Triple Bottom Line performance of reverse logistics: Graph Theory Approach

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Abstract: Reverse logistics has gained importance because of growing attention towards circular economy and environmental concerns. Reverse logistics is an important component of circular economy and makes a significant contribution to sustainability. However, literature review indicates that there are very few studies related to incorporating reverse logistics into the concept of sustainability. Also, the performance evaluation models are mostly traditional focusing on its economic performance. The article is aimed at developing a performance measurement model based on economic, environmental, and social sustainability, known as triple bottom line concept. The model utilizes Graph Theory Approach for developing the frame work of performance measure model. A case of mobile manufacturing firm is considered for the illustration of the model. The permanent function value of the matrix developed is referred as reverse logistics performance index. The findings of the study and RL performance index will help the firm in evaluating the reverse logistics performance from triple bottom line perspectives. The model will help academicians, and industry for evaluating, and benchmarking the RL performance.

Keywords: Reverse logistics; Sustainability; Triple bottom line; Performance; Graph Theory Approach

I. INTRODUCTION

In last few years reverse logistics (RL) has become a part of business of many organizations because of increased pressure of consumers and regulatory authority for managing end of life products. Also, product returns have been increased because of competitiveness among business. Implementation and adoption of RL practices enables manages to manage their products efficiently in an effective manner. RL activities involved collection of returned products through retailers, or directly, or through third party service providers. The collected items are inspected and segregated into different categories. These items are then disposition for either remanufacturing or refurbishing, or recycling depending on the quantity of returns and status of quality of retuned products. However, RL implementation faces several challenges such as uncertain timing and quantity of returns, uncertainties of product/component/materials recovery and their value in terms of economics benefits, and the consumer awareness. Despite all these challenges, many organizations like HP, Dell, Kodak and many more have successfully implemented RL system. One of challenges is to develop a performance measuring system for RL so that performance could be traced, evaluated, and improved. Various methodologies, for measuring RL performance have been developed in the past. Analytical methodologies include the model developed by Neely et al. [1] is based on efficiency of various actions. Shaik and Kader [2] combined AHP with balanced score card and proposed a RL system for measuring its performance. They also developed a performance measurement system based on balanced score card and DEMATEL methodology [3]. The Balanced scorecard, developed by Kaplan and Norton [4] is based on the four perspectives including economic, customer, internal business process, and learning & growth perspectives. Various qualitative techniques have also been utilized for measuring the RL performance. Lambert et al. [5] proposed a scenario-based framework considering factors at strategic, operational, and tactical level performance. Bai and Sarkis [6] introduced a framework which is scenario based and utilized rough-set methodology. There are models developed considering both qualitative and quantitative factors for measuring RL performance [7]. The performance measuring system of RL are mostly focused on economic aspects of the performance and very few also considers the environmental performance of RL. According to Devika et al. [8], there are very few studies considering social aspects of the RL. Sudarto et al. [9] developed a framework for measuring the social performance of RL. Sangwan [10] proposed a framework for selecting performance measure based on RL activities. According to Hutomo et al. [11], RL activities significantly enhances the sustainability of organizations. The research on RL considering economic, social and environmental aspects of sustainability (popularly known as triple bottom line (TBL)) together is limited [12], [13]. Agrawal et al. [14] developed a RL performance evaluation system using fuzzy-AHP approach which is based TBL aspects of sustainability. However, this framework provides comparative study of the electronics industry [14]. Also, the AHP considers hierarchy among different levels and interaction among variables is not allowed. While ANP allows the interaction among variables, it does not have hierarchy at various levels. In order to take advantage of both methodologies, proposed study utilizes graph theory approach (GTA) for developing the TBL based RL performance index.

The remainder of the article is organized as follow. Section 2 discuss the literature pertaining to reverse logistics and identifies the key performance measures for measuring RL performance. Section 3 explains the step by step of graph theory approach. A case of mobile manufacturing firm is discussed for the illustration of methodology in section 4. It consists of profile of the firm, development of model, and results and discussion. The article is concluded in section 5.

