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Introducing Quality of Service Criteria into Supply Chain Management for Excellence

Roman Gumzej, University of Maribor, Slovenia
Brigita Gajšek, University of Maribor, Slovenia

ABSTRACT

This article is focused on a sub domain of quality, namely, quality of service. Considering supply chain management, the authors believe that it is important to distinguish between a quality of product (also service) offered by producers and service providers and a quality of service which is achieved between any supplier and customer, not only a consumer, along a supply chain. Quality of product represents producer’s/service provider’s commitment and is subject of various quality certificates issued by inspection authorities. This research examines the quality of service, which is provided by a supplier to its customer along the supply chain, between any pair of chain elements fulfilling this relation, including the common retailer-consumer relation. The authors introduce measurement points into a consumer-centric supply chain model for the defined criteria and defined the method of their monitoring and overall supply chain quality of service evaluation. Finally, the authors assess the envisaged impact of the results of their measurements on supply chain excellence, providing management with an opportunity to identify weak spots.

Keywords: Customer-Centric Supply Chain, Information and Communication Technology Support, Management, Measurement, Model, Quality of Service Criteria

INTRODUCTION

Linear supply chain structure (on left hand side of Figure 1) was appropriate and sufficient in times of great economical growth. However, its shortcomings became obvious, when the growth stopped and adaptability to quick market changes was sought. Since the supply overgrew demand on the global level, the economic situation of the companies involved grew worse. At that time mainly the medium and small-sized companies managed to live up to their competitive edge. They could more quickly adapt to market changes because of their smaller-sized production and logistics. It became obvious that in times of quick market changes the linear supply chain model, which was aimed at large scale production, was no longer appropriate. One could speculate that the secret of success in the demanding economical situation lies within a different kind of supply chain model and its management automation by employing information and communication technology. Evolution towards a consumer-
centric supply chain model (on right hand side of Figure 1) benefited from quicker adaption to reduced demand and easier adoption of new kinds of products/services. Through its introduction and the mentioned technological support capitalization of market changes was made possible.

Different authors (Ketchen, Rebarich, Hult, & Meyer, 2008) emphasize the importance of delivering superior total value to the customer in terms of promptness, cost, quality and flexibility rather than focusing primarily on promptness and cost. The presented article is focused on quality of service (QoS), which encompasses all listed terms in relation to the customer. Considering supply chain management (hereinafter referred to as SCM), we believe that it is important to distinguish between a quality of product or service offered (hereinafter referred to as “item”) that is produced by one or more suppliers and a QoS which is achieved between any supplier and customer, not only a consumer, along a supply chain. Quality of an item represents producers’ commitment and is the subject of various quality certificates issued by inspection authorities. Although the practice occasionally reports difficulties with given items’ quality, despite the adopted quality certificate, we understand these unpleasant cases as examples of unjustified trust of a supply chain towards a specific subordinated production/service element.

We identified QoS among supply chain elements as vital for supply chain existence and source of trust between supply chain elements. In literature we noticed plenty of contributions dealing with item quality management and methods for assuring and improving their quality. On the other hand, we discovered a lack of research on QoS, which would monitor one or more items’ handover between a supplier and a customer. Our research is focused on the QoS, which is provided by a supplier to its customer along the supply chain, between any pair of chain elements fulfilling this relation, including the common retailer-consumer relation. We are convinced that most supply chains are lacking a consistent method for keeping track of individual connection’s and total supply chain’s QoS.

It is reasonably argued that satisfied customers will have positive influence on sale, keeping trust and conducting advanced forms of relations. Fact is that customer needs are mostly multifaceted. Consequently, supply chains have to provide their outcomes in terms of overall customer satisfaction in every chain phase. We are focused on the service, which is needed to establish the flow of items and their associated information. Like some other authors, Chowa et al. (2008) summarizes that in competitive environments customers, in need for their own satisfaction, require from business enterprises better and cheaper items, shorter
response times, more product lines, and higher service levels. Consequently, to improve service level, it is important to measure current system performance on the level of the supply chain. Measuring it just on the level of any particular company is insufficient. As mentioned in the previous research (Chowa et al., 2008), business executives and managers recognize that the ultimate success of any enterprise is no longer built around a firm’s capability and capacity, but on a supply chain’s capability and capacity. We discovered a few recent studies which begun to consider both the upstream and downstream side of a supply chain simultaneously.

Further more, traditional selling channels are supplemented by e-commerce. Key to satisfying customers that purchase over the internet is an effective logistics system that successfully delivers the items and related information in an efficient manner. Otherwise, customers will switch to other internet stores or switch back to more traditional channels (Moberg et al., 2000). From previous research, we could also identify the significance of observability and transparency of availability. Consumers’ access to the internet has greatly expanded their ability to compare offers across a wide array of retailers (Rabinovich, 2007). We found several published works where authors study the relations between e-service quality and consumers’ perceptions of performance, satisfaction, and loyalty. Here, great emphasis is put on timeliness, correctness, security, safety, and, in very recent time, ecology issues. This study will fill the research gap in the field of supply chain QoS.

The purpose of this article is to extend models of adaptable consumer-centric supply chains by introducing key QoS criteria into them for their evaluation. The introduction of appropriate measurement points into a consumer-centric supply chain model for the defined criteria is discussed and the envisaged implementation of their monitoring and evaluation by employing information and communication technology is indicated. Adaptable SCM models for different lines of industry are investigated. Finally, the possible impacts of measurements’ results on SCM excellence will be assessed. The criteria introduced and their continuous observation should support managements in achieving it by identifying and improving the phases which diminish customer satisfaction. In the conclusions an outlook is given on where and how the presented solutions may be put into use.

**SCM PERFORMANCE MEASUREMENT OVERVIEW**

In the constantly changing global economy flexible production and services are sought. According to SCM approach, organizations do not seek to achieve cost reductions or profit improvements at the expense of their supply network partners, but rather strive to make the supply network more competitive as a whole (Romano, 2003). When considering improving SCM and the fact whether it really pays (Otto & Kotzab, 2003) a holistic approach to supply chain modeling (Chan & Qi, 2003) has been identified as the approach that enables its appropriate assessment. One wishes to reason on the performance of SCM in order to determine its efficiency, which ultimately leads to its excellence (Krivda, 2005).

According to (Chan & Qi, 2003), the main reasons for employing a holistic approach in its evaluation are represented by the otherwise identified absence of connection with a strategy, lack of system thinking, in which a supply chain must be viewed as one whole entity, lack of a balanced approach integrating financial and non-financial measures, as well as loss of supply chain context, thus encouraging local optimization. A supply chain is not just a collection of independent, self-centered enterprises, nor is SCM the coordination of interfaces between the fragmented functions of supply chain members. By its very initiatives, the supply chain should be viewed as an integrated entity, and all the members should be functionally coordinated as an extended enterprise (Holmberg, 2000; Lambert et al., 1998). The inward-looking view neither promotes excellent management of supply chains, nor results satisfactorily in performance measurement.
Many metrics, used in supply chain performance evaluation, have been designed to measure operational performance, evaluate improved effectiveness, and examine strategic alignment of the whole SCM (Beamon, 1999). A metric is defined as a verifiable measure, stated in either quantitative or qualitative terms and defined with respect to a reference point. Ideally, metrics are consistent with how an operation delivers value to its customers as stated in meaningful terms (Melnyk et al., 2004). Individual measures of supply chain performance have usually been classified into four categories: quality (Beamon, 1999; Shepherd & Günter, 2006), time (Bolstorff, 2003; Shepherd & Günter, 2006), cost (Bolstorff, 2003; Gunasekaran et al., 2004), flexibility (Angerhofer & Angelides, 2006; Beamon, 1999). They have been grouped by their attributes – quality and quantity, cost and non-cost, strategic/operational/tactical focus, and supply chain processes (Gunasekaran et al., 2004; Shepherd & Günter, 2006).

Changed supply chains models and the encouraged holistic approach to SCM are putting the relevant quality criteria into a new perspective. The quality of a product or service is not regarded solely from the producer-consumer perspective. Since customer-supplier relations exist throughout the entire supply chain and can be established between any pair of elements, quality depends not only on the quality policy of the producers but on quality of each link in the supply chain and eventually, so does the price. Hence, we talk about QoS from the customer perspective, regardless of the fact, whether it is from the consumer’s or another element’s standpoint in the supply chain.

QoS criteria pertain to all phases in the supply chain and mainly concern seamless supply, correctness of production and manipulation procedures, transportation processes, product information up-to-datedness, dependability of supply, production and transport, liability of producers and service providers, as well as security of financial transactions and sensitive information sharing. In order to assess these criteria, clearly, all actors in a supply chain need to be considered by systematic examination and evaluation of these and other relevant criteria. In order to support supply chain benchmarking and supply chain element targeted decision-making based on them, a check-list of predominantly quantitative performance measures needed to be defined and, in the case of SCM, they could be defined even for criteria, which by their nature are qualitative.

Introducing QoS Criteria into SCM

Companies have been measuring the performance of their operations for quite some time. Extending this measurement into the realm of collaborative, inter-enterprise operations is challenging because it is difficult to know, if the right things are being measured and what the target performance should be (Rabin, 2002). In recent years, a number of firms have realized the potential of SCM in day-to-day operations management (Sharma & Bhagwat, 2007). Since the “performance criteria” concern different aspects of supply chain efficiency, although they mainly measure customer satisfaction in supplier-customer relations throughout the chain, we introduce the term QoS as a common denominator of all criteria under consideration. In a linear SCM model they would mainly address the retailer-buyer relation; on the other hand, customer-led supply chain organization encourages QoS observations for every pair of elements of the supply chain to which the supplier-customer relation applies. It is clear that for effective SCM, measurement goals must consider the overall method and the metrics to be used. A list of indispensable criteria and the method of their assessment will be elaborated in more detail in the sequel.

The main issues associated with outstanding QoS in a supply chain are for instance, timely, correct, flexible, available services on available items, liability on items, observability and integrity of the supply chain (e.g. selling channels and service locations), maintainability of supply chain links (production lines), integrated inverse logistics services with managed and transparent environmental impact, etc. In
the sequel, the individual criteria are assessed in detail and their roles within the context of the supply chain are explained.

**Timeliness**

*Timeliness is the ability to meet all deadlines.* It terms of the element of a supply chain it represents the ability of a supplier to meet all deadlines towards its customer(s) defined in a supply chain management strategy. Timeliness on the supply chain level incurs meeting deadlines throughout the entire supply chain, which means that transactions between all pairs of actors (in a sequence) occur on time. Usually, there is no bonus for premature transactions, since this could consequence in e.g. inventory stocking at customer-side, hence, producing dissatisfaction due to increased inventory cost. On the other side, however, the cost of a postponed transaction may be anything – from reasonably low to unreasonably high. In both cases, meeting deadlines ensures timely transactions, contributing substantially to QoS in the supply chain, whereas not meeting them could increase the cost associated with SCM indefinitely.

Timeliness is required between all pairs of actors in a supply chain, although the restrictions on the time are different for different phases and may range from a few minutes (performing a payment) to a few months (for inverse logistics and maintenance). It is crucial to enable Just in Time/Just in Sequence (JIT/JIS) performance.

**Correctness**

*Correctness implies faultlessness and preciseness.* These two terms, being sometimes also used as synonyms to correctness, have different meanings with respect to transactions in the supply chain. On one hand *faultlessness represents the absence of erroneous transactions*, whose correction would result in additional cost for their correction as well as extra time to perform, possibly diminishing timeliness. On the other hand, *preciseness adds the predicate of precision to faultless transactions*, diminishing the need for repeated transactions to achieve the desired performance.

Correctness at all levels on the other hand must be ensured regardless on the phase/stage and operation. Possible errors may have pre-set fixed times for their elimination or correction. Timeliness and correctness must be assessed separately, although they are interrelated, since correcting faults always takes time and leads to delays that may compromise timeliness.

In a supply chain correctness applies to, e.g., correct amounts of supply or production, faultlessness of items, amounts and types of transport units, transport paths and target locations, pricing, payments, etc. Correct performance in a supply chain is the sum of the listed and other relevant operations and transactions among the actors of the chain. It may include also timeliness of operations in case temporal constraints are defined as prerequisite for the correctness of an operation (e.g., payments, delivery times, etc.).

**Dependability**

*Dependability is the collective notion of availability, reliability, safety, security, integrity, and maintainability* (Avizienis, Laprie, & Randell, 2001). A certain degree of dependability is expected of any business regardless of its kind. Based on it, usually a liability assurance is issued, especially for food and products and services that have longer life-cycles with the associated need for inverse logistics consideration. The individual QoS criteria that constitute dependability will be described in more detail hereafter.

*Availability is the proportion of time a system is in a functioning condition.* In the case of the supply chain this would mean the proportion of time in which supplier is functionally available to its customers. Collectively they represent supply chain’s availability denoting the amount of supply chain’s “up-time” – the proportion of time when all links in a supply chain were available.

*Reliability is the degree of a system’s ability to perform its required functions under...*
stated conditions for a specified period of time. This holds and should be measured for all links of a supply chain separately, although an integral value could represent the reliability of the entire supply chain. The measured values could consist of faults when performing foreseen transactions among links of a supply chain. When reasoning on the reliability of the supply chain the minimum value should be chosen to represent its reliability – “it is as reliable as its weakest link.”

Safety represents the degree of protection against risks of errors. It is closely related to reliability and robustness, which both support safety. Robustness is a degree of a system’s resilience under stress or when confronted with invalid input or changes in internal structure or external environment. In a supply chain the stress is represented by any irregularities or changes in its structure or demands. In the case of the supply chain safety represents the inherent mechanisms which prevent faults from occurring. This includes any checking mechanisms on actor level as well as any associated corrective measures.

Security is the degree of protection against consequences of failures being induced from the environment of a system. In the case of a supply chain, security represents protection of the supply chain to outside influences. As with safety it is increased by preventive and corrective measures on actor-level.

Integrity represents the absence of improper system state alterations. It is prerequisite for safety, availability, and reliability, and is rarely considered as a stand-alone attribute. In supply chain context it should be considered for the entire supply chain (the system), whereby any occurring irregularities causing the reduction of safety, availability and reliability would diminish it, whilst any actions improving them would increase it. While the measures for ensuring reliability, safety and security apply to supply chain links, their collective effect is meant to increase the integrity of the supply chain as a whole.

