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Determinants and environmental outcome of green technology innovation adoption in the transportation industry in Malaysia

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Determinants and environmental outcome of green technology innovation adoption in the transportation industry in Malaysia

Suhaiza Zailani\textsuperscript{a}, Mohammad Iranmanesh\textsuperscript{b\ast}, Davoud Nikbin\textsuperscript{b} and Herina Binti Jumadi\textsuperscript{c}

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In the twenty-first century, transportation services and infrastructure will play a central role in the logistics systems of corporations competing in the global market. As transportation and logistics systems continue to integrate, their impact on the physical environment will become a major issue. This study investigates the antecedents and outcomes of green technology innovation adoption in transportation companies in Malaysia. A questionnaire survey on the green technology innovation adoption of Malaysian transportation companies was conducted, in which 252 samples were analysed. Based on the survey results, this study finds that the quality of human resources, customer pressure, and environmental uncertainty significantly influence green innovation adoption for transportation companies, while the influence of organizational and governmental support is not significant. In addition, the findings of this study indicate that there is a significant relationship between green technology innovation adoption and environmental outcome. The practical implications of the research findings are discussed.

Keywords: determinants; green technology innovation; environmental outcome; transportation industry; Malaysia

1. Introduction

While Malaysia enjoys rapid industrial and economic growth, it suffers from numerous serious environmental problems. These problems include air pollution, energy waste, and water pollution. Among them, air pollution is a major issue that affects human health, agricultural crops, forest species, and ecosystems (Afroz, Hassan, and Ibrahim 2003). In the face of these problems, the Malaysian businesses, in order to compete globally, are looking at green innovation as a potential area for growth as well as positioning its products as environmentally friendly and sustainable. It aims to reduce carbon emissions by 40% by 2020. Realizing its importance to economic development, the Government launched the National Green Technology Policy in August 2009. The intent of the policy is to provide direction towards the management of a sustainable environment.

The transport sector is one of the main sources of strain on the environment, particularly in terms of air pollution (Aronsson and Brodin 2006). The substantial contribution of large transport vehicles to air pollution and other gaseous or airborne pollutants has become an important issue as it increases CO\textsubscript{2} emissions and accelerates global warming (Thompson and Taniguchi 2001). When compared to power stations and the industrial sector, Malaysia’s transport industry

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produces the most emissions, CO₂ (98%) and NOₓ (67%), as evidenced by the increasing number of lorries and vans (Zailani, Amran, and Jumadi 2011). Thus, environmental concerns have made companies more aware of the need to innovate. In the past, innovation was predominantly driven by the intention to exceed customer expectations or to create simpler and less costly processes, whereas today, many organizations are required to respond to environmental demands (Nunes and Bennet 2008).

Green innovations have a major impact on reducing the environmental burden of the transportation industry, particularly in terms of pollution and greenhouse gas emissions, thus creating a need for integrating green innovations in logistics (Lin and Ho 2008). With the emergence of green innovations, the logistics industry has gone beyond the standard logistical imperatives for efficient, effective, fast handling, and movement of goods. Now, it takes into account measures for protecting the earth’s environment. This is sometimes referred to as the ‘green logistics’ approach. With the significant contribution to environmental pollution coming from the transport industry, questions arise concerning the determinants of green technology innovation adoption in the transport industry, and the impact of integrating green technology innovation within the transport industry’s process for reducing their environmental impact.

Although little research has been conducted on environmental issues in the transport industry, it does appear to have expanded over the last few years (Wolf and Seuring 2010). For instance, previous research on the determinant factors affecting green innovation adoption for logistics companies was conducted by Chapman, Soosay, and Kandampully (2003), Aguila-Obra and Padilla-Melendez (2006), Lin and Ho (2008, 2010), while other studies examined the factors of innovation adoption, such as Aguila-Obra and Padilla-Melendez (2006), Lin and Ho (2008, 2010).

While most of the literature has been written from the perspective and experience of developed countries, e.g. the USA, Europe, China, and Japan, few studies have considered green innovation in the context of emerging economies like Malaysia. The main focus of this paper is that the green innovation practices that have been developed, evolved, and matured in developed economies should also be applicable in the developing world. In addition, there is little or no research that exists on determinants of green technology innovation adoption. Furthermore, the studies only investigated the factors affecting green practices (Chapman et al. 2003; Aguila-Obra and Padilla-Melendez 2006; Lin and Ho 2008, 2010). Additionally, previous studies of environmental issues did not analyse empirically the influences of organizational factors and the external environment on green technology innovation adoption. This has been particularly neglected in the logistic industry, a concern which is addressed in the current study. An understanding of the determinant factors is essential for successful implementation of green technology innovation in transportation companies. This adoption can provide significant benefits to the individual companies and society. In addition, the results may help researchers to understand the issues of green technology innovation adoption in the logistic industry.

