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Analysis of Linkages between Logistics Information Systems and Logistics Performance Management under Uncertainty

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Abstract

Logistics performance management has received more attention by government and organizations in recent years as it becomes the critical success factor of the supply chain. The study of logistics performance management in this paper aims to analyze dimensions and relevant factors of logistics information system (LIS) usage that affects logistics performance management under uncertainty. A survey was conducted on distribution activity and applied Technology Acceptance Model to extrapolate the intention to use LIS. Exploratory factor analysis and ANOVA were employed to examine the association among the dimensions that influent on LIS usage. A case study was taken from a large household product firm whose business survival depended on logistics performance. We analyzed various logistics activities to determine the associativity among these activities. As such, related linkages can be established for subsequent logistics performance monitor and improvement. Summary of findings and future work are reported.

Keywords: Logistics information systems; Logistics performance management; Uncertainty management; Technology acceptance model.

1. Introduction

Logistics management has received much attention over the past decade from practitioners and government. Realizing the importance of sustainability in logistics management is critical for competitive advantage (Buyukozkan et al., 2008) because operational performance has a positive impact on company's financial performance (Horvath et al., 2005; Liu and Lyons, 2011). In business, sustainability is defined as a capability to possess and hold continuous competitiveness (Kang et al., 2012; Hassini et al., 2012). Logistics management consists of activities from customer service, orders processing, inventory management, transportation, storage, packaging, demand and forecasting, production planning, purchasing and procurement, facility location, and distribution that are supported by enormous information flow (Celebi et al., 2010). Therefore, logistics performance is managed in order to ensure sustainability of the firm. Many firms applied information technology such as enterprise resource planning (ERP) and information systems (IS) in operational process management to cost effectively serve the customer's requirements (Tilokavichai and Sophatsathit, 2011; Ngai et al., 2008; Cheung et al., 2003). Thus, IS and strategic partnerships can be integrated to achieve the desired service level (Su and Yang, 2010). However, the unavoidable uncertainties will have an influence on logistics performance management (Hsiao et al., 2010) such as demand and price which are uncertainty parameters (S.A, 2008). These inherent uncertainties affect the performance of logistics operations (Hsiao et al., 2010).

The advent of information technology (IT) revolutionizes logistics operation. Poor logistics performance reflects the firm's information capability which indirectly impacts financial performance (Shang and Marlow, 2005). As we aim to derive factors that affect LIS usage in logistics performance management, the following questions are addressed: (1) how does the perceived support of LIS usage impact logistics performance management? (2) how does the perceived ease of LIS usage impact logistics performance management? (3) how does firm size impact the perceived usefulness of LIS usage? (4) how does the perceived ease of use impact the perceived usefulness of LIS usage? (5) how does the perceived usefulness of LIS usage impact uncertainty management in logistics activities? and (6) how does the perceived usefulness of LIS usage impact logistics performance management?

The organization of the paper is as follows. Section 2 reviews some related literature and important issues in the area. Research objectives and methodology are elucidated in Section 3. Analysis results are presented in Section 4. Section 5 demonstrates the analytical validity of the finding through a case study. Section 6 summarizes the

findings and future research directions.

