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IT resources and quality attributes: The impact on electronic green supply chain management implementation and performance

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A R T I C L E I N F O

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A B S T R A C T

Although electronic green supply chain management (e-GSCM) has been increasingly adopted into organizations, there is limited empirical research examining antecedents and consequences of e-GSCM implementation. By integrating resource-based and information system success perspectives, this study aims to examine how information technology (IT) resources (i.e., IT infrastructure, IT human and IT relationship resources) and quality attributes (i.e., system quality, information quality, and service quality) influence e-GSCM implementation, which in turn influences firm performance. Partial least squares structural equation modelling (PLS-SEM) is used to analyze the survey of 264 IT managers in large Taiwanese firms. The results show that IT human resources, IT relationship resources, system quality, and information quality significantly drive both e-GSCM internal integration and external collaboration. However, IT infrastructure resources only influence e-GSCM internal integration, and service quality only influences e-GSCM external collaboration. The results also demonstrate that both e-GSCM internal integration and external collaboration are conducive to superior environmental performance and firm competitiveness. Based on the findings, this study discusses the implications for researchers and practitioners.

1. Introduction

Due to both economic and environmental pressures, it has become increasingly important to adopt electronic green supply chain management (e-GSCM) which facilitates individuals, organizations, governments and society to transform towards effective sustainability initiatives [1–3]. E-GSCM is defined as an information technology (IT) enabled green innovation that uses IT to incorporate environmental considerations into supply chain processes and fulfill the environmental protection requirements [4–6]. Specific IT examples include adopting auto-identification technologies to real-time track and improve energy and resources flows [7,8], using cloud computing services to analyze and simulate environmental impact [9,10], and implementing joint decision support systems to foster environmental collaboration and coordination among supply chain partners [11,12]. E-GSCM is different from traditional IT-enabled SCM that focuses more on controlling the final product and economic concern as the single objective [13]. In contrast, e-GSCM concentrates on reducing the negative environmental impacts during production and distribution, while it takes into consideration economic, environment and social concerns as objectives [14–17]. Moreover, e-GSCM in organization is complex; it also involves the management and deployment of scalable IT resources and ensures high availability of IT-based services [5,18,19]. Therefore, identifying and understanding IT-related factors influencing e-GSCM implementation and its impact on firm performance is one of the fundamental requisites to successfully develop e-GSCM.

Many scholars have realized that firm-specific resources (e.g., IT resources) provide a flexible and effective foundation to facilitate the implementation success of IT-enabled green innovations [19–21]. Meanwhile, based on the resource-based view (RBV), firms that possess and effectively deploy IT resources, including technology (i.e., IT infrastructure), human (e.g., IT knowledge and skills), and relationship (e.g., partnership quality) elements, have more strategic options for green management practices compared to firms that do not [18,22–25]. However, IT infrastructure and managerial resources (e.g., IT expertise and partnership quality) have different characteristics, which may realize different levels of e-GSCM implementation. On the other hand, the main reason why IT-enabled projects fail is because they cannot meet business needs and various new technology innovations introduced by firms are either rejected or underused by system users [26]. Although numerous benefits are expected at the early IT-enabled projects adoption stage, users would not be satisfied with it until they

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perceive the system as useful to their decision-making needs. In the light of information system (IS) success model, IT quality attributes (such as high-quality system functions, information outputs, and service delivery) is most commonly used to measure the success of a variety of IT-enabled projects, such as Internet-based systems [27–29] and IT-enabled SCM [30–32]. As higher levels of IT quality attributes are positively associated to higher user satisfaction or actual usage [27]. Compared with Internet-based systems or IT-enabled SCM, e-GSCM frequently encompasses environmental goals; moreover, it can also support the firm to apply environment-friendly products, information, and services. Hence, it is necessary to assess e-GSCM success and extend IS success model into the e-GSCM context.

RBV and IS success model have emerged as two dominant models and together provide a theoretical foundation upon which IT-related factors are likely to result in IT deployment success. There is still a lack of empirical research integrating RBV and IS success model for identifying the critical factors that influence e-GSCM implementation. Therefore, this study attempts to bridge the gap in the literature by proposing an integrated model to examine how different IT resources and quality attributes may differentially impact e-GSCM post-implementation phase. Motivated by the issues identified as above, this research pursues a threefold objective. First, it integrates two theories (RBV and IS success model) into the research model that improve our understanding the antecedents and consequences of e-GSCM implementation. RBV emphasizes the value of IT resources and IS success model emphasizes IT quality attributes. Second, it empirically tests the hypothesized model using the partial least squares structural equation modelling (PLS-SEM) method with responses from 264 manufacturing firms that implemented e-GSCM. Third, it aims to examine the effects of different types of IT resources and quality attributes on e-GSCM implementation (in terms of internal integration and external collaboration) and its subsequent impact on firm performance. The findings can provide managers to better leverage IT strategies to achieve superior e-GSCM performance.

2. Literature review

2.1. E-GSCM implementation

E-GSCM implementation focuses on management and coordination of intra- and inter-organizational processes (through IT use) to minimize the overall environmental impact of both upstream and downstream supply chain practices [33–35]. E-GSCM implementation alleviates environmental problems in two ways. First, one main task of e-GSCM is to help the firm incorporate environmental issues into its competition strategy [36]. Through e-GSCM, firms can integrate green practice into internal production or operations and encourage employee engagement in the greening process. Second, e-GSCM is the collaborative use of advanced IT to develop environment-friendly products or services and to enhance the communication efficiency with supply chain partners [37, 38]. Through e-GSCM, firms can more easily monitor their supply chain partners' green practices and work together to create and reinforce competitive advantages.

