Determinants of Sustainable New Product Development and Their Impacts in Manufacturing Companies

Sudeshna Roy, Nipu Modak and Pranab K. Dan

Abstract Necessity of sustainable new product development (S-NPD) has becoming increasingly relevant in the present era for sustaining in the global competition. Though S-NPD has been neglected earlier, its vital role in business and academic perspectives indulges the companies to be involved in S-NPD for their own sake. This research identifies seven critical success factors (CSFs) of S-NPD and their indicators as well. After recognition, it realizes the importance for implementation of these factors in Indian manufacturing companies. It recognizes the CSFs such as structural configuration, learning practice, strategic configuration, internal perspectives, external issues, PLC analysis and additional performance for S-NPD. This S-NPD can be achieved by effort to reduce cost and increase profitability, achieving resource efficiency, customer satisfaction and reduction of environmental pollution created by the product, health and safety aspects, social aspects and life cycle analysis. This study accumulates the primary data from 255 manufacturing experts mainly from design and development team for data analysis. The structural equation modeling (SEM) approach is been employed to analyze the combined impact of these CSFs on sustainable NPD by using IBM SPSS AMOS 21.0 software. This study interprets that all the CSFs have positive impact on sustainable product development for enhancing the S-NPD. Strategic configuration has been identified as the most impacted success factor for S-NPD. Among success measures, customer satisfaction is recognized as the most vital measure followed by health and safety aspects, life cycle analysis, social aspects, resource efficiency, reduction of environmental pollution created by the product and reduced cost and increased profitability. This empirical research helps to draw the managerial implications for highlighting the success factors and measures as per their importance for S-NPD.

Keywords Sustainable new product development (S-NPD) · Critical success factors (CSFs) · Structural equation modeling (SEM) · International society of waste management · Air and water

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1 Introduction

New product development (NPD) is a process of introducing products completely new to market through series of activities for fulfilling the customers' need (Booz 1982). NPD influences cost, quality, development time, customer satisfaction and financial performance of the firm for achieving industrial sustainability. The idea of sustainability is incorporated with NPD focusing on sustainable new product development (S-NPD) by involving sustainability with each phase of NPD to value their customers (Schaltegger 2011; Paramanathan et al. 2004). Environmental issues add a different dimension to NPD process of the firm which is often been neglected. Cleaner production and eco-innovation have been introduced, but these activities are remained as a 'term' for the small and medium-scaled enterprises (SMEs) (Schaltegger and Wagner 2011). In this era of globalization, the NPD is not only an affair of developing something innovative, but to produce new products by considering its adverse effect on environment (Hansen et al. 2009). Environmental hazards have reached an alarming position where each person needs to be concerned about hazardous effects of their consumables. S-NPD is an approach to deliver new products by considering social, economic and environmental aspects together in a single frame (Paech 2007). Association of NPD activities along with the organizational configuration to produce environment-friendly new products is initiated for achieving industrial sustainability (Rennings 2000). The S-NPD activities of large scale and SMEs are different due to their difference in nature, size and innovation attributes (Hillary 2000). The drivers of S-NPD of SMEs are needed to be recognized to facilitate S-NPD for industrial sustainability. These drivers are famously known as critical success factors (CSFs) (Ernst 2002). There are researches identified the CSFs for S-NPD to achieve eco-innovation. Structural configuration, learning practice, strategic configuration, internal perspectives, external issues, product life cycle (PLC) analysis and additional performance are identified as the factors critical to success for S-NPD (de Jesus Pacheco et al. 2017). The combined impact of these variables on S-NPD is essential to measure the performance of the firm in terms of social–economic and environmental aspects. In this scenario, the integrating framework considering the CSFs of S-NPD and the success measures are needed to be developed which is largely unexplored. The consideration of environmental issues for better performance outcome is required to be developed and the essential steps to build the support system and create a conducive ambience for successful implementation of the implications drawn from the analysis.

The objective of the study is to develop an integrative model for realizing the combined impact of environmental aspects along with the organizational and strategic issues of the SMEs for implementing those practices efficiently for achieving desired social, economic and environmental success. The structural model is constructed considering the aforementioned CSFs, and their combined impact on S-NPD is tested by structural equation modeling approach using IBM SPSS AMOS 21.0.

