Exploring the Impacts of Technological Integration and Green Process Innovations on Environmental Performance: An Empirical Study of Medium and Large Manufacturing Firms in Kerala

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Abstract

Poorly regulated manufacturing activities paved the way to global warming, ozone layer depletion and increased pollution levels, creating problems worldwide (King and Lenox, 2001; Shukla, Deshmukh and Kanda, 2009). The purpose of this study is to examine the influence of technological integration on green process innovations thereby its impacts on environmental performance. The mediating effect of green process innovations is also analyzed in the study.This descriptive study was conducted among a sample of 174 manufacturing firms - 65 large and 109 are medium manufacturing units in Kerala which constitute of 38.83% of total population. Survey method has been adopted to collect data. Meaningful insights have gained through Partial Least Square method of Structural Equation Modeling, specifically Warp PLS 6.– The findings of the study suggest that technological integration is having an positive influence on green process innovations and have an impact on environmental performance. A theoretical framework has been developed linking the variables technological integration, green process innovations and environmental performance .The study has emphasised implications for theory and practice.The insights of the study provide value-added information to various professional levels;managers can facilitate green and future scope for research.

Keywords: Manufacturing Firms, Technological Integration, Green Process Innovations, Environmental Performance.

1. Introduction

For overall economic growth, the manufacturing sector is considered as a driving force. However, global environmental issues due to various production and product-related activities cause severe ecological impacts.Organisations integrate various strategies such as specific environmental management strategies for promoting sustainable growth, thereby developing better green performance.A detailed investigation must be required to identify the core drivers that can influence the

organisational strategies. Companies often adopt advanced technology as part of eco-innovation to achieve environmental sustainability and create a long-term competitive advantage (Teece, 2007; Wagner and Llerena; 2011).The new product development projects with a high level of TECOR achieve superior new process and product performances and a better EP than projects with a low level of TECOR. Green Innovation (hereafter GI) concept and practice are getting significant attention due to its focus on addressing various environmental issues and research has found multiple antecedents of firms engaging in green innovation (Qi, Zeng, Tam, Yin and Zou, 2013).According to Eiadat, Kelly, Roche and Eyadat (2008) the company's positive green performance and green innovation strategy are linked positively and consequently continue to win-win solutions for environmental problems. However, some studies found no direct association between technology integration and green process innovation (hereafter the term is represented as GRPSI) . As quoted by Chen (2001) environmental performance (hereafter with EP) does not necessarily improve with GRPSI of the organisation. Hence the study focuses on gaining better insights by examining the influence of technological integration on GRPSI and thereby its impact on EP within the context of medium and large manufacturing firms in Kerala. Since the manufacturers are under increased scrutiny regarding EP, of their process and products, the study has also attempted to understand whether the core innovative green strategies such as GRPSI can mediate the technological integration and EP.

2.Review of literature and theoretical framework

2.1 Technological Integration

The effective utilisation of technological possibilities rather than technology explains why firms differ in their innovation efforts (Lindman, 2000).Zhou, Yimand Tse (2005) noted that consumers prefer products and services that maintain technological superiority. The appropriate use of technology in practising eco-innovation has often curbed the negative impacts of human involvement (Doran and Ryan, 2012).The organisations need to give careful consideration towards GI and the use of environment-friendly technologies for the practical usage of resources while developing the environmental practices and efficiency (Galdeano-Gomez, Aznar-Sanchez and Perez-Mesa, 2013). Frambach and Schillewaert (2002) state that the degree to which an organisation is receptive to new ideas will influence its propensity

to adopt new technologies. Hubert and Xuereb (1997) define technology- oriented firms as those with the ability and will to acquire substantial technological background to develop new products.Hojnik and Ruzzier (2015) and Cao and Wang (2017) describe technology as a push factor for eco-innovation, which encourages companies to conduct R & D activities in the development stage the better production efficiency of an enterprise. Based on the studies mentioned above, it has revealed that those firms that can sense and respond to technological advancements are the first to acknowledge various benefits. Hence the study considers TECOR as one of the major driver influencing GI.