Several studies argued that GSCM seeks improved performance through effective development of internal and external linkages, thus creating seamlessly inter-organizational relationships and enabling the achievement of sustainability goals [39–43]. Since e-GSCM can be viewed as an IT-based enabler in inducing changes intra- and inter-organizational processes that minimize the negative environmental impacts throughout the supply chain [35]. Therefore, both internal and external perspectives are necessary to view the e-GSCM scope. In line with above literature, this study conceptualizes that e-GSCM implementation forms two distinctive dimensions: internal integration and external collaboration. Internal integration is the degree to which e-GSCM is integrated with major organizational green activities. In contrast, external collaboration is the degree to which e-GSCM facilitates the collaboration and synchronization among supply chain partners for environment-sustaining activities.

2.2. IT resources in the e-GSCM context

Extending the RBV to the green management context, IT resources can be defined as the degree to which technical and managerial IT applications are used to reduce environmental problems by promoting green-thinking within and across organizational boundaries [44]. Previous research has suggested that IT resources subsume IT infrastructure, IT human and IT relationship elements, which enable the firm to adopt and implement its IT-enabled projects more successfully [45–48]. IT resources is an important driver of IT-enabled green innovations because they help firms simultaneously develop and adopt various green management practices [49,50]. For instance, a flexible IT infrastructure can improve the firm ability to monitor costs, waste, and emissions of each phase of the supply chain and facilitate employee involvement in green initiatives [34,51]. Competent IT staff can align IT strategies with clean technology strategies, enable firms to develop energy-efficient solutions, and foster the diffusion of green technologies [18,25,52]. A team of IT professionals with good partnerships are expected to facilitate communication, coordination, and transparency between the firm and its supply chain partners, which increases external confidence in the firm's green activities [24,44].

E-GSCM is designed to assist firms in tracking and improving energy, material, or goods flows through an integrated technological platform with open standards [19,53]. IT resources are critical for e-GSCM because e-GSCM requires close collaborations and information exchange within and across firms enabled by IT applications [18]. Firms need to maintain a portfolio of IT resources (such as IT infrastructure, personnel expertise, and relationship resources) that are both supportive and compatible with e-GSCM implementation [18,22–25]. Hence, from the perspective of RBV, three types of IT resources (including IT infrastructure, IT human and IT relationship resources) may consider the potential predictors of e-GSCM implementation. Furthermore, previous studies have focused primarily on the effects of general IS support (e.g., IT investments, Internal IT use, and IT assets) on the adoption of IT-enabled green innovation [18,54,55], but failed to provide empirical evidence on a specific type of IT resources. For example, one type of IT resources may be the most important factor in explaining e-GSCM internal integration, whereas another type of IS resources may be the most important factor in explaining e-GSCM external collaboration. As such, this study fills this gap in the e-GSCM literature by investigating the relationship between different IT resources and e-GSCM implementation (in terms of internal integration and external collaboration).

2.3. IT quality attributes in the e-GSCM context

Within the IS success model, IT quality attributes are composed of system quality, information quality, and service quality that affect the extent of IT implementation, which in turn is direct predictor of net benefits [27]. System quality measures the quality of information processing itself, information quality measures the quality of IT outputs, service quality measures the level of service delivered by the IT, user satisfaction and system use measure the extent of IT implementation, and net benefits are the measures of IT effectiveness [27,56,57]. Excellent in IT quality attributes involve providing easy-to-use system functions, high quality shared information, and fast responses to user queries regarding system delivered services. The high quality IT-enabled project can meet user requirements, and lasting increase the frequency of actual usage. Khayer et al. [29] and Ravasan et al. [58] have also revealed that service quality along with system quality and information quality are recognized as important antecedents that lead to the success of IT-enabled project deployment and implementation. Therefore, the quality of IT-enabled project is the most critical for ensuring its successful implement and incorporation within or across organizations.

E-GSCM implementation success should not only focus on incorporating green practices into the supply chain system, but also depend on the overall quality of IT that tends to be perceived as sufficient for user needs [36,59]. Designing user-friendly interfaces, providing user information requirements, and delivering high-quality service can carry out e-GSCM with the least time and effort that will help firms to integrate the e-GSCM with existing green management activities. IT quality attributes may therefore affect the success of e-GSCM implementation. The IS success model provides a theoretical underpinning to our study and helps us examine how IT quality attributes influence the e-GSCM implementation which ultimately facilitates performance outcomes. This study attempts to contribute to a better understanding the relationship between the multi-dimensional IT quality and e-GSCM that implemented from internal to external boundaries of the organization, as proposed in the IS success model and hence the focus of this study.

3. Research model and hypotheses

With theoretical grounding in both the RBV and IS success model, this study developed the research model shown in Fig. 1. Two major types of drivers—IT resources and IT quality attributes—are determinants of internal integration and external collaboration of e-GSCM, which in turn, influences environmental performance and firm competitiveness. In the research model, IT resources are represented by three constructs: IT infrastructure, IT human and IT relationship resources. IT quality attributes are represented by three kinds of IS success measures, including system quality, information quality, and service quality. Each variable involved in the research model and hypotheses are discussed next.

3.1. Effects of IT resources on the e-GSCM implementation

IT infrastructure resources refer to the firm shared technical assets (including computing platform, databases, and electronic communication networks) which are characterized by issues like connectivity, compatibility and modularity [60,61]. They are carefully developed technological foundations on which current and future IT applications are built [62,63]. IT infrastructure resources are likely to lead to e-GSCM implementation because they provide an efficient platform to support environment-friendly operations. For example, the connectivity of IT infrastructure is an essential linkage for achieving cross-functional and cross-firm process integration, and then enables the alignment between IT applications and green management activities [5,64]. Moreover, the compatible IT infrastructure enables the firm to share and communicate any type of information which easily integrates the smooth flow of information into IT applications [61,65]. High levels of modularity help the firm easily reconfigure IT applications and integrate IT applications with supply chain partners' systems [61,66]. Such modularity also enables the firm to modify its IT applications to meet environment protection requirements (e.g., in e-GSCM). Accordingly, it is hypothesized that e-GSCM internal integration and external collaboration require support from IT infrastructure resources.