2 Research Methodology

2.1 Methods

Structural equation modeling (SEM) is a method for representing, estimating and testing the relations between latent variables and their manifests. It is mainly a combination of exploratory factor analysis and multiple regressions (Ullman 2001). Latent variables are those which cannot be measured directly. Manifest variables of the latent construct are the observed or measured variables through which the latent can be measured. SEM comprises two models, namely measurement model and structural model. In measurement model formation, the confirmatory factor analysis (CFA) is performed. The structural model represents the interrelation among the latent constructs and observed variables (Schreiber et al. 2006). This study identifies the role of factors of S-NPD for successful development of sustainable new products in terms of social, economic and environmental aspects. The analysis of the developed framework is performed on the basis of primary data collected from 263 experts of Indian manufacturing industries. The reliability of the accumulated primary data has been tested by using composite reliability (CR) and Cronbach's alpha reliability testing using IBM SPSS AMOS 21.0. The average variance extracted (AVE) is been calculated for testing the discriminant validity of the collected data. The threshold value of CR and AVE is 0.5, whereas in case of α it is 0.8 (Ong et al. 2004). The exploratory factor analysis is performed to measure factor loadings (FLs) to their respective constructs. SEM is employed by using IBM SPSS AMOS 21.0 to develop the structural framework testing the hypotheses developed from the available literature and the experts' opinion. CFA is performed for calculating the standard regression weights (SRWs) of the manifest variables in measurement model section. In case of structural model formation, path estimation between the latent constructs is performed by using maximum likelihood method.

2.2 Hypothesis Development

This work involves development of seven hypotheses relating the CSFs to S-NPD for realizing their impact on performance attributes of development of sustainable new products. Structural configuration of SMEs is one of the critical components which are to be concerned for developing new products. Organizational structure, methods adopted for NPD, external collaboration with suppliers and customers, R&D activities, risk management and moreover managerial support are the essential criteria each firm must be concerned for successful NPD (Aykol and Leonidou 2014; Ackermann and Eden 2011). Learning practice is another constituent essential for S-NPD activities. It includes proper training in both internal and external bases, practice to cooperate with extern stakeholders and strong technological background with advisory committee to develop sustainable new products (Ackermann and Eden 2011;

Blackburn 2007). Strategic configuration is another constituent of the firm which develops the strategy of success. Managerial insight is the most vital indicator of the strategy development. It also comprises strong synchronization among internal teams and variations in strategies as per market changes occurred (Boly et al. 2014; Blackburn 2008). Besides these organizational and strategic issues, product life cycle (PLC) analysis is essential to associate environmental aspects for S-NPD. The awareness about the raw materials having hazardous impacts on environment, usage of recycled materials, recycling of scrap metals along with all valuable components and optimized design of the new product to be developed (Ackermann and Eden 2011; Blackburn 2008; Bertoni et al. 2015). Moreover, there are additional performance aspects like brand image, attraction of customers and employers and lean manufacturing to reduce the waste are also considered as one of the vital CSFs of S-NPD to be taken care of (Ackermann and Eden 2011; Bertoni et al. 2015). The social, economic and environmental issues are considered as the performance attributes of the S-NPD which covers reduction of cost and increment of the profit of the firm, resource efficiency, customer satisfaction, minimization of environmental pollution, health and safety aspects, social aspects and life cycle analysis. The hypotheses developed from the above discussions are listed below. The path model developed from these developed hypotheses is represented in Fig. 1:

H1: Strategic configuration of the firm motivates the S-NPD.
H2: Learning practice enhances S-NPD activities of the firm.
H3: Proper strategic configuration can boost up S-NPD performance.
H4: Internal perspectives influence S-NPD of the firm.
H5: Effective handling of external issues motivates S-NPD.
H6: Product life cycle analysis adds an additional feature to S-NPD on which the development of new products depends.
H7: Additional performance positively encourages S-NPD activities of the firm.

