Green Suppliers with Environmental Performance in the Supply Chain Perspective

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Abstract

This study examines the relationships found in supplier involvement in the course of operational life-cycle stages, environmentally-friendly practices, and environmental performances. Using sampling data gathered from 157 managers of automotive firms, obtained via a benchmarking questionnaire, three hypotheses are tested employing a Structural Equation Modeling analysis. The findings are generally consistent with the literature, with three hypotheses supported. In addition, this study explores the criteria of selecting or assessing alternative green suppliers. The major contribution of this research lies in its suggestions for decision makers to improve environmental performance using green supply chains.

Keywords: Operational life-cycle, environmentally-friendly practice, green supply chain

1. Introduction

Globalization has resulted in pressure on multinational firms to improve environmental performance. As a consequence of this pressure, and the efforts to address it, environmental management issues have become relevant to operations management researchers (Sanchez and McKinley, 1998; Murty and Kumar, 2003). Handfield et al. (1997) proposed six strategies for dealing with environmental issues, including resistant adaptation, embracing without innovating, and being reactive, receptive, constructive, and proactive. Given mounting public perception that corporate responses to environmental challenges have been inadequate, there is a mandate to move beyond constructive strategies. Companies need to adopt proactive strategies that shape a new vision of their short- and long-term environmental responsibilities.

Automotive firms worldwide likewise face increasing pressures in the environmental arena. Over the past decade, there has been a consistent trend toward the reduction of environmental releases in the automotive manufacturing sector. One potential path for achieving improvement in environmental performance, while maintaining production quality and cost goals at the plant level, is unique partnerships with suppliers (Geffen and Rothenberg, 2000).

Prior to the 1980’s, automakers’ relationships with suppliers are characterized by short-term contracts, arms-length relationships, and multiple suppliers per part (Helper, 1991). To the present, researchers have shown evidence of a movement toward closer and more cooperative supplier-manufacturer relationships (Dyer and Ouchi, 1993). The close supplier-manufacturer relationships observed in Japan’s auto industry are thought to be a key factor in

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the success of Japanese manufacturers, as they contributed to decreased development time, lowered costs, and increased product quality (Cusmano and Takeishi, 1991). However, the extent of supplier involvement varies significantly between automotive companies (Flynn and Belzowski, 1996).

Most of automobile manufacturers and customers are concerned about the environmental and safety impact generated by the use of automobiles. While the major environmental impact that occurs during the life cycle of an automobile is generated during the use of the product itself, the environmental impact of the automobile manufacturing process is also of significance (Keoleian et al., 1997).

Companies often carry out the retail process for production companies. One main industry with interest in an extended supply chain management perspective is the automotive industry. Car manufacturers became global companies with global development, sourcing, manufacturing and selling. From 2007 onwards, car manufacturers will be forced by European Union Law to recycle new cars sold within the European Union. Therefore, these firms have a rising interest in optimizing their supply chain network from the development to recycling stages.

Accordingly, this paper emphasizes the role of suppliers in green supply chain management and hence examines whether suppliers’ involvement in different operational life-cycle stages will or will not significantly influence the automakers’ environmentally-friendly practices and environmental performance. In turn, this paper employs an environmental viewpoint to explore the evaluation criteria and selection procedure of green suppliers assessment for decision-makers.

2. Literature review and hypotheses

2.1 Supply chain

The popularity of the supply chain concept has its origins in many areas: quality revolution (Dale et al., 1994), notions of materials management and integrated logistics (Carter and Price, 1993), growing interest in industrial markets and networks (Jarillo, 1993) and influential industry-specific studies (Lamming, 1993). Wikner et al. (1991) examine five supply improvement strategies on a supply chain model: (a) fine-tuning the existing decision rules, (b) reducing time delays at and within each stage of the supply chain, (c) eliminating the distribution stage from the supply chain, (d) improving the decision rules at each stage of the supply chain, (e) integrating the flow of information and separating demands into “real” orders, which are true market demands, and “cover” orders, which are orders that bolster safety stocks.