Maintainability represents the degree of the ability to undergo repairs and modification. Maintainability of an actor in the supply chain is in part supported by flexibility to support sustainable long-term operation, hence supplementing its long term availability in the changing environment. The measures and mechanisms applied with maintenance should not diminish supply chain integrity. Flexibility represents the degree of a system’s ability to adapt to a new environment. In case of the supply chain we may also consider it as resilience of an actor in the supply chain in recovering from a shock or disturbance originating from (a change in/of) its supply chain environment. Flexibility and maintainability are crucial for facilitating the changes, which occur within the lifecycle of a company and supply chain to which it belongs. In response to market changes fluent production/service line changes are necessary. Hence, a managed production process is required to identify the phases and components, which need to be exchanged in order to perform the requested change in the production line.

Liability

In law a person is said to be liable, if he/she is financially and legally responsible for something. The liability of actors in a supply chain refers to their obligation to fulfill their responsibilities towards related actors (e.g., manufacturers providing faultless products on time in the agreed amount within and during an agreed period of time). Liability relies on verifiability of products and ability of getting quality-certificates for them whereas with services it is considered the sole criterion of trust among the customer and its supplier.
Observability

Observability is a measure for how well internal states of a system can be inferred by knowledge of its external outputs. The outputs of a supply chain are products and services, although ideally (considering inverse logistics and putting the consumers into the supply chain) there should be none. With respect to the mentioned outputs, observability represents transparency of the supply chain. This means that every product and service can be traced back to its origins and even to its components.

Most important aspects of observability from the consumer perspective are the transparency of selling channels, service channels and inverse logistics channels. Based on the first, the decision on the most suitable purchase location (e.g., closest, certain origin, certain make, etc.) can be made. Based on the second, the decision on the most suitable (e.g., nearest) service station can be made. Based on the third, the decision on where to dispose the product, once it is worn-out or irreparable, can be made.

From the perspectives of other actors in the supply chain, observability must be ensured at least for their preliminaries and successors, hence, forming a traceability chain for tracking and tracing purposes. The absence or reduced observability of (a portion of) supply chain may diminish the relevance of previous assumptions on (the part of) supply chain’s QoS.

Ecology

In general, ecology studies the relationships of living organisms with their environment. In our case the relationship applies to humans running the actors of a supply chain. Today it is becoming more and more important to assure the transparency of the environmental impact of supply chain performance. When reasoning on this aspect of a supply chain, the organized disposal of worn-out or defective products is also evaluated in connection with inverse logistics. Here, especially the environmental impact of activities connected to items is considered to facilitate regulations on the ecological suitability of the items offered.

Price

The bottom line of all considerations of QoS in a supply chain is the associated cost of the measures applied. Of course management shall wish to minimize the financial impact of “overhead” measures; however, since these measures constitute the operations in a supply chain, some financial overhead with respect to “basic” production and distribution processes is inevitable but should be constrained. The increased QoS among elements of the supply chain with established observability enables transparency for the planning as well as cost-prediction process and eases price-setting decisions.

Price as a QoS criterion is still often a key factor in the decision-making process of an item-supplier selection as well as customer satisfaction. For price-evaluation it is important to collect reference prices (e.g., average market prices, producers’ recommended prices) and mutually compare them with planned cost of transactions among links between supply chain elements. In case of perceptible differences it is important to clarify circumstances.

QoS and Added Value Improvement

In the sequel the typical supply chain models for three different lines-of-industry are considered with their specifics. Finally, the impact of the defined QoS criteria on a business process is investigated.

Food Growth

The food-growth supply chain is somewhat specific, because the turnover time is typically more critical than with other disciplines. Hence we may wish to ponder timeliness, dependability and ecology higher than other QoS criteria, although the price criterion is also a key factor here. To ensure quality of supply fresh food is partly delivered directly to retailers and consumers, which is not so usual with other types of supply chains. Although already the linear supply chain (on left hand side of Figure 2) considers this fact, consumer orientation was
made even more obvious by (Ngah, 2003), putting them into the supply chain together with other actors in the process (on right hand side of Figure 2).

Production

In production by reorganizing SCM into a so-called “adaptive supply chain” in a similar fashion as in food growth the greatest savings are possible. Putting consumers into relation with all other actors in the supply chain (see Figure 3) enables greater flexibility of service and their different roles in the supply chain, hence influencing the development of a product from raw materials and components to its final form. This again contributes to their quality and most importantly increases their market value, since their coherence with the consumer’s expectations may be ensured in advance. Since our model of customer-oriented supply chain was derived from the production supply chain, an equally balanced model of QoS criteria applies here, unless management decides otherwise.

Services

By reorganizing the services supply chain possibly even greater savings than in production can be achieved, since the purchasing of services is typically less closely monitored and less tightly managed as the purchase of products (Tate, Ellram, & Billington, 2008). As opposed to buying products buying services is hence more demanding although their supply chain is much simpler (no explicit input/output logistics). The problem with services is that they rarely come with an ISO certificate on quality, which puts liability as a criterion into the front-line, besides timeliness and correctness that are obvious.

Since services operate with a higher added value, the insight into their supply chain and that of their customers would be very beneficial for both parties – it would provide the service companies with the ability for cost optimization, while on the other side it would provide their customers with some insurance on the managed level of quality introduced by the services offered.

Impact of Supply Chain QoS on a Business Process

The introduction of QoS-aware SCM in the adaptable supply chain network emphasizes its value based on the offered QoS. As can be seen in Table 1 this approach introduces improvements throughout the entire supply chain, as well as customers and employees involved where added value improvements identified by (SAP, 2003) are aligned with QoS criteria from our model. Besides general customer-centric SCM properties, like the focus switch from the “factory and its product” to the “product for the customer”, the relation among

Figure 2. Linear and customer-centric adaptable food-growth supply chains
“workers” and “leadership” being replaced by a “partner” relationship among employees, also, QoS criteria are emphasized – as opposed to the hierarchical supply chain model the value of predictability is being replaced by the value of dependability, responsiveness/timeliness, and flexibility. The importance of QoS-aware SCM is emphasized also by exchange of position power by information power, hence, making informed decisions becoming the initiator of all business process actions.

The business process is best considered through a model, representing the virtual enterprise-network facilitating the decision making process. For this purpose a flexible supply chain model has been defined with the QoS criteria evaluation built-in. The analytical model for supply chain QoS evaluation and quick diagnostics, presented in the sequel, shall form a basis of a later implementation of a simulation model, which, based on the characteristic data for every supply chain element and the same previously defined QoS measurement, would enable supply chain virtualization and fine-tuning by performing “what-if” scenarios.

**QoS Evaluation Method**

Our evaluation method is based on the adaptable (customer-led) supply chain model and considers any supply chain as a whole. Probes are inserted on every link among two elements of the supply chain. Every transaction on the link is monitored and evaluated based on the provided reference values for the individual criteria. The results are logged and may be used by any element of the supply chain to determine weak spots or bottle-necks in the supply chain. The gathered data may be used for analysis of supply chain excellence. This metrics is enabled by joining the results from the individual probes. In order for the benchmark to be meaningful, all measured values must lie within a predefined threshold. It shall be used to enable quick diagnostics and comparison among supply chains. By constructing a decision or simulation model based on the gathered data, however, closed loop analysis and performing “what-if” scenarios shall be possible.

**Introducing Probes for QoS Evaluation into the Supply Chain Model**

The adaptive supply chain model and probe placement is outlined in Figure 4. All possible interconnections between supply chain members are outlined in the figure. The probes, denoted by $q$, carry two indexes from index sets, marked by first letters of names of the interconnected
supply chain elements. The individual supply chain elements carry the names of typical representatives in singular; however, the names only denote the type of supply chain elements and not the number thereof. Hence, there may be any number of, e.g., consumers, producers, service-providers, etc. cooperating to perform the same (kind of) transaction between supply chain elements. Because of this there may be a number of, e.g., \( q \), values, being associated with the same supply chain.

The \( q \) is a 7-tuple (T, K, D, L, O, E, P) representing the quality on a specific link between a pair of supply chain elements based on the previously defined criteria, where the individual values represent:

- **T** – Timeliness (the proportion of met deadlines by lead times),
- **K** – Correctness (the proportion of correct transactions),
- **D** – Dependability (an integral value comprising \( A \) (availability), \( R \) (reliability), \( S \) (safety), \( C \) (security/confidentiality), \( I \) (integrity) and \( M \) (maintainability/flexibility), preferably calculated as a weighted average value of these parameters),
- **L** – Liability (the proportion of transactions for which liability could be established),
- **O** – Observability (the proportion transparent transactions – for which all measured criteria could be identified),
- **E** – Ecology (the proportion of transactions meeting all ecological normatives and for which also inverse logistics could be established), and
- **P** – Price (the ratio among the price and the average market price for the business transaction, representing the overhead for the link-logistics).

The individual values from the \( q \)-tuple are limited to the \((0, 1) \in \mathbb{R}\) interval. Since different types of adaptable supply chains (e.g., for specific lines of industry) may have more severe demands on individual criteria concerning dependability, their impact on it shall be emphasized by pondering individual parameters (see Eq. 1), where the values of ponders (a, r, s, c, i, m) are limited to a fixed interval (e.g., \((1, 10) \in \mathbb{R}\)). For the sake of simplicity, the authors of this work do not suggest any pondering, meaning that initially ponders should all be the same and equal to 1.
To determine overall supply chain QoS, unfortunately, one cannot average or simply sum-up the individual values of $q$. When doing this, two supply chains could end up with the same overall QoS although their structure, strengths and weaknesses are very different. More important for the reasoning on the measured values are the values of individual QoS parameters and the distribution of their values across the supply chain. We shall set a reference value and a threshold for any of the measured criteria. If the measured values lie near this value and within this range, we have a fairly well functioning supply chain. However, if individual values lie beneath or above the defined threshold this indicates problems which require our attention (“weak links” in the supply chain). Hence, we must investigate the sources of the deviate values and correct them – herewith fine-tuning the supply chain to constrain deviations from reference values defined for the individual criteria.

To determine overall supply chain QoS and obtain a benchmark for comparison the distribution of QoS criteria measurements around the given reference values are important. Hence, we suggest calculating it as a sum of standard deviations from reference values of $q$-components for every criterion (see Eq. 2 and 3):

$$Q = \sigma_T + \sigma_K + \sigma_D + \sigma_L + \sigma_O + \sigma_E + \sigma_P$$

where the individual summands are calculated based on the formula (equivalent to):

$$\sigma_T = \sqrt{\frac{1}{N} \sum_i \sum_j (t_{i,j} - \bar{t}_{i,j})^2}$$

where $t_{i,j}$ denotes the value, $\bar{t}_{i,j}$ the reference value for timeliness and $N$ the respective number of probes.

A lower value of $Q$ stands for more excellent supply chain. At the same time the values of individual summands indicate the supply chain...
quality from the respective aspects. Hence, $Q$ represents the merit of supply chain excellence, based on which similar supply chains (from the same line-of-industry) can be compared. Of course it is too soon to set some reference values of excellence, which would then serve as a certification criterion, however in time and by working with a large enough sample, also this would be possible. The model may be broadened to model interconnected supply chains in the same way – by simply adding nodes and links with probes to form a larger supply chain – however, because of possibly complex (multiple) interconnections among the chains elements, it is unreasonable to expect that linking two “good” supply chains would result in a “good” supply chain. Hence, the analysis would have to be performed again for the new links and joined in the calculation with the existing results. In the global market and to perform macro-economical analysis, this scenario is very likely. However, at this stage and for the sake of simplicity, our consideration of supply chain excellence is focused on a single supply chain.

The Role of Information Support in Supply Chain QoS Evaluation

Customer-centric adaptable supply chains theoretically allow any combination of processes, functions, activities, relationships and pathways along which items, related information and financial transactions move in and between individual elements of supply chain network. Satisfied consumer is aspired (required) on the end of any supply chain element combination and because of this customer satisfaction needs to be established on every link in-between. Therefore it is very important to manage supply chain link-by-link and to have an effective measurement system, as proposed, for weak link diagnostics. Subsequent treatment must be done according to overall supply network strategy and minimal total cost per sold item to the consumer.

In the proposed model we placed measuring points between supply chain elements, on the output of the previous and on the input of the following one. This approach is sufficient for the purpose of diagnosis and at the same time appropriate to protect the privacy (confidentiality) of each pair of evaluated elements. Both elements in a sequence are engaged in the measurement of QoS per link. For example, in SCM the gained information about timeliness is used for preventing/abolishing out of stock and too much stock situations as well as minimization of the probability of early and late deliveries after identification of weak connections.

Information and communication technology support is required for measuring and storing the data acquired from probes in the supply chain model for their analysis and fine tuning. Spreadsheets are sufficient to process the assembled QoS values. The associated tools also enable us to represent them visually by quality (spider charts), which shall be used to present the $q$’s values at individual probes. Visualization should assist in the decision-making process of fine-tuning a supply chain. Building a simulation model based on characteristic information on the nodes and incorporating the same probes, shall enable “what-if” analysis and additionally support and fasten the decision-making process.

To collect all required data no additional data inputs and/or additional activities of employees without added value are need. Calculation includes exported data from supply chain elements’ local databases, which are usually fed in by inputs through ERP software interfaces. Inputs are made either by hand, or by barcode scanning, or by the use of RFID. There are no interferences of existent processes manner, nothing is added or removed from supply chain elements interactions on transaction level. Changes in the information system are needed in the context of the decision-making and strategic planning at both, at the level of individual supply chain elements as well as the entire supply chain. A transparent and performance oriented supply chain model may serve as a source of information for management information systems (MIS) (Laudon, 2003). A MIS is then used as a switchboard (“electronic kanban”) when performing “what-if” analysis and for transferring the current supply chain parameters from the model into the real world.
In order to support the implementation of the required measures identified, SCM also relies on information support. It is used to facilitate timeliness and to minimize the probability of errors. Order and delivery times are managed to accommodate the agreed-upon due times. On the other hand also production, service, maintenance intervals and inverse logistics are handled by information systems. Tagging provides for tracking the products to the consumers. At the same time it ensures that the quality of the product delivered is in correspondence with the companies’ quality policy and that it is equal with equally labeled products delivered. It also enables tracing products through the supply chain for inverse logistics or market interventions, when products of reduced quality have been identified by customers and must hence be withdrawn from the market. Finally, information support facilitates payments whose temporal constraints also apply to their correctness.