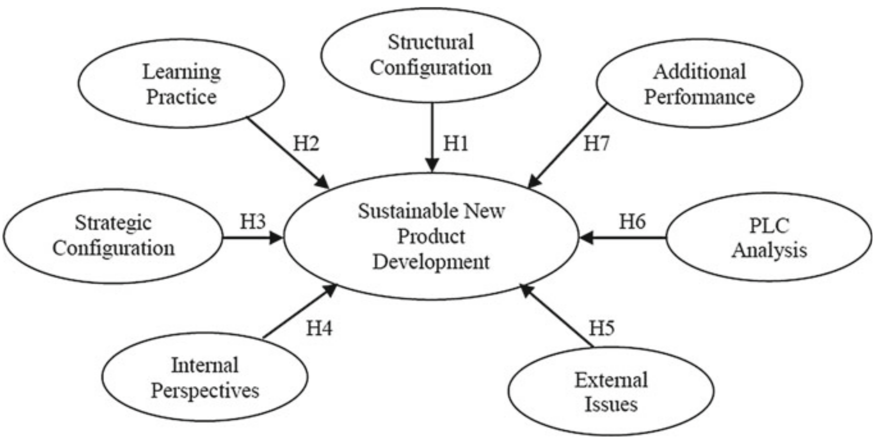

Fig. 1 Path model of latent constructs with their estimated hypotheses

2.3 Development of Questionnaire

A semi-structure questionnaire is developed for accumulating the primary data from the industry experts. The questionnaire is divided into three sections. First section gathers the information regarding the respondent's profile. The second section comprises input CSFs and their manifest variables collecting the information about the input variables. The last and final section acquires manifests of output construct which is S-NPD. The second section is again segmented into two subsections. One is degree of importance of the manifest variables, and another is their rate of implementation in practical field. Seven-point Likert scale has been used to quantify the response of the samples. In this scale, 1 represents strongly agree and 7 strongly disagree for recording the importance of the manifests. In case of implementation and output, 1 shows very low and 7 very high implementation rate. A scope for sharing the own views of respondents for additional manifest variables is also provided for further value addition to the questionnaire.

2.4 Sample and Data Collection

This empirical research is performed considering the scenario of Indian manufacturing industries. Experts from small and medium-scale manufacturing companies mainly developing the engineering products are considered for this analysis. A pilot study based on the developed questionnaire is conducted by surveying from 36 experts of Kolkata and Howrah mainly for the content validation of the developed questionnaire. Design and development experts are treated as the targeted samples for the survey through direct interviewing or telephonic interview. Demographic profiles of the respondents are mentioned in Table 1.

3 Results

3.1 Analysis of Measurement Validity

Principal component-based factor analysis is performed to test the loadings of manifest variables for dimension reduction purpose. Variables having loadings less than 0.6 are rejected as per the conventional practice. In Table 2, the values of factor loadings are enlisted showing that all of the 34 variables have the loading values greater than 0.60 such as 0.676 to 0.675. This implies all of the manifests are considered for the framework development. The values of CR, α and AVE are also mentioned in Table 2 as obtained from the analysis of IBM SPSS AMOS 21.0 software. The values of CR range from 0.75 to 0.84, and values of α range from 0.720 to 0.858. In case of AVE, the values are from 0.46 to 0.59. It shows that values of reliability

Table 1 Number of respondents from various manufacturing sectors of India

Sectors	Number of respondents	Sectors	Number of respondents
Fabrication	46	Hydraulics and pneumatics	25
Electrical equipments	33	Burner and heater	22
Industrial valves	32	Material handling equipment	21
Textile machineries	27	Cell and battery	14
Firefighting equipment's	26	R&D sectors	9
Total respondents = 255			

indices (CR and α) and discriminant validity (AVE) are greater than their threshold values depicting the reliability of the collected data. In case of α, there are few values slightly less than 0.8, but they are also considered as reliable as their values are greater than 0.7.

3.2 Measurement Model Results

CFA is performed for estimating the unidimensionality of the model fit. The SRWs of the manifest variables are calculated showing the weights of the manifests associated with their respective construct. The values of SRWs range from 0.23 to 0.99 (Table 2) showing the positive correlation. The validation of the measurement model is checked by estimating the model fitness. The fitness tests show that the model has good model-to-data fit as per the obtained values χ^2/degrees of freedom = 1.96, RMSEA = 0.053, GFI = 0.871, AGFI = 0.832 (Chen 2016; Hu and Bentler 1998) with respect to the desired range of χ^2/degrees of freedom $\geq$ 2, RMSEA = 0.05 for good fit and 0.08 for moderate fit, GFI = 0.90 and AGFI = 0.90 (Byrne 2010).