2. Model conceptualization and hypothesis development

The environmental effect of the transportation industry as one of the main users of natural resources and generators of waste has become a challenging issue in this sector. In order to deliver products and services to customers in a more environmentally friendly manner, logistics service providers need to make more efforts towards dealing with environmental issues. Because of this, green solutions and environmental protection are a necessity in the twenty-first century. Due to this necessity, the impact of green technology innovation adoption in the logistic industry on environmental outcome (EO) is investigated in the current study.
Innovation consists of any practice that is new to organizations, including equipments, products, services, processes, policies, and projects. Distinguishing types of innovation is necessary for understanding organizations’ adoption behaviour and identifying the determinants of innovation amongst them. Amid numerous examples of innovation discussed in the relevant literature, the concept of administrative and technical innovation is commonly used (Damanpour 1991). Referring to the study undertaken by Wu and Sun (2008), green technology innovation is considered as a classification of technology innovation, which is in line with the needs of sustainable development. Lin (2007) and Lin and Ho (2007) stated that technological innovation in logistics services consists of data acquisition technologies, information technologies, warehousing technologies, and transportation technologies. In this study, three categories of technology innovation are considered: data acquisition, information, and transportation technologies related to transportation activities as part of logistic services.

A number of explanations as to what factors influence innovation can be found in the topic-related literature. Previous findings are relevant for modelling green practice adoption from the perspective of innovation. The political and legal environment, the availability and quality of internal resources, external knowledge, knowledge transfer activities, and the perceived innovation characteristics are all relevant for the adoption of technical innovations. In general, the adoption of technical innovations is affected by technological, organizational, and external environmental contexts (Tornatzky and Fleischer 1990; Scupola 2003; Jeyaraj, Rottman, and Lacity 2006; Ramamurthy, Sen, and Sinha 2008). Technological factors such as perceived ease of use, perceived usefulness, and complexity are not considered in the present study as the aim of this study is to explore the determinants of green innovations from managers’ point of view, not users of green technology in transportation companies (Davis 1989). Therefore, the present study explores the influences of organizational and environmental factors on the adoption of green technology in the Malaysian transportation industry. Figure 1 illustrates the research framework of the study. Organizational factors include: organizational support (OS) and quality of human resources (QHR). Environmental factors include: customer pressure (CP), governmental support (GS), and environmental uncertainty (EU).

![Figure 1: Proposed theoretical model.](image-url)
2.1. Determinants of adopting green technology innovation

Logistics companies, especially in transportation, need to invest much more effort into environmental issues (Murphy and Poist 2003; Sarkis, Meade, and Talluri 2004). This study aims to analyse the factors influencing green technology innovation adoption in the Malaysian transportation services. Some researchers have suggested that individual, organizational, and contextual factors influence the adoption of technological innovation (Kimberly and Evanisko 1981). Previous scholars found that the organizational level and size in particular, are the best clear predictors of innovation. Chapman et al. (2003) define factors that influence innovation adoption as technology, knowledge, and relationship networks. However, others suggest that the adoption and implementation of technological innovation are affected by the organizational context and external environment (Aguila-Obra and Padilla-Melendez 2006; Lin and Ho 2008, 2010). The following subsections explain the two factors listed above.

2.1.1. Organizational factor

The organizational factors comprise the structure, climate, and culture of the organization that will influence the adoption of innovation (Kimberly and Evanisko 1981; Tornatzky and Fleischer 1990). Likewise, Daugherty, Chen, and Ferrin (2011) found that organizational factors have a positive relationship with innovation. Lin and Ho (2008) consider that a company with a higher QHR, such as better education or training, will have greater ability in technological innovation. Therefore, the organizational readiness and QHR most likely influence the adoption of green innovations (Lin and Ho 2008). This is supported by Tornatzky and Fleischer (1990) who state that the informal linkages and communication among the employees, the QHR, the top management leadership behaviour, and the amount of internal resources may all significantly influence the adoption of technological innovation. Therefore, this study focuses on the organizational factors, which include OS and QHR (Lin and Ho 2010). These factors are more in line with the focus of the study on green technology innovation.

OS: OS is essential for the development of environmental management. Organizations will find it easier to provide this support because the resources required for adopting green practices will become more easily accessible and employee enthusiasm to execute green behaviour will increase (Lin and Ho 2010). Providing incentives for innovation adoption and ensuring the availability of financial and technical resources for innovation have a positive effect on the adoption of technical innovation (Lee, Lee, and Kwon 2005; Jeyaraj et al. 2006). Most importantly, the upper management plays an important role in OS. According to Lin and Ho (2010), most green practices require collaboration and synchronization from different departments during the adoption phase. In order to ensure successful implementation, green initiatives are usually endorsed and encouraged from the top management. Therefore, we hypothesize:

H1: Organizational support has a positive influence on green technology innovation adoption among transportation companies.