II. LITERATURE REVIEW

RL has gained a lot of preference both from the academicians and industry because of consumer awareness and their concerns for environment, and regulatory requirements in many countries. Rogers and Tibben-Lembke [15] provided the most acceptable definition of RL and defined RL as “the process of planning, implementing, controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.” Key functions of RL include the collection of products after their acquisition, their inspection, separate them into different categories, and disposition them. The disposition options in RL include repairing, reusing, remanufacturing, recycling, or sell them as it is in the secondary markets. However, it greatly differs to forward logistics both conceptually and operationally. Forecasting, planning and scheduling is easy in forward logistics because less uncertainty in terms of quantity, quality, and timing of product returns. In general, forward logistics flows works on pull type production system based on consumer demand while RL is based push type system in which process starts only when product returns. these returns are uncertain which makes RL system complex [16]. The costs of operations also vary between the two because of less visibility in RL operations [17]. Because of all these reasons, measuring RL performance is also a challenge. However, “the performance measurement systems can provide companies with relevant, appropriate, complete and accurate information. The companies have opportunities to monitor and reposition their management and operations to obtain highly competitive environment” [18].

The number of performance measuring systems have been developed in the past. Bansia et al. [19] developed a fuzzy AHP based RL performance measurement model for a battery manufacturer. Yellepeddi [20] developed a model based on the ANP and fuzzy logic to measure the overall performance of the RL system of an organization. Yellepeddi et al. [21] also utilized balance scorecard and developed RL performance index for an electronics enterprise. Shaik and Kader [2] combined AHP with balanced score card and proposed a RL system for measuring its performance. They also developed a performance measurement system based on balanced score card and DEMATEL methodology [3]. Biehl et al. [22] proposed as performance evaluation system considering economic and environmental factors. Paksoy et al. [23] considered total transportation costs, total environmental costs, emission rates, and customer demand while developing a RL performance measurement system.

Bai and Sarkis [6] developed a RL performance measurement system considering economic, environmental, and operational factors. Presley et al. [12] conceptualized the relationship between RL and sustainability by highlighting the importance and role of RL in achieving the TBL aspects of sustainability. TBL components include economic, environmental, and social aspects of sustainability. The social component refers to support the formation and growth of skills, and the competences of the employees so that they could meet current and future needs of generations [24]. Agrawal et al. [14] developed a performance measurement system based on fuzzy AHP methodology and considered the factors from TBL perspectives.

Table 1. TBL performance measures

Performance Measures	Description	References
Economic Performance		
Improved Profitability	It measures the performance in terms of improvement in profitability because of RL practices	Huang et al. [25], Ferguson et al. [26]
Resale revenue	It is the revenue generated because of the resale of the returned products	Shaik and Kader [3], Larsen et al. [27], Lai et al. [28]
Disposal Costs	It is the cost reduction of disposal due to adoption of RL practices	Kilic et al. [29], Shaik and Kader [3], Niknejad and Petrovic [30]
Return on RL investment	It is the return on the investment in developing RL system	Prakash and Barua [31], Presley et al. [12], Zhou and Zhou [32]
Environmental Performance		
Compliance with regulatory requirement	Measuring the extent of compliance with regulatory requirement	Huang et al. [25] Shaik and Kader (2014), Bazan et al. [33]
Improved brand image	It is the measure of improved brand image because of environmental initiatives under RL	Huang et al. [25], Rubio and Beatriz (2017), Khor et al. [34]
Reduced waste	It represents the waste reduction in the organization after implementation of RL	Niaki et al. [35], Kuik et al. [36]
Reuse of raw material	It is measure of reuse of raw material recovered after recycling	Shaik and Kader [3], Dapiran and Kam [37]
Social Performance		
Community issues	How frequently and number of complaints received by an organization	Presley et al. [12], Piecyk and Björklund [38], Bai and Sarkis [6]
Health and safety of stake holders	Contribution and improvement in the health and safety of stake holders	Shaik and Kader [3], Islam et al. (2018)
Employability	Training and skill development efforts for increasing employability	Khalili et al. [40], Nikolaou et al. [13]
Corporate social responsibility	How the organization is doing in achieving corporate social responsibility target through RL	Gong et al. [41], Nikolaou et al. [13], Yu et al. (2016)

III. GTA METHODOLOGY

The RL performance measurements systems have been developed by utilizing approaches such as AHP, ANP, and DEA. TOPSIS and AHP are suitable when the performance measures are independent (Rao and Padmanabhan, 2006). While AHP represents hierarchy among different measures, ANP does not consider hierarchical relationship among measures. According to Rao and Padmanabhan (2006), DEA is not adequate for discrimination among different measures. Graph Theory Approach (GTA) considers both hierarchy among measures and at the same time inter-relationship among them.