A number of organizations and individuals within the automobile industry are already moving towards supply chain management through the use of partnering, framework agreements, and techniques to rationalize their supplier base (Fernie et al., 2000). It should be noted that if a supply chain does not demonstrate its attributes, then neither a concurrent engineering approach nor supply chain management efforts will deliver the benefits sought. This point has been made clearly by both Egan (1998) and Latham (1994).

Stevens (1989) describes the supply chain as an interconnected series of activities concerned with planning and controlling raw materials, components, and finished products from suppliers to the final consumer. Mabert and Venkataramanan (1998) define the supply chain as the network of facilities and activities which perform the functions of product development, procurement of materials, movement of materials between facilities, manufacturing of goods, distribution of finished goods to customers, and after-market support. A supply chain is an integrated manufacturing process wherein raw materials are converted into final products, then delivered to customers. At its highest level, a supply chain is
comprised of two basic, integrated processes: (a) production planning and inventory control process, and (b) distribution and logistics process (Beamon, 1998). The production planning and inventory control processes encompass the manufacturing and storage sub-processes and their interface(s). More specifically, production planning entails the design and management of the entire manufacturing process (including raw material scheduling and acquisition, manufacturing process design and scheduling, and material handling design and control).

2.2 Supplier involvement and environmental performance

Stevens (1989) describes the supply chain as an interconnected series of activities concerned with planning and controlling raw materials, components, and finished products from suppliers to the final consumer. Mabert and Venkataramanan (1998) define the supply chain as the network of facilities and activities which perform the functions of product development, procurement of materials, movement of materials between facilities, manufacturing of goods, distribution of finished goods to customers, and after-market support. Supply chain management covers the short- and long-term collaboration of a company with other companies to develop and manufacture products with the required internal and inter-company organization, planning and control of the flows of materials, financial value, and information along the business processes (Stadtler, 2000; Schönsleben, 1998).

Recently, companies have had to integrate other members of the supply chain into their environmental management processes, which is tantamount to a “green supply chain” (Zhu and Cote, 2004). In developing a green supply chain, they also address three main approaches: (a) maintaining close relationships with their main suppliers; (b) obtaining a larger market share through competition with other domestic material suppliers by improving product quality and reducing costs; and (c) ensuring the sustainability of their operations include reducing the environmental impact.

Geffen and Rothenberg (2000) find that paint shop suppliers can create new automotive products to achieve cost and environmental efficiencies facility-wide. Significant improvements in environmental performance are achieved when the plant implements a partnership with the appropriate supplier. Handfield et al. (1997) suggest that in order to be successful, environmental management strategies must be integrated into the value chain, which includes all of the operational life-cycle stages. Manufacturers have a number of suppliers at each operational stage. For example, the green materials/components supplied are recognized as critical to success in developing green products. In this sense, a cooperative relationship with suppliers allows a firm to improve its environmental performance. Hence, the following hypothesis is posited.

Hypothesis 1: The higher degree of supplier involvement in operational life-cycle stages (OLC), the better environmental performance (EP) realized by the automotive firm.

Hanssen (1998) shows that there are significant differences between the environmental impacts related to life cycles stages, while the most important stages are in general raw material processing, use of the product, and especially, final waste management. Combinations of business processes lead to supply chain networks in which materials, financial values, and information are dispatched and exchanged in a manner that involve all participating companies (Fandel and Stammen, 2004).

Therefore, starting from supplier cooperative strategies, environmentally-friendly practices and environmental strategic management for individual business processes must be determined as essential tasks for developing the green supply chain. Wu and Duun (1995) indicate that logistics can be an indispensable part of integrated environmental management programs because of its cross-functional nature. They provide an example that packing is used to protect the products from damage and is then undesired once the products are consumed, but proper management and awareness of the environmental implications of logistics

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activities can significantly reduce the negative impact. In short, “correct” operational decisions spanning product design, procurement, manufacturing and assembly, packaging, logistics, and distribution are highly connected with environmentally-friendly practices. Therefore, we propose the following hypothesis.

Hypothesis 2: Higher degrees of supplier involvement in operational life-cycle stages (OLC) will allow the automotive firm to implement more effective environmentally-friendly practices (EFP).

