Integration of Environmental Impacts in Sustainable New Product Development

S. Roy, N. Modak and P. K. Dan

Abstract Introduction of new products has become a strategic area globally for sustaining a competitive advantage. There are several factors contributing to new product development (NPD) success known as critical success factors which are essential for firms' ultimate success. As per the survey, environmental concern should greatly be increased in magnitude in Indian manufacturing companies for success and survival. This study concerns about the identification of manifests used to signify the environmental impacts on NPD success where the success of firms has also been expressed by the environmental aspects. As empirical data and experiences have accumulated, manifests of environmental factor are eco-friendliness of the product, adverse effect of the product on environment, sustainability of the product, the environmental goal achievement rate of the new green products, compliance of new green products with the consumers' preference, meeting government policies for product development, recycling rate of the new green products, and hiring responsible employees. Same as the factor, environment-related measure is expressed by reduced cost, healthy relationship with investors, regulatory approvals, life-cycle analysis, and customer satisfaction. A semi-structured questionnaire has been developed, and detailed research interviews have been collected from design and development experts of Indian manufacturing companies. Reliability of the survey data has been tested by Cronbach's alpha reliability testing using IBM SPSS 21.0 software. The main objective of this study is to develop a framework using structural equation modeling (SEM) approach by IBM SPSS AMOS 21.0 software to analyze the effects of environmental impacts on NPD success. The hypothesis testing performed by using SEM approach proves that the environmental impact is positively related to product development success. In addition, identification of obstacles faced by manufacturing companies to implement environmental factor adds an extra novelty in this empirical research which will help to overcome the problems in future days.

S. Roy (✉) · N. Modak
Mechanical Engineering, Jadavpur University, Kolkata, India
e-mail: sudeshnaroy689@gmail.com

P. K. Dan
Rajendra Mishra School of Engineering Entrepreneurship, Kolkata, India

1 Introduction

NPD practice has become one of the necessary parts of the firms and organizations for sustainability in the competitive market environment. This situation has been enhanced by rapid escalation in global market and unpredictable market environment [1]. According to previous researches, there are various factors expressed as critical success factors as they are critical for success and survival of the firm [2, 3]. So, identification of these factors has become one of the most challenging areas of interest for researchers for confirming sustainability of NPD success. Various factors such as technology [4–6], research and development (R&D) [6–10], top management support [7, 11–17], cross-functional team collaboration [7, 8, 17–20] are mostly discussed by researchers in existing literature. This research concerns environmental impacts on sustainable NPD. Environmental impacts on product development are another issue which has been considered as one of the vital factors by researchers [21–25]. In the present scenario, globally manufacturing companies are facing a pressure for developing products which are less harmful to the environment [26]. This study is focusing on environmental impacts for sustainable new product development. Same as the success factors, there are various success measures identified by researchers which have been used to measure the NPD success of firms and organizations. These success measures have been manifested by various manifest variables such as market success, meeting budgets and schedules, speed-to-market [27], success rate, percentage of sales by new products, profitability relative to spending, technical success rating, sales impact, profit impact, meeting sales objectives, meeting profit objectives, profitability versus competitors [7], customer acceptance, customer satisfaction, meeting revenue goal, revenue growth, meet market share goal, meeting unit share goal, break-even time, attaining margin goal, attaining profitability goal, attaining return on investment goal, development cost, launch on time, achieving product performance goal, meeting quality guideline, and percentage of sales by new product [28] as described by researchers.

In this study, we consider environmental impacts as success factor and environment-related measures as success measure of new product development success (PDS) to develop a framework using structural equation modeling to build relationships among them and identify the obstacles to implement this factor in terms of its manifest variables, so as to overcome those issues in future.