2. Literature Review

2.1 Logistics Performance Management

Logistics management plays an important role of adding competitive advantage to a firm in customer support and business excellence (Buyukozkan et al., 2008). Effective logistics management provides the right product in the right place at the right time. It involves control of product and information flow to create value-added activities such that delivery is accomplished through suitable distribution channels (Narasimhan & Kim, 2001). It is managed to yield minimize cost and time but maximize service level, for example, on time delivery, minimum stock level, high quality or non-damage products (Celebi et al., 2010; Lai et al., 2010; Murthy et al, 2004). Thus, logistics management is a one of the contributing operations that encompasses activities ranging from customer service, order processing, inventory management, transportation, warehouse management, packaging, demand and forecasting, production planning, purchasing and procurement, facility location, and distribution. All of these are supported by enormous information flows (Celebi et al., 2010; De Haan et al., 2007). A typical structure of a logistics network is illustrated in Figure 1. Performance measurement is usually carried out in financial and non-financial terms, focusing on planning and controlling to monitor and improve logistics management (Garcia et al., 2011; Wegelius-Lehtonen, 2001). Nevertheless, financial measures are not sufficient for decision making in strategic and policy planning. Additional non-financial measures such as quality, reliability, flexibility, and delivery performance (Laitinen, 2002) must be incorporated to complement the decision. Further analysis of the relationship between logistics activities and logistics performance are depicted in Figure 2. This relationship scheme represents the conceptual logistics distribution network. For example, inventory management is related to transportation (Mutha and Pokharel, 2009; Pishvaee et al., 2009) based on time performance (aka on-time delivery to customers), reverse logistics relates to order processing (Lee et al., 2010; Pishvaee et al., 2009) which is measured by returned value per sale, and purchasing and procurement activity directly relates with inventory management by right quantity (Zhao et al., 2010) measured by stock accuracy. With the help of balance scorecard (BSC), firm can establish a map from business objectives to the operational objectives on financial, customers, internal processes, learning, and growth. As a consequence, relevant performance indicators for each strategic objective with actual values and targets (Quezada et al., 2009) can be identified.

2.2 Uncertainty Management

The function of traditional logistics is to achieve profit through cost reduction. This operational objective is too narrow to accommodate modern logistics activity management. Recent trends in business sustainability are to conduct business with a long term goal of maintaining the well-being of the economy, environment, and society by efficiently utilizing the limited sources, flexibly coping with changing business environment, and timely responding to new customer demands. Such goal-seeking attempts inevitably expose to uncertainty (Kang et al., 2012; Hassini et al., 2012) of minimizing costs, time, opportunity loss, and maximizing flexibility. Uncertainties have affected performance of logistics operations and have important roles in decision making (Hsiao et al., 2010; S.A, 2008). A number of uncertainty management activities such as customer complaints, support, order cancellation, product damage in inventory and packaging, transportation cost, lead time, warehouse distribution, volume of product return in reverse logistics, and price variation in purchasing and procurement (Yu and Li, 2000; Biehl et al., 2007; Salema et al., 2007; Pishvaee et al., 2009; Hsiao et al., 2010; Kim et al., 2011; Tsao, 2011) instigate further investigation to mitigate consequential business risks.

2.3 Technology Acceptance Model

Many researches have indicated that enterprise resource planning (ERP) and information systems (IS) play an important role in managing, supporting, and monitoring logistics processes so as to gaining business competitive advantage (Tilokavichai and Sophatsathit, 2011; Celebi et al., 2008; Ngai et al., 2008; Cheung et al., 2003; Narasimhan et al., 2001). To validate such claims, technology acceptance model (TAM) is used to assess utility and acceptance of logistics information technology with respect to the relationship of perceived ease of use (PEOU) and perceived usefulness (PU) of IT applications, both of them are influential factors on individual's decision to IT application adoption (Bienstock et al., 2008).

3. Research Objectives and Methodology

The proposed methodology exploits pertinent fundamentals established in the aforementioned literature to derive our research framework. The primary focus is on LIS usage and various factors that affect logistics performance management as shown in Figure 3. The research framework and hypotheses on various factors affecting logistics performance management under uncertainty are shown in Figure 4. A set of hypotheses were applied to gauge the validity of the proposed framework, namely, *Ha, Hb, Hc, Hd, He*, and *Hf*. *Ha* denotes perceived support of LIS having an effect on logistics performance management; *Hb* denotes perceived ease of LIS usage having an effect on logistics performance management; *Hc* denotes firm size having an effect on perceived usefulness of LIS; *Hd* denotes the perceived ease of LIS usage having an effect on perceived usefulness of LIS; *He* denotes perceived usefulness of LIS usage having an effect on uncertainty management in logistics activities; *Hf* denotes the perceived usefulness of LIS usage having an effect on logistics performance management. The objectives are to address the above questions by analyzing the relationship between (1) perceived support and logistics performance management, (2) perceived ease of LIS usage and logistics performance management, (3) perceived usefulness of LIS usage and firm size, (4) perceived usefulness of LIS usage and perceived ease of use, (5) perceived usefulness of LIS usage and uncertainty management in logistics activities, and (6) perceived usefulness of LIS usage and logistics performance management.