Therefore, GTA has been utilized for developing RL TBL performance index. GTA has been utilized in the past for developing indices and models for various problems including the RL systems. Agrawal et al. [42] utilized this approach for developing disposition decision index and disposition-decision making in RL. The approach was also utilized for selection of collection centers locations [43].

In GTA, directional graph also known as di graph are used to represent the inter-relationship between the performance measures. These digraphs are translated into matrices if number of parameters are large and relative importance of performance measures is assigned based on the selected scale. Scale shown in table 2 is used for the proposed study. Off diagonal elements represent the relative importance values of performance measures. Diagonal elements represent the absolute importance of performance measures. The absolute performance is compared based on scale shown in table 3. The RL performance index may be determined by calculating permanent function value of matrices.

Table 2. Scale for relative importance of performance measures

Description	a_{ij}	$a_{ji} = 1\text{-}a_{ij}$
Two measures are equally important	0.5	0.5
One measure (i) is slightly more important over the other (j)	0.6	0.4
One measure i) is strongly more important over the other (j)	0.7	0.3
One measure (i) is very strongly important over the other (j)	0.8	0.2
One measure is extremely important over the other	0.9	0.1
One measure is exceptionally more important over the other	1	0

Table 3. Scale for absolute performance measures

Description	*Diagonal element* D_i
Exceptionally low	0.0
Extremely low	0.1
Very low	0.2
Low	0.3
Below average	0.4
Average	0.5
Above average	0.6
High	0.7
Very high	0.8
Extremely high	0.9
Exceptionally high	1.0

Performance measures defining the RL performance of an organization are selected and a hierarchical model is developed. After selecting performance measures, a digraph is prepared showing all the performance measures and their inter-relationship. Let us assume that there are N number of performance measures with relative each having relative importance represented by a_{ij} , where i presents the i^{th} performance measure and j represent the j^{th} performance measure.

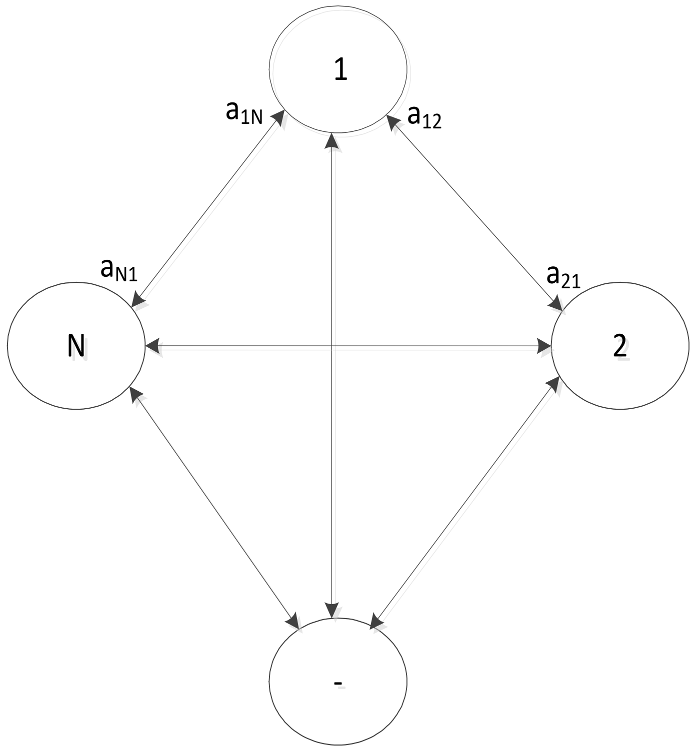

Figure 1. Representative digraph of N performance measures

The diagraph for N number of performance measures, shown in figure 1 is converted into the matrix form. It is an NxN matrix showing relative importance and absolute importance represented by D_i, where i = j=1,2,…N.

$$[A] = \begin{bmatrix} & 1 & 2 & - & N \\ 1 & D_1 & a_{12} & - & a_{1N} \\ 2 & a_{21} & D_2 & - & a_{2N} \\ - & - & - & - & - \\ N & a_{N1} & a_{N2} & - & D_N \end{bmatrix}$$

In general, the permanent of an N×N matrix, [A] with measures a_{ij} defined by Forbert and Marx [44] as

$$\mathrm{Per}(A) = \sum_{p} \prod_{i=1}^{N} a_i\, , P(i)$$

Where, the sum is overall permutations P.