The same QoS criteria that were defined as our supply chain QoS parameters also apply to the corresponding information systems used in it. Flexibility of the information system in correspondence with the controlled production process ensures that all changes applied during a reconfiguration in the process are also accounted for in associated processes throughout the supply chain. Besides production (re)configuration information support is also utilized for ensuring the dependability of machinery involved in the production/service process with product/service quality in mind. Thus it is increasing its maintainability and integrity. It monitors their life-cycles and maintenance intervals to increase their availability. The sensor and communication technology support the observability of the service/production processes. It enables the monitoring and detection of relevant production states as well as final quality control. By regular updates on the state of production, possibly with automated control allowing for stopping and re-starting the process, errors can be removed early, preventing greater damage and/or financial losses, hence increasing safety and security. At the same time confidence can justifiably placed on them and companies liability can be established.

By employing information technology (e.g., RFID), also item tracking is ensured, increasing observability. Herewith, not only item tracking is enabled but also traceability of the sequence of supply chain elements on item-level is assured. These are prerequisite for accurate calculation of total supply chain QoS. This is important, since, as mentioned before, customer-centric adaptable supply chains theoretically allow any combination of processes, functions, activities, relationships and pathways along which items, related information and financial transaction move in and between individual elements of supply chain network. On the other hand traceability of products and their components also eases their correct decommissioning and ecologically aware recycling with inverse logistics. Hence, we may conclude that the information and communication technology is strongly integrated with the adaptable customer-centric SCM providing it with increased QoS also from the ecological aspect – thus sustaining the quality of life.

**CONCLUSION**

In the article the main characteristics of contemporary SCM have been outlined. With adaptive customer-orientation the efficiency of SCM is substantially improved. However, the main emphasis should be on the provided QoS, which should be continuously improved in response to constant observation of supply chain performance and of the market and the customers’ needs. The QoS criteria introduced into the adaptive supply chain model provide management with the needed information and handles to do so.

By studying several proposed models for measuring supply chain performance (Lai et al., 2004; Agarwal et al., 2006; Li et al., 2005; Bhagwat et al., 2007) we found out about their similarities and differences. Although, we are aware of the dual purpose of SCM: to improve
the performance of an individual organization, and to improve the performance of the entire supply chain (Li et al., 2005), unlike other authors, we also took the fact that relations between the organizations in customer centric supply chains in reality are not always long-term (Li et al., 2005) into our consideration. From this point of view we proposed installing diagnostics of weak supply chain elements before the renewal of internal business processes in supply chain organizations. In contrast to performance measurement, where internal and external criteria are measured simultaneously, consequently resulting in performing a large amount of measurements yielding results of varying importance, we proposed a compact measurement of crucial QoS criteria for possible further investigation, if necessary. What also makes our approach original is simultaneous consideration of both the upstream and downstream sides of the supply chain.

Based on the exploration of our model QoS values are obtained for comparison with a preset target value for the supply chain. We have established that in order for this comparison to be meaningful, the distribution of \( q \) components’ values should be small and constrained. The exploration of our model shall deliver the allowed distributions of \( q \) components and the foreseen mechanisms that should be applied in order to equalize them around their reference values and consequently improve the overall supply chain QoS. With contemporary information, communication and sensor technology support the necessary changes in response to the established supply chain QoS shall be efficiently integrated into SCM on corporate and global levels.

The advantage of our model also lies in the fact that results will not suffer from respondent bias within each firm and across partner firms in the supply chain. The empirical implication of the model will allow enterprises to evaluate their QoS at any point in time and compare the results with their competition. It is our goal to assess QoS on long-term basis and track the changes of QoS at specific points in time for the selected lines of industry. We shall also exclude the perception of individual organizations on their QoS.

Of course the introduction of the proposed solution will require some time especially in large enterprises with complex supply chains. However, the experience of the current global economical crisis shows that the introduction of the mentioned concepts and associated technological improvements is not only highly recommended, but could be considered crucial for the long term prosperity of companies acting in the global market.

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Roman Gumzej, born 1970 in Maribor, Slovenia, received a doctorate in computer science and informatics from University of Maribor in 1999. He worked both in industry (Institute of Information Science, IZUM Maribor) and academia (University of Maribor), before he was elected assistant professor at the Faculty of electrical engineering and computer science at University of Maribor in 2004. He was a visiting researcher at ifak e.V. Magdeburg, Germany in 2002 and at the Chair of Computer Engineering at Fernuniversität in Hagen, Germany in 2007. Currently he is assistant professor at the Faculty of logistics at the same university. His research interests comprise all major areas of hard real-time computing with special emphasis on operating systems, co-design and quality-of-service in embedded and logistics applications. He has conducted a national and co-operated in several national and international research projects. He has authored or co-authored several refereed book chapters, and about 40 journal publications and conference contributions, and is involved in international professional organizations and program committees of several conferences.

Brigita Gajšek, born 1974 in Celje, Slovenia, graduated at the Faculty of mechanical engineering in 1998 and received a master’s degree in Organization and Management of Information Systems from the Faculty of organizational science at the University of Maribor in 2003. For several years she worked in metal processing industry as project manager before she was elected teaching assistant at the Faculty of logistics at University of Maribor in 2007. Her research interests comprise technique and technology in logistics. She is currently working towards her PhD thesis.
The Development of Synergy Model on Internal and External Suppliers for Asian Airlines Industry

Yudi Fernando, Universiti Sains Malaysia, Malaysia
Norizan Mat Saad, Universiti Sains Malaysia, Malaysia
Mahmod Sabri Haron, Universiti Sains Malaysia, Malaysia
Suhaiza Zailani, Universiti Sains Malaysia, Malaysia

ABSTRACT

This paper examines the airline industry to develop a synergy model in internal and external suppliers for Asian airlines industry. An extensive literature review is conducted to present a synergy model to develop Asian airline competitiveness, safety and service quality. The literature review is highlighted to seek the relationships between internal marketing and internal service quality and identify whether the relation of supplier can moderate them. The review reveals that a synergy model based on internal marketing, internal service quality and supplier relations can overcome the Asian industrial phenomenon, especially in maintaining the service consistency and competitiveness. This model is needed for developing airline service and safety. Research in airline business is critical, as the quality of the airline service is declining in contrast with this industry’s growth. This paper provides insight into two important suppliers needed for the success of the airline industry.

Keywords: Airline Development Process, Business Model, Internal Marketing, Internal Service Quality, Supplier Relations

INTRODUCTION

In the age of mobility, the global economy is driving the growth of air travel more than ever before. There is a hyper competition in the airline business. Markets have been fundamentally transformed by the emergence of new business models which demand a better service (Rhoades & Waguespack, 2008), information system capabilities (Cunningham et al., 2005), and supplier relationship (Ahmed et al., 2006). The future of the global airline business is expected to be profitable. In addition, Asia Pacific will become the largest world aviation market over next 20 years, since it has one-third of the world air traffic (Boeing, 2010). In other words, Asian
countries have the biggest potential to lead the global airline growth in the near future. Ten to dozens of new air carriers have been popping up across Asia to reach the demand of the industry’s booming.

In contrast with the growth, the Asian airlines are facing an increasing risk of bankruptcy. This is probably due to the fact that the management spends a lot of time focusing on the airline infrastructure, soaring fuel costs, investments, competitor thus overlooking the role of internal and external suppliers towards the success of an organization. Indeed, a string of deadly accidents have raised fresh concerns about service and safety, from board and ground crew, pilot shortages and the quality of budget airlines. Aircrafts of accidents in Asia have been increasing and have injured and killed people (e.g., Indonesia and Thailand).

Consequently, the airline service and safety quality will suffer when the internal and external suppliers give less attention towards the airline service process. Most of the international airlines employ thousands of people (Frost & Kumar, 2000). As the airline expands, so does their staff population. Generally, when this happens, employee matters somehow fall by the wayside and are replaced by more pressing issues such as company growth and maximizing profits (Heskett et al., 1994). Subsequently, the organization loses touch with the individual worker within the organization. Thus, in order to achieve the growth and profit objectives, research into employee issues cannot be ignored (Berry et al., 1994). Scholars have stated that the delivery of high quality service becomes a marketing requirement in tandem with the increase of the competitive pressures on an air carrier (Ostrowski et al., 1993).

Besides, the external supplier also plays considerable role in the success of an airline. Air China for example assigns its employees to work closely with supplier on various aspects. This effort is to meet the organization’s economically and socially objectives (Ahmed et al., 2006). Managing supplier relationship gives many benefits. If many buyers and suppliers build a close relationship, these could have far-reaching implications, not only for both parties, but also for the operations of the market. Strongly bonded relationships could form an effective barrier to entry for new entrants, and switching partners may have all sorts of repercussions, apart from purely financial ones. The real competition is not between a company and a company but between a supply chain and a supply chain (Christopher, 1992).

It is hard to find a study on how internal and external airline suppliers worked together to improve competitiveness, safety, and service quality. It is argued that the role of internal and external suppliers in an airline service quality must be studied. This is to construct the competitiveness of Asia airlines and improve service and safety quality. This paper focuses on the issue of the airline business and how they can build a synergy relationship with suppliers to enhance safety and service quality. Hence, building a high quality long-term relationship with internal and external suppliers is not an easy endeavor.

This study utilizes the literature review to find the link of the model based in internal and external suppliers. The model is necessary to develop the Asian airline competitiveness. In fact, the Asian region still consists of many developing countries that need strong partnership to survive and compete in airline industry.

This paper is organized as follows. First, it gives a review of related literature on the airline industry, internal marketing, internal service quality and supplier relations. This approach attempts to underpin the model based on the literature. The essence of this approach is to identify the research gap, contextualize the research agenda and build an understanding of the theoretical concepts (Rowley & Slack, 2004). The relationships between these constructs have conceptualized on synergy model. Based on this model, the researchers then proposed two propositions for future research. The argument and idea on the synergy model will be described next. Finally, the method and directions for future research are also provided.
LITERATURE REVIEW

A competitive advantage which comes from the service level is provided by the employees. Employee is internal supplier in an organization. Gummesson (1993) has presented a multi perspective approach that consists of four group models. Each model associates with four groups of actors namely customers, contact staff, support staff, and management. All of these perspectives need to be taken into consideration since the four groups hold different perspectives. In addition, each model is relevant to the whole service experience. Actors possess their own knowledge, logic, and objectives, and each offers a different perspective. Although the marketer and the organizational behaviorist say that the relevance of internal customers within the context of service delivery process is frequently referred to the literatures, there is a paucity of published research on the support staff’s perspective (Reynoso & Moores, 1995). Normally, what employees feel about the quality of service is represented by the justification of the external customers.

The management should also consider employees as their internal customers. Management should create, continuously encourage, and enhance an understanding of employees in the organization and develop an appreciation for their roles in the organization. It will be able to retain customer-conscious employees (Keller, 2002). It is observed that not all kinds of behaviors and actions of customer-contact employees can be directed and controlled by the management during the service (Malhotra & Mukherjee, 2003). Hence, service quality will suffer when employees are unwilling or unable to perform a service at the required level (Zeithaml et al., 1996). On top of that, George (1990) also concurs with this premise; if a management wants to make their employees to do a great job for the customers, the employees must be prepared to do a great job with the employees. Therefore, scholars have identified that internal marketing may contribute to the firm’s competency and success (Frost & Kumar, 2000; Keller, 2002; Ahmed et al., 2003).

This section explores the literature regarding the effects of internal marketing on internal service quality and identifies whether the level of supplier relationship can moderate the relationships between the internal marketing and internal service quality in commercial airlines. The essence of this study is to build the Asia airline competitiveness, to change the traditional airline management perspective which is more service-marketing mindset, and to prevent service and safety failures. At the end, a new synergy model between internal and external suppliers that can be used to provide a direction for the improvement of the airline service quality is developed.

Airline Service Quality

The airline industry is a very competitive industry which needs to establish strategic competitive advantages through the supply of chain relationship in today’s world. The challenges in the airline business are recapitalization to restructure, reengineer and outsource to the increasingly of complex business focus, personnel, e-commerce application, and cost reduction and alliance management. An Airline will find it hard to compete against its competitors without establishing long term relationships with the suppliers. To survive, an airline is expected to deliver a high quality service with a reasonable ticket price. For example, the Southwest (US) airlines experience one of the world’s leading low fare, high frequency, point-to-point carrier is also one of the most profitable. It has managed to build the supplier relationships especially in spare parts and maintenance operations. Southwest has created its next generation maintenance automation team to deliver a well planned, comprehensive maintenance and engineering solution that would provide operational improvements, significant cost savings, and increased financial controls. According to Rhoades (2006), the mission statement of Southwest did not mention profitability, market share or superior returns to share holders. However, it mentioned about people, namely customers and employees. They should be able to fulfill this
mission since they are also committed to treat their employees with the same care and respect that they expect to be received by the customer.

**Internal Marketing**

The idea of internal marketing has first appeared in several articles which are written by classical scholars (Sasser & Arbe, 1976; Berry et al., 1976; George, 1977; Thompson et al., 1978). But the term internal marketing has not been directly used by them. For instance, in the early 1980s, the concept of internal marketing had formerly emerged in the services marketing literature (Grönroos, 1985, 1981; Berry, 1981) and was later adopted by the service management literature (Normann, 1984; Carlzon, 1987) and industrial and relationship marketing (Grönroos, 1985; Gummesson, 1987). The advantage of internal marketing has been discussed in the academic literature for more than a decade (Foreman & Money, 1995; Piercy, 1995; Bak et al., 1994; Azzolini & Shillaber, 1993; Harari, 1991, 1993; Harrell & Fors, 1992; Davis, 1992; Bhole, 1991; Piercy & Morgan, 1991; George, 1990; Piercy & Morgan, 1990). However, Heskett (1987) observed that the shift towards internal marketing was due to the high performance service companies that have gained their status in large measure by turning the strategic service vision inward.