Welford (1995) indicates that environmental protection activities are embedded in business operations. Zhu and Sarkis (2004) suggest that the degree of environmental performance is, in part, dependent on environmentally friendly practices in manufacturing organization. While companies adopt proactive environmental strategies, they may focus efforts on making technology or process change toward environmentally friendly practices in manufacturing (Handfield et al., 1997).

For example, Maclaine-Cross (2004) finds the replacement of fluorocarbons in mobile air conditioning systems (e.g. most R290/600a leaking in use) may reduce CO₂ emission and potential flammable. Amey (1995) indicates that automotive component innovation (e.g. the evolution of fuel delivery systems of Honda-MacLaren) can enhance the development and diffusion of engine management technologies in the automobile industry. Taking another example, the last action of reverse logistics is to recycle. Wu and Dunn (1995) suggest increasing the use of recycled materials in the logistics system. Cardboard boxes, plastic wrappers, used motor oil, and worn out tires must be collected, transported, and disposed of properly to minimize the environmental impact. Overall, these environmentally-friendly practices will reduce total waste and pollution in automotive firms. The environmental technology innovation may be made to facilitate the move toward environmentally-friendly practices in manufacturing or other functions (Handfield et al., 1997). Therefore, we expect to observe the result as follows:

Hypothesis 3: Enterprises adopting higher levels of environmentally-friendly practices (EFP) will have more improved their environmental performance (EP).

2.3 Research framework and measurement

This study establishes its conceptual research framework in accordance with the literature and three hypotheses (see Figure 1). Handfield et al. (1997) mention that all of the operational life-cycle stages range from product design, procurement, manufacturing and assembly, packaging, logistics to distribution. For example, the success of product eco-design requires the internal cross-functional cooperation among the entire company and the external cooperation with other partners in the whole supply chain (Lenvis and Gretsakis, 2001). In the manufacturing area, the company has worked to be an industry leader in water-based transfer processes for coatings, and has sought to limit the amount of formaldehyde emitted by its adhesives.

The business processes are not limited to the framework of product design, procurement, manufacturing and assembly, packaging, logistics, and distribution. They are extended to the operational functions of waste reduction, recycling, reproduction, reuse and disposal -- all of which are demonstrated “pockets” of environmentally-friendly practices in different areas of their respective supply chain functions.

Birou and Fawcett (1994) indicate that almost all the firms interviewed consider their environmental performance according to quality, cost, and flexibility. In this study, we also use these three indicators -- Quality, Cost, and Flexibility -- as a judgment of the firm’s environmental performance. The framework of supplier involvement and environmental performance in Figure 1 is developed from the literature to guide this research.
2.4 Criteria of green suppliers assessment

Green supply chain management (GSCM) becomes a hot topic; there is a worldwide trend for manufacturers to choose their green suppliers for constructing their green supply chain (Zhu and Sarkis, 2004). Many international companies including Sony, HP, Dell, Apple, etc. have already established their green supply chains. A supply chain management ranges from one edge (supplier) to the other edge (customer). However, this study emphasizes the supply-side of companies, but not the demand-side. Integrating with the supply-side gives higher performance than for low integration companies (Germain and Droge, 1998). The main objective of GSCM is to ensure that material cycles in the supply chains are managed in an environmentally, socially, and economically responsible manner. Normally, this means that a product must generate as little waste as possible and conserve energy at each stage of the product’s life cycle (Gramer, 1996).

Consideration of this issue clearly demonstrates the growing importance played by the environmental dimension in the overall supply chain and highlights that companies need to change their relationships with suppliers, shifting from competitive to a co-operative behavior aimed at integrating the vendors in green product/technology innovation process. Suppliers have to reduce the quantity of supplied components with low environmental performance and, hence, to comply with environmental regulations. One major job of GSCM is to access basic suppliers for delivering green components.

Carter et al. (1998) define “environmental purchasing” as purchasing behavior in activities that include reduction, reuse, and recycling of materials. Stock (1992) suggests that life-cycle issues concerning the ultimate disposition of materials must be considered as an integral part of the purchasing and procurement process. “Green purchasing” or “environmental
purchasing” is now well covered in the Logistics literature, and is becoming a key component of green supply chain management (GSCM).