IV. CASE ILLUSTRATION

A case of mobile manufacturing firm has been considered for the illustration of methodology. The case is explained in the following section.

A. Profile of the firm

A case of mobile manufacturing firm, ABC limited has been considered for the case illustration. The ABC limited is one of the key mobile manufacturing firm in low cost segment in India. Since its start in 2009, the firm has grown up to more than 15000 employees having turnover of approximately USD 1.2 billion. The firm is situated in Noida, NCR Delhi, India and running operations in whole of the country and neighboring nations including Sri Lanka, Nepal, and Bangladesh. The firm's market share in India was 8% of total mobile market in last financial year. The firm has vast distribution network of 900 distribution with single tier supply chain system. The firm is committed to "Make in India" initiative and establishing mobile design center in India. The firm has taken initiative for e-waste management and corporate social responsibility. The firm is interested in developing a performance measurement in terms of economic benefits along with their performance in environmental and social perspectives. Data were collected through visits to the firm's manufacturing facility and corporate office both situated in NCR Delhi, India. Discussions were held with people involved in operations, sales and distribution, corporate social responsibility, human resource management, and finance department. Additional discussions were held with plant manager along with two of the vendors supplying parts to the firm.

B. Development of RL performance measurement model

The RL performance measurement model is based on the GTA and triple bottom line concept of sustainability. Since GTA involves hierarchical structures among variables. The first level of performance measures has been selected based on economic, environmental, and social performance of the RL. These are represented as ECP, ENP, and SCP respectively. The economic performance, environmental performance, and social performance are represented by the ECP, ENP, and SCP respectively. The second level of performance measures are selected for all respective three first level of measures. The first economic performance measure improved profitability is represented as EC-1, similarly resale revenue as EC-2, disposal costs as EC-3, and return on RL investment as EC-4. The environmental performance measures compliance with regulatory requirement, improved brand image, reduced waste, and reuse of raw material are represented as EN-1, EN-2, EN-3, and EN-4 respectively. The social performance measures community issues, health and safety of stake holders, employability, and corporate social responsibility are represented as SC-1, SC-2, SC-3, and SC-4 respectively. The hierarchical structure for measuring RL performance is shown in figure 2.