The literature on internal marketing is broad, complex, often contradictory, and contains stimulating debates (Little et al., 2005). Many definitions of internal marketing are found within literatures in the past three decades. Those definitions introduced the internal marketing in a broad conception (Varey & Lewis, 1999), as management technology (Fisk, 1986; Sweeney, 1972), a philosophy or a management practice (Wilson, 1991; George, 1990), either relating to human resource management (Van-Haastrecht & Bekkers, 1995; Berry & Parasuraman, 1991; George, 1977, 1990; Berry, 1981, 1984), service marketing (Gummesson, 1987; Grönroos, 1985) or changing management (Piercy, 1995). There has been a heated debate over whether internal marketing should even exist. However, the internal marketing literature has been growing rapidly in the hands of marketing researchers (Sargeant & Asif, 1998; Piercy, 1995; Varey, 1995; Piercy & Morgan, 1991; George, 1990; Barnes, 1989; Berry, 1981; George, 1977).

Internal marketing has been defined by several scholars in various perspectives. Internal marketing attracts, develops, motivates, and retains qualified employees through job products that satisfy their needs. Internal marketing is also the philosophy of treating employees as customers and it is the strategy of shaping job-products to fit human needs (Berry & Parasuraman, 1991, p. 151). Internal marketing is a plan of effort that uses a marketing-like approach to overcome organizational resistance to change and align, to motivate and inter-functionally co-ordinate and integrates employees towards the effective implementation of corporate and functional strategies to deliver customer satisfaction through a process of creating motivation and customer orientation employees (Rafiq & Ahmed, 2000). The scholars debated on where internal marketing should belong to, and what internal marketing is. We have argued that internal marketing is a wide-ranging strategy that could be well applied in the service industry. This is to enhance organization competitiveness and service orientation based on internal capabilities.

**Internal Service Quality**

The concept of designing an internal service system was first introduced by IBM in the 1960s (Davis, 1992) and it has led to a concept called service blueprinting (Shostack, 1987). Hammer (2001) defined internal service quality process as an organization group of related activities that together create a result of value for customers. Internal service process includes simplifying standard operations, procedures, and activities that support the business functions to interact with customers (Voss et al., 2005). Service quality is an outcome of the effort that every member of the organization invests in satisfying customers. The employees are the
key in the delivery of a quality service, and organizational success depends on the ability and the motivation that its employees bring to their jobs (Sargeant & Asif, 1998). Service organizations can be described as open systems with highly permeable boundaries in which the perception of organizational practices is visible both to employees and customers (Reynoso & Moores, 1995). The outstanding delivery of an airline service to customers depends on the employees’ ability. For example, to make the organization fly its aircrafts, it needs high quality pilots, friendly flight attendants, and an excellent maintenance team. The service production process as a system of systems is built up by interrelations and interdependence between a number of sub processes. Every service operation comprises internal service functions which support each other. If a poor internal service exists then the final service received by the customers will be unsatisfactory (Grönroos, 1990).

**Supplier Relations**

The supplier relationship is also discussed in the marketing and operations studies. In the marketing literature, the original relationship has been discussed generally in industrial and business-to-business marketing. It is because industrial firms spend over half of their sales revenues on industrial purchasing (Hutt & Speh, 1992). Industrial firms have recognized the supplier management is crucial to the firm’s competitiveness. In the context of marketing relationship, there are two divergent views concerning supplier management that have been discussed both in theory and practice. They are contractual (arms-length) view and the relational view. The first view is for less dependence on suppliers with the object of maximizing bargaining power (Provan & Gassenheimer, 1994), and avoiding commitment (Boyle et al., 1992). Second, the relational view that supplier management is a key aspect of marketing relationship (Kim & Michell, 1999).

Nowadays, the industrial service sector is concerned with the supplier management. It is fully applied in the airline business that requires service supplier and maintenance logistic. Besides maintenance logistic, the airline service suppliers also include bank (credit card provider), insurance, hotels, car rentals, airports and travel agents. However, maintenance logistic is a function of strategic decision to build the competitive advantage of a company. Maintenance logistics involves the process of planning, implementing, and controlling the efficient, cost effective flow of spare parts, in-process inventory and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Tibben-Lembke & Rogers, 1998).

The airline industry is facing severe challenges because of the effects arising from global competition to ensure the value of effectiveness. It is increasingly becoming essential as the service process gets more complicated. Several handling problems confuse end-users: inventory for returned products, unidentified or unauthorized return, and idle time during the return process. It is suggested that the airlines need to establish a long-term relationship with logistics service provider. The formulation of good supplier relationships is the ability to provide its customers with stable and reliable flights (Choy et al., 2007). An empirical supplier relationship studies have been done mostly in a manufacturing context (Carr et al., 2008; Wasti et al., 2006; Kannan & Tan, 2006; Theodorakoglou et al., 2006), but now those are found to provide new insights in service studies (Field & Meile, 2008; Choy et al., 2007; Doran et al., 2005). Therefore, supplier relations study in the service sector may not be generalized from manufacturing; there is important a need to recognize the differences between manufacturing and services. It is to develop models and empirical studies that focus specifically on service supply chains (Baltacioglu et al., 2007).

The emerging literature on buyer-supplier relationship has recently been reported in various industries (Saccani & Perona, 2007; Mukherji & Francis, 2007; Caniels & Gelderman, 2007; Hult et al., 2007; Barnes et al., 2007).
Baglieri et al., 2007; Hawkins et al., 2007; Bharadwaj & Matsuno, 2006; Emberson & Storey, 2006; Large, 2005; Kamp, 2005; Bonner & Calantone, 2005; Gao et al., 2005; Prahinski & Benton, 2004; Humphreys et al., 2004; Leek et al., 2004; Hutt & Speh, 1992), yet there is less report on how the role of suppliers in support of internal service quality. The airline business needs several suppliers to support its service process, for example aircraft manufacturing, maintenance, airport, government, IT provider, catering, insurance, travel agent and bank. To become the winner in the airline competition, firms need to build a successful relationship throughout the supply chain that has a potency to render efficiency and profits or to create cost reduction (Bharadwaj & Matsuno, 2006). It will improve quality, continuity of supply, and human specialization (Burt et al., 2004).

Burt et al. (2004) have predicted the winners in the future marketplace will be those linked companies that can combine their internal advantages into a powerful value chain which is faster, more efficient, more agile and innovative, and ultimately more profitable than other competing supply chains. Particularly, the economic performance of an airline depends on its achievement of the highest degree of operational efficiency (McLean, 2006). In the airline industry, the role of the suppliers in improving process of the internal service to satisfy their external customers has yet to be fully addressed. The supplier’s role is to offer a greater competition at the ground-handling stage, provide the operating airlines with an alternative in quality ground service, which encompasses ramp, cargo and warehousing, passenger and baggage handling, flight operations, and aircraft servicing to serve the passengers. Here, the role of supply chain relationship is required to support the airline industry in attaining a possible lower cost and streamlining operations and processes to make the air travel more affordable for travelers while at the same time making it more profitable for the airlines themselves. The role of the supplier in providing support on the ground for schedule and charter flight covers a) representation, administration and supervision, b) passenger services, c) ramp services, d) load control communications and operations, e) cargo and mail services, f) support services, g) security, and h) aircraft maintenance.

THE SYNERGY BETWEEN INTERNAL AND EXTERNAL SUPPLIER

The marketing concept is important to the entire departments of a company. Marketing works in every management function and helps the company to become more customer minded. The marketing philosophy is one of the necessary guidelines for managerial level, flight attendants, flight engineers, pilots and ground engineers and all other employees in the airline industry. The airline service has to go through a complicated process to deliver service quality to the customers. To serve their customers better, the airline needs to establish a long-term relationship with the suppliers to reduce the cost and improve the competitiveness, safety, and service quality.

The airline business also has a three P’s component that needs management’s concern in order to be sustainable in the market. Figure 1 demonstrates the three airline development components which consist of people, process, and performance. To achieve a superior performance, an airline needs to develop the first component. It stands for internal and external people, namely employees and suppliers. It is argued that the success of an airline lies in how they manage service oriented employees and maintain excellent relationships with the suppliers. There are at least five elements of internal marketing that are appropriate for the internal supplier. First, it is a senior leadership with vision. The airline organization needs to have a senior leadership that can inspire all stakeholders at all levels. The senior leadership should have a clear vision to achieve the organization’s goals. At the same time, it should have the ability to use direct and indirect influence to build a service-oriented organization.
Moreover, the airline management needs to ensure that all levels of employees can receive all information regarding organization mission, vision, strategic goals, activity, and achievement. Here, the role of internal communication will work through meeting, intranet, report, employee handbook, periodically review employee and department outcome, and so forth. The third element is training and development. The management of an airline should invest money and time to train employees for continuous improvement. Normally, the organization’s expert will transfer knowledge and skills to improve the employees’ productivity. The development of the employees will be seen after the training. It aims to prepare the employee on the future challenge of the organization. The fourth element is empowerment. Empowering the employees can give them more control over their own decision during service encounter. The final element for internal supplier is a reward. It is a way for an organization retains and motivates the employees. Airline management should consider a fair and effective reward system to encourage high performance. However, it has been argued that the additional source of Asian airline capability is supplier relations.

The synergy between internal and external supplier will produce high productivity and cost saving. The process of selecting the right supplier might be a time consuming. The right supplier is external counterpart which can match and capable to work with an organization to achieve goals. Once found, then the long-term relations should be maintained. The airline is advised to manage a high degree of coordination and communication between the activities of primary supplier and organization. This is important to secure the cost, safety, and service quality.

Figure 2 shows how the synergy model is working between internal and external supplier. There are two sides in this model. The first one is the internal side. The internal side explains how internal supplier works in the airline. The management sets up the airline system and procedures to deliver excellent service. The senior

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Figure 1. The three airline development components

![Diagram of the three airline development components]

*Note: SL=Senior Leadership; T&D=Training and Development; IC=Internal Communication; Em=Empowerment; RW=Reward; SSP=Supplier Selection; LR=Long-term Relationship; CC=Coordination and Communication*
manager has communicated the philosophy and tactical strategy to middle managers. Thus, they are interpreting, communicating and directing to the supervisors. Supervisor also guides the employee to do their best on every process involved. Here, the internal marketing approach is working to motivate, communicate, maximize the use of employee’s skill and capabilities to achieve the goal and rewards them. At the same time, the management also uses the internal service quality to maintain service consistency prior service delivery.

The management has asked employee to evaluate interdepartmental service which served them. The feedbacks from employees are then used to improve the service process continuously. Some of airlines outsource service process to supplier. The management who is represented by the organization has dealt with supplier and communicate on how important safety and service quality for the organization’s competitiveness. The supplier has supplied various products or services to particular department. The supplier performance also needs to be measured. The interdepartmental service evaluation is utilized.

The external supplier is divided into three: intermediate, independent, and dependent suppliers. Besides managing external supplier relationship, management also needs to communicate on how safety and service excellence are important for organization competitiveness. The employee who has outsourced by supplier also delivers service for particular department.

Figure 2. Synergy model between internal and external suppliers in the Asian airline business
Some of them have service encounters with customers. Their service also needs to be evaluated by other department in the organization. Two sides of suppliers are contributing to internal service quality approach. The outcome of internal service quality approach will deliver consistent service quality to the customer. The customer will enjoy the excellent service with affordable price. Customer satisfaction is key to get customer loyalty and enhance organization performance. The loyal customer will come back and tells their friends and relatives about the superior of airline service. Thus, it is the reason why the management has put customer in the first place for company success.

Figure 2 demonstrates the synergy between internal and external suppliers. This model is based on the previous study. The researchers have explored the important role of marketing component for implementing supply chain management (Min & Mentzer, 2000). Cooper et al. (1997) have posited the implementation of supply chain management, which involves reducing channel inventory, increasing channel cost efficiencies, maintaining long-term relationships, encouraging inter-firm cooperation, and sharing risks and rewarding among the partners.

Lings (2000) has demonstrated a model of service quality which is based on both internal and external customers and supplier groups in supply chain partnering. He has used internal marketing to encourage a firm to become truly market-oriented. Then, he argues that the internal service quality will have the effect of increasing employees’ motivation to perform their tasks. The overall service in supplier–customer relationship will then increase as the service quality of departmental relationships which constitute the organizational relationship increase (Lings, 2000). Service quality study between internal customers and internal suppliers was conducted in an international airline. The results provide information on areas where more attention is needed to enhance internal service quality (Frost & Kumar, 2001). Reynoso and Moores (1996) have suggested that internal customers and suppliers will become more responsive to the wants and the needs of the external customers.

Services for commercial airlines emphasize the critical needs for coordination of the management activities between airline processes such as maintenance and engineering, purchasing, procurement, and material management. On top of that, there is no existing research model that is able to discuss the synergy between internal and external suppliers in order to improve Asian airline competitiveness, safety and service quality. Because of the gaps in the current literature review, the agenda is to propose the examination of the effect of both of them in service quality. Future research propositions include.

Proposition 1:

Internal marketing becomes a fundamental instrument of the maximize of the internal service quality in order to improve the airline service quality.

Internal marketing agenda is to implement the market to the internal supplier. Internal marketing contributes to HR’s effectiveness. Internal marketing has to be treated as a separate construct, not merely as the representation of a number of human resources management functions (Ewing & Caruana, 1999). Babba and Koufteros (2008) found that the human element in a service encounter has a significant effect on airline passenger satisfaction. The objective of internal marketing is to encourage, retain, and to motivate the potential employees to enhance the uniqueness of internal service quality. The internal marketing is developed to reduce the inconsistency of service in an organization. Internal marketing is streamed into all levels and functions in an organization. The organization of internal marketing in three distinct interrelated functions are a) internal marketing to internal customers, b) internal marketing in internal market, and c) internal marketing as a facilitator of strategy and change (Mahnert & Torres, 2007).

Zampetakis and Moustakis (2007) have studied the implication of the changes in the public sector. They found that practicing internal marketing could produce positive outcomes towards fostering public entrepre-
neurship based on public service choices and attitudes. The empirical results demonstrated that a significant relationship existed between internal marketing and consumer satisfaction and between internal marketing and service quality (Bansal et al., 2001; Ewing & Caruana, 1999).

Prasad and Steffes (2002) argued that the internal marketing strategy was one of the secret recipes of Continental Airlines.