2 Methodology

Structural equation modeling (SEM) is a methodology for representing, estimating, and testing a theoretical network of (mostly) linear relations between variables, that is, measured variable and latent constructs [29]. The SEM approach is used here to develop the relationship among factors which are critical for organizational success and survival and correlate them with the new product development success. It is a comprehensive statistical approach for analyzing hypotheses about relations among manifest and latent variables [30]. This study concerns about the role of the environmental factor and its manifests and sets hypothesis to relate this factor with the product development success (PDS) which is again measured by environment-related measures. This empirical research considers the Indian manufacturing industries for the survey purpose, and data has been collected from their NPD personnel, design and development experts and managers. The statistic used in this work is obtained from the respondents of 36 engineering product development companies, especially electrical manufacturing and structural fabrication companies in India. Cronbach's alpha reliability testing has been performed for testing the reliability of the survey data by calculating the value of alpha (α) [31] using IBM SPSS 21.0 software. Structural equation modeling (SEM) approach has been used to develop the framework of the interrelationship of environmental constructs and product development success (PDS) and their manifest variables. IBM SPSS AMOS 21.0 software package has been used to perform the analysis.

This work involves formulation of the hypothesis which has been tested using structural equation modeling (SEM) on primary data set obtained from survey. The hypothesis is mentioned below:

H1: Environmental factor (E) positively influences the product development success (PDS) which is again measured by environment-related measures.

3 Results

3.1 Analysis of Measurement Validity

A thorough data survey has been carried out from Indian manufacturing industries for the accomplishment of the research objectives. Here, the manifests of the constructs have been divided into two segments, i.e., importance of that manifest to measure the latent construct and another is implementation which is the degree of execution of that manifest in practical scenario. This segmentation adds an extra novelty to this study. All measures are based on 7-point Likert scale where 1 denotes strongly disagree and 7 denotes strongly agree for importance, whereas 1 denotes very low and 7 denotes very high for implementation and in case of the output latent construct which is PDS here. The reliability of the collected data has

been tested by Cronbach's alpha reliability test using IBM SPSS 21.0 software package, and the reliability values of each construct have been enlisted in Table 2. As values of α for all variables are above threshold value which is 0.8, it proves that the collected data is reliable [31, 32]. Now, for developing the interrelationship of the constructs and estimating the hypothesis, the structural equation modeling (SEM) analysis has been conducted using IBM SPSS AMOS 21.0 software package (Table 1).

The path diagram displayed in Fig. 1 demonstrates the hypothesized relationships among the latent constructs and their manifests. The values over the arrows indicate the associated standardized regression weights obtained after execution of SEM analysis using IBM SPSS AMOS 21.0 software package.

The statistics of path estimates which are the factor loadings of the manifest variables are listed in Table 2. Same as the statistics of path estimates to relate latent constructs is stated in Table 3. Different fitness measures such as goodness of fit index (GFI), adjusted goodness of fit index (AGFI) and root mean square error approximation (RMSEA), chi-square statistics, and degree of freedom estimates were computed to validate the developed model. The standardized values of the fit indices are listed in Table 4, and the values obtained from the test are also listed in Table 5. As per the data of Table 3 where statistics of path estimates of constructs have been listed, it can be interpreted that the hypothesis which has been considered is proven right. The inferences drawn here are on the basis of the path estimate value which shows that the hypothesis is significantly and effectively correct.

In the proposed model, the fit indices are above the accepted level of 0.90 as shown in Table 3. The chi-square value is also satisfactory, the value of χ^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 said or proved that integration of environmental factor for successful new product development plays a vital role for industrial sustainability of Indian manufacturing companies.