QHR: Adopting technical innovation requires qualified employees with competent learning and innovative capabilities (Tornatzky and Fleischer 1990). A company with high-quality professional development, such as better education or training, will be more capable of technological innovation (Lin and Ho, 2008). Russo and Fouts (1997) argue that adopting green practices is a complicated process requiring cross-disciplinary harmonization and significant changes in the existing operation process (Russo and Fouts 1997). Implementing green technology innovation is human resource intensive. Employee involvement and the development and growth of their
inferred skills are key to its success. (Hart 1995; Del Brio and Junquera 2003). Employees with competent learning capabilities will be easily involved in training programmes that can advance green practice adoption. The degree to which an organization is receptive to new ideas will influence its propensity towards adopting new technologies (Frambach and Schillewaert 2002). A company with higher innovative capacity will be more likely to successfully realize an advanced environmental strategy (Christmann 2000). Therefore, we hypothesize:

**H2:** The quality of human resources has a positive influence on green technology innovation adoption among transportation companies.

### 2.1.2. Environmental factors

External environmental factors will influence innovative capability as well as intention to adopt innovations (King and Anderson 1995). Environmental complexity, uncertainty, and GS influence the willingness to adopt green innovations by logistics service providers (Lin and Ho 2008). Additionally, GS is important for technology innovation. This support comes in the form of financial providers, pilot projects, and tax breaks to stimulate technological innovation within logistics companies (Lin and Ho 2008). Environmental factors include CP, GS, and environmental support (Lin and Ho 2010). Furthermore, Joo and Kim (2004) found that the external environment is one of the determinants for technology innovation adoption. From their study, there are two environmental factors – external pressure and buying power. External pressure includes the influences from the organizational environment, such as competitive pressure and imposition by others. This ‘pressure’ and ‘imposition’ can come from a parent company, industry associations, or governmental units. Buying power refers to the degree to which a buying firm’s influence is perceived in the market. Suppliers are typically dependent upon customers who provide them with a large proportion of their sales revenue. However, buying power is not relevant to this study, in that its focus is the logistics industry. Therefore, this study will focus on CP, GS, and environmental support (Lin and Ho 2010).

**CP:** Stakeholders can be divided into those individuals or groups affecting a company’s activities and being affected by that particular company’s activities. Therefore, they play an important role in the organizational environment and are widely involved in research on environmental issues (Etzion 2007). Stakeholder pressure is regarded as the most prominent factor influencing a company’s environmental strategy (Buysse and Verbeke 2003; According to stakeholder theory, organizations carry out activities to satisfy their main stakeholders. Among the various groups of stakeholders, customers are arguably viewed as a company’s most important stakeholders (Christmann 2004; Etzion 2007). Vast research reveals the positive relationship between a firm’s environmental activities and CP (Christmann 2004; Lee 2008). Therefore, we expect that customers will positively affect the adoption of green practices. Hence:

**H3:** Customer pressure has a positive influence on green technology innovation adoption among transportation companies.

**GS:** To some extent, technical innovation relies on the availability of external resources. Several researchers have suggested that GS is a relevant environmental factor influencing technical innovation. Governments can advance technical innovation through encouraging policies, such as providing financial incentives, technical resources, pilot projects, and training programmes (Tornatzky and Fleischer 1990; Scupola 2003). Similarly, the availability of external resources will influence the adoption of green practices. The availability of a large amount of resources in the business environment increases a company’s engagement in environmental
management (Aragon-Correa and Sharma 2003; Rothenberg and Zyglidopoulos 2007). The government can increase its assistance by providing governmental subsidies or tax incentives for alternative energy technologies, bank financing at lower rates for environmentally friendly technologies, and lower insurance premiums for lower environmental risks (Aragon-Correa and Sharma 2003). In a study of Korean small and medium enterprises (SMEs), Lee (2008) also suggests that GS for green initiatives has a positive influence on a firm’s willingness to participate in the green supply chain. Therefore, we hypothesize:

\[ H_4: \text{Governmental support has a positive influence on green technology innovation adoption among transportation companies.} \]