2.2 Green Process Innovation

The role of the manufacturing sector towards the socio-economic development of a country is very crucial. However, the growing global issues are primarily attributed to the growth of manufacturing industries leading to environmental degradation, severe health hazards to humanity and a risk to sustainable development. Innovation in the manufacturing industry is more radical and has a more substantial impact on performance than in the service sector (Prajogo, 2006). Frenken and Faber (2009) emphasised that GI has commonly recognised environmental innovations that provide an essential key to sustainability and reduce the firm's environmental impacts and enables the organisation to achieve eco-targets and ecological benefits (Bernroider, 2002).Leal-Rodriguez, Ariza- Montes, Morales-Fernandez and Albort-Morant (2018) reminded us that GI aims to realise a win-win solution for reducing the conflicts between economic development and environmental protection. Hence there is an urgent need to examine and identify the core innovative green strategies in the manufacturing sector to bring sustainable growth.Here comes the relevance of GRPSI which can address the most critical issues facing companies due to pollution, increased waste generation and energy shortages.

Process innovation brings new elements in an organisation's production in terms of input materials, task specifications, work and information flow mechanisms, equipment used to produce a product or render a service to achieve lower costs, higher product quality (Damanpour, 1987; Reichstein and Salter, 2006). Studies (Brunnermeier and Cohen, 2003; Chen et al., 2006; Chiou, Chan, Lettice and Chung, 2011; Conding, Habidin, Zubir, Hashim and Jaya, 2012; Santamaría, Nieto and Miles,

2012) support GRPSI application in a broad context. These studies indicate that GRPSI involves process-related to energy- saving, preventing pollution, low energy consumption, recycling, reuse and re-manufacture material. Moreover, the use of cleaner technology to make savings and prevent pollution is crucial. Hence Wong (2012) indicated that GRPSI is applying innovative initiatives to design and manufacture new products that significantly reduce the negative impact on the environment and promote sustainability.Hence the study extended its focus on understanding whether GRPSI creates an impact on EP.

2.3 Environmental Performance

The growing number of manufacturing firms, along with environmental issues, is increasing on one side.The fundamental cause of performance differentials is mainly because of organisations' resources and capabilities which offer competitive advantages (Teece, 2007; Barney, Ketchen and Wright, 2011).According to Shoham, Rose and Kropp (2005) organisations need to manage their relationship with the environment to maximise their performance. Since better EP can achieve through different types of innovative green practices and that not all these practices have the same effects on EP, managers are increasingly probing to identify, manage and improve green sustainability drivers that deliver better performance (Epstein, 2008). An empirical study that identifies the prominent driver that influence GRPSI and its influence on EP of medium and large manufacturing firms in Kerala has not yet been undertaken so far. Hence the primary phase of the study has mainly focused on filling this gap.-

3.Theoretical framework and hypothesis development

This research study is aimed at identifying the relationship between technology integration ,green process innovation and environmental performance. The lack of technical information and knowledge will lead to difficulties in finding alternative solutions in designing new technologies, materials, operations and industrial processes related to green innovation initiatives (Van Hemel and Cramer, 2002). Higher capacity to assimilate new environmental technologies is more likely to bring GRPSI (Albornoz, Cole, Elliot and Ercolani, 2014). In the words of McWilliams and

Siegel (2011) GRPSI requires firms to invest resources in enhancing manufacturing and production by utilising green technology and upgrading green capability.

Hamdoun, Jabbour and Othman (2018) indicated that technology turbulence continues to influence organisational processes. The creative teams can also quickly develop creative ideas to produce several alternatives by which GRPSI may engender. Hence technological knowledge accumulation increases the firm's ability to evaluate and use new technologies and product innovation skills (Zahra and George, 2002).According to Utterback and Abernathy (1975) and Guoyou, Saixing, Chiming, Haitao and Hailiang (2013) three crucial elements involved in GRPSI are the reduction in the emission of hazardous substances or waste, the consumption of water, electricity, coal and oil and the use of raw materials. GRPSI is more to new methods that can contribute to environmental protection by minimising production waste, enhancing resource efficiency (Chang, 2011), uses inputs with high efficiency and the least environmental effects (Amemba, Nyaboke, Osoro and Mburu, 2013). The adoption of GRPSI help firms enhance their EP and reap the benefits of sustainability and profitability (Hojnik and Ruzzier, 2016; Huang and Li, 2017; Ramanathan, He, Black, Ghobadian and Gallear, 2017), financial and non- financial performance (Peng and Lin 2008).