Zhu and Sarkis (2004) demonstrate that JIT (just-in-time) programs with internal environmental management practices may cause further degradation of environmental performance. Therefore, they argue, manufacturers should implement GSCM (green supplier choice management) programs in place of JIT programs, from an environmental perspective. Ofori (2000) indicates that the development of supplier evaluation systems that place significant weight on objective environmental criteria can play a major role in influencing supplier activities. Thus, companies include a past environmental track record in their criteria for selecting material suppliers.

2.4.1 Quality

Walton et al. (1998) suggest that companies will thrive only when they act as whole systems including all stakeholders, and integrate total quality environmental management (TQEM) into their planning and operations. TQEM indicates the company makes efforts at continuous environmental improvement through Total Quality Management programs. The improvements includes (a) waste water: these indices consist of total water consumption, some specific critical water wastes (COD, total nitrogen, phosphorous, dissolved salts) due to the supplier’s plants; (b) air emissions: these are related to a supplier’s emissions of critical substances, such as SO2, NH3, CO, NHx, HCI and organic gas; (c) solid wastes: these express the total volume of solid wastes achieved by the supplier each year; (d) energy consumption: such an indicator points out the supplier’s total amount of energy consumption within the year. Ciribini and Rigamonti (1998) urge clients to select, at the pre-qualification stage, suppliers complying with, or certified to, both ISO 9000 and ISO 14000. The link between quality and the environment is emphasized by the fact that ISO 14000 certification was modeled after its predecessor, the ISO 9000 quality certification (Handfield et al., 1997). Quality can be defined broadly. In this paper, we define it as two main activities: TQEM and ISO 14000 certification as sub-criteria of the “quality” indicator of environmental performance.

2.4.2 Cost

Decisions with respect to costs made at the designed and engineering stages have a significant impact on manufacturing and service costs, as well as the quality of the final product (Dixon and Duffy, 1990; Monden and Hamada, 1991; Kreuze and Newell, 1994). Weitz et al. (1994) emphasize that environmental costs associated with life cycle stages potentially influence product design, operations and maintenance decisions, recycling, and reuse activities, as well as disposal methods termed the “life cycle (LC) cost”. To define the life cycle cost of the supplied component, managers have to consider purchase costs and all other costs that the company must bear during the product life cycle. These are related to (a) costs for component disposal when they have been used to achieve the final product, but have been detected as defective within the company’s plants; and (b) costs for the disposal and/or recovery of the end-of-life components (Noci, 1997).

Increasing costs of cleaning coupled with advances in materials and process technology are now driving some companies to raise emphasis on environmental problems. For example, one of the most effective means for reducing emissions and hazardous wastes from automotive painting is to reduce the level and number of input chemicals through material substitution, such as waterborne and powder paints, leading to lower levels of pollutants for treatment or control. Accordingly, we use LC cost and cleaning cost as sub-criteria of the “cost” indicator of environmental performance.
2.4.3 Flexibility

Response means to respond in time to any requirement, especially in environmental needs. Innovation refers to an evolution or revolution to support green products or processes. Orihata and Watanabe (2000) suggest that innovation has the meaning of both the process of long-term and progressive change as well as including dynamic processes. One of the benefits to automotive manufacturers acquired from stronger relationships with suppliers has been increased external information on and experience with different technologies (Clark and Fujimoto, 1991). Accordingly, we use Response and Innovation as sub-criteria of the “flexibility” indicator of environmental performance.

Overall, this paper establishes three main criteria and six sub-criteria for selecting the best and most appropriate supplier. These criteria are Quality (TQEM and ISO 14000 certification), Cost (LC cost and Cleaning cost), and Flexibility (Response and Innovation). Three alternative suppliers have been identified as providing potential green materials/components. The environmental performance goal here is to select a supplier satisfying all criteria in the best way.

3. Methods

3.1 The sample

Regarding the data collected, a random sample of 300 functional area managers was drawn from manufacturing organizations found in the Taiwan Transport Vehicle Manufacturers Association (TTVMA) that employ more than 100 people. It was not expected that firms with less than this number of employees would have clearly defined responsibility centers to which managers would be appointed. Each manager was contacted by telephone and requested to take part in the study. On agreeing to do so, each manager was mailed an anonymous questionnaire together with cover letter and a stamped addressed envelop for its return. The design of the questionnaire facilitated the respondent sample providing a data source for other research topics unrelated to this one, thereby allowing significant research
efficiency. A telephone follow-up was conducted two weeks later to enhance the response rate. The follow-up also provided considerable assurance that the targeted managers had completed the questionnaires themselves.