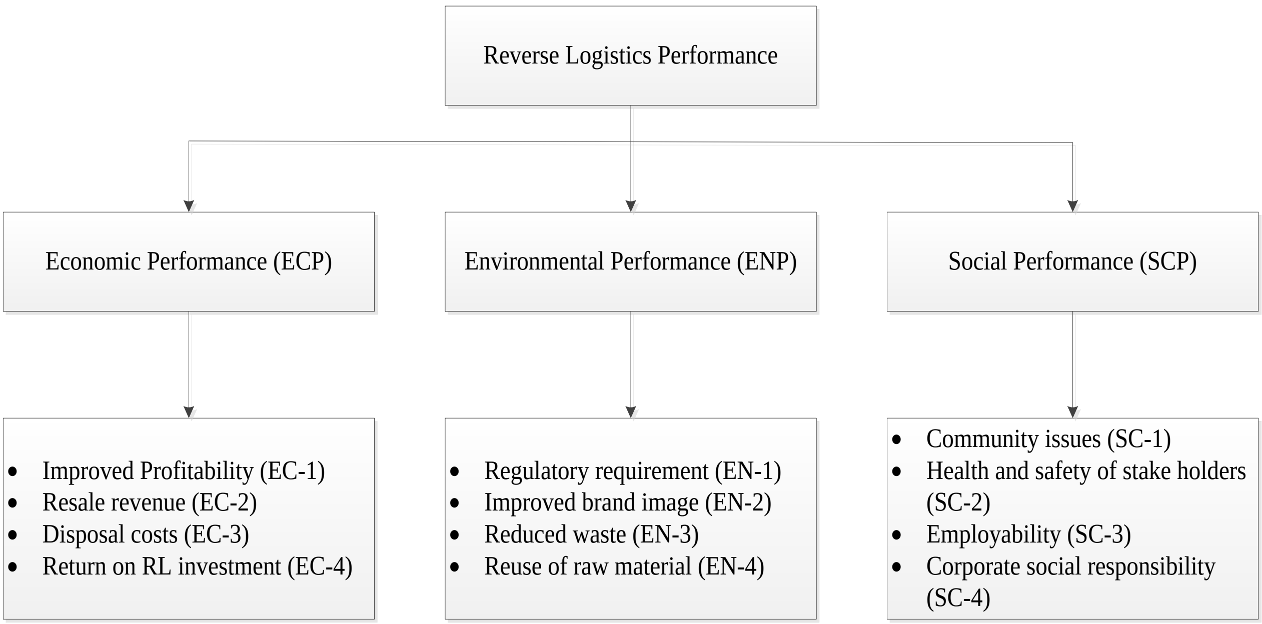

Figure 2. Hierarchical structure of the performance measures

C. Results and Discussion

To measure the RL performance, TBL concept of sustainability has been utilized. Three components of TBL, that is economic, environmental, and social performance have been selected as first level of performance measures. The second level of measures for each first level performance measure have been selected from the past literature review. These performance measures are shown in table 1. Since GTA has been applied for measuring RL performance, A hierarchical model is developed as shown in figure 2.

The next step is to prepare digraph for each level of performance measures. The digraph for measuring RL performance has three performance measures i.e. economic, environmental, and social performance. The digraph for the three performance measures is shown in figure 3.

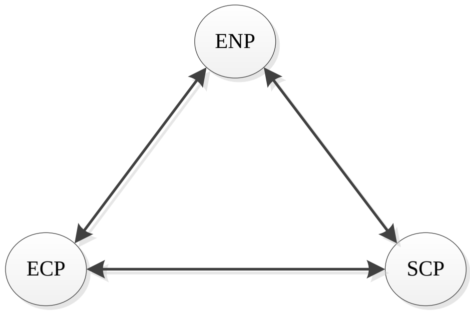

Figure 3. Digraph for first level of performance measures

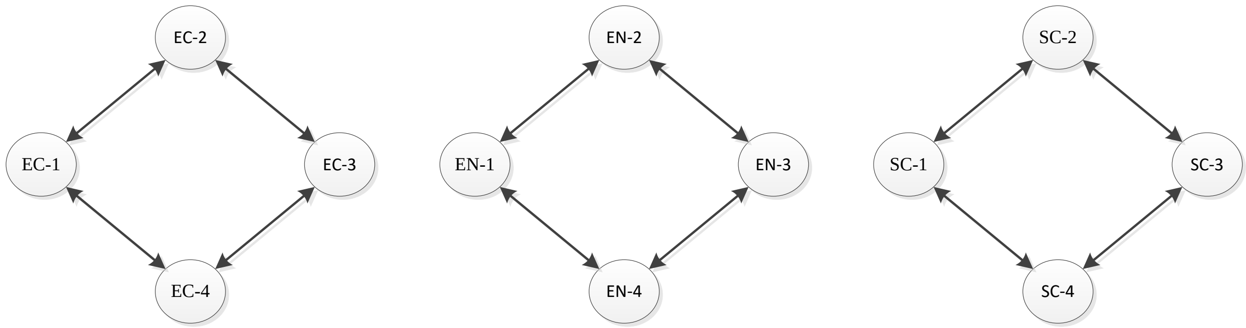

Figure 4. Digraphs for second level of performance measures for (a) economic performance (b) environmental performance (c) social performance

The next step is to convert these digraphs into matrices. The values for the off-diagonal elements and diagonal elements are selected by using the table 2 and table 3 respectively. For first level performance measures, experts were asked to compare the three performance measures and give their opinion. Based on opinion of all the experts, high mode value has been selected and all the values of relative performances are shown in the matrix. The off-diagonal values of elements will come from the permanent function values of respective second level values.

Matrix for the first level of performance

$$\text{Matrix for over all performance}[A] = \begin{bmatrix} & ECP & ENP & SCP \\ ECP & & 0.7 & 0.8 \\ ENP & 0.3 & & 0.6 \\ SCP & 0.2 & 0.4 & \end{bmatrix}$$

For second level of performance measures, matrices [ECP], [ENP], and [SCP] are developed for economic, environmental, and social performance respectively. The experts were asked to compare the respective performance measures for each matrix on the scale shown in table 2. The off-diagonal values are selected based on responses received from the experts. Then, experts were asked to select values for diagonal elements from the scale shown in table 3.