Adopting new and better-performing technologies could foster implementing corporate, varied standards of EP and compensations (Renwick, Jabbour, Muller-Camen, Redman and Wilkinson, 2016). Green operational management can provide a solid foundation for externally oriented green, practice implementation (Green et al., 2012), great potential for performance improvement (Schrettle, Hinz, Scherrer-Rathje and Friedli, 2014; Jabbour, Sousa Jabbour, Govindan, De Freitas, Soubihia, Kannan and Latan, 2016). i.e., GRPSI is having an essential role in maintaining a firm's green image (Chen, 2008).The technology-oriented organisations encourage R & D activities, acquisition and use of the latest technologies, thereby accumulating rich technology knowledge with the help of experiences and processes Gatignon and Xuereb (1997). Al-Ansari, Altalib and Sardoh (2013) and Lee, Dedahanov and Rhee (2015) highlight a significant and positive relationship between TECOR and innovation.The study gains more relevance among medium and large manufacturing firms unlike on small firms and the study hypothesize that:

H1 : Technological Integration have a positive influence on Green process innovations.

H2 : Green process innovations have a positive influence on environmental performance.

H3 : Green process innovations mediate the relationship between technological orientation and environmental performance

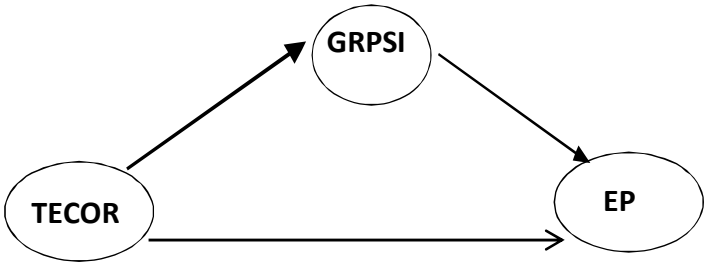

Fig 3.1 The Conceptual Frame Work of the Study

4.Research methodology

4.1 Overview of sample and procedures

The study used an online survey to increase the response rate and avoid the time-consuming interview process. The hard copy of a questionnaire was forwarded to those firms that demanded the same. A total of 174 valid responses was collected,65 large and 109 are medium manufacturing units,translating into a response rate of 38.83 %.Out of the 174 firms surveyed the major industrial categories are Food products (19.5%), Chemical products (18.4%), Rubber and plastic products (14.4%), Electrical and electronic products (12.6 %), Pharmaceutical products (10.3 %), Leather and related products (6.9 %), Paper products (4.0 %), Textiles (2.9%), Non-metallic, Glass and mineral products (2.9 %) , tobacco products (0.6%) and others (2.9 %), Wearing apparel (1.1%), Metallic products (1.1%), Wood products (1.2%), Petroleum products (0.6%), Transport equipments (0.6%).

The major industrial sector belongs to the food sector followed by chemical ranks second with Rubber and Plastics Products in the third position. Most of the companies offered their products at various market levels. The operational area of 25.3% of the firms is in the national market, 24.7% in the international market, 22.4 % in the local

and regional markets, 16.1% in the local/regional, national and international market, 9.2% in the national and international market and (2.3%) in the local /regional market and a national market.72.4 % of the respondent firms belong to the private sector,21.3 % to the public sector and 6.3% to the joint venture.9.2 % of the firms in the survey started their operations before 1950, 13.8 % between 1950 and 1975, 47.7% between 1976-2000 and 29.3% from 2001 onwards.Regarding the firms' annual sales turnover 33.9% of firms are having 11-50 crores, 27.6% of firms are with less than 10 crores, 19.5% of firms are having 101-500 crores and 19% are with 51-100 crores.Regarding the ownership details of the firms participated in the research study, 72.4 % of the respondent firms belong to the private sector,21.3 % to the public sector and 6.3% to the joint venture.The majority of the respondents of the study were production /operations managers of medium and large manufacturing firms.

4.2 Measures

TECOR is measured using a four-item scale developed by Zhou and Li (2010) and adapted from Gatignon and Xuereb (1997) capturing firm's willingness and readiness to pursue, accept and use of sophisticated technologies in the process and product development. The GRPSI is measured using the four-item scale developed by Huang and Li (2017) adapted from Chen, Lai and Wen (2006), Chen (2008) and Chiou, Chan, Lettice and Chung (2011). The study measures the EP using the scale of Zhu, Sarkis and Lai (2008) with six items. The respondents are asked to indicate the extent to which the organisation reduces waste, usage of hazardous materials, air pollutants emission, environmental accidents frequency thereby improve the environmental situation.All the items are measured in a five-point Likert scale with options ranging from 'Strongly Disagree' (1) to 'Strongly Agree' (5).