We designed a set of survey questionnaire covering the above objectives in four topics, namely, (1) factors that support usage, (2) managing uncertainty that is inherent to logistics activities (3) usefulness of LIS, and (4) current logistics performance management. The questionnaire uses a 5-point Likert scale with 1 being "Strongly disagree" and 5 being "Strongly agree" to distinguish the variations in feedback response. In order to validate the contents of these questionnaire prior to data collection, a preliminary survey was conducted on experienced logistics manages and operational staffs. The focus of this study is on investigating logistics management of firms in Thailand. Out of 250 questionnaires, 99 or 39.6% feedback response were returned and used in the analysis. Table 1 summarizes the respondents' company profile.

4. Data Analysis and Results

We applied the Chi Square test to measure itemized categorical association. Exploratory factor analysis (EFA) was used to reduce irrelevant items. Factor loading was computed with the help of principal component analysis (PCA) and rotated with varimax method. The eigenvalue of any factor should be greater than one (Hair et al., 1998). The Kaiser-Meyer-Olkin (KMO) measure was applied on the remaining relevant data to detect whether or not they were properly factored, using the minimum acceptable value of 0.5 (Kaiser, 1974) that satisfied the prerequisite of a good factor analysis. Moreover, factor validation was accomplished on items having factor loading exceeding 0.4 (Nunnally, 1967). Data reliability and validity were carried out by Cronbach's alpha that measured the internal consistency of multi-item scales to be as low as 0.6 (Nunnally, 1967) for each category. The EFA results of logistics performance management are shown in Table 2 and uncertainty items are shown in Table 3. Logistics performance management consists of only KMO as the factor set to be 0.87, having total percentage of variance is 64.24. There are four factors associated with uncertainty items in logistics activities, namely, internal uncertainty factor, customer uncertainty factor, vendor uncertainty factor, and natural uncertainty factor. The KMO value and total percentage of variance are 0.85 and 74.8, respectively. Pearson correlation coefficient of logistics performance management was also tested on LIS usage items. The results are shown in Table 4. We found all items of perceived usefulness of LIS having positive association with logistics performance management and perceived ease of LIS usage item having positively associate with logistics performance management at the significant value of 0.05. In addition, all items of perceived usefulness had positive association with ease of LIS usage and almost all the items of perceived support had positive association with logistics performance management except after-sale service items. On the contrary, LIS usage for improving logistics performance had negative association with internal uncertainty factors. The rationale is quite straightforward. If the firms can manage internal uncertainty at high level, LIS is of little use for improving logistics performance. Nonetheless, it positively associated with vendor uncertainty factor simply because if the firms could manage uncertainty induced by vendors at high level, LIS was still of much use for improving logistics performance. This was by virtue of shared information cooperation with vendors. The same results were obtained from daily logistics activity support and decision making of logistics activity support. However, all items of perceived usefulness had no association with natural uncertainty factor.

The one-way analysis of variance (One-Way ANOVA) and least significant difference (LSD) for multiple factor comparisons yielded different comparative results in each group-pair. The results are shown in Table 5, where firm size has no effect on LIS usage for daily logistics activity support and for communicate with customers. This is because all firm sizes realize the necessity of improving and controlling logistics performance to reach higher level of customer's satisfaction. A closer look into size difference reveals that small/medium and large firms use LIS for different purposes. The former tries to improve logistics performance in hope to compete, survive, and grow in the business, whereas the latter wants to sustain its competitive advantage in the business.