Internal marketing is a strategy of the marketing people to ensure the availability of excellent service to serve customers and ensure a company’s sustainability in the competitive market. Only happy employees can produce superb service quality to satisfy existing customers and attract new ones. Most airlines services provide similar products. However, they differ only in the quality of safety and service provided by the employees. Internal marketing also reflects the internal supplier’s capability to work effectively with external supplier to enhance the airline service quality. This is because previous definitions have failed to explore the role of supplier that contributes to the organization service.

Proposition 2:

A higher degree of moderating role of supply chain relationship will contribute to a higher level of relationship between internal marketing and internal service quality

Malhotra and Mukherjee (2003) have suggested that worldwide organizations achieved their success if the organizations could provide excellent customer service through satisfying their employees. Internal marketing is originally proposed as an approach in service management, which entails the application of the traditional marketing concept. The associated marketing mix aims inwards within an internal market, in which employees are treated as customers of the organization as to improve the corporate effectiveness through improving internal market relationship (Helman & Payne, 1992). The high standard of internal service quality leads to employee’s satisfaction, enabling them to deliver higher service quality to external customers (Hart et al., 1990).

Another reason for the word of people in this study is the importance of the external relationships to the success of an organization at the inter-organizational level, and this will be examined in terms of supplier connection. This study also examines how airlines build external relationships with the suppliers. If they have a good relationship with the suppliers then, the material, maintenance and time consumed for bargaining will be reduced. Maloni and Benton (2000) have shown empirically that a stronger buyer-supplier relationship will enhance performance throughout the chain. Benton and Maloni (2005) have emphasized a direct, long-term association, encouraging mutual planning and problem-solving effort in supplying chain partnership.

A performance examination is valuable for understanding successful quality practice. Indeed, analysis of quality management and other processes implemented by an external supplier is equally important in explaining the process performance association (Forker, 1997). The service performance has been conceptualized on two dimensions: (a) an internal or operations-oriented dimension of service quality performance and (b) an external or marketing-oriented dimension (Collier, 1991). This can be conceptualized on the relationship between internal and external relationships that enable an organization deliver excellent service to the external customer (Hart et al., 1990). Worthington and Harbisher (1997) found that service organization needs to have a strong relationship with supplier. The strong relationship is a tool to achieve a mutual benefit for both parties.

DISCUSSION

A firm’s supply chain consists of three major parts, internal functions, upstream suppliers and downstream customers (Handfield & Nichols, 1996). The internal functions include all of the different processes (procurement, production, and distribution) that are used to transform raw materials to the finish product. The coordination
and schedule of these processes are essential. The management of the upstream supplier network ensures that the right material is received at the right time and at the right location. The focus is on selecting a few good suppliers and maintaining good relationships with them. The management of downstream customer network ensures that the customers receive the products they want on time. The ultimate goal is the achievement of customer's satisfaction through good pricing and timely delivery (Abdinnour-Helm, 1999). The idea of selecting and maintaining supplier relations from manufacturing counterparts also would be well applied in an airline industry. The top three reasons why the airline business needs to build long term relation with the suppliers are as follows:

a. For all airlines, after labor, jet fuel is the second largest operating expense which constitutes 10 to 25 percent of their annual operating costs. To optimize fuel levels, airlines have turned to information technologies with sophisticated forecasting and auto replenishment capabilities. The fuel procurement supply chain is essentially a network consisting of suppliers, distributors and customers (Oppenheimer, 2007).

b. Airline management needs to be current and accurate to ensure that planes are safe and reliable for flight. Here, the role of Maintenance, Repair and Overhaul (MRO) needs to be properly maintained to boost the overall efficiency of their MRO operations. The principal of MRO activities include servicing, repairing, modification, overhaul, inspection and determination of condition (Knotts, 1999). MRO represents around 10 to 15 per cent of an airline’s operational costs. Establishing an airline MRO process is therefore associated with a high investment in capabilities. For many airlines, especially new entrants, this is not possible because a large capital investment is required. Hence, the outsourcing is considered as an alternative to vertical integration (Al-kaabi et al., 2007; Heikkila & Cordon, 2002).

c. Sales and distribution contribute to the third-high operating cost in airline business (International Air Transport Association, 2000). Commitment to the lowest distribution costs channels is necessary to stay in such a competitive market. The airline information technology is a tool that connects directly to the airline’s reservation system to store passenger records, manage information and book tickets. Today, airline’s management captures attention in technology, including the Internet, the World Wide Web (WWW), broadband, and wireless technology. They have expanded the scope of airline business. Advance in information technology will reduce the sales and distribution cost.

**CONCLUSION**

The model is an alternative way to enhance Asian airlines competitiveness, safety, and service quality through people. The collaboration between internal and external suppliers becomes a necessary tool to gain success. Indeed, the essence of the model is to maximize the internal and external supplier capabilities to deliver excellent service to the customer. The external supplier capabilities are important to boosting airline service as well as performance. Thus it will enable the company to survive in a hypercompetitive market. Perhaps this model may work in supply chains against supply chains era where company chains are compete with competitor chains. Based on the review of the existing literature, the synergy model is proposed.

The operationalization of the synergy idea is employees in a company. They are included as the team members who work closely with the external supplier to deliver an excellent service as well as the early customers who experience the quality of service before it is ready for them. Hence, the employees will be able to judge their own company service, do evaluations and give recommendations for improvement. Based on
the schematic service quality process, it would be able to prevent service failure and enhance airline service performance because the suggestions are given by employees who will improve the quality of service and safety. In this scenario, the employees represent the customers.

This argument is supported by Schneider and Bowen’s (1985). They have reported that there is a strong correlation between internal and external customers’ perceptions. Today, in order to revamp the problem of an airline service quality, companies need to emphasize the study of internal customers. Hence, the only first customers to determine the quality of company service are the employees. The employees would be able to assess whether the airline service quality is good or, otherwise, needs efforts to improve.

Research in airline business is very critical because the quality of an airline service is declining, in contrast with the growth of the industry. Probably the airline business is required to deliver an excellent service with minimum cost in today’s world. This model may be applicable for the Asian region where sources are limited. There are two important suppliers to be considered for the success of the airline industry. A higher level of employees’ capabilities is necessary to deliver excellent service to the customers. Hence, companies need to acquire, motivate, communicate, retain, empower, and reward the skillful employees whenever they implement their business strategy (full-service or low-cost carrier airline) because the airline service value lies in the heart of happy employees. If they are happy, then their performance in serving the customers will be affective. They will ensure excellence and show their concern at every single stage of the airline service process. The second is the external supplier. In the rapid growth of the airline business, it is highly important to establish long-term relationships with suppliers.

Airline service process is complex compared with other service industries. An airline will be hard to compete with others in the market when it involves high investment and other operational costs. Consequently, the synergy with external suppliers is necessary. To maintain competitiveness airlines are outsourcing their service processes to other parties. The outsource strategy is implemented to reduce the costs and effects of poor airline service and safety. The airline management should create close relationships with those parties as the key suppliers will improve their airline service. At the same time they have to keep communicating with external supplier on how important the quality of service is for business competitiveness. If the airline service quality suffers, it will affect the company’s image and its business performance. Subsequently, the company also notices their importance in supporting the airline business since high quality suppliers can be a competitive weapon in the industry.

This article shows the synergy model between internal and external supplier. Then, it proposes the Asian airline competitiveness as well as the enhancement of airline safety and service. This article is written as an alternative to develop Asian airlines competitiveness and provides research propositions. The future winners in airline industry will be those who have lower operation costs and consider their employees as the important assets to become customer oriented. This paper is conceptual in nature and encourages future researchers to validate and test it. An area for future research is to examine the model in hybrid method (qualitative and quantitative).

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Yudi Fernando is a PhD candidate from the School of Management, Universiti Sains Malaysia. He is an MBA graduate from the School of Management, Universiti Sains Malaysia, Penang, Malaysia. He earned his first degree in management from Universitas Andalas, Indonesia. His current research interests are internal marketing, internal service quality, supplier relations and logistics. Thus far, he has published in several journals such as *International Journal of Information Management, Journal of Accounting, Management and Economics Research, International Journal of Productivity and Quality Management, International Journal of Value Chain Management, Journal of Technology Management and Innovation, International Journal Logistics Systems and Management, International Journal Logistics Systems* and so on. He is corresponding author.
Norizan Mat Saad is currently a lecturer in marketing at Universiti Sains Malaysia, Penang, Malaysia. He earned his Ph.D., from the Management Centre, University of Bradford, UK, his MBA from the University of Hull, UK and his BBA (Hons) in marketing from Coventry University, UK. He has published scholarly papers in internationally refereed journals and proceedings. In summation, his works have been published in five journals including two published under widely cited Emerald journals. It should be noted, that one article has been published in the European Journal of Marketing. As an acknowledgement, EJM is one of the most referred international journals in marketing area and is included in ISI Social Sciences Citation Index recently. Dr Norizan has also published about twenty articles in international conferences.

Mahmod Sabri Haron is a marketing lecturer at the School of Management Universiti Sains Malaysia. His received a PhD from the Management Centre University of Bradford, UK, and his MBA and B.Sc in International Business from Bridgeport, CT. He also has a Diploma in Business Studies from Institute technology Mara, Malaysia and Pg. Diploma in research method from Bradford, UK.

Suhaiza Hanim Mohamad Zailani is an Associate Professor of Operations Management at the Graduate School of Business, Universiti Sains Malaysia. She received a PhD and MSc from Lancaster university, United Kingdom and B.S. degree from Universiti Putra Malaysia. She has been teaching for the past 10 years as well as being involved in a few management consultancies focusing on the areas of operations management. She has more than 150 Research Publications in International/ National Seminars and Journals. She is quite comfortable in operations related projects. Her areas of interest are supply chain, logistics, and transportations by involving in few important projects, which are suited to her capability.
Building an Expert-System for Maritime Container Security Risk Management

Jaouad Boukachour, University of Le Havre, France
Charles-Henri Fredouet, University of Le Havre, France
Mame Bigue Gningue, University of Le Havre, France

ABSTRACT

Until lately, transportation risk management has mostly dealt with natural or man-made accidental disasters. The September 11th tragedy has made transportation operators, as well as shippers and public authorities, aware of a new type of risk, still man-made but this time intentional (Abkowitz, 2003). Securing the global transportation networks has thus become an important concern for governments, practitioners and academics, and all the more so as:

1) beyond terrorism-related risks, lie numerous other intentional man-made transportation risks such as drug smuggling or tax avoidance: e.g., “South African ports face a relatively low risk of international terrorist attack, but high incidences of illegal

INTRODUCTION

Until lately, transportation risk management has mostly dealt with either natural or accidental man-made disasters (Merrick, Dorp, Mazzuchi, Harrald, Spahn, & Grabowski, 2002) focusing therefore predominantly on incident prevention and consequence mitigation.

9/11 tragedy has made transportation operators, as well as shippers and public authorities,

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human movements through stowaways and trafficking as well as smuggling of illegal substances" (Maspero, Van Dyk, & Ittmann, 2008).

2) in a widely spread time-based competition context, securing transportation operations should not be sought for at the expense of delay effectiveness in physical and informational flow processing: e.g., “the WCO passed a unanimous resolution in December 2007, expressing concern that implementation of 100 percent scanning would be detrimental to world trade and could result in unreasonable delays, port congestion, and international trading difficulties” (Caldwell, 2008).

In the past 5-6 years, various initiatives have been launched reflecting this concern (Bichou, Bell, & Evans, 2007) for a detailed presentation of these initiatives), as “Governments and industry have all responded with proposals to create more confidence in supply chain security, while maintaining smooth flows of goods and services in a global supply chain” (Lee & Whang, 2005):

• As from 07/01/2004, the International Ship and Port facility Security (ISPS) Code launched by the International Maritime Organization (IMO), aims at detecting security threats, assessing security and ensuring that adequate measures are in place, based on collection and exchange of security information and the establishment of roles and responsibilities in the risk management process.

• The Container Security Initiative (CSI) has been designed in 2002 by the US Customs and Border Protection (CBP) Administration to identify potentially high-risk containers and evaluate the risk actually brought by these containers before they are shipped to the US, using such screening devices as X-ray scanners.

• Adopted in 2003, the SAFE Framework of Standards to Secure and Facilitate Global Trade is World Customs Organization’s initiative to promote security and facilitation standards for international trade, security-centric networking between national customs administrations, and, through the Authorized Economic Operator (AEO) concept, a cooperation between customs and business operators likable to the US C-TPAT (Customs-Trade Partnership Against Terrorism) program.

Academics and practitioners have also begun addressing this topic:

Following an informal and rather natural thread,

• Some authors have contributed to the definition of the concept of supply chain risk management (Juttner, Peck, & Christopher, 2003) and have defined this concept as “the identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole”;

• Other academic writers have looked into the sources of risk for the supply chain: e.g. based on the robust classification of risks into three types (environmental, organizational and network-relates), Das and Teng (1998) have identified the first two uncertainties as sources of risk to the members of the supply chain, whereas network-related uncertainties would be sources of risk arising from these members.

• An important body of literature is dealing with the risk assessment dimension of supply chain risk management: Gilbert and Gips (2000) have mentioned that implementing supply chain-wide risk assessment may get more and more difficult as the number of links involved in the assessment gets higher.
Regarding risk mitigation, which stands as the final step of a risk management process, it has been addressed mainly as a trade-off issue, risk mitigating strategies being designed to strike the best possible balance between safety/security and such other supply chain performance criteria as costs and lead-times: Sheffi (2002) has suggested to mitigate product disruption risk by building a number of safety stocks and/or keeping a set of local suppliers, dedicated to the handling of specifically high disruption emergencies.

Beyond these various instances of research activities led in this field, a wider review of supply chain risk management literature shows that security risk is dealt with mostly as a supply-chain disruption issue (Mentzer & Manuj, 2008), and using the traditional three-step risk management process: risk identification, risk assessment and risk avoidance/mitigation (Bichou, 2008).

Among all possible contributions to this trend, involving multiple stakeholders at the crossroads between local border protection and global supply-chain performance, stands the design and implementation of relevant decision support systems. Consequently, a project of this type has been set up, to help secure international transportation networks’ seaport nodes. In its first phase, it has followed a case-based methodology for field data collection, calling on specific process and risk analysis resources. The project has now reached the stage of prototyping a decision-support system dedicated to container transportation, security-wise, decision making: it features an expert-system architecture, well-suited for the modeling of the ill-structured patterns shown by risk management decision processes.