4.3 Data analysis

The hypotheses related to influence of TECOR on GRPSI and their impact on EP have analysed using SPSS version 23 and PLS-SEM specifically Warp PLS 6 and PROCESS MACRO 4 for mediation analysis .Cronbach's Alpha and Composite Reliability coefficients for the sample are above the 0.7 recommended threshold, meaning the instrument used has adequate reliability (Nunnally, 1978).The study

found that TECOR,GRPSI and EP is having Cronbach's α value (0.924), (0.86), and (0.951) respectively and composite reliability as TECOR (0.946), GRPSI (0.905) and EP (0.961).Composite Reliability was higher than the recommended 0.7 value (Nunnally and Bernstein, 1994). The Convergent Validity of the measurement model, established by acceptable criteria and the significant indicator loading on latent constructs are above 0.5.The square root of AVE (values have shown in shaded columns in Table 4.1) values is higher than the off- diagonal values (which represent the inter-construct correlations), which is the condition for Discriminant Validity (Peng and Lai, 2012). The analysis has provided good results for reliability, Discriminant Validity and Convergent Validity, indicating the measurement model's soundness.

Table 4.1: Discriminant Validity Measures among Latent Variables with Square roots of AVEs

Variable	TECOR	GRPSI	EP
TECOR	0.902	0.689	0.673
GRPSI	0.689	0.839	0.612
EP	0.673	0.612	0.897

Table 4.1 reveals that the square root of AVE (values have shown in shaded columns) values is higher than the off- diagonal values (which represent the inter-construct correlations), which is the condition for Discriminant Validity (Peng and Lai, 2012).

5. Results

Analysis of Structural Model

Since the analysis has provided good results for reliability, Discriminant Validity and Convergent Validity, indicating the measurement model's soundness further analysis can be taken to the next stage of structural model evaluation.This study's structural model was assessed through PLS-SEM's path analysis technique to test the stated hypotheses. study's structural model was assessed through PLS-SEM's path analysis technique to test the stated hypotheses. All the indices such as APC is 0.203; ARS is 0.565; AARS is 0.555. It has recommended that the p values for APC, ARS and AARS be equal to or lower than 0.05; i.e., Significant at 0.05 level. The study results

show that APC, ARS and AARS values are significant at the 0.05 level. The AVIF values are 2.269; AFVIF is 3.066; Tenenhaus GOF is 0.658. The SPR is 1.000, RSCR is 1.000; SSR is 1.000 and NLBCDR is 0.941. All these indices are within the threshold limit. Warp PLS estimates path significance (p-values) for the path coefficients (beta value) in the model. Table 5.1 shows the path coefficients and significance of the relationships among variables under the study.

Table 5.1: Path Coefficient and Significance of Relationship

Hypothesis	Structural path	Path coefficient	P-values	Std.Error	Effect Size
1	TECOR □-□ GRPSI	0.155	0.018	0.073	0.107
2	GRPSI □-□ EP	0.423	<0.001	0.069	0.263

The table 5.1 shows the analysis of path coefficients and significance values of relationships leads us to conclude that all the hypotheses are supported. TECOR exhibited positive relationship with GRPSI as well as GRPSI with EP(β=0.155; p=0.018; β = 0.423; p=<0.001), thereby supporting H1 and H2. Study uses PROCESS macro for testing the mediation effect of variables.Utilised the bootstrapping method using model 4. The number of bootstrap samples for percentile bootstrap confidence intervals is 5000. The Sample Size of the study is 174.

Table 5.2 : The Significance of the Influence of TECOR on GRPSI

Outcome	Model	coeff	se	t	p	LLCI	ULCI
GRPSI	Constant	1.5924	.2294	6.9431	.0000	1.1397	2.0452
	TECOR	.6383	.0512	12.4705	.0000	.5373	.7393

Table 5.2 shows that TECOR significantly influences GRPSI because (p<.05). Hence it is stated that the TECOR significantly influences the mediator.