We aim to derive factors that affect LIS usage in logistics performance management. The results show that the perceived support of LIS usage such as requirement responsiveness and correct information has positive impact on logistics performance management, but after-sale service has no impact. In addition, it has positive impact on all of items in the perceived usefulness of LIS, which in turn positively affecting logistics performance management. On the contrary, support decision making in logistics activity and daily logistics activity have negative impact on internal uncertainty since any advanced decisions on daily and planned operations cannot respond fast enough to accommodate such unanticipated uncertainty. Although firm size has no impact on daily logistics activity support, small firms have more logistics activity decision support than medium firms. The case remains valid for medium firms in comparison with large ones. As for logistics performance improvement, only large firms are attentive to the issue.

5. Case Study

A case study was taken from a large retail business in household products which will be referred to by VT company for identity confidentiality purpose. The firm applied IT to operational support and logistics management such as ERP, Business Intelligence (BI), intranet, vendor management inventory, warehouse management system and delivery system. The traditional performance measurement is shown in Table 6. Each department possessed its own performance indicators but they were not linked to other departmental performance indicators. As a result, it was difficult to attain any substantial improvement on various activities. In 2009, the company adopted ERP of SAP and BI in operational activities. After deciding to deploy new IT system, the company implemented TAM to assess the usefulness of the IT system to improve logistics performance. Information logistics from SAP system was used to analyze and set up strategy map as shown in Figure 5. This map depicted corporate level key performance indicators (KPIs), encompassing logistics performance indicators, to be reported on the balanced scorecard.

The essential operations begin at innovation and learning perspective which serve as the stepping stones to drive the remaining operations in other perspectives. The color code of each operational measures, i.e., turnover of staffs, skills of staffs, and excellent IT/IS are conducive toward relating operations. Such relational linkages contribute directly to LIS and various logistics activity performance management. For example, from internal process perspective, the company can improve transportation performance and inventory management process by investing on staff's skills and excellent IT/IS deployment. This in turn drives on-time delivery, thereby retaining existing customers, increasing revenue, and maximizing profits in accordance with customer and financial perspectives, respectively.

Based on this strategy map, some of the company's logistics performance measurements are summarized in Table 7. Valuable benefits precipitated from these linkages are executive decision support. For example, the warning status (yellow or light grey) of on-time delivery will alert executives to follow the links, unraveling its root causes, i.e., transportation performance and inventory management process. The corresponding statistics can be verified in Table 7.

A noteworthy finding from our analysis is the discrepancies between the target and actual performance projection. Case in point, in on-time delivery, the target performance is set at 95%, while the actual achievement merely reached 85%. Following the links to order cycle time, we see that order cycle time is 40 minutes, but the actual operation could not achieve the target. This induces a domino effect to inventory management and transportation performance. By virtue of such linkage, the company can monitor logistics performance over time for improvement and gain competitive advantage over their business rivals.

6. Conclusion and future research

In this study, we have explored the relationships between logistics performance management and logistics

information systems under uncertainty. We also applied TAM to analyze LIS usage. The results show (q1-q2) positive association between perceived support/ease of LIS usage and logistics performance management, and (q4-q6) positive association between perceived usefulness of LIS usage and perceived ease of use/uncertainty management in logistics activities/logistics performance management. However, firm size (q3) does not affect LIS usage to support daily logistics activities in because all firms exercise LIS to run logistics management, keeping current with their competitive edge in this digital age. On the other hand, perceived usefulness of LIS to improve logistics performance and support for daily logistics activities have negative association with internal uncertainty factors. This offers companies to systematically plan their logistics management strategy, thereby more efficient and higher performance can be achieved. All in all, our findings not only reaffirm the vitality of LIS existence in logistics management, but also reveal the hidden benefits of linking various logistics activities and LIS as an integrated performance tuning in the presence of uncertainty. As such, the risks involved can be mitigated and, in some cases, avoided entirely. The benefits of TAM assessment help measure how successful new software applications are deployed in the company from ease of use, usefulness, and support standpoints. A noteworthy analysis in VT company is the linkage association that give rise to effective administering internal uncertainty. For instance, firm can share information with vendors to better handle customer's demand, quantity and quality of product, etc. This in turn enables the firm to attain their target KPIs, reaching the ultimate goal of maximizing the profit established in the strategy map. We envision future research to incorporate stochastic process toward managing uncertainty in logistics activities.