*EU*: EU has been viewed as the most relevant environmental characteristic that influences a company’s decision making (Li and Atuahene-Gima 2002). EU refers to the frequent and unpredictable changes in customer preferences, technological developments, and competitive behaviour perceived by the managers of a company (Lin and Ho 2010). Managers facing an uncertain business environment tend to be more proactive and use more innovative strategies than managers in less turbulent environments. Under high EU, companies will attempt to gather and process information frequently and rapidly to address environmental changes (Gupta and Govindarajan 1991), and will also tend to exert more efforts into innovation and increase the rate of technical innovation to maintain a competitive advantage (Kimberly and Evanisko 1981; Damanpour 1991; Zhu and Weyant 2003). Some researchers (Aragon-Correa and Sharma 2003; Rothenberg and Zyglidopoulos 2007) also suggest that companies are more likely to adopt green innovations to generate the capacity to improve performance in uncertain environments. Therefore, it is hypothesized:

\[ H_5: \text{Environmental uncertainty has a positive effect on green technology innovation adoption among transportation companies.} \]

### 2.2. Green technology innovation adoption

Green innovation refers to the creation of novel and competitively priced goods or services with minimal use of natural resources and minimal release of toxic substances (Reid and Miedzinski 2008). Green innovation reduces the environmental impact by increasing energy efficiency, reducing waste or greenhouse gas emissions and/or by minimizing the consumption of non-renewable raw materials (OECD 2013). Green technology innovation is a part of technology innovation, which is in line with the needs of environmental sustainable development (Wu and Sun 2008). A higher level of organizational environmental sustainability is reached by the minimization of environmental impact, and by the creation of a positive impact on the environment (Nunes and Bennett 2008). Technology is an important tool in the logistics and transportation industry in reducing its carbon footprint (Kewill 2008). Therefore, the following hypothesis is developed:

\[ H_6: \text{Green technology innovation adoption has a positive effect on the environmental outcome of transportation companies.} \]

### 3. Research methodology

#### 3.1. Measures of constructs

A survey questionnaire was used. It consisted of four sections: (1) demographic information, (2) information concerning the organization, (3) organizational and environmental factors, and (4)
green technology innovation. The selected measurement items must ensure the content validity of the measurement. Therefore, to ensure content validity, the measurement items in this study were mainly adapted from prior studies (Appendix 1). Specifically, the scale for environmental factors was adapted from Lin and Ho (2008, 2010). The five-point scale for organizational factors was adapted from measures developed by Lin and Ho (2010), and Tomatzky and Fleischer (1990). Green technology innovation was measured using items based on Lin (2009, 2007), and Lin and Ho (2007). Finally, the items for EO were adapted from Rao (2002), Zhu, Sarkis, and Lai (2007). All items were measured on a five-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Podsakoff, Shen, and Podsakoff (2006) and Hair, Hult, Ringle, and Sarstedt (2013) suggest that researchers should employ second-order constructs when a construct is complex, because such models regard each dimension as a critical component of the construct. In the current study, green technology innovation is proposed as a reflective-formative second-order construct. According to the guidelines of Petter, Straub, and Rai (2007), the rationale for considering green technology innovation adoption as a formative second-order constructs is fourfold. First, according to the definition of technology innovation by Lin (2007), and Lin and Ho (2007), three sub-components – data acquisition, information, and transportation technologies – form technology innovation in logistics services. Second, with respect to the nature of technology innovation in the logistics industry, technology innovation is a composite measure of data acquisition, information, and transportation technologies innovation. Third, as innovation in data acquisition technology (DAT), information technology (IT), and transportation technology (TT) are clearly unique, distinguishable, and not interchangeable; they do not share a common theme. Fourth, DAT, IT, and TT are theoretically independent. A change in one sub-component (opinion conforming) is not necessarily expected to be associated with a change in any of the other sub-components (buyer enhancing).

The positively and negatively worded items were mixed in the questionnaire, to check and reduce the common method variance. The negative items were recoded to make all the constructs symmetric. Un-rotated factor analysis was conducted to check the existence of common method variance (Podsakoff and Organ 1986). The results of un-rotated factor analysis showed that the first normalized linear combination only explained 21.60% of the total 78.16% variance, indicating that there is no common method variance issue.

3.2. Sample and data collection

As discussed previously, the scope of this study only concerns transportation among logistics service providers in Malaysia. Transportation in logistics includes sea freight, airfreight, land, and rail transport. Therefore, the data for this study were derived from a questionnaire survey of transportation companies in Malaysia. Based on the Malaysia Logistics Directory, there are 825 transportation companies in Malaysia; thus, based on Sekaran (2009), the required sample for a population of 825 is 260. Since the study is concerned with environmental issues under green initiative from the aspect of business and technology innovation, the target respondents should have knowledge thereof. Consequently, the target respondents comprised the top management in the form of owners, CEOs, MDs, GMs, directors, senior managers, and middle management, such as managers, senior engineers/executives. Accordingly, the unit of analysis is the individual firm.