By February 2006, 77 questionnaires had been completed. After three weeks, a second questionnaire was sent out, which meant 157 questionnaires altogether. This study uses an ANOVA to test for sample bias between questionnaires returned in the first and second rounds, but finds no significant differences. A total of 157 managers responded, representing a response rate of 52.3%. The sample comprised 36 marketing and 52 production managers, 24 R&D engineers, 34 project directors, together with 11 others from a range of areas of responsibility. Their average age was 44.5, the mean years of experience in the areas they managed was 11.8. They had held their present position for average of four years and the mean number of employees in their areas of responsibility was 85. Firms sampled were involved in the manufacture of automobile manufactures.

3.2 Structural equation modeling with LISREL

The methodology for this study was the Structural Equation Modeling (SEM) to test Hypotheses 1, 2, and 3. The primary aim of SEM is to explain the pattern of a series of interrelated dependence relationships simultaneously between a set of latent (unobserved) constructs, each measured by one or more manifest (observed) variables (Reisinger and Turner, 1999). First of all, this study has to verify how important OLC and EFP are to EP. Based on the prerequisite of significant relationships exhibited between OLC, EFP and EP, it reveals that the higher degree of green suppliers involvement, the better environmental performance may be realized. Therefore, this issue will be discussed which criteria are to evaluate the green suppliers for the firm’s managers or decision-makers.

Liner Structural Relationships (LISREL) is computer program for covariance structure analysis. It is a multivariate technique which combines (confirmatory) factor analysis modeling from psychometric theory and structural equations modeling associated with econometrics (Reisinger and Turner, 1999). Thus, this study examined the collected data and executed an empirical analysis using the LISREL model following Hair et al. (1998).

The next stage is to portray the relationships in a path diagram of causal relationships. In this study, the three hypothesized factors are considered exogenous constructs. The path diagram, including the variables measuring each construct, is shown in Figure 1 and Figure 3.

Once the overall model fit has been evaluated, the measurement of each construct can then be assessed for unidimensionality and reliability. While a model is established as providing acceptable estimates, the goodness-of-fit must then be assessed at several levels: first for the overall model and then for the measurement and structural models separately. The Goodness-of-fit Index (GFI) measures the correspondence of the actual or observed input (covariance or correlation) matrix with that predicted from the proposed model. In order to achieve a better understanding of the acceptability of the proposed model multiple measures should be applied (Hair et al., 1998).

4. Results

4.1 Reliability and validity

Respondents are asked to rate on multi-item scales their degree of OLC, EFP, and EP. The degree is measured with a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). In this study, the method of reliability measurement is Cronbach’s coefficient α. Cronbach’s coefficient α is calculated for each of these factors to assess the internal consistency of the model constructs. According to Price and Mueller (1986), a standard coefficient α of 0.60 or higher generally is considered acceptable when using a measure. If statistical significance is
not achieved, the research may need to eliminate the indicator or attempt to transform it for a better fit with the construct. The values of Cronbach’s coefficient $\alpha$ of latent variables (OLC = 0.852, EFP = 0.925 and EP = 0.962) all exceed 0.70 and that of some constructs even exceed 0.90. This indicates that the research has good consistency and stability. In addition, content validity should be relatively acceptable because this part of the question items is adapted from existing literature and also is reviewed closely by practitioners.

4.2 Descriptive statistics

The relationships between the variables are assessed simultaneously via correlation analysis. The correlation matrix is used to understand the relationship patterns of constructs. It is not used to explain the total variance of a construct as needed in theory testing. Thus interpretation of the results and their generalizability to different situations should be made with caution, when the correlation matrix is used (Hair et al. 1998). The correlation matrix for the hypothesized model is presented in Table 1. The most widely used method for computing the correlations or covariances between manifest variables Pearson product-moment correlation and the correlation matrix is computed using Prelis (Jöreskog and Sörbom, 1989).