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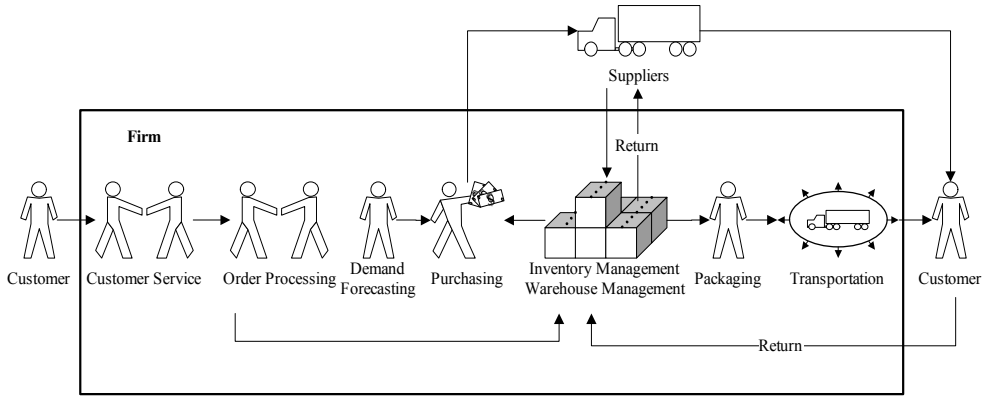

Figure 1. General structure of a logistics network at firm level.

Figure 2. Logistics activity relationship and performance measurement.

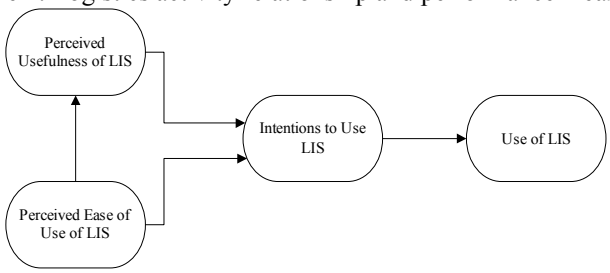

Figure 3. Technology acceptance model of LIS usage.

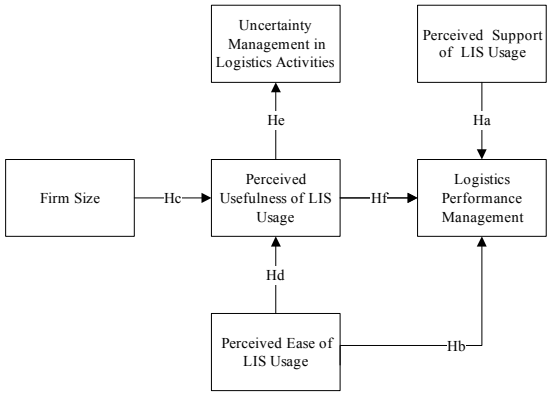

Figure 4. Research framework of the study.

Table 1. Profile of respondent companies (99 total).

Variable	Category	Frequency	Rate (%)
Firm size	Small	50	50.5
	Medium	16	16.2
	Large	33	33.3
Operation (Yrs)	<1 Yrs	3	3
	1-3 Yrs	15	15.2
	4-6 Yrs	20	20.2
	7-9 Yrs	4	4
	>= 10 Yrs	57	57.6
Revenue (Baht)	Retail	45	45.5
	Wholesaler	17	17.2
	Service	13	13.1
	Manufacturing for industry	19	19.2
	Manufacturing for consumer	5	5.1

Table 2. Results of exploratory factor analysis of logistics performance management.