H1. IT infrastructure resources positively influence e-GSCM (a) internal integration and (b) external collaboration.

In the present study, IT human resources refer to the degree to which IT personnel have technical and business skills to foresee the development of emerging technologies and effectively leverage them in the alignment of business processes with environment-sustaining activities [24,67]. Firms with strong IT human resources are likely to develop reliable IT applications that support business needs of the firm faster than competition [45]. Likewise, appropriate IT human resources can be used to undertake assigned tasks within and across firms in the supply chain [68,69]. Watson et al. [70] also point out that the success of e-GSCM adoption depends on the IT personnel ability to understand "what is" and "what could be" of IT projects in relation to environmental sustainability. The pursuit of environmental sustainability is an important task and should connect corporate social responsibility via various stakeholders (such as employees and supply chain partners) [18,71,72]. Firms that have IT personnel with superior green knowledge and IT solutions can deliver environment-friendly values to internal (employees) and external (supply chain partners) stakeholders, which would foster the success of green IT initiatives [22,25,73,74]. These discussions lead us to posit that IT human resources result in firms to realize a smooth digital transformation and extend their e-GSCM implementation.

H2. IT human resources positively influence e-GSCM (a) internal integration and (b) external collaboration.

The major components of IT relationship resources are the degree of

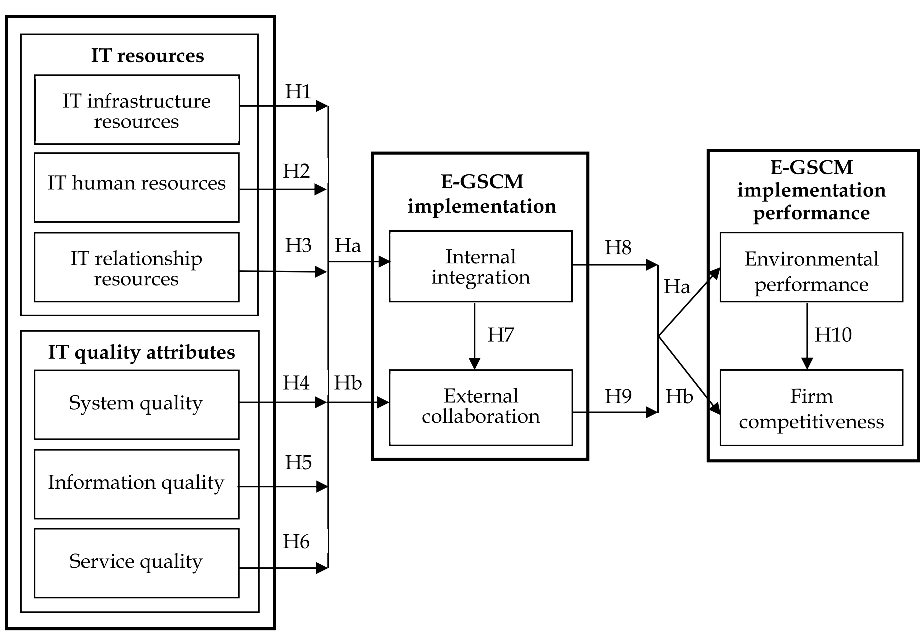

Fig. 1. The research model.

mutual dependence, trust, communication, and coordination between IT department and supply chain partners, which can make effective use of IT applications [75,76]. E-GSCM implementation involves social interaction mechanisms between all supply chain members. IT department and supply chain partners must develop an appreciation and understanding of each other's environment, which is necessary for e-GSCM to effectively facilitate inter-firm system integration [18,42,77]. E-GSCM also requires close inter-organizational relationships among members serving different mechanisms to jointly develop environmental solutions [15,78]. Relationship building may facilitate wider dialogue between IT department and supply chain partners, and then involves easing e-GSCM's integration with organizational green activities [79]. Additionally, integrated and synergistic IT relationship resources enable the organization to conduct joint learning activities and develop green innovation, thereby increasing the possibility to foster an extensive e-GSCM implementation. Hence, it is suggested that increased IT relationship resources will improve the likelihood of successful e-GSCM internal integration and external collaboration.

H3. IT relationship resources positively influence e-GSCM (a) internal integration and (b) external collaboration.

3.2. Effects of IT quality attributes on the e-GSCM implementation

System quality is the user evaluation of the IT functionality and its usability. It is measured by attributes like whether or not there are errors in the IT applications, ease of use, response time, and flexibility [26,28,57]. In the case of e-GSCM, system quality is defined in terms of system reliability, easy to access, faster response time, and flexibility in meeting the requirements of environment-friendly operations. Many studies have found that higher system quality could lead to higher user satisfaction and IT actual usage [27,29,80]. In contrast, the system that is poor designed and constructed would be detrimental supply chain system implementation, which increases implementation costs [31,81]. Further, if e-GSCM is well-designed and constructed, the firm can accelerate decision-making in various green management processes, and ultimately facilitate the expansion and wider use of e-GSCM. Accordingly, this study developed the following hypotheses.

H4. System quality positively influences e-GSCM (a) internal integration and (b) external collaboration.

Information quality is the user evaluation of the IT output (i.e., the quality of information produced, delivered and presented by the IT). It refers to characteristics such as accuracy, completeness, timeliness and suitable format of the information generated by the IT [30,32]. In the e-GSCM context, intra- and inter-firm environmental practices may imply hidden risk than speed and cost problems because there is more information uncertainty, asymmetry and opportunism in the firm and its supply chain partners [82]. High quality e-GSCM information can be considered as the critical indicator to solve the problem of information asymmetry, reduce the level of uncertainty, and mitigate opportunistic behaviors both within the firm and between the firm and its supply chain partners [81]. Conversely, low information quality (such as inaccurate, incomplete or out-of-date information) may cause serious information distortion in the green supply chain; these barriers would impede the e-GSCM implementation. On the basis of above arguments, e-GSCM with high-quality information will have a better chance to facilitate its internal integration and external collaboration. Hence, the following hypotheses are proposed.