Table 1 List of manifest variables of latent constructs including results of reliability testing

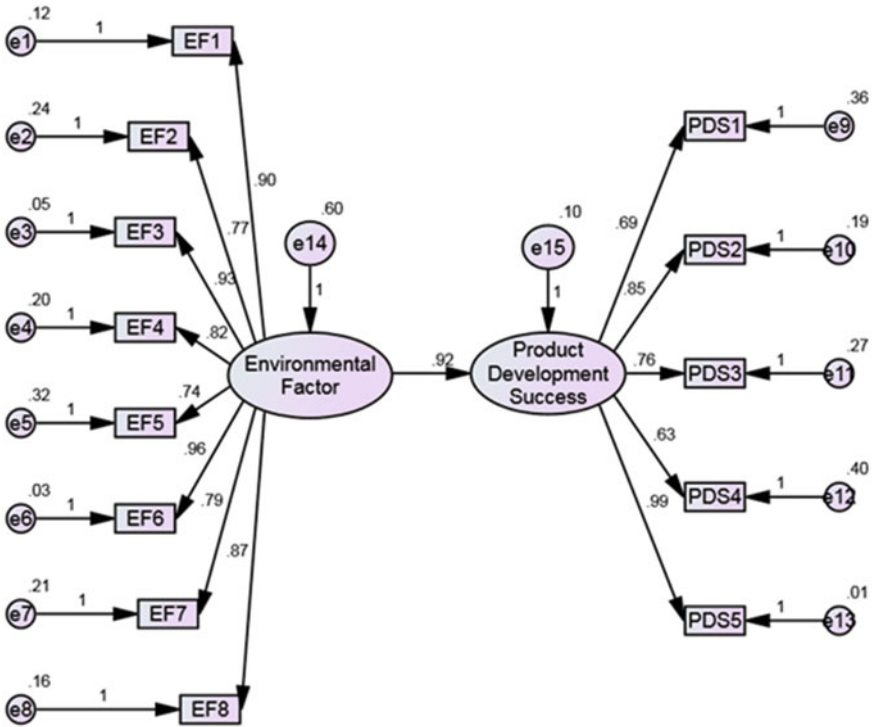| Latent variables	Measurement variables	Cronbach's alpha (α)
Environmental factor (E)	1. Eco-friendliness of the product (EF1) 2. Adverse effect of the product on environment (EF2) 3. Sustainability of the product (EF3) 4. The environmental goal achievement rate of the new green products (EF4) 5. Compliance of new green products with the consumers' preference (EF5) 6. Meeting government policies for product development (EF6) 7. Recycling rate of the new green products (EF7) 8. Hiring responsible employees (EF8)	0.863
Product development success (PDS)	1. Reduced cost (PDS1) 2. Healthy relationship with investors (PDS2) 3. Regulatory approvals (PDS3) 4. Life-cycle analysis (PDS4) 5. Customer satisfaction(PDS5)	0.985

Fig. 1 Structural equation modeling (SEM) model after execution

Table 2 Statistics of path estimates

Latent variables	Manifest variables	Factor loadings
Environmental factor (E)	1. Eco-friendliness of the product (EF1)	0.90
	2. Adverse effect of the product on environment (EF2)	0.77
	3. Sustainability of the product (EF3)	0.93
	4. The environmental goal achievement rate of the new green products (EF4)	0.82
	5. Compliance of new green products with the consumers' preference (EF5)	0.74
	6. Meeting government policies for product development (EF6)	0.96
	7. Recycling rate of the new green products (EF7)	0.79
	8. Hiring responsible employees (EF8)	0.87
Product development success (PDS)	1. Reduced cost (PDS1)	0.69
	2. Healthy relationship with investors (PDS2)	0.85
	3. Regulatory approvals (PDS3)	0.76
	4. Life-cycle analysis (PDS4)	0.63
	5. Customer satisfaction(PDS5)	0.99

Table 3 Statistics of path estimates

Description	Path	Hypothesis	Cronbach's alpha (α)	Estimate	Inference drawn
Environmental factor and product Development success	E-PDS	H1	0.893	0.92	Supported

Table 4 Fitting indices

Fit indices	Desired range
χ^2/degrees of freedom	≤ 2.00
RMSEA (root mean square error of approximation)	Values less than 0.05 show good fit Values as high as 0.08 represent reasonable fit Values from 0.08 to 0.10 show mediocre fit Values > 1.0 show poor fit
Goodness of fit index (GFI)	≥ 0.90
Average goodness of fit index (AGFI)	$\geq 0..90$