In order to ensure the content validity of the measurement instrument, the questionnaire was developed through a two-stage process. First, an initial questionnaire was designed based on a review of the literature analysing similar theoretical constructs as well as a discussion with at least two experts in environmental management. Second, the initial questionnaire was modified
by accommodating some suggestions of logistics managers to ensure that each item was adapted to the transportation industry and interpreted as expected. Afterwards, the final version of the questionnaire was mailed to the sampled logistics companies with business models conforming to logistics services. Mail questionnaires were used because of the advantage of being able to cover a wider geographical area in less time and for less cost (Sekaran 2009). Out of the 825 questionnaires distributed, 283 were returned. However, those instances in which a large portion of the questionnaire was not answered were excluded from the survey, leaving 252 questionnaires usable for subsequent analysis. The total usable rate of 30.55% meets the requirement for empirical studies in operations management (Wang, Yeung, and Zhang 2011).

Non-response bias was assessed using procedures recommended by Armstrong and Overton (1977). The last one-quarter of responses received were assumed to be most similar to non-respondents, since their replies took the longest time and the most effort to obtain. Therefore, the last quartile was compared to the first three quartiles. At the 5% significance level, no differences between the ‘early’ and ‘late’ respondents were detected, suggesting that non-response bias was not a problem with regard to the data collected in this study.

About half of the firms (45.2%) that participated in the current study had more than 150 employees and it is believed that they are among the largest logistics firms in Malaysia. The newly established firms in the sample (18.2%) were few and most of the firms were well established (more than 15 years). The male respondents contributed 46.0% and female respondents 54.0%. There were 124 (49.2%) respondents between the ages of 21 and 30 years, followed by 93 (36.9%) respondents between the ages of 31 and 40, and only 35 (13.9%) respondents fell into the age group of above 41 years. About 190 (75.4%) low managers dominated the survey, all of whom mentioned that they understood the process and activities in the company.

3.3. Analysis

The two-step approach was utilized in data analysis, as suggested by Hair et al. (2013). The first step involved the analysis of the measurement model, while the second step tested the structural relationships among the latent constructs. The two-step approach establishes the reliability and validity of the measures before assessing the structural relationship of the model. This study applied partial least squares (PLS) using Smart PLS M3 Version 2.0 (Ringle, Wende, and Will 2005), because PLS allows the latent constructs in the proposed model to be analysed as formative or reflective indicators. PLS places minimal restrictions on measurement scales, sample size, and residual distribution (Chin and Newsted 1999). In addition, PLS is suitable for identifying the key driver constructs (Hair et al. 2013), which matches the aim of the current study.

4. Results

4.1. Measurement model results

The PLS test of the measurement model has three primary aspects: (a) individual item reliability, (b) internal consistency of the entire scale, and (c) discriminant validity. Individual item reliability was assessed by examining the factor loadings of each measure on its corresponding construct. Igbaria, Gumaraes, and Gordon (1995) suggest accepting items with loadings of at least 0.5. Since the loadings associated with each of the scales were all greater than 0.5 (Table 1), individual item reliability was considered acceptable. The construct internal consistency was assessed using composite internal scale reliability, which is similar to Cronbach’s alpha. All constructs satisfy the Hair, Black, Babin, and Anderson (2010) rule of thumb of at least 0.7 for composite reliability.
(Table 1). Internal consistency can also be evaluated using the average variance extracted (AVE), which is a measure of variance accounted for by the underlying variable. The AVE of all constructs was above 0.5, satisfying the recommendation of Fornell and Larcker (1981) and providing further support for the internal consistency (Table 1).

Two approaches were used to assess the discriminant validity of the constructs. First, the cross loadings of the indicators were examined, which revealed that no indicator loads higher on an opposing construct (Hair, Sarstedt, Ringle, and Mena 2012). Second, following the Fornell and Larcker (1981) criterion, each construct’s square root of AVE was greater than its correlation with the remaining constructs (Table 2). Both analyses confirmed the discriminant validity of all constructs.

The measurement quality of the formative second-order constructs was tested in two steps (Hair et al. 2013). In the first step, the variance inflation factor (VIF) of the first-order constructs was computed to assess the multicollinearity. VIF values greater than or equal to 5 would indicate the existence of excessive multicollinearity and raise doubts about the redundancy of the indicator (Hair, Ringle, and Sarstedt 2011). There was no multicollinearity issue between the first-order constructs of green technology innovation as the VIF values varied from 1.098 to 3.410 (Table 3). In the second step, the significance of the relationships between green technology innovation and its first-order constructs was established. Namely, DAT, IT, and TT were assessed, which indicated the relative contribution of each first-order construct to the green technology innovation adoption construct (Hair et al. 2013). All first-order dimensions were found to make a significant contribution.