H5. Information quality positively influences e-GSCM (a) internal integration and (b) external collaboration.

Service quality is the user evaluation of the overall service delivered by the IT, which is widely recognized as an important dimension that leads to the IT adoption intention and continued use [27,56]. In the current study, service quality can be defined as the various attributes such as assurance (secure operations), responsiveness (providing prompt service), and empathy (individual attention and caring) involved with the e-GSCM services [30,83]. By having high-quality IT services that induce assurance, responsiveness, and empathy in cross-functional teams, can likely to enhance the operational efficiency [84]. Research carried out SCM domain suggests that better service quality increases the level of internal (employees) and external (supply chain partners) user satisfaction that can be addressed as the IT implementation success [31,85]. Thus, it is estimated that focus on the e-GSCM service quality may facilitate intra-firm integration and inter-firm collaboration which leads to the formation of the following hypotheses.

H6. Service quality positively influences e-GSCM (a) internal integration and (b) external collaboration.

3.3. E-GSCM internal integration and external collaboration

E-GSCM encompasses all the activities associated with internal green activities (e.g., monitoring and mitigating environmental impacts) and external GSCM practices (such as collaborating with supply chain partners to design eco-friendly processes and products and enhance resource efficiency) [38,53,82]. Internal integration can be explained as the degree of inter-connectivity among IT applications and organizational green activities. In the context of e-GSCM, the aim of technology integration is to help firms accompany strict environmental regulations and monitor environmental impact of their products and services, thereby extending green practices to supply chain partners [37,50]. When the firm has a high level of e-GSCM internal integration, it is likely to impose environmental regulations on its supply chain partners, as well as facilitating green collaborations with those partners to work together to reduce environmental impact [36,86]. Moreover, researchers have observed that external green collaboration with supply chain partners should be based on internal GSCM practices to be successfully implemented [37,87]. Thus, this study hypothesizes that firms with higher degrees of internal integration of e-GSCM are more likely to facilitate external green collaboration with supply chain partners.

H7. E-GSCM internal integration positively influences its external collaboration.

3.4. E-GSCM implementation and performance

When e-GSCM implementation is properly executed, it is practically possible to mitigate environmental damages while increasing competitive advantages [88,89]. Therefore, this study uses two concepts to measure e-GSCM implementation performance: environmental performance and firm competitiveness. Environmental performance refers to implementing e-GSCM solutions to achieve environmental protection and environmental management policies [24]. Firm competitiveness refers to improving the firm's relative position in competition through e-GSCM implementation [79].

E-GSCM implementation for internal green practices enables the firm to respond to the environmental protection pressure and improve resource efficiency in internal production [14,90]. Integrating internal green practices and e-GSCM can be regarded as the task-technology alignment to support organizational operations for sustainable development [6]. E-GSCM internal integration helps employees carry out green management and technology activities together, leading to an increased environmental performance. Some scholars also believe that cross-functional green management such as e-GSCM has a positive association with organizational performance [91]. The firm that adapts its operational processes to e-GSCM strategies is more likely to solve all kinds of environmental problems. This can help the firm to achieve competitive advantage in green innovation.

Through e-GSCM, the firm is more likely to form collaborative relationships with supply chain partners and involve mutual understanding of environmental risks and responsibilities [43]. Greater green collaborative activities can facilitate stable long-term interactions among supply chain members, enabling the firm to achieve environmental common goals [92]. Similarly, de Sousa Jabbour et al. [93] found that green collaboration with supply chain partners is positively related to environmental performance. Furthermore, e-GSCM enables supply chain partners to jointly make green objectives and strategies, which in turn reveal new ways to add value to core competency and new opportunities to establish green image [94–96]. Such potential benefits lead to improvement in business competitiveness.

Achieving long-term competitive advantage is the final objective of every organization. Hart and Dowell [49] pointed out that green management practices are associated with organizational profits. Appropriate environmental protection initiatives help firms attract customers who care about the environmental issues, thus gaining market competitiveness [97]. These arguments have been confirmed by previous researchers, such as Ahmed et al. [43] and Yang et al. [98] also found that making effective use of raw materials results in better economic payoffs in the long term, and thus achieve organizational competitive advantage. Firm's environmental protection policy can increase stakeholder satisfaction and green image which bring greater business competitiveness [24]. Thus, the following hypotheses are proposed.

H8. E-GSCM internal integration positively influences (a) environmental performance and (b) firm competitiveness.

H9. E-GSCM external collaboration positively influences (a) environmental performance and (b) firm competitiveness.

H10. Environmental performance positively influences firm competitiveness.

4. Research methodology

4.1. Sample and data collection

Samples were restricted to the listed companies in order to include large-scale manufacturing firms in Taiwan. Annual survey of Taiwan's large enterprises by Common Wealth Magazine is the source for sampling because it analyzes top 1000 Taiwanese manufacturing firms. Therefore, in this study, the population is the top 1000 Taiwanese manufacturing firms, published by Common Wealth Magazine. To ensure that IT managers received the questionnaire and maximize the response rate, five researchers spent one month telephoning each firm; if the target firm that has not adopted e-GSCM or lacked permission to participate in the survey were removed from the list. As the result, about 900 firms formed the sampling frame for this study. The final questionnaires were mailed to the 900 IT managers (currently and directly in charge of e-GSCM projects). A stamped return envelope was enclosed, along with the covering letter explaining the purpose of the present study.