Reset in the triple frame of global supply chain’s continuous drive for performance improvement (Part 1), a literature review on decision-support systems dedicated to transportation risk management (Part 2), and the presentation of the various steps of expertise modeling in a transportation risk management context (Part 3), this paper describes the different components of the expert-system’s prototype (Part 4).

SECURITY: A NEW PERFORMANCE CRITERION FOR THE GLOBAL SUPPLY CHAIN

Since the 1990s, the international economic context has favored the reduction of trade barriers (Nonneman, 1996), the decrease of custom duties (Minyard, 1997), and the surge of international sourcing (Swenson, 2005).

As time passes by, the transportation industry brings up new development opportunities for this globalization of economic activities (Douglass, 2001); the expansion of dedicated, network-structured, transportation infrastructures ensure that shipments are optimally delivered. Maritime ports get larger and larger, adjusting to the continuous growth of containerization (Amerini, 2008).

To profit by the obvious economic advantages of international sourcing (Ferdows, 1997), companies are looking world-wide for commercial partners, suppliers and customers.

Besides, wherever they stand along the global supply chain, they tend to externalize a growing number of logistics related activities.

Finally, as sea-borne trade is increasing strongly and rapidly, global supply chains are becoming more and more difficult to design and control, compared to local ones (MacCarthy & Atthirawong, 2003), with an ever tighter dependency from international transportation networks.

Before the 9/11 tragedy, global supply chain’s performance relating to maritime transportation was measured in terms of cost, delay, and a quality of service particularly focused on container’s integrity, cargo theft being a critical risk for many companies.

Since 9/11, a new era has begun, characterized by a high probability of terrorist acts. The attention of international trade stakeholders has turned to the possibilities of using containers
to hide and ship weapons of mass destruction and/or terrorist agents. All around the world, security managers have started to fear that the maritime transportation system might be used as a target and/or vector for further terrorist attacks.

As to global supply chain managers, they have always been faced, in a changing environment and a strongly competitive market, with conventional disruptions due to ill-operated procurement processes, capacity constraints, and/or quality issues in factories. Today, they also have to deal with a high uncertainty, arising from war against terror, and the probability of further attacks, notwithstanding the consequences of port congestion in the wake of a possible incident.

Therefore, global supply chain vulnerability has become a capital issue for all of the logistics networks’ partners, and security, together with effectiveness, is now an unavoidable high performance factor for the maritime (including container) transportation system.

**Maritime Transportation System’s Securisation**

In seaports, a large variety of products is in transit, in great quantity, from diverse origins, to several destinations. These products are more and more often shipped in containers: maritime container transportation becomes the first transportation mode for the manufacturing industry. In 2002, the International Container Bureau (BIC) had estimated the containers to a world-wide number of 15 000 000 (Organisation for Economic Co-operation and Development [OECD], 2005). Every day, those millions of containers, carrying each more than 20 tons of products, are conveyed to and from seaports on trucks, carriages, barges and ships.

However efficient and reliable such flows may now be, this huge volume of container movements, besides significantly increasing the complexity of the global maritime transportation system (Robinson, 1998), appears as a formidable challenge to freight and people security, more specifically during the seaport transit operations.

Containers have for long been used for clandestine immigration, illegal weapon and drug smuggling, but associated risks are in no way comparable to those created by weapons of mass destruction. One of the major possible consequences of the explosion of such devices in a major maritime port would be the complete shutdown of all of this port’s facilities, with its related impacts on national economies through multiple disruptions of the international trade activities.

Besides, all the more so as container carriers’ capacities are getting larger and larger (over 10 000 TEU), ships themselves can be used as a support for, or viewed as a target of, terrorist attacks, and may also indirectly help collect funds for terrorist organizations. Consequently, and whatever the associated costs, governments, port authorities and all international trade operators need, as they have already started to do since 9/11, to collaboratively design and implement world-wide a hopefully sufficiently efficient array of technical, regulatory and organizational measures, for enhanced safety and security of freight and people.

**Technology-Based Security Measures**

Security risk management in the maritime transportation network being a concern for each partner in the global supply chain, responsibilities for this management are shared between federal agencies, state agencies, local agencies, border protection administration, logistics and transportation operators, freight shippers, notwithstanding each individual’s potential contribution (Abkowitz, 2003).

More specifically, Port Authorities focus on two levels of security:

- The assets level, where security issues regarding port facilities and access to port premises are handled, and
- The in-transit level, at which physical and informational flows security problems are dealt with.
In this context, a growing number of relevant inspection-like control processes are being implemented in seaports, a priori leading to extra delays and additional costs in the handling of the containers. However, all along the global supply chain and including within the seaport link, new information and communication technologies help companies combine efficient security management and time-effective operations management through various improvements in such fields as facility access, container handling and transport document processing. Among the security-wise equipment supporting these improvements stand out container sealing systems, risk-centric container targeting systems, RFID-based container stuffing, moving and loading, supervision systems (Juels, 2005; Kearney 2004; Weis 2003), and smart boxes and x-rays or y-rays scanners (Massey, 2005).

**Regulatory-Based Security Measures**

Regulatory actions have also been taken, some at a national level, others at international and even world-wide levels, as a result of collaborative projects which have been launched to define common strategies dedicated to reducing the risk of terrorist attacks within the maritime transportation system. These strategies focused on container tracking, ships and port facilities security, seamen identification and freight integrity (JBW Group International, 2009).

The United States has adopted institutional measures such as the Act of Maritime Transportation Security in 2002, the Arrival Notification Rule (96 hours advance notice), compulsory visas for crew members, and the Advanced Manifest Rule (24 hours before ship loading). Moreover, they have promoted voluntary programs such as CSI, intended to increase container security, and C-TPAT, to enhance shippers’ motivation in fighting terrorism through cooperation with the US Customs and Border Protection agency.

In the European Union, comparable initiatives have been taken, such as the Custom Security Program, and the optional audit-based qualification procedure of supply chain members as Authorized Economic Operators.

International Maritime Organization (IMO) has designed regulation rules stemming out of SOLAS (Safety of Life at Sea) Convention modifications and ISPS Code extension.

Finally, World Customs Organization (WCO), which has shown continuous interest since the years 2001-2002 in the enhancement of global supply chain security, has adopted the SAFE Framework of Standards to secure and facilitate global trade during its June 2005 annual Council Sessions.

The implementation of all those regulatory actions has brought mixed feelings among supply chain operators:

Advanced notice of information on inbound containers may speed up the average transit-time at the port of entry, and the security-centric handling of C-TPAT or AEO labeled freight may prove less time-consuming.

More generally speaking, improved accuracy, reliability and availability of ship- and freight-related information, as a result of security measures implementation, is a well-reckoned contribution to a more efficient and more effective operation of the global supply chain (Kearney 2004; Bhatnagar & Viswanathan 2001; Sheffi, 2001; Sheffi & Rice, 2005).

Conversely, a number of non-US international logistics networks’ stakeholders, including Port Authorities, fear that worldwide extension of CSI-inspired, but unwisely-implemented, physical inspections of containers may increase port congestion and globally slow down freight flows along and out of the supply chain. This feeling has actually been reinforced recently by the legislation passed in 2007 by the US Congress to have 100% of the US-bound containers be scanned before leaving their port of exit.

Besides, because of its requirements for large numbers of highly-qualified personnel and high-technology equipment, the full implementation of the above-mentioned security measures within each link of a given global supply chain may be excessively costly.
**Associated Costs**

One of the key decision factors for security measures implementation is the comparative analysis of associated action vs inaction costs.

Obviously, the global cost of securing, the cost of a security-dedicated such complex organizations as are transportation networks, may be huge.

For instance supply chain redesign could amount to more than USD 65 billion (Russel & Saldanha, 2003), not only because the relevant equipment is presently very expensive (e.g., RFID-based data acquisition system), but also because the comprehensive cost of the whole project should include installation costs, maintenance costs, operation costs, and so forth.

Also, the total costs induced by the application of the advanced manifest rule for example are estimated between 5 and 10 milliards dollars per year (Organisation de Cooperation et de Developpement Economique [OCDE], 2003).

As to container scanning systems, they can cost up to 5 USD million dollars (OCDE, 2003), while handling from 4 to 20 containers per hour, depending upon the technology used.

Potential costs associated with reaching C-TPAT or AEO status are quite high too: companies must invest heavily to protect their own assets and to meet the status-related requirements.

Notwithstanding other, possibly equally high, and most likely organizational, cost items, financial cost of implementing security measures is therefore a formidable burden for all global supply chain stakeholders, would they be public institutions or private companies.

Yet, the maritime transportation system is so vulnerable that a large scale multi-point terrorist attack would cause losses amounting to tens of billions of US dollars (~USD 58 billion only for the US system). There is then no sensible way for any public authority, a priori involved in securing freight and people transportation, to avoid addressing this issue in the most possible efficient manner.

Besides, as it is now well-agreed upon that security has become a component of supply chain performance as important as cost or delay can be, any company (including seaport communities) knows that, in the years to come, it will be renewed as a member of a logistics network, or will be offered the opportunity of entering a new one, only if it has adjusted to a sufficiently high level of operational security (Fredouet, 2007).

In such a context where they are led to assess and possibly redesign their risk management strategy and processes, actors of global transportation systems may feel the need for dedicated risk identification, evaluation and mitigation decision-support systems.

**DECISION-SUPPORT SYSTEMS FOR TRANSPORTATION RISK MANAGEMENT**

Depending upon the nature of the processed data, one of two types of risk analysis (Gleyze, 2000), quantitative and qualitative, and a number of tools and methods are usually applied in risk management, among which stand the Monte-Carlo method, decision trees, heuristics, and fuzzy sets. Risk management covers several areas (Camara, Kermad, & El Mhamedi, 2005): risk management project, financial risk management, software risk management, product/service risk management and process risk management.

The risk analysis can be deterministic or probabilistic by quantifying uncertainties. The interpretation of this quantification can follow a diagram of deductive logic (tree of failures or defects) or an inductive diagram (tree of events).

The quantitative risk analysis, in the case of complex systems, is done by stochastic methods applying to a large number of events, the occurrence of which is hard to quantify (natural risks, risks generated or not by human activity). Generally, an inductive step is activated in such methods (Leroy & Signoret, 1992).

The events can be individualized, in which case one speaks about microscopic data. The macroscopic data are associated with events which cannot be quantified individually.
Among the inductive methods, there are preliminary risk analysis (PHA), hazard and operability study (HAZOP), and failure mode and effects analysis (FMEA/FMECA). Fault Tree Analysis (FTA) is one of the most important deductive methods.

**Maritime Transportation**

Since seaports are open gateways to world markets and significant contributors to the development of world economy, many research works have focused on maritime transportation. The logistics tracking system designed by Tsai (2006) addresses the issue of risk-related information integrity. This system, initiated by a Taiwanese seaport, is dedicated to smuggling risk avoidance/mitigation during container transiting operations. The analysis of information integrity is done using the FMEA methodology. Each risk, quantified by priority number, is assessed as intolerable, negligible or in-between. The tracking system deals with information unreliability stemming out of human and/or organizational errors, as well as with information inconsistency coming from technical error.

Degre (2003) uses the SAMSON methodology (Safety Assessment Models for Shipping and Offshore in the North Sea) to estimate the number of maritime accidents. A quantitative risk assessment using FSA (Formal Safety Assessment) aims at improving safety in seaports. FSA methodology identifies risks, quantifies their level and specifies risk reducing measures. This paper deals more precisely with risks of such possible accidents as collisions, stranding, contacts (collisions with man-made structures), damages, fires, and explosions. These accidents depend upon many factors including the ship’s type, size, age, and registration flag. More recently, Yip (2008) studied accidents in the Port of Hong Kong using regression analysis.

**Hazardous Goods Transportation**

In the case of hazardous goods transportation, Egidi, Foraboschi, Spadoni, and Amendola (1995) analyzed the major risks of accident (fire, explosion, toxic emanations) as connected with warehousing and transportation activities within the densely-populated area of Ravenna (Italy). Bubbico, Maschiob, Mazzarottaa, Milazzob, and Parisi (2006) studied the same problem. They used a transportation risk analysis to assess the risks associated with different modes (road and rail) hazardous goods transportation. Risk mitigation is sought by changing route and/or transportation mode using a combination of road, rail and inter-modal solutions. After mitigation, an F-N societal risk curve for land transportation is calculated. Frequency-Number (F-N) curves can show the societal risk in a situation where there is a potential for accidents impacting more than one person. These are obtained by plotting the cumulative frequency (F) of accidents scenarios that cause N or more fatalities per year as a function of N (usually on a log-log scale) (Casal, 2008).

The societal risk is also calculated in (Gheorghe, Birchmeier, Vamanu, Papazoglou, & Kröger, 2005) in the usual format of a CCDF (Complementary Cumulative Distribution Function) for any railway traffic segment based on location-specific infrastructural and environmental data. Different calculations have been conducted, including LOC (Loss Of Containment) frequency and accident consequence estimation. However, event- and fault- trees have been developed for investigating significant events following the identification of the immediate cause of a derailment and/or a collision. A detailed Master Logical Diagram including fault/event tree analysis determines LOC frequency.

Still in the field of hazardous goods transportation risk management, more specifically in a case of NP hard-classified risk transportation programming, Mavrommatis and Panayiopoulos (2004) have designed a mathematical model of the situation, and built a dedicated problem-solving heuristics. External factors such as weather, war, strikes, and accidents, may alter transportation schedules, and therefore modify costs within a given planning horizon. In order to spread risks, the final purpose is to find a set of dissimilar paths in route planning for the transportation of hazardous materials.
Unlike these studies that focus on prediction and probability of occurrence of a risk or optimization, we are particularly concerned with in detection of risks due to the occurrence of some known events. Our risk management is based on monitoring and tracking the physical flow of goods (Bechini, Cimino, Marcelloni, & Tomas, 2008; Planas, Pastor, Presutto, & Tixier, 2008). Developed around the need of our partners, our research focuses on using a tracking system as a tool for risk management.

**AI Applications**

There are also a number of artificial intelligence (AI) applications to the solving transportation management problems. AI is actually quite suitable to address those problems which so far have been difficult or impossible to solve using classical mathematics.