Table 5 Model fitting parameters

Chi-square (χ^2)	Df	χ^2/df	GFI	AGFI	RMSEA
85.152	64	1.330	0.960	0.943	0.033

4 Discussion and Conclusion

This study recognizes the impact of environmental factor on PDS in Indian manufacturing industries. The manifest variables to quantify the success factor which is environmental factor in this case have been identified from previous literature as well as from the experts' opinion from 36 manufacturing companies through a detailed survey from Indian manufacturing companies. Same as the success factor, the manifests of success measure which is PDS in terms of measures related to environmental aspects have been identified. Addition of experts' opinion based on their real-life experience adds an extra novelty to this research. Though environmental effects of newly developed products have long-term impact on companies' success and survival as well as it affects the human life, they often remain neglected. This study emphasizes on environmental factor and quantifies this factor by eco-friendliness of the product, adverse effect of the product on environment, sustainability of the product, the environmental goal achievement rate of the new green products, compliance of new green products with consumers' preference, meeting government policies for product development, recycling rate of the new green products, and hiring responsible employees. Though the importance of these variables has been admitted, still the practical implementation somehow remains ignored. This research concentrates on importance as well as implementation of manifests of environmental factor for companies' betterment which will improve

their performance by reducing cost of development with lesser environmental risks, healthy relationship with investors, ease of regulatory approvals, life-cycle analysis, and customer satisfaction. In case of implementation of environmental factor, companies have to face various obstacles in real-life scenario. The limited number of government-approved eco-waste recycler in India is one of the problems for recycling. But, in present days, government has become strict and conscious for restricting the environmental hazards for the sake of nature and humanity as well.

References

1. Bevilacqua, M., Ciarapica, F. E., & Giacchetta, G. (2012). Integration of design for environmental concepts in product life cycle. In *Design for Environment as a Tool for the Development of a Sustainable Supply Chain* (pp. 11–32). London: Springer.
2. Bhuiyan, N. (2011). A framework for successful new product development. *Journal of Industrial Engineering and Management, 4*(4), 746–770.
3. Bras, B. (1997). Incorporating environmental issues in product design and realization. *Industry and environment, 20*(1), 7–13.
4. Buyukozkan, G., & Arsenyan, J. (2012). Collaborative product development: A literature overview. *Production Planning & Control, 23*(1), 47–66.
5. Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. New York: Taylor and Francis Group LLC.
6. Chorda, I. M., Gunasekaran, A., & Aramburo, B. L. (2002). Product development process in Spanish SMEs: An empirical research. *Technovation, 22*(5), 301–312.
7. Cooper, R. G., & Kleinschmidt, E. J. (2007). Winning business in product development: The critical success factors. *Research-Technology Management, 50*(3), 52–66.
8. Deniz, D. (2002). *Sustainability and environmental issues in industrial product design*.
9. Ernst, H. (2002). Success factors of new product development: A review of the empirical literature. *International Journal of Management Reviews, 4*(1), 1–40.
10. Ernst, H., Hoyer, W. D. H., & Rübsaamen, C. (2010). Sales, marketing, and research and development cooperation across new product development stages: Implications for success. *Journal of Marketing, 74*(5), 80–92.
11. Fain, N., Kline, M., & Duhovnik, J. (2011). Integrating R&D and marketing in new product development. *Journal of Mechanical Engineering, 57*(7–8), 599–609.
12. Fazilah, A. A., Jaafar, N. N., & Suraya, S. (2014). Critical success factors of new product development and impact on performance of malaysian automotive industry. *Advanced Materials Research, 903*(3), 431–437.
13. Felekoglu, B., & Moultrie, J. (2014). Top management involvement in new product development: A review and synthesis. *Journal of Product Innovation Management, 31*(1), 159–175.
14. Gouda, S. K., Jonnalagedda, S., & Saranga, H. (2016). Design for the environment: Impact of regulatory policies on product development. *European Journal of Operational Research, 248* (2), 558–570.
15. Holland, R., Kim, B. Y., Kang, B. K., & Mozota, B. B. D. (2007). Design education for successful cross-functional cooperation in NPD. In *Proceedings of International Conference*

on Engineering and Product Design Education. Newcastle, UK: University of Northumbria September 13–14, 2007.