Two hundred and seventy-four of the 900 firms responded, with 264 having complete data available for subsequent analysis, yielding an effective response rate of 29.3%. Basic information of respondents and companies are depicted in Table 1. Additionally, this study conducts two statistical analyses to ensure the absence of non-response bias [99]. First, this study compares the responding and non-responding firms in terms of company assets and employee numbers. This information is available from the Common Wealth Magazine, and the independent sample *t*-test revealed no significant difference between the two groups ($p = 0.092$ and 0.124, respectively). The respondents are then divided into two groups based on return dates. Comparison of the two groups in terms of company assets and number of employees again revealed no significant differences based on the independent sample *t*-test ($p = 0.137$ and 0.115, respectively). Therefore, non-response bias should not be a problem in this study.

Table 1
Basic information of respondents and companies ($n = 264$).

	Frequency	Percentage
Basic information of respondents		
Education Level		
High school or below	42	15.9
College/University	131	49.6
Graduate school or above	91	34.5
Working experience (years)		
Less than 5 years	8	3.0
5–10	26	9.9
10–15	85	32.2
15–20	71	26.9
More than 20	74	28.0
Respondent title		
Chief information officer	126	47.7
IT manager	78	29.6
Other manager in IT department	23	8.7
Others (IT analyst, IT specialist / Engineer, other manager)	37	14.0
Basic information of companies		
Industry types		
Traditional manufacturing	116	43.9
High-tech manufacturing	148	56.1
Number of employees		
Less than 500	43	16.3
501–1000	61	23.1
1001–3000	80	30.3
3001–5000	68	25.8
More than 5000	12	4.5
Total assets (NT$)		
Less than $10 billion	76	28.8
$11 - $50 billion	113	42.8
$51 - $100 billion	51	19.3
More than $100 billion	24	9.1

4.2. Construct operationalization

Measurement items were developed from the previous research and modified to fit the e-GSCM context. Then, the survey was pretested to refine measurement items and ensure content validity. During the pretest phase, three IT managers and three information management profession were asked to comment on the questions and wordings. The construct measures were refined based on the comments of these six individuals. The measurement items of independent and dependent variables are listed in the Appendix and discussed below.

Independent variables. IS infrastructure resources were measured on four items which were adapted from Byrd and Turner [60] and Benitez et al. [61]. These items asked respondents to evaluate connectivity (such as inter-connectivity and multiple entry points), compatibility and modularity of e-GSCM infrastructure. Using a four-item scale, IT human resources were assessed the extent to which IT personnel has the ability to manage e-GSCM, learn new green technologies, develop appropriate e-GSCM solutions, and work effectively in cross-functional teams [24,47,75]. IT relationship resources were measured by four items that measured the extent to which the relationship between IT department and supply chain partners reflect benefit and risk sharing, trust, communication, and coordination while using e-GSCM [15,46,48]. The scales for IT quality attributes were measured using items adapted from previous IT implementation studies [27,56,57]. System quality was measured using four items which focused on reliability, easy to access, response time, and flexibility of e-GSCM. Information quality measured using a four-item scale which focused on accuracy, completeness, timeliness and suitable format of the information provided by e-GSCM. Service quality was measured using three items that assessed the extent of assurance, responsiveness, and empathy of e-GSCM services.

Dependent variables. This study used two variables, internal integration and external collaboration, to measure the e-GSCM implementation. Internal integration was measured by the degree of integration of e-GSCM in five major green management activities, including total quality environmental management, green production and marketing planning, green material and inventory control, product-related and packaging-related eco-design [98,100]. External collaboration was assessed using four items by asking respondents to indicate the extent to which e-GSCM facilitates collaboration with supply chain partners for environment-sustaining activities [41,47]. Regarding e-GSCM implementation performance, eight items are divided into two broad groups — environmental performance (four items) and firm competitiveness (four items). The measure of environmental performance consists of compliance with environmental regulation, decreased energy consumption costs, reduced the usage of harmful materials, and lower frequency for environmental accidents [24,33]. Firm competitiveness measures the improvement in competitive position, productivity, profitability, and corporate image [79,101].

5. Data analyses and results

The partial least square structural equation modeling (PLS-SEM) was used to test the research model; data analysis was performed by SmartPLS 3 software. The PLS-SEM procedure has two steps [102]. First, the measurement model is estimated using confirmatory factor analysis (CFA) to confirm reliability and validity of the constructs. In the second step, the structural model examined the hypothesized relationships in the research model.

5.1. Measurement model

The measurement model analysis includes the assessment of reliability, convergent validity, and discriminate validity. As shown in Table 2, the composite reliability values ranged between 0.833 and 0.949, which exceeds the recommended threshold value of 0.70 [102], indicating acceptable construct reliability. For the convergent validity assessment, loadings of all items are above 0.60 at the significant level of 0.01, with average variance extracted (AVE) values exceed the recommended cut-off level of 0.50 [102]. These results support convergent validity. Table 2 also presents that the squared root of AVE is higher than the correlation among the constructs [103], further confirming adequate discriminant validity. Hence, it is concluded that the proposed model had acceptable reliability and validity.

5.2. Common method bias

One of the major concerns in using a single-informant approach is the threat of common method variance (CMV). This study took two steps to reduce CMV, as recommended by Podsakoff et al. [104]. First, this study used neutral wording for the items and multiple items for constructs, which help reduce the occurrence of CMV. Second, this study used the Harman's single-factor test examines whether a single factor emerges from principal component analysis, or if one factor overwhelmingly accounts for the majority of covariance among the variables in an unrotated factor analysis. The results indicated that multiple factors emerged to explain the data variance. Hence, CMV does not appear to be a serious concern for the current research.