Table 5.3: The Influence of GRPSI on EP

Outcome Model	coeff	se	t	p	LLCI	ULCI
Constant	.2385	.2756	.8655	.3880	-.3055	.7826
TECOR	.1181	.0887	1.3321	.1846	-.0569	.2931
GRPSI	.3888	.0737	5.2782	.0000	.2434	.5342

Table 5.3 shows the second stage of mediation analysis, which tests the relationship between mediator and the dependent variable. Considering both the cases, the p-value

is (p <.05). Therefore, it indicates that GRPSI (mediating variable) have a significant influence on EP.

Table 5.4: Total Effect of TECOR - EP

Direct	Effect	se	t	p	LLCI	ULCI
	.6603	.0552	11.9542	.0000	.5513	.7694

Table 5.5: Direct Effect of TECOR - EP

Direct	Effect	se	t	p	LLCI	ULCI
	.1181	.0887	1.3321	.1846	-.0569	.2931

Table 5.5 shows the direct effect of TECOR on EP is insignificant since p>.05.

Table 5.6: Indirect effect(s) of TECOR -EP

	Effect	BootSE	BootLLCI	BootULCI
Total	.5422	.0859	.3699	.7114
GRPSI	.2482	.0567	.1410	.3639
CI	-.0459	.0895	-.2243	.1287

Table 5.6 shows the indirect effect of TECOR on EP through the GRPSI tested using PROCESS Macro Model 4. Results reveal a significant indirect impact of TECOR on EP through GRPSI since value zero does not appear between bootstrap intervals (Boot LLCI=.1410 and Boot ULCI = .3639). Thus, hypothesis 3 is also supported.The last section of the table 5.6 indicates the result of contrast analysis. There is a significant indirect effect of TECOR on EP through GRPSI. The contrast analysis shows that the indirect effect difference is not significant since the confidence interval range covers the value zero (Boot LLCI= -.2243 and Boot ULCI = .1287).

Table 5.7: Summary of Hypotheses Tests Results

Variables Path	Status
TECOR → GRPSI	Supported
GRPSI → EP	Supported
TECOR → GRPSI → EP	Supported

Note: Supported indicates a hypothesis as found statistically significant.

6.Discussions

The study results point out that TECOR has a significant positive influence on GRPSI thereby supporting the hypotheses (H1). The findings justify the views of Madrid-Guijarro Garcia and Van Auken (2009) that the insufficient availability of market, technical knowledge on environmentally friendly products and processes prevent firms from proceeding to the next level of product or process innovations. Based on the findings, the study confirms that TECOR is more advantageous and helpful for organisations to perform better in GRPSI.Firms use improved EP to lower their costs by reducing waste in their production processes (Shrivastava, 1996). The study stresses the findings of Tseng, Divinagracia and Divinagracia (2009) that low energy consumption, such as water, electricity, gas and petrol during production/ use/disposal and use of cleaner technology make savings and prevent pollution. In short, the study highlights the view of Chiou et al. (2011) that when focusing on GRPSI companies or manufacturers can save cost, increase efficiency, productivity and better product quality leading to improved green performance.GRPSI mediate TECOR and EP of the firm (H3 is supported). Shrivastava's (1995a) findings that green technologies reduce the firm's negative influences and trigger EP improvement. Green technology deployment is critical to support environmental innovations, to minimise environmental degradation and to reduce GHG emissions in the production stage (Fernando, Wah and Shaharudin, 2016). Hence the advanced and result oriented TECOR enables the organisation to have a better and improved EP through the efficient GRPSI in terms of reduced pollution, waste reduction or waste management, energy savings and reduced water consumption.

7.Implications of the Study

Klassen and McLaughlin (1996) and Kralj (2008) mentioned that increased environmental issues could not be managed in isolation from manufacturing activities; manufacturing has linked to environment-related practice management within the firm. The study points out that GRPSI are the most crucial strategies adopted by manufacturing organisations to improve EP.The mediating role of GRPSI between the independent variable and dependent variable has proven statistically. Through extensive literature review, a theoretical model has developed to show the influence of TECOR on GRPSI and its impacts on medium and large manufacturing firms. The data were validated empirically by statistically analysing the data collected from 174 firms in Kerala state.Various empirical studies were already done in the area of GI but these studies focused more in developed countries and dominate existing literature. There are only a few studies in developing countries and no such studies in Kerala state on this topic. Hence this is one of the initial empirical studies in Kerala state based on medium and large manufacturing firms.