Table 1. Correlation matrix for the hypothesized model

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<th>Variables</th>
<th>$x_1$</th>
<th>$x_2$</th>
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<th>$x_4$</th>
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4.3 Measurement model results

In order to specify the measurement model, we make the transition from factor analysis, in which the researcher has no control over which variables describe each factor, to a confirmatory mode, in which the researcher specifies which variables define each construct (factor). The manifest variables we collected from the respondents are “indicators” of the measurement model, as we use them to measure, or indicate, the latent constructs (factors). The most obvious difference between the measurement model and factor analysis is that the former has a much smaller number of loadings and resembles the exploratory mode of factor analysis. Researchers can specify a measurement model for both exogenous constructs and endogenous constructs.
Table 2 presents $\lambda_x$ and $\lambda_y$ coefficients from a LISREL analysis of a hypothesized causal model of environmental performance. All the coefficients are moderately high, approximately 0.62 or more. In addition, all the loadings are statistically significant. The strong statistically significant correlation between the factor and their measures suggest the presence of convergent validity. It may be concluded from these results that each of the three latent factors is well defined.

Table 2. Measurement model parameter estimates

<table>
<thead>
<tr>
<th>Latent variable</th>
<th>Observed variable</th>
<th>$\lambda_x / \lambda_y$</th>
<th>Error variance ($\delta_x, \epsilon_y$)</th>
<th>Latent variance $\zeta_y$</th>
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<td>OLC</td>
<td>Product design ($x_1$)</td>
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<td></td>
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<tr>
<td></td>
<td>Manufacture/assembly ($x_3$)</td>
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<td></td>
<td>Distribution ($x_4$)</td>
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<tr>
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<td>Logistics ($x_5$)</td>
<td>0.62**</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Packing ($x_6$)</td>
<td>0.77***</td>
<td>0.40</td>
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</tr>
<tr>
<td>EFP</td>
<td>Waste reduction ($y_1$)</td>
<td>0.76***</td>
<td>0.55</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Recycle ($y_2$)</td>
<td>0.74***</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reproduce ($y_3$)</td>
<td>0.84***</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reuse ($y_4$)</td>
<td>0.85***</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disposal ($y_5$)</td>
<td>0.89***</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>Quality ($y_6$)</td>
<td>0.92***</td>
<td>0.12</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>Cost ($y_7$)</td>
<td>0.86***</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility ($y_8$)</td>
<td>0.89***</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

Note: Level of significance: **$p<0.001$.

4.4 Structural model results

As Figure 3 shows, with the path analyses of supplier involvement in operational stages, environmentally friendly practices, and environmental performance, three hypothesized paths are supported at a significant level (less than 0.05). We find that there is a significant correlation between supplier involvement in operational stages and environmental performance (path coefficient = 0.88, $t = 2.82$). In addition, we also find that supplier involvement in operational stages will significantly influence the extent of environmentally-friendly practices (path coefficient = 0.98, $t = 3.35$). Moreover, the firm’s environmentally-friendly practices are significantly and positively related to environmental performance (path coefficient = 0.58, $t = 1.92$).

4.5 Overall model fit

The fit of the model was evaluated with various measures (Bentler, 1995; Jöreskog and Sörbom, 1989). Kelloway (1998) suggests that the use of chi-square test is reasonable when the study involves a large sample. The first measure is the likelihood ratio chi-square statistic. While the value has a statistical significance level above the minimum level of 0.05, the statistics support the argument that the differences of the predicted and actual matrices are insignificant, indicative of an acceptable fit. In this study, when the chi-square/df is 2.95
(≤ 3.00), this shows an excellent fit. The model fit assessment approach is involved, using several diagnostics to judge the simultaneous fit of the measurement and structural models to data collected for this study. The goodness-of-fit index (GFI) is another measure provided by LISREL. The adjusted goodness-of-fit index (AGFI) is an extension of the GFI, adjusted by the ratio of degrees of freedom for the proposed model to the degrees of freedom for the null model. The GFI for the overall model is 0.99 and the AGFI is 0.97.