The 2007 Transportation Research Circular E-C113 of the Transportation Research Board (Transportation Research Board, 2007) describes the state of the art of AI tools and methods (see Table 1), namely knowledge-based systems (KBS), neural networks (NN), fuzzy sets (FS), genetic algorithms (GA) and agent-based models (ABM), usually applied in transportation management. Additionally, for a wide range of transportation problems, the document helps decide what tools to implement, under what conditions, and for what specific applications. For each paradigm or method, a brief description is given as well as its strengths and weaknesses, and the types of problems it is best suited for solving.

In addition, the circular points out at three reasons to use AI:

- Transportation problems deal with qualitative data, which makes it most appropriate to use KBS- and FS-based decision-support systems,
- Transportation systems’ behavior is so hard to model that the best solution is to build empirical models of these systems based on observed data, and for which NNs are perfectly relevant, and
- For optimization problems which abound in transportation management, there is a need for alternative meta-heuristic approaches, such as GA’s, to help deal with over-sized and non linear decisional situations.

Combining AI with data analysis, Bayesian Network (BN) stands out as a tool frequently

<table>
<thead>
<tr>
<th>Method</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBS</td>
<td>Symbolic AI</td>
<td>Include expert-systems and case-based reasoning, together with FS, are described as quite appropriate for the support of uncertainty-loaded decision processes, and the solving of problems requiring human expertise.</td>
</tr>
<tr>
<td>NN</td>
<td>computational</td>
<td>Made of sets of neurons connected together in such a way that they are able to learn nonlinear behaviors from a limited set of measurement data, and adaptively respond to inputs in accordance with a relevant learning rule. These networks are useful for function approximation or for input-output mapping. They are also excellent pattern classifiers (pattern recognition and classification problems).</td>
</tr>
<tr>
<td>FS</td>
<td>computational</td>
<td>Based on probability / possibility distribution functions, are widely used in the modeling of ill-defined input data, problem-solving knowledge and/or awaited solutions.</td>
</tr>
<tr>
<td>GA</td>
<td>computational</td>
<td>Specifically stochastic optimization algorithms.</td>
</tr>
<tr>
<td>ABM</td>
<td>Symbolic AI</td>
<td>Models an organizational system from down to top, starting with its individual actors (agents) and defining their potential interactions. The simulation of these interactions generates the system-level (top) behavior. ABM seems therefore appropriate for the in-depth exploration of complex systems’ behavior.</td>
</tr>
</tbody>
</table>
used in (transportation) risk management. In the case of a transportation-related risky context, Bouchiba and Cherkaoui (2007) have followed a BN approach when building a graph of all events likely to generate accidents within the Moroccan railroad network. BN is a powerful decision-support tool, although it cannot take into account multiple-attribute and fuzzy expressions. The nodes of the graph represent hazard variables (uncertain events) and the edges represent the probabilistic causal dependence among the variables. A network allows a qualitative description of the relationships between different variables (causal graph) and a quantitative description of the relationships between events. BN makes it possible to analyze a large quantity of data, in order to enrich the knowledge base from which the decision will be made, to control the behavior of the monitored system, and/or to identify the likely cause(s) of a given phenomenon.

In Trucco, Cagno, Ruggerri and Grande (2008), the Maritime Transport System (MTS) is described through the modeling of its different actors and their mutual influences. Within the model, the risk analysis process is based partly on FTA and partly on a Bayesian Belief Network (BBN) to account for the risk Human and Organizational Factors (HOF).

Yang, Bonsall, and Wong (2009) have integrated BN in MAUT (Multiple Attribute Utility Technique) to make for uncertain attributes. Additionally, the BN incorporates a notation of preference. They studied the case of a container transportation lead-time, and designed a decision-making scenario dedicated to the choice of the appropriate transportation mode of transportation for lead-time reduction. Fuzzy logic was used to take into account crisp values (which represent uncertain data), fuzzy numbers and linguistic variables.

Among all those possible approaches to decision support in transportation risk management, this paper focuses on expertise modeling, leading to the design of an expert system, therefore within the field of knowledge-based systems.

**KBS AS APPLIED TO TRANSPORTATION RISK MANAGEMENT**

Rather than on data analysis, transportation security-dedicated decision support systems may rely on the modeling of human expertise in relevant risk identification, assessment and hedging. In that case, the whole decision-support process consists in the best possible duplication of the problem-solving protocols followed by various experts in transportation security risk management.

The design of such a knowledge-based system goes follows a two-stage path: one is the knowledge acquisition stage; the other is the knowledge representation stage.

**Knowledge Acquisition**

Collecting human expertise faces a variety of difficulties, which are accounted for through a range of dedicated techniques.

**The Difficulties Encountered**

Knowledge acquisition potential problems relate respectively to the content of the knowledge to be acquired and to the personal behavior of its holder.

Most of the time, the human expert-led risk management process is both complex and pervaded with uncertainty (Vale, Ramos, Faria, Santos, Fernandes, Rosado, & Marques, 1997):

- Risk identification is based on a large number and wide variety of qualitative as well as quantitative criteria (Yang, Shyu, Lin, & Hsu, 2005). Each of these criteria characterizes a specific standpoint, from which a potentially risky situation should be looked at to build for it a measurable and reliable description. Furthermore, risk identification data often are not as complete, as precise and/or as reliable as they should be, to ensure that the decisions which they support reach an acceptable level of certainty.
Risk assessment and hedging may follow various paths, mostly heuristic in nature, as they result from the experts’ years of practice (Zsidisin & Ritchie, 2009). These assessment and hedging scenarios are structured in some kind of individual meta-knowledge, which each specialist uses to dynamically adjust his/her analysis of a given risky situation to the context encountered. While such heuristics obviously speed up the assessment/hedging process, they at the same time greatly contribute to the complexity of the problem-solving knowledge base.

The knowledge is sought from experts whose individual cognitive behaviors, as well as personal attitudes towards the acquisition process itself, are likely to be different:

• Whereas some people have a rather synthetic cognitive style, which means they can make their decisions using relatively simple decision-trees, each based on a limited number of data, some other people have a more analytical cognitive style; they require a larger amount of data for context and problem description, which leads to the densification and complexification of their decision networks (El-Najdawi & Stylianou, 1993).

• Moreover, different people feature different cognitive capacities, partly in the way that some are able to simultaneously handle a larger number of data than others at a given step of a given decision process, therefore shortening and narrowing this process (O’Leary, 1996).

• Besides, when being asked whether they would agree to participate in the building of a KBS based (partly) on their knowledge, experts take stands which go from sincere willingness to frantic opposition (McGraw & Seale, 1988). When knowledge acquisition is constrained into situations close to this latter case, the quality (including reliability) of the knowledge retrieved from the expert is likely to be rather poor. Incidentally, the experts involved in the design of the KBS described later in this paper, who work for most of them for the Customs administration, have spontaneously adopted a definitely cooperative attitude; the assumption regarding this matter is that, as they are civil servants and the expert-system project is at this stage only a research project, they felt no threat for their job.

The Techniques Available

Apart from the rather theoretical option of letting experts conduct a self-interview, self-transcription informal process, knowledge acquisition is usually dealt with by knowledge engineers through the implementation of dedicated techniques (Reitman & Rueter, 1987).

Traditionally, retrieving its knowledge from an expert is done via a series of more or less structured interviews. However, using this technique is rather time-consuming and costly, and the knowledge retrieved may not be as complete and unbiased as it should: e.g. willingly or not, the risk management expert may speak out only part of his/her assessment and hedging processes, or the knowledge engineer may have a wrong understanding of the expert’s discourse (Cullen & Bryman, 1988).

Therefore, based on a heuristic, rather than algorithmic, concept of experts’ thought processes, it may be worth turning to other techniques, more specifically coming from the field of cognitive psychology (Cooke, 1992). Among these knowledge elicitation techniques, protocol analysis stands out as one of the most widely-used.

In the present risk management context, a protocol is the expression by the expert of his/her assessment/hedging process in a given risk-loaded situation. Once it has been collected, the protocol is analyzed in order to identify the pieces of expertise actually implemented for ad hoc problem evaluation and solving (Ericsson & Simon, 1993):
Three main options have to be taken during protocol collection: One is between written or verbal protocols; admittedly, a written protocol would eliminate the risks of information alteration or even loss in the course of a verbal protocol transcription; however, the more complex, the lesser structured, thought processes are, the better verbal protocols seem to be suited for their identification, in terms of knowledge completeness and reliability.

The second option is in vitro collection vs. in vivo collection; although in vitro collection is less time-consuming and probably allows for a better control of the on-going acquisition process, in vivo collection is likely to bring out a richer knowledge, would it only be because most of the time the expert feels more motivated when handling ‘real-life’ than ‘lab-like’ on-the-job situations.

The third option is the choice of collecting protocols when expertise is actually implemented or later; a posteriori collection is worth practicing in the way that it gives time to the expert to re-think his/her past evaluation/decision process, and in the end build a more thorough description of this process than he/she would have during a ‘live’ collection. However, having protocol collection coincide with expertise implementation preserves the spontaneity of the expert’s behavior, and therefore avoids the self-censuring and/or post-rationalization attitudes which experts rather frequently adopt during a posteriori collection.

Protocol analysis consists in two main activities, described in some detail by Bainbridge and Sanderson (1995): “once they have been collected, the first activity [in protocol analysis] is the preparation and description of the protocols […]. The second activity is the analysis of the explicit and implicit content and structure of the protocols”.

First step in preparing the protocol for analysis consists in identifying the structure of the recorded material, by isolating hopefully meaningful words or sets of words. Through more complex segmentation of this material into sentences, the next step is to look for instances of specific mental processes likely to have been activated by the expert. From these processes may then be inferred the general structure of the mental activities.

Beyond this first level of analysis, a number of qualitative as well as quantitative, non-exclusive, techniques have to be implemented, to extract from the protocols retrieved their full significance regarding the research issue to be addressed. Among these techniques, two are widely practiced: content analysis (Ford, Stetz, Bott, & O’Leary, 2000), which typically relies on counting the frequency of occurrence of words or sets of words or sentences; sequential analysis (Fisher & Sanderson, 1993) rather searches for (repetitive) sequences of sentences or group of sentences in the expert’s flow of thinking.

Once the knowledge acquisition step is over, expertise modeling enters the knowledge representation stage.

Knowledge Representation

Knowledge acquired from experts using such a collection process as protocol analysis, is formulated for the most part in these experts’ respective personal natural languages. Therefore, so as to be effectively stored and efficiently retrieved and implemented, expert knowledge needs to be represented through some kind of common standardized structure (Huang, & Tseng, 2009). This structure may frame in different ways the information needed for evaluation and decision making, and the processing of this information:

Information Modeling

Following standard IS design principles, the information may be structured into a data-base combining object-oriented technology and
relational architecture, thus maximizing the diversity of information that could be stored in the data-base.

Regarding risk management decisional activities, database management systems (DBMS) are helpful in the way that they provide both a dedicated frame to host the information feeding the risk identification / assessment / hedging processes, and a query language to retrieve the information relevant to a given step of a given decisional activity (LaFue, 1983; Jarke & Vassiliou, 1983).

But, even if part of the information processing knowledge may also be re-formulated using a DBMS structure (knowledge components are framed into a set of objects and object classes, characterized by a number of attributes and relationships) (see the Ksys architecture in Wiederhold, 1995), this structure is generally not fit for the representation of the experts’ most of the time inferential thought processes.

**Process Modeling**

Experts’ information processing may be formalized using expert-systems shells, which supply the risk management DSS designer / builder with a set of tools for the transcription of human problem-solving processes into a three-component standard model: an expert-system made of a database, a knowledge base and an inference engine. Each of these components represents one of the three dimensions of a decisional activity: have knowledge of the types of problems needing to be solved, have information on the specific situation calling for the decision, apply the former (available knowledge) to the latter (problem to be solved):

- **In the knowledge base** is stored most of the acquired expertise, made of both a basic domain-specific knowledge, and a meta-knowledge which helps prevent the combinatorial explosion that would result from the systematic exploration of the whole knowledge base. The knowledge representation mode most commonly used in transportation risk management expertise modeling are the production rules, which require that the knowledge be formulated as sequences of IF (hypotheses) THEN (conclusions) (Hou, Li, & Wang, 2009).
- **In the database**, most likely using a DBMS-structure, is stored the information relating to the specific problem to be solved. More specifically, in a transportation risk management context, at least part of the data used in the risk identification phase needs to be collected and transmitted in real time, so that risk assessment and possible hedging actions may be led as soon as possible after the risk has been identified. Global positioning systems, various kinds of sensors as well as EDI networks are therefore among the technological resources supporting data base feeding within the risk management expert-system (Skorna, Bode & Wagner, 2009).
- **Standing as the model of the expert’s thought process**, the inference engine uses the knowledge available in a given field of expertise to help solve a problem within this field (Southwick, 1991). It follows a three-phase operating cycle, from the detection phase to the deduction phase, through the choice phase:
  - The detection phase is dedicated to the identification, within the knowledge base, of all the elements of knowledge likely to contribute to the solving of the problem.
  - The selection phase retains, from all the elements of knowledge identified during the detection phase, only those which will actually be used for improved problem-solving.
  - The deduction phase applies the elements of knowledge retained to the present step of the evaluation/decision process, thus leading to a better understanding of the situation and preceding a step forward in the solving of the problem.
Built from the expertise collected during the knowledge acquisition phase, based on a variety of knowledge representation modes, the expert-system is ready for use as a support for transportation risk management decision-making.

To illustrate part of this rather long DSS design and building process, the following section describes the implementation of the different components of an expert-system prototype, designed for transportation security risk management.

**PROTOTYPING A TRANSPORTATION SECURITY RISK MANAGEMENT EXPERT-SYSTEM**

Our methodology encompasses the three core elements of (1) risk modeling, (2) risk assessment and (3) risk management.

Risk modeling is process-based. It is an “activity-resource” model well suited for logistics systems analysis and the associated security-centric performance monitoring. The data-collection methodology followed at this stage is case-based, within a set of typical Supply Chains involving internal (e.g., Port of Le Havre) and also external logistics actors. The processes taken into account go from the origination port to point of destination (for imports) and from point of origin to the destination port (for exports).