The study provides insights for managers by a better understanding of TECOR that influence GRPSI thereby its influence on EP. Suitable manufacturing technologies can provide an organisation with considerable operational and competitive benefits (Sohal and Terziovski, 2000). TECOR, specifically technology-based applications, is crucial in facing the competition and availing of various benefits. Green activities like solid waste management (Shanklin, Petrillose and Pettay, 1991), energy savings (Chan and Lam, 2003), water conservation (Chan and Lam, 2001), air pollution control (Shanklin, 1993), product recycling and reuse lead to better business performance (El Dief and Font, 2010). Hence managers can ensure to have a sufficient allocation of funds for technological aspects.For effective adoption and integration of newer technologies, green training could reinforce team members' capabilities in attaining set environmental sustainability objectives (De Medeiros et al., 2014). The TECOR is crucial to foster result-oriented GRPSI with a less negative impact on the environment. Hence the top management must have a keen interest in various core areas such as technological upgradations, technological policies, adoption of result-oriented technologies, allocating sufficient funds towards implementing the right technology and adequate technical training to develop

technically oriented experts. The study results show that GRPSI has a direct environmental outcome and positive impact in improving EP; the managers have to consider GRPSI as a crucial part of management decisions.

EP and its indicators are very useful at various levels of users such as corporate managers, production plant managers, marketing managers, purchasing managers, investors and shareholders to achieve and evaluate their specific objectives. EP plays a critical role in firms' sustainability (Claver, Lopez, Molina and Tari, 2007).The research study has implications for society as well. Industries in Kerala, especially the chemical, pharmaceutical, food, electric and electronics sectors, have the efficiency and capability to become the world leaders in manufacturing. Such growth has come out after a long run and rapid industrialisation has generated numerous environmental problems. Since the natural environmental issues increase, firms are more likely to be more focused on building up a social image essential for companies to improve their market position, affirm their brand's reputation and attract customers. Hence GI can perform as a win-win proposition for both individual firms and society as a whole. Society communicates its expectations for GIP to the firm through external stakeholders' demands, including downstream members of the supply chain (Alan Greenspan, 2002). GRPSI practices improve EP and help firms to enact in a more socially responsible manner, strengthening the social legitimacy and existence in the eyes of society or the public. The study also emphasises that better profits and social benefits have ensured through GRPSI thereby better EP.

8.Limitations and Scope for Future Research

According to Damanpour (1996) and Vega-Jurado, Gutierrez- Gracia, Fernandez-de-Lucio and Manjarres-Henríquez (2008) innovation and innovative performance in organisations vary from sector to sector. The cross-sectional data do not consider the degree of unobserved heterogeneity among firms, the cause and effect relationship in the model fully and the changes in GI over time (Ghisetti and Rennings, 2014). The study results are based on a sample size of 174 firms drawn from different sectors with different size, production processes and products. It focuses on analysing the relationship between the constructs rather than generalising the findings with a specific industrial sector.The study measures the critical variables at a single point of

time, limiting the ability to discern any changes in the variables such as GRPSI, EP. over time and thereby infer causation. The study does not view changes in performance over time.The analysis has been based on top management personnel's perceptual data and did not measure the actual environmental or firms' performance outcomes.

Kerala is a consumer state. The study area is medium and large manufacturing firms in Kerala state, which differs from firms operating in different markets and states in India. Future studies can test the theoretical framework with data from medium and large manufacturing firms of other states within the home country to examine the similarities and differences that could add to the GRPSI and EP literature.Rather than having a snap short nature model, future research with a broader frame of reference has to consider through incorporating more potential drivers in terms of firm resources and capabilities, additional dimensions of GI as mediating variables, even moderating variables such as environmental investment for further insights into the mechanisms that trigger GI success and its impact on EP.The present study about the manufacturing firms does not consider the GIP, EP of the service sector. Thus, future research may examine the applicability for service sectors since the service sector has been growing much faster in many developing nations, including India. Therefore, it is necessary to pay more attention to study new green services (King and Lenox, 2002).The study used a single key informant or respondent on measuring independent, mediating and dependent variables. A multiple informant approach can be used in future research to provide a more reliable model test. Data collection can be from various respondents both from inside and outside the organisations such as corporate employees, suppliers, customers, policy-makers.

9.References

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