5.3. Structural model

After establishing the reliability and validity of the measures, the structural model was used to test the hypothesized relationships. Table 3 shows the results of the structural model. To evaluate the model's quality, it is essential to ensure the amount of variance explained (R^2 value) in the endogenous variable (i.e., internal integration, external collaboration, environmental performance, and firm competitiveness). According to Cohen [105], the R^2 value higher than 26% is considered to be substantial. The results showed that R^2 values of all endogenous variables exceed the recommended benchmark (ranged from 0.360 to 0.595), indicating good explanatory power of the structural model. Additionally, the predictive relevance of the model is assessed based on the Q^2 value. The results show that Q^2 values for all endogenous variables were greater than zero, thus supporting the predictive relevance of the model [102]. Meanwhile, the standardized root mean square residual (SRMR) is 0.086, which less than 0.1 is considered a good model fit [102].

Within the IT resources, IT infrastructure resources have a significant influence on e-GSCM internal integration (β = 0.146, $p < 0.5$), but shows non-significant on e-GSCM external collaboration. Thus, H1a is supported, but H1b is not supported. IT human resources have a significant influence on both e-GSCM internal integration (β = 0.385, $p < 0.001$) and external collaboration (β = 0.121, $p < 0.5$), supporting H2a and H2b. IT relationship resources also have a significant influence on e-GSCM implementation in terms of both internal integration (β = 0.127, $p < 0.5$) and external collaboration (β = 0.198, $p < 0.01$). Thus, H3a and H3b are supported.

Table 2
Results of the measurement model.

Construct	Range of standardized loadings[a]	Composite reliability	Average variance extracted	Inter-construct correlations									
				(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) IT infrastructure resources	0.742–0.919	0.913	0.724	0.851									
(2) IT human resources	0.723–0.915	0.919	0.741	0.524	0.861								
(3) IT relationship resources	0.712–0.844	0.948	0.583	0.742	0.630	0.764							
(4) System quality	0.863–0.944	0.949	0.824	0.754	0.473	0.738	0.908						
(5) Information quality	0.858–0.893	0.928	0.764	0.611	0.378	0.554	0.676	0.874					
(6) Service quality	0.874–0.891	0.913	0.777	0.490	0.758	0.584	0.437	0.308	0.882				
(7) Internal integration	0.649–0.790	0.849	0.530	0.637	0.631	0.652	0.630	0.587	0.491	0.728			
(8) External collaboration	0.688–0.793	0.833	0.555	0.518	0.566	0.609	0.555	0.487	0.506	0.633	0.745		
(9) Environmental performance	0.776–0.797	0.867	0.621	0.527	0.585	0.697	0.550	0.453	0.550	0.576	0.722	0.788	
(10) Firm competitiveness	0.842–0.917	0.932	0.776	0.371	0.711	0.455	0.325	0.284	0.04	0.483	0.562	0.531	0.881

Note. [a]All loadings are significant at $p < 0.01$ level. Diagonal elements are square root of average variance extracted (AVE) for that construct, while off-diagonal elements are inter-construct correlations.

Table 3
Results of estimation structural model.

Path from	Path to			
	Internal integration	External collaboration	Environmental performance	Firm competitiveness
Independent variables				
H1a,H1b: IT infrastructure resources	0.146*	0.077 ns		
H2a,H2b: IT human resources	0.385***	0.121*		
H3a,H3b: IT relationship resources	0.127*	0.198**		
H4a,H4b: System quality	0.128*	0.108*		
H5a,H5b: Information quality	0.218***	0.097†		
H6a,H6b: Service quality	0.069 ns	0.114*		
Dependent variables				
H7: Internal integration		0.296***		
H8a,H8b: Internal integration			0.157**	0.180**
H9a,H9b: External collaboration			0.662***	0.292***
H10: Environmental performance				0.205**
R^2	0.593	0.501	0.595	0.360
Q^2	0.295	0.264	0.355	0.271

Note: ns Non-significant;†< 0.10;*p < 0.05;**p < 0.01;***p < 0.001.
Standardized root mean square residual (SRMR) = 0.086.

Within the IT quality attributes, system quality has a significant influence on both e-GSCM internal integration (β = 0.128, $p < 0.05$) and external collaboration (β = 0.108, $p < 0.5$), whereas information quality has a significant influence on e-GSCM internal integration (β = 0.218, $p < 0.001$) but marginal effect on external collaboration(β = 0.097, $p < 0.1$). Thus, H4a, H4b, H5a and H5b are supported. Service quality is an important determinant of e-GSCM external collaboration (β = 0.114, $p < 0.5$), but is not important for e-GSCM internal integration. Thus, H6b is supported, but H6a is not supported.

On the other hand, e-GSCM internal integration has a significant influence on its external collaboration (β = 0.296, $p < 0.001$), supporting H7. Furthermore, e-GSCM internal integration has a significant influence on environmental performance (β = 0.157, $p < 0.01$) and firm competitiveness(β = 0.180, $p < 0.01$), supporting H8a and H8b. E-GSCM external collaboration has a very significant influence on environmental performance (β = 0.662, $p < 0.001$) and firm competitiveness (β = 0.292, $p < 0.001$), supporting H9a and H9b. Finally, environmental performance has a significant influence on firm competitiveness (β = 0.205, $p < 0.01$). Thus, H10 is supported.

6. Discussion and implications

6.1. The role of IT resources in the e-GSCM implementation

The results indicated that IT infrastructure resources are critical to e-GSCM internal integration. This observation confirms that IT infrastructure capability can be used to facilitate organization's GSCM efforts [5,64]. IT infrastructure resources, indicated by the attributes of electronic links and connections (connectivity), information integration among supply chain members (compatible), and easily reconfigure IT applications (modularity), are considered to provide a basis for the seamless integration of IT applications into green management activities. However, contrary to the expectation, there is an insignificant relationship between IT infrastructure resources and e-GSCM external collaboration. One possible explanation may be that interconnected, compatible, and modular IT infrastructure is valuable but not rare; therefore, the effect of IT infrastructure investments may have time lag as argued in Kohli and Devaraj [106]. IT infrastructure may influence the early stage in e-GSCM integration with organizational green activities, but less influential in more-extensive environmental collaboration with supply chain partners.