**Table 1:** Measurement model evaluation.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Items</th>
<th>Factor loadings</th>
<th>CR</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>2</td>
<td>0.589–0.941</td>
<td>0.753</td>
<td>0.616</td>
</tr>
<tr>
<td>QHR</td>
<td>3</td>
<td>0.538–0.907</td>
<td>0.738</td>
<td>0.497</td>
</tr>
<tr>
<td>CP</td>
<td>2</td>
<td>0.686–0.857</td>
<td>0.750</td>
<td>0.603</td>
</tr>
<tr>
<td>GS</td>
<td>2</td>
<td>0.742–0.851</td>
<td>0.778</td>
<td>0.637</td>
</tr>
<tr>
<td>EU</td>
<td>3</td>
<td>0.725–0.946</td>
<td>0.876</td>
<td>0.705</td>
</tr>
<tr>
<td>DAT</td>
<td>6</td>
<td>0.726–0.844</td>
<td>0.911</td>
<td>0.632</td>
</tr>
<tr>
<td>IT</td>
<td>4</td>
<td>0.625–0.962</td>
<td>0.892</td>
<td>0.680</td>
</tr>
<tr>
<td>TT</td>
<td>4</td>
<td>0.532–0.864</td>
<td>0.801</td>
<td>0.509</td>
</tr>
<tr>
<td>EO</td>
<td>4</td>
<td>0.523–0.790</td>
<td>0.799</td>
<td>0.504</td>
</tr>
</tbody>
</table>

Note: CR = composite reliability; AVE = average variance extracted.

**Table 2:** Discriminant validity coefficients.

<table>
<thead>
<tr>
<th></th>
<th>OS</th>
<th>QHR</th>
<th>CP</th>
<th>GS</th>
<th>EU</th>
<th>DAT</th>
<th>IT</th>
<th>TT</th>
<th>EO</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>0.785</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QHR</td>
<td>-0.384</td>
<td>0.705</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>-0.176</td>
<td>0.446</td>
<td>0.777</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GS</td>
<td>-0.224</td>
<td>0.587</td>
<td>0.255</td>
<td>0.798</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>-0.396</td>
<td>0.529</td>
<td>0.086</td>
<td>0.551</td>
<td>0.840</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAT</td>
<td>-0.407</td>
<td>0.668</td>
<td>0.311</td>
<td>0.441</td>
<td>0.592</td>
<td>0.795</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT</td>
<td>-0.222</td>
<td>0.418</td>
<td>0.353</td>
<td>0.472</td>
<td>0.329</td>
<td>0.506</td>
<td>0.825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TT</td>
<td>-0.391</td>
<td>0.672</td>
<td>0.403</td>
<td>0.572</td>
<td>0.640</td>
<td>0.821</td>
<td>0.586</td>
<td>0.713</td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>-0.220</td>
<td>0.528</td>
<td>0.341</td>
<td>0.400</td>
<td>0.469</td>
<td>0.454</td>
<td>0.372</td>
<td>0.585</td>
<td>0.710</td>
</tr>
</tbody>
</table>
4.2. Assessment of the structural model

With the satisfactory results in the measurement model, this study subsequently evaluated the structural model to confirm the relationships among the constructs via the PLS method. The illustrative power of the research model was examined in terms of the total explainable variation of the model. The results suggested that the model is capable of explaining 60.3% of the explainable variation on green technology innovation adoption and 28.5% of EO variation. Besides estimating the magnitude of $R^2$, researchers have recently included the predictive relevance developed by Stone (1974) and Geisser (1975) as an additional assessment of model fit. This technique represents the model adequacy to predict the manifest indicators of each latent construct. Stone-Geisser $Q^2$ (cross-validated redundancy) was computed to examine the predictive relevance using the blindfolding procedure in PLS. Following the guidelines suggested by Chin (2010), a $Q^2$ value of greater than zero implies that the model has predictive relevance; in the present study, a value of 0.531 for green technology innovation adoption and a value of 0.284 for EO were obtained, which are greater than zero.

Nonparametric bootstrapping was applied as suggested by Efron and Tibshirani (1993), and Wetzels, Odekerken-Schroder, and van Oppen (2009) with 5000 resamples (Hair et al. 2013) to test the significance and relative strength of direct effects specified by the research model (Table 4). The results revealed that QHR ($\beta = 0.364, p < 0.001$), CP ($\beta = 0.158, p < 0.05$), and EU ($\beta = 0.335, p < 0.001$) had a significant effect on green technology innovation adoption among transportation companies. In addition, green technology innovation adoption ($\beta = 0.534$, $p < 0.001$) had a significant effect on EO. Hence, H2, H3, H5, and H6 are supported, whereas H1 and H4 are not supported.