Factor	Logistics performance management
Cronbach's α = 0.92, KMO = 0.87, % variance = 64.24, Eigenvalue = 5.78	Satisfaction in customer service, Order processing, Purchasing, Transportation, Warehouse management, Inventory Management, Demand and Forecasting, Packaging, Reverse logistics

Table 3. Results of exploratory factor analysis of uncertainty items in logistics activities.

Factor	Internal uncertainty	Customer uncertainty	Vendor uncertainty	Natural uncertainty
Cronbach's α = 0.936 KMO = 0.85	Packaging quality Delivery lead time Number of vehicles in transportation Damage product IT systems Partner cancellation	Number of order Sale order cancellation Customer's demand Customer's satisfaction Transportation cost Price of product Returned product	Product quality Vendor's lead time Product quantity Transport schedule	Natural disaster
% variance	31.57	22.28	13.87	7.15
Eigenvalue	6.31	4.46	2.77	1.43

Table 4. Summary of LIS usage items and logistics performance management association.

LIS usage	Association		Results
Perceived usefulness of LIS usage	Improve logistics performance	LPM	Associated (+)
	Support decision making in logistics activities	LPM	Associated (+)
	Cooperate with partner	LPM	Associated (+)
	Support for daily logistics activities	LPM	Associated (+)
	Communicate with customers	LPM	Associated (+)
Perceived ease of LIS usage	Ease of LIS usage	LPM	Associated (+)
Perceived support of LIS usage	Response time	LPM	Associated (+)
	Requirement responsiveness	LPM	Associated (+)
	Correct information	LPM	Associated (+)
	Price	LPM	Associated (+)
	After sale service	LPM	No Associated
Perceived usefulness of LIS usage	Improve logistics performance	Ease of LIS usage	Associated (+)
	Support decision making in logistics activities	Ease of LIS usage	Associated (+)
	Cooperate with partner	Ease of LIS usage	Associated (+)
	Support for daily logistics activities	Ease of LIS usage	Associated (+)
	Communicate with customers	Ease of LIS usage	Associated (+)
Perceived usefulness of LIS usage	Improve logistics performance	Internal uncertainty	Associated (-)
	Support decision making in logistics activities	Internal uncertainty	Associated (-)
	Cooperate with partner	Internal uncertainty	No Associated
	Support for daily logistics activities	Internal uncertainty	Associated (-)
	Communicate with customers	Internal uncertainty	No Associated
Perceived usefulness of LIS usage	Improve logistics performance	Customer uncertainty	No Associated
	Support decision making in logistics activities	Customer uncertainty	No Associated
	Cooperate with partner	Customer uncertainty	Associated (-)
	Support for daily logistics activities	Customer uncertainty	Associated (-)
	Communicate with customers	Customer uncertainty	No Associated
Perceived usefulness of LIS usage	Improve logistics performance	Vendor uncertainty	Associated (+)
	Support decision making in logistics activities	Vendor uncertainty	Associated (+)
	Cooperate with partner	Vendor uncertainty	Associated (+)
	Support for daily logistics activities	Vendor uncertainty	Associated (+)
	Communicate with customers	Vendor uncertainty	Associated (+)
Perceived usefulness of LIS usage	Improve logistics performance	Natural uncertainty	No Associated
	Support decision making in logistics activities	Natural uncertainty	No Associated
	Cooperate with partner	Natural uncertainty	No Associated
	Support for daily logistics activities	Natural uncertainty	No Associated
	Communicate with customers	Natural uncertainty	No Associated

Logistics performance management: LPM

Table 5. Results of the ANOVA.

Perceived usefulness of LIS	SM	SL	ML
Improve logistics performance	No diff	No diff	Diff (-)
Support decision making in logistics activities	Diff (+)	No diff	Diff (+)
Cooperate with partner	No diff	No diff	Diff (+)
Support for daily logistics activities	No diff	No diff	No diff
Communicate with customers	No diff	No diff	No diff

S: Small firms, M: Medium firms, L: Large firms

Table 6. The traditional performance measurement of VT company.