Both IT human and IT relationship resources, as two important IT resources, are vital enables of e-GSCM implementation and have different effect on its dimensions. IT human resources are significantly more important for e-GSCM internal integration than for external collaboration. Specifically, the impact of IT human resources is significantly higher than other antecedents on e-GSCM internal integration. In contrast, IT relationship resources are more beneficial for e-GSCM external collaboration than for internal integration. These findings extend our understanding of the RBV used in the e-GSCM literature. As suggested by Mao et al. [48], firms that have highly competent of IT personnel are better positioned to integrate new technologies into existing business processes than those do not. IT personnel with superior e-GSCM implementation knowledge can not only increase their willingness to take the responsibility for green management but also help enterprises to incorporate e-GSCM into green management activities. Thus, firms that possess highly skilled IT personnel may be able to benefit a high level of seamless integration of e-GSCM with practicing environment conscious activities. Additionally, successful e-GSCM external collaboration would rely more on IT relationship resources, as noted by Huo and Han [14] that "in terms of resource efficiency, allocating social resources to improve external information integration is more efficient." As the social interaction mechanism, the close relationships between IT department and supply chain partners provide more opportunities for them to work together; then help firms establish a good surrounding for an extensive e-GSCM implementation. Thus, firms seeking to improve e-GSCM external collaboration need to pay more attention in maintaining or enhancing the long-term relationship between IT department and supply chain partners.

6.2. The role of IT quality attributes in the e-GSCM implementation

This study validated system quality and information quality as two important antecedents of successful e-GSCM implementation, confirming prior IT implementation research [31,81]. This implies that the level of e-GSCM internal integration and external collaboration is determined by various aspects of system quality, such as reliability, easy to access, faster response time, and flexibility in meeting user requirements. Furthermore, firms that implement e-GSCM are more concerned about the information quality (i.e. accuracy, completeness, timeliness and suitable format) that captured and processed by the e-GSCM systems. This study also finds that compared with system quality, e-GSCM internal integration is greatly influenced by information quality. This implies that useful information output can solve the problems of information asymmetry and distortion, then, will be expected to effectively facilitate seamless integration of e-GSCM and environment-friendly operations.

Previous studies on IT implementation have argued that service quality enhances the incentive of IT adoption intention and continued use [27,56]. This study also demonstrates that service quality has a strong impact on e-GSCM external collaboration, and this means that firms highly expect better e-GSCM service quality to achieve extensive external diffusion. Therefore, service quality attributes (such as secure operations, providing prompt service, and individual attention and caring) are enablers to promote the high-level of e-GSCM external collaboration. However, service quality does not have a significant effect on e-GSCM internal integration. It may be explained that to actually integrate IT applications and green management activities (like e-GSCM) will not be an easy task; users prefer to learn the system more quickly and with less effort to operate. Given the challenges inherent in e-GSCM internal integration, users may be more concerned about system characteristics such as easy-to-use, user-friendly interface, and output quality.

6.3. The role of e-GSCM implementation in improving environmental and firm performance

The results find that e-GSCM internal integration is the antecedent of effective green collaboration with supply chain partners, consistent with previous research suggests that internal green practice is a necessary first step prior to external green initiatives [36,86]. The results also show that both e-GSCM internal integration and external collaboration are significantly and positively associates with better environment performance. These findings are in line with previous studies indicating that cross-functional and cross-firm green IT adoption contributes positively to environmental performance [6,92]. Regarding the relative impact of e-GSCM internal integration and external collaboration on environmental performance, e-GSCM external diffusion has a stronger impact. However, GSCM literature generally reports that internal green practice has a stronger effect on improving environmental performance [14,36]. One possible reason may be that an effective green supply chain collaboration involves various and complex issues. It requires the firm and its supply chain partners to bring mutual benefits and participate at multiple levels. Through e-GSCM, the firm is more likely to form collaborative relationships with supply chain partners and jointly develop environmental solutions, which in turn achieve greater environmental common goals.

In terms of firm competitiveness, the results show that e-GSCM internal integration and external diffusion lead to better firm competitiveness. These findings are supported by previous studies. For example, Li et al. [36] and Zhu et al. [37] find that internal and external supply chain environmental initiatives can facilitate green competitive advantage in organizational operations. Accordingly, it can be interpreted that both e-GSCM internal and external implementation can bring green image and operational performance improvement. With increasing green image and operational performance, enterprises can hopefully gain business competitiveness in the longer term. The results show further that firm competitiveness is affected by strong environmental performance through e-GSCM implementation. This observation agreed with pervious findings by Chuang and Huang [24] and Yang et al. [98]. Thus, organizational competitive advantage may be achieved in the longer term after environmental performance improvements have occurred.

6.4. Theoretical contributions and managerial implications

For researchers, this study provides several theoretical implications to the literature. Frist, this study reduces the gap in the e-GSCM literature, as there is currently a lack of empirical studies concerning the influence of IT resources and quality attributes on e-GSCM implementation. Using empirical data from 264 manufacturing firms in Taiwan, this study found strong support for the research model, and the two dimensions proposed (IT resources and quality attributes) are significant for e-GSCM implementation (in terms of internal integration and external collaboration), which in turn influences environmental performance and firm competitiveness. This is one of the first research efforts to provide empirical evidence concerning how IT-related factors affect e-GSCM implementation and its subsequent impact on firm performance. Furthermore, previous studies have suggested that combining theories or models can provide a wide variety of interesting and helpful perspectives [29,107]. This study proposes an integrated model which combines the strengths of RBV theory and IS success model pursuant of comprehensively understanding the antecedents and consequences of e-GSCM implementation. Thus, this study not only provides a research model which integrates RBV theory and IS success model in the e-GSCM context but also puts forward results which are amenable to generalization in other settings of IT-enabled green innovations.

