approach" are the two strongest predictors for NPD Performance for the company under study. NPD umbrella is such a wide variety of subjects that it is difficult to keep track of them all. Therefore, the identification of constructs with the strongest correlation with NPD performance is crucial. This study suggested that for the multi-located R&D company that under study, the implementation level of "CE tools and techniques application" and "Top down CE approach" could be used as predictors or the key performance index (KPI) for NPD performance.

7. Summary

The research has recommended a methodology on the measurement of NPD implementation effectiveness and identification of "under-focus" and "over-focus" NPD constructs at pre product launch stage. The findings presents an interesting managerial implication where the NPD constructs that are perceived as important NPD performance constructs are not implemented effectively within the R&D based company that under study. The research has also proposed a methodology on the prediction of NPD performance through regression analysis. The development of NPD performance prediction model enlightens the critical elements that compose the performance of NPD prior to product launch, i.e. the strongest NPD performance predictors. Another implication is that a particular attention is needed to be placed on the strongest NPD performance predictors because by improving the predictors, companies can greatly increase the likelihood of new product success. .

8. Future research

Future research could be conducted in R&D companies from other sectors such as semi-conductors, pharmaceuticals, food and medical industries. Different sectors of business might apply CE approach on NPD differently. Research in other sectors will help to acquire a bigger overall picture of CE in NPD.

In addition, as an expansion of this research, future research could focus on the details of CE tools and techniques application, such as type of CE tools, application, and degrees of usefulness of CE tools on non-R&D; co-located R&D as well as multi location R&D organization. If the long term viability of CE depends on effectively developing and deploying CE tools, the assumptions about how CE design tasks are most successfully performed and the role of tools in facilitating that work should be carefully reviewed.[20]

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