Other types of fit measures include the Comparative-Fit Index (CFI), Normed Fit Index (NFI), the Root Mean Square Residual (RMR), and the Standardized Root Mean Square Error of Approximation (RMSEA). We use CFI to explain the difference between the model and the independent model without co-variables. The closer the value is to 1, the better the model fit. NFI value means the observed measure covariance explained by the composition model. Further, RMR is the square root of the mean of the squared residuals -- an average of the residuals between observed and estimated input matrices. Other diagnostics for this model include NFI = 0.95, CFI = 0.97, RMR = 0.03, and RMSEA = 0.02. The structural model results in Figure 3 show that overall model fit is within an acceptable level.

![Figure 3. Structural model results](image-url)

Chi-square/df = 2.95
GFI = 0.99; AGFI = 0.97
CFI = 0.97; NFI = 0.95
RMR = 0.03; RMSEA = 0.02

5. Discussion

5.1 Conclusion

The results of this study make the main contribution to offer new insights into the issue of how automotive firms might improve the environmental performance through suppliers and the sustainability of their supply chain. Organizations have become increasingly aware of the propensity for environmental pollution incidents within their supply network to cost them in
penalties, cleanup and consumer backlash. This relatively new expectation for upstream suppliers goes beyond the more traditional requirements of their customers to reduce costs and improve quality and service (Lambert and Cooper, 2000).

This research reveals significant relationships among supplier involvement in operational stages, environmentally-friendly practices, and environmental performance. Consistent to our initial hypotheses, the results show there are significant correlations among the three factors; Hypotheses 1, 2, and 3 are all supported. In other words, an assessment of a supplier’s impact on the state of operational stages (product design, procurement, manufacturing/assembly, logistics, packing, and distribution) allows an automaker to verify how it performs with respect to environmental friendly practices and environmental performance.

On the whole, auto suppliers/assemblers place a higher level of importance on environmental technology and innovation. In light of these issues, automotive firms implementing a pro-active green strategy must consider a supplier’s environmental performance. The automotive firms need to verify whether the supplier will be able to work with them to carry out new green supply chain management. Overall, the results of this study emphasize the importance of assessment methodologies that allow a purchasing team to select only eco-efficient suppliers.

5.2 Managerial implications

The contribution of this paper lies in creating links between suppliers and makers as a mechanism of green supply chain management to adapt to radical technological change, firm innovative output, and industry and firm performance in the post-innovation period. The results support the notion of Choi and Hartley (1996) that no differences among the auto assemblers, direct suppliers, and indirect suppliers are found in regard to the importance placed on technological innovation and environmental issue. Consequently, the need to continuously improve corporate environmental performance will force firms to involve suppliers in their environmental programs connected to operational stages. Insights into the importance of seller-buyer’s collaboration for research are provided based on extensive empirical analyses of Taiwan’s automotive firms. Establishing inter-firm collaborative relationships is considered to be vital as enhancing firms’ environmental performance.

Despite our results are encouraging, they should be interpreted with caution because of the study’s limitations. While there are several important benefits for single industry studies, the fact that this research was conducted in the automobile industry might limit the generalization of the findings. Although Taiwan’s automotive firms still lag behind the USA, Europe, or Japan, the Taiwanese have been carrying out an extremely well coordinated effort to excel in this field of green supply chain management. Taiwan’s automotive firms should intensify their successful approaches, learned from other suppliers/partners, to advance the development of environmentally friendly practices, and build strong networks to maximize synergic efficiency.

5.3 Further research

The literature regarding the criteria of assessing the green supplier shows that Quality, Cost, and Flexibility are important selection items, regardless of the position in the supply chain. They also indicate the selecting first-tier or second-tier suppliers based on the potential of Quality, Cost, and Flexibility. However, this study just explored the importance of green supplier assessment for improving the environmental performance of automotive companies. In further research, this comprehensive study of green supplier assessment addressing actual environmental performance may be conducted by fuzzy AHP analysis. The fuzzy AHP approach can be used to solve any large-scale selection problem that might occur in practice (Saaty, 1989). The hierarchical structure of green supplier assessment has implication for
adopters of green supply chain management practices. In other hands, some studies mention that there are also non-hierarchical approaches to evaluating green supply chains (e.g., Sarkis, 2003).

Reference