16. Holland, S., Gaston, K., & Gomes, J. (2000). Critical success factors for cross-functional teamwork in new product development. *International Journal of Management Reviews, 2*(3), 231–259.

17. Hoyle, R. H. (1995). The structural equation modelling approach: Basic concepts and fundamental issues. In R. H. Hoyle (Ed.), *Structural equation modelling: Concepts, issues, and applications* (pp. 1–15). Thousand Oaks, CA: Sage Publications Inc.

18. Huang, X., Soutar, G. N., & Brown, A. (2004). Measuring new product success: An empirical investigation of Australian SMEs. *Industrial Marketing Management, 33*(2), 117–123.

19. Kastensson, Å. (2014). *Managing product innovation in the automotive industry: In light of the environmental challenge*.

20. Lau, A. K. W. (2011). Critical success factors in managing modular production design: Six company case studies in Hong Kong, China, and Singapore. *Journal of Engineering and Technology Management, 28*(3), 168–183.

21. Lynn, G. S., Chen, J., Reilly, R. R., & Li, G. (2005). The critical factors for improving companies' abilities to develop new product faster and more successfully. In Proceedings of IEEE International Conference on Engineering Management (Vol. 2, pp. 632–636).

22. Lynn, G. S., Reilly, R. R., & Akgün, A. E. (2000). Knowledge management in new product teams: Practices and outcomes. *IEEE Transactions on Engineering Management, 47*(2), 221–231.

23. Mendes, G. H. D. S., & Ganga, G. M. D. (2013). Predicting success in product development: The application of principal component analysis to categorical data and binomial logistic regression. *Journal of Technology Management & Innovation, 8*(3), 83–97.

24. Nunnally, J. C. (1978). *Psychometric Theory*. New York: McGraw Hill.

25. Ong, C. S., Lai, J. Y., & Wang, Y. S. (2004). Factors affecting engineers' acceptance of asynchronous e-learning systems in high-tech companies. *Information & Management, 41*(6), 795–804.

26. Rigdon, E. E. (1998). Structural equation modelling. In G. A. Marcoulides (Ed.), *Modern methods for business research* (pp. 251–294). *Mahwah,* NJ: Lawrence Erlbaum Associates Publishers.

27. Sivasubramaniam, N., Liebowitz, S. J., & Lackman, C. L. (2012). Determinants of new product development team performance: A meta-analytic review. *Journal of Product Innovation Management, 29*(5), 803–820.

28. Steen, B. (1999). *A systematic approach to environmental priority strategies in product development (EPS): Version 2000-general system characteristics* (p. 4). Gothenburg: Centre for Environmental Assessment of Products and Material Systems.

29. Thamhain, H.J. (2011). The role of team collaboration in complex product developments. In *Proceedings of IEEE International Conference on Technology Management in the Energy Smart World* (pp. 1–7).

30. Wang, K. J., & Lestari, Y. D. (2013). Firm competencies on market entry success: Evidence from a high-tech industry in an emerging market. *Journal of Business Research, 66*(12), 2444–2450.

31. Wei, F., Ou, L., & HuiTing, H. (2009). The influence of enterprise senior management to NPD projects: An empirical study. In *Proceedings of IEEE International Conference on Management and Service Science* (pp. 1–5).

32. Yeh, T. M., Pai, F. Y., & Liao, C. W. (2014). Technology using a hybrid MCDM methodology to identify critical factors in new product development. *Neural Computing & Application, 24*(3–4), 957–971.