3.3 Structural Model Results

Analysis of measurement model is followed by the structural model analysis. It represents the linkages among the latent constructs. The path estimates between the latent variables are calculated using maximum likelihood estimation. It shows that path values range from 0.29 to 0.69 as listed in Table 3. All the estimated values are positive which depict that relation between the constructs is positive which means

Table 2 List of manifest variables of latent constructs including results of reliability testing

Latent with their manifest variables including reliability indices	FL	SRWS
Structural configuration [α= 0.858; CR = 0.84; AVE = 0.59]	–	–
1. Organizational structure for supporting S-NPD (m1)	0.836	0.36
2. Managerial support (m2)	0.804	0.92
3. Adoption of methods essential for S-NPD (m3)	0.801	0.77
4. Supplier involvement for successful NPD (m4)	0.789	0.87
5. Customer involvement (m5)	0.761	0.59
6. Role of R&D for assuring lower impact of newly developed products on environment (m6)	0.723	0.70
7. Risk managing for eliminating negative environmental impacts generated from newly developed products (m7)	0.711	0.67
Learning practice [α= 0.775; CR = 0.78; AVE = 0.48]	–	–
1. Internal and external training regarding environmental awareness (m8)	0.890	0.83
2. Learning to cooperate with external stakeholders (m9)	0.844	0.59
3. Technological advisory within the firm for environment-friendly new product development (m10)	0.829	0.97
Strategic configuration [α= 0.834; CR = 0.82; AVE = 0.56]	–	–
1. Managerial insights about strategic relevance of S-NPD	0.725	0.90
2. Variations in strategies according to the changes occur in the market	0.708	0.79
3. Strategies adopted for continuous improvement of S-NPD	0.688	0.60
Internal perspective [α= 0.851; CR = 0.83; AVE = 0.57]	–	–
1. Availability of both tangible and intangible assets essential for S-NPD (people, technology, knowledge)	0.935	0.64
2. Support and motivation for innovative strategies encouraging for developing new products	0.895	0.23
3. Synchronization among the internal teams	0.812	0.73
External issues [α= 0.790; CR = 0.80; AVE = 0.51]	–	–
1. Government rules and policies for promoting S-NPD	0.850	0.54
2. Impartiality in regulations for both SMEs and large-scale industries	0.763	0.87
3. Governmental support for developing sustainable products	0.741	0.68
Product life cycle analysis [α= 0.798; CR = 0.79; AVE = 0.52]	–	–
1. Avoid those raw materials having hazardous impact on environment	0.852	0.72
2. Use of recycled materials having no metal emissions	0.816	0.43
3. All scrap metals are recycled into pure fractions	0.756	0.94
4. Optimized design of the product to be developed	0.731	0.28
5. Recycling of all valuable components of the newly developed product after the end of the life cycle	0.693	0.31
Additional performance [α= 0.720; CR = 0.75; AVE = 0.46]	–	–
1. Brand image for reputation of the firm	0.788	0.81

(continued)

Table 2 (continued)

Latent with their manifest variables including reliability indices	FL	SRWS
2. Acceptability to the employees and customers	0.732	0.68
3. Capability of the firm to learn the issues regarding sustainable new product development	0.676	0.90
Sustainable new product development [α= 0.840; CR = 0.81; AVE = 0.52]	–	–
1. Reduced cost and increased profitability	0.884	0.63
2. Resource efficiency	0.860	0.75
3. Customer satisfaction	0.801	0.99
4. Reduction of environmental pollution created by the product	0.799	0.75
5. Health and safety aspects	0.757	0.98
6. Social aspects	0.722	0.88
7. Life cycle analysis	0.684	0.94

Table 3 Statistics of path estimates depicting the linkage of latent constructs

Path description	Hypothesis	Estimate	t values
Structural configuration → S-NPD	H1	0.69 (***)	11.221
Learning practice → S-NPD	H2	0.29 (***)	4.685
Strategic configuration → S-NPD	H3	0.58 (***)	9.674
Internal issues → S-NPD	H4	0.41 (***)	6.335
External perspectives → S-NPD	H5	0.43 (***)	6.940
PLC analysis → S-NPD	H6	0.36 (***)	5.800
Additional performance → S-NPD	H7	0.54 (***)	9.201

[***p < 0.01]

proposed hypotheses are supported. The validation of the structural model is tested with χ^2/degrees of freedom, RMSEA, GFI and AGFI. The values obtained show the good model-to-data fit as well (χ^2/degrees of freedom = 1.35, RMSEA = 0.048, GFI = 0.893, AGFI = 0.862) (Chen 2016; Hu and Bentler 1998). The structured model comprising of both measurement model and structural model is represented in Fig. 2.