For managers, this study provides several practical implications about the antecedents of e-GSCM implementation and firm performance. First, managers should understand that IT resources are important enablers to build e-GSCM internal integration, which lead to external diffusion. IT human resources are more important than other antecedents for building e-GSCM internal integration. Managers should provide appropriate training methods (e.g., didactic presentation, seminars, coaching, or experiential exercises) to educate IT personnel about the value of green management and increase their knowledge and skills in the area of e-GSCM. Second, this study suggests that e-GSCM implementation success significantly depends on the overall IT quality (i.e. system quality, information quality, and service quality). Compared to system quality and service quality, information quality is relatively more beneficial for e-GSCM internal integration. Thus, managers should focus their efforts to improve the quality of information outputs (such as accurate and concise information), which increase the transparency and efficiency of information flow and then facilitate e-GSCM internal integration. Finally, it is notable that e-GSCM implementation is not a burden. It is possible to generate win-win solutions for both of environmental performance and firm competitiveness. Additionally, to improve environmental performance, managers should deploy more IT relationship resources to achieve e-GSCM external diffusion, which plays a more important role than internal integration in enhancing environmental performance.

6.5. Limitations and future research

This study has some limitations that suggest directions for future research. First, the present study uses a single respondent from each target firm in examining the research model. Although IT manager insights and experiences are important information sources in studying e-GSCM implementation, in the absence of further respondents from the same firm exist which do not enable evaluation of the e-GSCM perceptions of the whole group. Future research must collect data from several knowledgeable responses in each firm to obtain the notion of collectively held e-GSCM implementation. Second, although the use of subjective (self-report) measures of e-GSCM implementation performance is theoretically and popular accepted method, however, self-reported competitive advantage is susceptible to response bias. To minimize such bias, future research is recommended to use both objective (physical performance data) and subjective (self-report) measures to evaluate e-GSCM implementation performance. Using mixed methods would help to develop a holistic understanding of e-GSCM implementation performance and make the research more practically relevant. Third, this study examined some IT resources and quality attributes that impact e-GSCM implementation. Several other factors, such as organizational absorptive capacity, senior manager attitudes, market turbulence, could also influence e-GSCM implementation. This is another area for future research. Fourth, in line with the e-GSCM-related literature [36,37,86,87], this study focuses on how e-GSCM internal integration affects its external collaboration. Since it is likely that great e-GSCM external collaboration may motivate internal integration to improve implementation performance, further analysis of the reciprocal relationship between internal integration and external collaboration will be carried out. Finally, this study uses 264 manufacturing firms in Taiwan as the research subjects. Hence, the research model should be tested further using samples from other countries, since the findings may be influenced by cultural differences between Taiwan and other countries, and further testing thus would provide a more robust test of the hypotheses.

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Appendix. Measurement items

Part I: Independent variables

IT infrastructure resources

1. Our firm has a high degree of electronic links and connections to support e-GSCM.
2. Our firm provides multiple interfaces or entry points (e.g., mobile app, web access) to support e-GSCM.
3. Software applications can be easily transported and used across multiple platforms while using e-GSCM.
4. Reusable software modules which are widely used while using e-GSCM.

IT human resources

1. Our IT personnel have professional knowledge and skills of e-GSCM.
2. Our IT personnel have the ability to quickly learn and apply new green technologies.
3. Our IT personnel are able to interpret business problems and develop appropriate e-GSCM solutions.
4. Our IT personnel have the ability to work effectively in cross-functional teams while using e-GSCM.

IT relationship resources

1. Our IT department and supply chain partners share benefits and risks of e-GSCM.
2. There is high degree of trust between our IT department and supply chain partners while using e-GSCM.
3. The goals and plans for e-GSCM are jointly developed by both the IT department and supply chain partners.
4. Conflicts between IT department and supply chain partners are rare and few in our firm while using e-GSCM.

System quality

1. The operation of e-GSCM was dependable.
2. E-GSCM made information easy to access.
3. The response time of e-GSCM was acceptable.
4. E-GSCM can be adapted to meet a variety of business needs.

Information quality

1. Information provided by e-GSCM is accurate.
2. Information provided by e-GSCM is complete.
2. Information provided by e-GSCM is up-to-date.
3. Information provided by e-GSCM is readable, clear, and well formatted.

Service quality

1. I felt safe in my operations with the e-GSCM.
2. In the case of any problem, I think e-GSCM would give me prompt service.
3. E-GSCM was designed with user's best interests at heart.

Part II: Dependent variables

Internal integration

Our firm has implemented e-GSCM in supporting …

1. Total quality environmental management.
2. Green production and marketing planning.
3. Green material and inventory control.
4. Design for products for reuse, recycle, recovery of materials.
5. Design for packing for reduced consumption of materials.

External collaboration

Our firm has implemented e-GSCM in supporting …

1. Exchange the environmental information with supply chain partners.
2. Collaboration with supply chain partners for environmental objectives.
3. Collaboration with supply chain partners for eco-design.
4. Collaboration with supply chain partners for cleaner production.

Environmental performance

Implementing e-GSCM helps our firm …

1. Improve compliance to environmental regulations.
2. Decrease energy consumption costs.
3. Reduce the usage of harmful materials.
4. Reduce the frequency for environmental accidents.

Firm competitiveness

Implementing e-GSCM helps our firm achieve …

1. Stronger competitive position.
2. Improved productivity.
3. Improved profitability.
4. Positive corporate image.

Note: Items for all constructs were measured using five-point Likert scales anchored between "strongly disagree" and "strongly agree".

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