Department	Company	Branch	Purchasing	DC	Marketing	HR
Key performance indicators	% Increase revenue	Sales target	% Margin	Delivery time to branch	New customer growth	% of training
	% Net profit	Order cycle time	Vendor's performance	Internal time performance	No. of loss customers	Turnover
	% Administration expense	Inventory turnover	% Back order	Transportation cost	Effective of promotion	

DC: Distribution Center

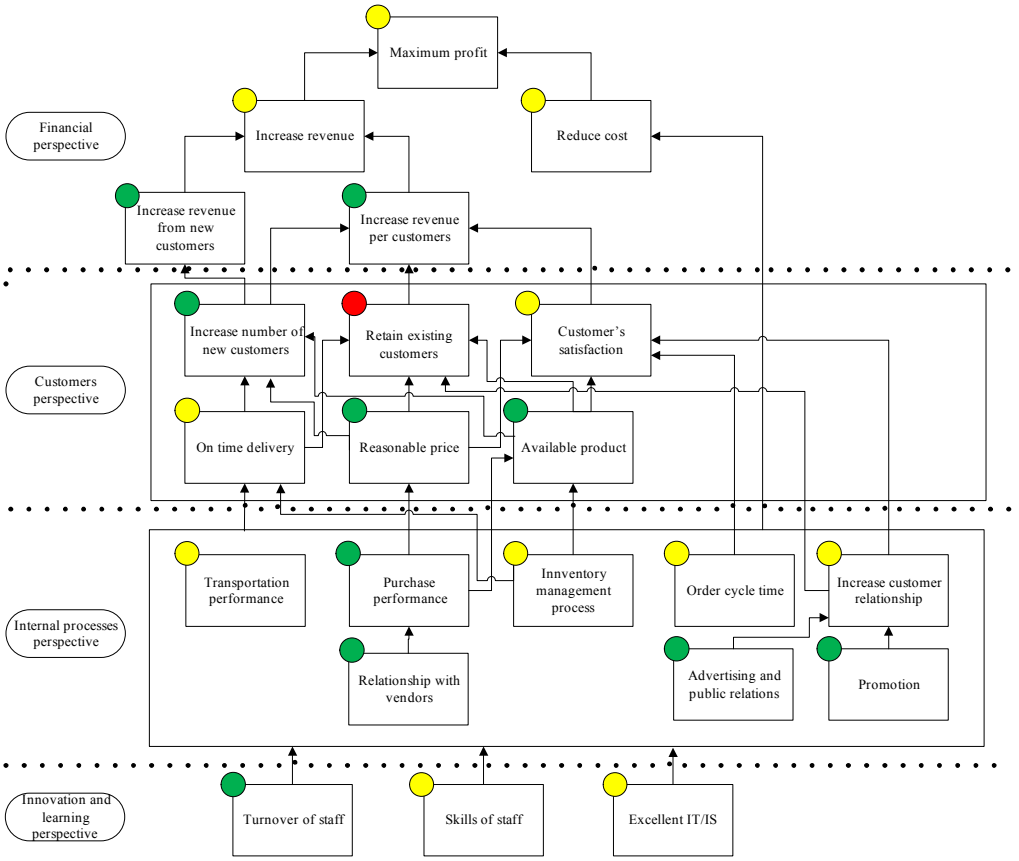

Figure 5. Strategy map of VT company.

Table 7. Logistics performance measurement of VT company in 2010.

Perspective	Logistics performance indicator	Actual	Target
Financial	Profit Margin	17%	20%
	Sales growth	17%	22%
Customers	New customers growth	30%	25%
	Number of loss customers	200	100
Internal Process	% of product returned	3%	1%
	Order cycle time	40 minutes	30 minutes
	On time delivery	85%	95%
	Value damage per sales	0.27%	0.3%
	Transportation cost per sales	3%	2%
	Stock day	60 days	45 days
	Time performance of distribution center	36 hours	24 hours
Innovation and Learning	% of employees trained	70%	80%
	Turnover of staff	0.5%	1%