5. Discussion and implications

The adoption of green technology innovation presents an opportunity for Malaysian logistics service providers to competently respond to the escalating expectation of the international

### Table 3: Second-order construct evaluation.

<table>
<thead>
<tr>
<th>First-order construct</th>
<th>Outer weight</th>
<th>Standard error</th>
<th>$t$-Value</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT</td>
<td>0.580</td>
<td>0.026</td>
<td>22.294***</td>
<td>2.553</td>
</tr>
<tr>
<td>IT</td>
<td>0.210</td>
<td>0.022</td>
<td>9.723***</td>
<td>1.098</td>
</tr>
<tr>
<td>TT</td>
<td>0.325</td>
<td>0.019</td>
<td>17.367***</td>
<td>3.410</td>
</tr>
</tbody>
</table>

$p < 0.05$.

$p < 0.01$.

$p < 0.001$.

### Table 4: Path coefficient and hypothesis testing.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Relationship</th>
<th>Path coefficient</th>
<th>Standard error</th>
<th>$t$-Value</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>OS $\rightarrow$ GTI</td>
<td>$-0.091$</td>
<td>0.090</td>
<td>1.008</td>
<td>Not supported</td>
</tr>
<tr>
<td>H2</td>
<td>QHR $\rightarrow$ GTI</td>
<td>0.364</td>
<td>0.111</td>
<td>3.267***</td>
<td>Supported</td>
</tr>
<tr>
<td>H3</td>
<td>CP $\rightarrow$ GTI</td>
<td>0.158</td>
<td>0.093</td>
<td>1.704*</td>
<td>Supported</td>
</tr>
<tr>
<td>H4</td>
<td>GS $\rightarrow$ GTI</td>
<td>0.083</td>
<td>0.102</td>
<td>0.813</td>
<td>Not supported</td>
</tr>
<tr>
<td>H5</td>
<td>EU $\rightarrow$ GTI</td>
<td>0.335</td>
<td>0.105</td>
<td>3.189***</td>
<td>Supported</td>
</tr>
<tr>
<td>H6</td>
<td>GTI $\rightarrow$ EO</td>
<td>0.534</td>
<td>0.060</td>
<td>8.875***</td>
<td>Supported</td>
</tr>
</tbody>
</table>

$p < 0.05$.

$p < 0.01$.

$p < 0.001$ (one-tailed).
community for resources conservation and to improve EOs. In the present study, the determinants and EOs of green technology adoption were investigated in the Malaysian transportation industry. Based on the survey results, it was found that QHR, CP, and EU affect the adoption of green technology innovation for Malaysian transportation companies. Therefore, Malaysian transportation companies are more likely to adopt green technology innovations when they have personnel with higher education and better training; there is pressure from the customer’s side and when managers perceive that there are frequent and unpredictable changes in customer preferences, technological developments, and competitive behaviour. However, in this study, the effects of organizational and GS on green technology innovation adoption were not supported. To summarize, the results of the analysis of the determinant factors for green technology innovation indicated that Malaysian transportation companies tend to respond to the QHR, CP, and EU, which in turn influences them to adopt green technology innovation.

The results on the relationship between the QHR and green technology innovation adoption is consistent with Lin and Ho (2008, 2010) who highlight that employees with higher education and learning abilities are crucial for adopting and implementing green practices in logistics. Use of green practices may add complexity to logistics processes such as production or delivery processes. It requires the commitment of organizational resources and improved skills from workers at all levels of the firm. This therefore requires a higher amount of continuing professional development programmes. Providing education and training for employees is important for managing environmental issues (Murphy and Poist 2003). Because of this necessary aspect of implementation, the process of adopting green practices consequently provides a company with certain resources such as organizational commitment and learning, cross-functional integration, and increased employee skills and participation. These are emerging as key resources in a contemporary and highly competitive environment. The training effects are positively associated with qualified tangible resources such as human capital that possess better learning and innovative competencies. In order to improve organizational learning capabilities, Malaysian transportation companies should recruit qualified employees, provide educational programmes, and build knowledge management systems.

In addition to the QHR, it was found that CP is relevant for the adoption of green practices. This result highlights that Malaysian transportation companies regard the customer as an important factor influencing green practice adoption. Therefore, the care and concern for the environment by customers and their request for improving the environmental performance of transportation companies in Malaysia affect green technology innovation adoption, which is consistent with Weng and Lin (2011) in their study on green innovation adoption for SMEs. Besides the two other dimensions discussed above, this study also found that EU is positively related to green technology innovation adoption. This clearly emphasizes that when managers of transportation companies in Malaysia face uncertain business environmental conditions, they become more proactive and more innovative. This result is supported by Kimberly and Evanisko (1981), who consider that when under high EU, companies tend to pay more attention to innovation to maintain their competitive advantage.