As shown in Fig. 2, it states that the CSFs of S-NPD, namely structural configuration, learning practice, strategic configuration, internal issues, external perspectives, PLC analysis and additional performance, are positively correlated with S-NPD. This depicts that the developed hypotheses are supported. The values of path estimates are enlisted in Table 3.

The proposed model comprises the path estimates between latent constructs ranging from 0.29 to 0.69. The corresponding t values of the respected path linkage between the latent constructs are also mentioned. Based on these t values, the p value is obtained which shows the path estimates are significant for $p < 0.01$. This infers

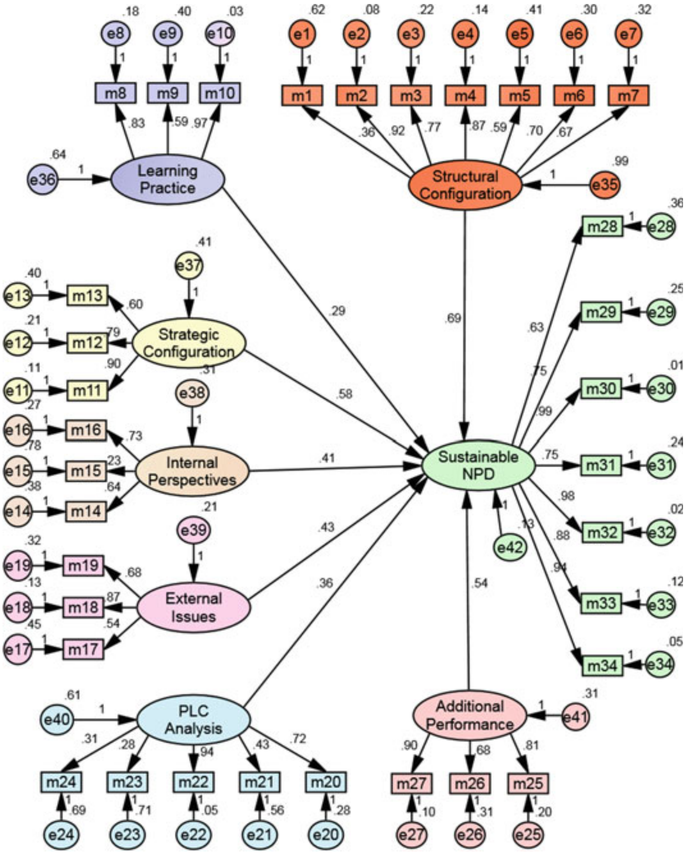

Fig. 2 Structural equation modeling (SEM) model after execution

that the identified CSFs are all positively linked with S-NPD of the firm and they have significant impact on S-NPD in turn the success of the SMEs.

4 Discussion and Conclusion

The study realizes the factors of S-NPD and its impact on social, economic and environmental aspects. According to the analysis, it has been observed that structural configuration is the highest impacted factor succeeded by strategic configuration, additional performance, external perspectives, internal issues, PLC analysis and learning practice. From this study, the important role of managerial support to establish better structural configuration for S-NPD has been identified. It also depicts the vital role of technological advisory within the firm for environment-friendly new product development for enriching the learning practice. Similarly, for strategic configuration managerial insights about strategic relevance of S-NPD are the imperative most measured variable which must be taken care of. For internal issues and external perspectives, synchronization among the internal teams and impartiality in regulations for both SMEs and large-scale industries has the highest impact on their respective latent construct, respectively. Recycling of all scrap metals has the highest priority for PLC analysis, whereas capability of the firm to learn the issues regarding S-NPD is focused for better additional performance. In this study, S-NPD is treated as output construct which has been measured by social, economic and environmental attributes. Among these, customer satisfaction is the first priority of the firm followed by health and safety aspects, life cycle analysis, social aspects, resource efficiency and reduction of environmental pollution created by the product and reduced cost and increased profitability. Among these, resource efficiency and reduction of environmental pollution created by the product have the equal contribution to measure the success of S-NPD. Adoption of these practices not only motivates the successful implementation of the CSFs, but also ensures successful development of sustainable new products. Moreover, the Indian government must be aware of the environmental hazards and take hard steps by implementing rules and regulations to reduce the pollution created by the developed products. Scope of recycling in India is very much limited which must be taken care of for further development.

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