Matrix for second level of performance

Matrix for the economic performance, [ECP]

$$= \begin{bmatrix} - & EC-1 & EC-2 & EC-3 & EC-4 \\ EC-1 & 0.6 & 0.6 & 0.6 & 0.4 \\ EC-2 & 0.4 & 0.7 & 0.4 & 0.6 \\ EC-3 & 0.4 & 0.6 & 0.4 & 0.5 \\ EC-4 & 0.6 & 0.4 & 0.5 & 0.5 \end{bmatrix}$$

Matrix for the environmental performance, [ENP]

$$= \begin{bmatrix} - & EN-1 & EN-2 & EN-3 & EN-4 \\ EN-1 & 0.4 & 0.5 & 0.6 & 0.7 \\ EN-2 & 0.5 & 0.5 & 0.4 & 0.6 \\ EN-3 & 0.4 & 0.6 & 0.5 & 0.7 \\ EN-4 & 0.3 & 0.4 & 0.3 & 0.4 \end{bmatrix}$$

Matrix for the environmental performance, [ENP]

$$= \begin{bmatrix} - & SC-1 & SC-2 & SC-3 & SC-4 \\ SC-1 & 0.5 & 0.6 & 0.5 & 0.4 \\ SC-2 & 0.4 & 0.3 & 0.6 & 0.6 \\ SC-3 & 0.5 & 0.4 & 0.4 & 0.7 \\ SC-4 & 0.6 & 0.4 & 0.3 & 0.3 \end{bmatrix}$$

The permanent function values for each second level matrices are calculated and found as follows.

Permanent function value of matrix [ECP] = 1.6582

Permanent function value of matrix [ENP] = 1.226

Permanent function value of matrix [SCP] = 1.173

The permanent function value for economic performance is 1.6582 which higher than environmental performance value of 1.226. this indicate that economic performance is better than the environmental performance. The environmental performance value is slightly higher than the social performance value (1.1173), indicates that environmental performance is slightly better than the social performance of the firm.

These permanent function values are then entered into matrix [A] and permanent function value of matrix [A] is as follows.

Permanent function value of matrix [A] = 3.405

RL performance index = 3.405

This RL performance index is 3.405. these values may be calculated from time to time and performance may be compared. These indices may standardize, and bench marked over a period. Similarly, economic, environmental, and social performance may be compared, and bench marked in future by the firm.

V. CONCLUSION

RL has become an essential part of businesses because of its ability to deal with product returns effectively. It makes significant contribution to the sustainability efforts of an organization. However, there is no mechanism to measure this contribution of RL. The article develops a frame work which is based on the TBL concept of sustainability. The performance measures from all three perspectives have been selected from the past literature review. The economic performance measures selected include improved profitability, resale revenue, disposal costs, and return on RL investment. The environmental performance measures include compliance with regulatory requirement, improved brand image, reduced waste, and reuse of raw material. The social performance measures community issues, health and safety of stake holders, and employability. The proposed performance measurement model utilized GTA for developing the frame work and a case mobile manufacturing firm is considered for the illustration of the model. A mobile manufacturing firm is considered because of its volume, increased volume of product returns and fast generating e-waste. A hierarchical structure is developed and digraphs were prepared as mandated in GTA. The digraphs were translated into the matrices and permanent function values for the matrices were calculated. The values of permanent function show that firm has the uppermost value for economic performance, followed by environmental performance and social performance. Devika et al. [8] also observed that firms have more attention on economic, and environmental performance while social performance measure has not been given much attention. The article contributes to very few studies available on RL in reference to TBL aspects of sustainability. The RL performance model may help academicians and researchers to overcome the limitations of present models. The article will guide them to further develop models based on TBL aspects of sustainability. The study motivates the researchers to look performance measures in holistic manner rather than only focusing on economic performance. One of the limitations of the study is that it utilizes the data from a single firm. More studies may be carried out in future for generalizations of the findings.

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Ethical statement: The author declare that he has followed ethical responsibilities

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