This study also hypothesized that organizational support and GS have a positive influence on green practice adoption for Malaysian transportation companies. However, the influencing effects are not statistically significant. This implies that changes in the level of government support and OS do not necessarily lead to changes in the level of green technology adoption. The result is quite different from most research on green technology innovation adoption. The potential reason is that big and well-established companies formed a large portion of the sample in the present study. The large transportation firms can more easily afford the cost of green technology innovation without government support (Beck, Demirguc-Kunt, and Levine 2005). Therefore, the government support does not play an important role in their green technology adoption.
In addition, large and well-established firms have resources for adopting new technology (Knight and Cavusgil 2004) and the OS cannot be a concern for adopting green technology in these types of firms.

Finally, this study found that green technology innovation adoption in transportation companies in Malaysia is positively related to the EO. This highlights that effective green practices innovation is critical for EOs. It has been mentioned in the previous literature that greenhouse gas emissions from the use of transport are a critical issue nowadays and are a significant source of pollutants that have a negative environmental impact (Aramex 2006). Therefore, green technology innovation in the transportation industry should provide rapid progress, as well as the development of new systems or equipment to conserve the natural environment and resources. This will reduce the negative impact on the environment. This study discloses the determinant factors for green innovation adoption in the logistics industry, and thus it can advance the knowledge of managers of logistics to understand the importance and value of green innovation practices and the relationship with EOs. This understanding is crucial to increase the understanding of environmental issues and their economic importance. In addition, it will enhance the competitive power of the logistics industry both globally and regionally. This study also indicates the significance of the effect of green technology innovation towards EOs. Thus, it will provide knowledge to identify the determinant factors and the green technology innovation impact on the environment. This knowledge can help managers or top management to design appropriate policies for identifying the determinant factors and the diffusion of green innovation within their organizations. Therefore, policymakers to improve logistics service sustainability might utilize the concepts and results of green technology innovation developed in this study.

6. Limitations and future studies

There are certain limitations that need to be taken into account for generalizing the results of this study. First, the study tested and verified the hypotheses with a questionnaire survey and only provided a cross-section of the study in nature. Therefore, it limits the ability to imply causality in the relationships among the variables. Thus, the result of the survey will be affected by the fact that this study cannot observe the dynamic change of green technology innovation adoption in the process of improving the determinants. As such, a longitudinal study should be attempted that examines the relationships for an extended period of time to be able to provide more precise results. Second, large and well-established firms make up a large portion of the sample. It is possible that the study’s results suffer from respondent bias. To overcome this limitation, future research could test the research model of this study by collecting data from small and new firms. Third, this study used a survey sample limited to Malaysian transportation companies. However, the determinants of green technology innovation adoption might be different between countries. Thus, future research could test the research model of this study in other countries. Finally, the response rate of this study was 30.55% and a large number of transportation firms were reluctant to participate in the study. Although the test results showed that the non-response bias did not create a problem with the data collected in this study, it would be beneficial in the future to replicate this study with different data collection methodologies and samples to triangulate the findings.

References


Appendix 1: Questionnaire items

**OS**
Top management encourages employees to learn green technology innovation knowledge.
Our company provides resources for employees to learn green technology innovation knowledge.

**QHR**
Employees are capable of learning new technologies easily.
Employees are capable of sharing knowledge with each other.
Employees are capable of providing new ideas for our company.

**CP**
Our customers required us to improve environmental performance.
Caring for the environment is an important consideration for our customers.

**GS**
Government provides financial support for adopting green practices.
Government provides technical assistance for adopting green practices.

**EU**
Predicting customers’ preferences is difficult.
Predicting competitors’ behaviour is difficult.
The advance in new logistics service modes is quick.

**DAT (My company has used . . . . .)**
Radio Frequency Identification Technology (RFID) to manage the physical goods.
RFID to facilitate real-time data communication.
RFID to close the information gaps.
RFID to increase handling efficiency.
RFID to track and trace the products in the process of distribution.
RFID to reduce the amount of paper waste.

**IT (My company has used . . . )**
The Internet to develop networking.
Online system to reduce paper print information or product data list.
Online system to reduce movement and reduce fuel usage.
Electronic ordering system to minimize use of paper ordering.

**TT (My company has used . . . )**
Transportation system to manage and control the services.
Transportation system to control and manage bottleneck.
Hybrid vehicles to reduce fuel consumption.
Hybrid vehicles to reduce green gas emissions.

**EO**
My company has significant improvement in its compliance with environmental standards.
Hazardous/harmful/toxic materials consumption has been significantly reduced in my company.
Energy consumption has been significantly reduced in my company.
Greenhouse emissions have been significantly reduced in my company.