Risk assessment is addressed with reference to security-dedicated standards as food industry Hazard Analysis and Critical Control Points (HACCP). HACCP is a method of risks identification, evaluation and control (Rivituso & Snyder, 1981; Walker & Jones, 2002) that helps to lead a risk analysis to identify potential risks, to decide which potential risks to manage, to specify the critical points to control and to define the risk indicators that must be evaluated. Table 2 shows an overview of the HACCP method with some critical control points.

Risk management is taken care of through the implementation of an expert-system coupling a database to a knowledge base. The database should be fed with real-time and automatically collected information from the monitored logistics operations. The knowledge base is fed with the expertise of, among others,

### Table 2. HACCP application

<table>
<thead>
<tr>
<th>Risk Point</th>
<th>Scenario</th>
<th>Risk</th>
<th>Indicator</th>
<th>Preventive actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>empty container depot</td>
<td>The owner is Not-AEO and no access control to the empty container depot</td>
<td>Modification of the empty container</td>
<td>Shape of the empty container shape</td>
<td>Check the shape of the empty container before packing and point out that the container is reserved</td>
</tr>
<tr>
<td></td>
<td>The owner is Not-AEO and the number of empty containers is unknown</td>
<td>Fraudulent container</td>
<td>Empty container number</td>
<td>Check and forward the number of the empty container before packing</td>
</tr>
<tr>
<td>Empty container pick up from container depot to a customer’s warehouse</td>
<td>The owner is Not-AEO and the driver is a risky person</td>
<td>Modification of the empty container</td>
<td>Shape of the empty container shape</td>
<td>Check the shape of the empty container before packing and point out that the container is reserved</td>
</tr>
<tr>
<td>Customer</td>
<td>Customer is Not-AEO and employees background is unknown</td>
<td>Intrusion</td>
<td>Container contents</td>
<td>Check the container before terminal arrival and scan the container on arrival at the port</td>
</tr>
</tbody>
</table>
customs / police / immigration agents, lawyers, and port authorities. To optimize container transit security and facilities, the expert-system inference engine first interprets information on the incoming (from sea or from land) container and then presents a solution for dealing with each cargo, on the basis of available expert knowledge. Our prototype was developed within a Research Institute for Securing and Facilitating International Logistic Chains, which includes University of Le Havre, French customs, SOGET (world leader in E-Maritime applications) and Port Authority of Le Havre.

In this specific instance of transportation risk management, the risks dealt with by the expert-system may occur at different stages of a given container seaport-bound transportation process.

The implementation of the knowledge-based system was carried out using CLIPS (C Language Integrated Production System). CLIPS is a forward-reasoning and pattern-matching KBS shell. It provides support for rule-based, object-oriented and procedural programming. CLIPS is extremely popular because of its high portability, low cost, and easiness of integration with external programs (Girratano & Riley, 1989). Knowledge in CLIPS is represented through a modular environment, a module being a set of constructs (deftemplate, defrule, deffacts).

CLIPS supplies mechanisms to store the rules, and an inference engine for rule selection and rule activation. Rules within CLIPS are expressed by the construct defrule, which contains a left-hand side (LHS) and right-hand side (RHS). The LHS is a series of conditional elements which consist of patterns to be matched against. The RHS contains a list of actions to be performed when the corresponding LHS conditions are met.

**Implementation of Knowledge Within CLIPS**

To help validate the expert-system, a test-bed has been built out of a set of 50 potentially risky situations. Each situation is composed of one or more premises and a conclusion (decision). A premise being composed of a name attribute linked by a relational operator, such as is equal to or is less than, with an attribute value to form logical expressions that can be evaluated as true or false.

We identified different risk scenarios thanks to our partners French Customs and Soget firm. We have thus collected many security risk situations according to the view point of French customs. Table 3 presents two situations and illustrates the way in which CLIPS expresses them the defrule definition. Defrule allows the statement of the rules by giving each of them a name and a salience (priority).

Several conditions are mentioned in the left side and should be checked with the facts reflected in the facts base.

One example is the fifth position, which includes two rules with the names “state-site-secure-conclusions” and “state-site-unsecure-conclusions”.

The conditions set out in the left side of the first rule such as:

- “state-site notisolated”,
- “guarding_time secure”,
- “badge_control perfect”,
- “enclosure_high secure”

must be verified with the facts existing in the facts base.

The “site is secure” is presented as the conclusion of this rule. The decision displayed by the function “repair” is “the site is sufficiently secure”. The second rule of the present situation where the site was not secured by the fact that one of the conditions of the left side is not satisfied. The decision to be taken is “the site is insufficiently secure, the container must be scanned.”

All these situations involve different classes: Container, Actor, Hazardous goods, Shipping, Country, Transport mode, Site, Transport Company and Driver. The Container class models the basic characteristics of a container (see Figure 1). This class is associated with Goods entity to track the contents of the container, especially dangerous goods. There is an association between Container and Actor
classes to enforce a container to be always associated with a responsible actor. Two associations exist between container and Site and between Container and transport mode. Thus, at each stage of the supply chain, we are able to retrieve the information about the site where the container has been processed or stored and about the various modes used for a movement. Finally, intermodal transport includes shipping through rail, sea, river and ground mode from/to many countries, some of them may be risky.

**USER Interface**

The man-machine interface presents the user with questions and information, and stores the answers in the system’s data-base, where they can be accessed by the inference engine. First, the system provides the user with a choice of one among the five different situations described here above.

Then, within the context of the situation retained, the user is guided through a series of questions depending upon the values he assigns to associated variables and the accuracy of these values. These values are included in the data-base.

Finally, after the inference engine has performed its three-stage (detection – selection – deduction) problem-solving cycle, conclusions reached are displayed to the end-user.

The following screenshot (see Figure 2) shows the case when a container must be inspected after the user has responded that the container is in transshipment. It was first controlled at the export port. It has already been transshipped once. The three operators that have interfered since the departure checking are all AEOs so the container may pass without inspection.

Then, within the context of the situation retained, the user is guided through a series of questions depending upon the values he assigns to associated variables and the accuracy of these values. These values are included in the data-base.

Finally, after the inference engine has performed its three-stage (detection – selection – deduction) problem-solving cycle, conclusions reached are displayed to the end-user.

The following screenshot (see Figure 2) shows the case when a container must be inspected after the user has responded that the container is in transshipment. It was first controlled at the export port. It has already been transshipped once. One of the three operators that have interfered since the departure checking is not an AEO so the container must be inspected.

The expert system allows to target risky containers according to multiple indicators. New scenario (see Figure 3) can be easily in-

### Table 3. Examples of risky situations

<table>
<thead>
<tr>
<th>Situation</th>
<th>CLIPS implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The container is in transshipment. It was first controlled at the export port. It has already been transshipped once. The three operators that have interfered since the departure checking are all AEOs so the container may pass without inspection.</td>
<td>(defrule state-container-secure-conclusions (declare (salience 10)) (type-armement-first oea) (type-armement-second oea) (type-shipper-first oea) =&gt; (assert (state-container secure)) (assert (container Crossdocking)) (assert (hiero-cross 1)) (assert (repair ”the container pass without inspection “)))</td>
</tr>
<tr>
<td>The container is a LCL/LCL(Less than container load) container. Shippers are all AEOs, but not the provider that has done the stuffing. In addition, some of the containers on board are travelling to destinations at risk. In such a case, the container must pass the scans.</td>
<td>(defrule normal-container-conclusions (declare (salience 10)) (state_container normal) =&gt; (assert (repair ”the container pass without inspection “)) (assert (type-container LCL)) (assert (type-shipper oea)) (assert (type-handling oea)) (assert (destination notrisk))) (defrule scanner-conteainer_conclusion (declare (salience 10)) (state-container suspect) =&gt; (assert (state-container LCL)) (assert (type-shipper oea)) (assert (repair ”The container must pass the scans.”)))</td>
</tr>
</tbody>
</table>
tegrated in order to make the suitable decisions considering future risky situations.

First results from the development have been successfully validated by custom advisor at Soget. We expect approval of the French Customs for assessment of applicability for real world problems.

**Further Research**

Our research is currently focused on a system for monitoring and tracking containerized goods, especially hazardous goods, through Le port of Le Havre and through the global supply chain for security purposes (Boukachour, Fredouet, & Chaieb, 2009). The aim is to provide a system capable of identifying security threats. The system combines different technologies, like container tracking and localization, container-integrated sensor technologies and data available on the container. This work is part of a wider research project in partnership with some supply chain operators, whose main goal is to provide a Web Services platform coupled with technological solutions to track and secure container shipping. To this end, key fields of technology in which research work should be conducted are those of risk analysis and security requirements engineering, risk and security modeling, model-driven development, general compliance in service-oriented architectures (SOA) and supply chains, and security in embedded systems. Regarding this last field of research, focus may be brought on how to ensure that real-world information, collected for instance
through radio frequency identifiers (RFIDs) and wireless sensor networks (WSN) can actually enhance the security of the supply chain.

**CONCLUSION**

Socio-economic organizations, whatever their level of complexity, are threatened by a great diversity of potential risks, which they try to avoid and/or mitigate by setting up dedicated risk management strategies and programs. Among all organizational risks, those relating to global transportation networks feature an increasingly important security component.

This kind of risk is partly but tightly linked to the actual widely-spread threat of interna-
tional terrorism. Obviously, as gates through national borders and transportation load breakpoints, seaports are therefore highly security risk-intensive transportation networks’ nodes, and dealing efficiently with security risks is for them a definite source of competitive advantage in the battle for keeping present, and gaining new, spots in world-wide supply chains.

Actually, properly managing transportation security risks has become a necessity for all supply-chain operators involved, all the more so as 1) security has joined cost, quality and delay in the list of logistics performance criteria favored by growingly disruption-averse customers and 2) securing transportation operations may at the same time facilitate these operations especially through enhanced process anticipation.

In a move towards improved seaport and supply-chain performance, while hopefully positively contributing to the academic risk management field, this paper has described a knowledge-based decision support system project showing two potentially interesting characteristics: one comes from the opportunity given to seaport / transportation networks’ operators and academic researchers to closely collaborate on a mutual advantage basis; the other lies in the opening of further research perspectives, especially in the fields of supply-chain management (performance measurement, physical flow optimization, and so forth) and information management (systems’ interoperability, pattern recognition, and so forth).

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Jaouad Boukachour is an Associate Professor at the Department of Computer Sciences, University Institute of Technology, University of Le Havre, France. He received his PhD in computer science from the University of Rouen, France and Accreditation to Supervise Research from the University of Le Havre, France. His primary research interests are in Scheduling problems, Hard optimisation, Supply chain and Logistics Information System. Jaouad Boukachour has more than 30 referred research papers. He has supervised a number of PhD researchers in areas such as logistics and scheduling aircraft landings. Currently, he is supervising six PhD students working on traceability, modeling road traffic and vehicle routing and presently acts as scientific director of various research projects.
Charles H. Fredouet, MBA, Ph.D., is a professor of supply-chain management at Le Havre University (LHU)’s School of Logistics. After 20 years of research in the field of information and decision-support systems, Prof. Fredouet turned to global logistics management (transportation network and logistics process modelling and simulation, local and global performance modeling and measurement); he has more than 50 publications in business administration and management reviews and conferences. A former vice-president of Le Havre University, Prof. Fredouet heads LHU’s School of Logistics research center; he is a member of the Supply Chain Council and reviewing for TRB’s International Trade and Transportation Committee. He presently acts as scientific director of various research projects accounting for more than USD 650,000 of public / private grants.

Gningue Mame Bigué is a PhD student at CERENE (Centre d’Etude et de Recherche en Economie et gestion logistique) located in Le Havre University, France. Her research interests include Supply Chain Management and Risk Management. Her PhD thesis is entitled “Security risk management in global supply chain”.
The 2008 Survey of Indian Third-Party Logistics (3PL) Service Providers: Comparisons with the 2004 Survey of Indian 3PLs and 2006 Survey of North American 3PLs

Subrata Mitra, Indian Institute of Management Calcutta, India

ABSTRACT

This paper presents a survey of Indian third-party logistics (3PL) providers and compares the state of the industry with that in 2004 based on an earlier survey. The 3PL industries of India and North America are also compared. The survey finds that the Indian 3PL industry lags behind North America in terms of global reach and breadth of service. Indian 3PL providers also underperform in key variables that determine performance levels. Other problems identified by the survey are the lack of awareness among Indian shippers, shortage of management talent, inadequate infrastructure, complex documentations, and multiple tax systems. Despite these limitations, the Indian 3PL industry is growing. Many global players are entering the Indian market through direct investments, acquisitions, and alliances. The Indian government is also improving the infrastructure, reducing paperwork, simplifying taxation systems, and implementing economic policies conducive to growth. This paper provides significant insights for logistics managers, government, and other stakeholders.

Keywords: India, Logistics Outsourcing, North America, Supply Chain Logistics, Third-party Logistics (3PL)

INTRODUCTION AND RESEARCH BACKGROUND

There is growing interest in third-party logistics (3PL) or logistics outsourcing among practicing managers and academicians alike as shippers worldwide are increasingly outsourcing their logistical activities in order to reduce supply chain complexities, curtail costs and overheads, and expand their global reach. By outsourcing logistics, companies are able not only to focus on their core competencies, but also to realize better delivery performance and therefore customer satisfaction. According to the research done by Armstrong & Associates, Inc., global gross 3PL revenues in 2007 were USD 487 billion, out of which the U.S. accounted for USD 122 billion or about 25% of the global market (Quinn, 2008).
Although due to the global recession and hike in fuel prices, the 3PL sector, like any other sector, has been affected, there are opportunities as well for 3PL companies since shippers are outsourcing transportation, warehousing and other logistical activities like never before in order to reduce costs and remain competitive (Thoppil, 2008). So far, there was lack of clarity on 3PL and their roles and responsibilities. However, very recently the role of a 3PL has been recognized by the U.S. federal law. The law accords the status of an intermediary such as a carrier or forwarder to a 3PL provider and specifically stipulates that a 3PL provider is not to be considered a manufacturer, distributor or retailer, exempting 3PL companies to a great extent from stringent legislations and regulations applicable to manufacturers, distributors and retailers towards rising concerns over cargo security and consumer safety (O’Connor & Anderson, 2008).

Due to the growing interest in 3PL, there have been many academic and trade publications. While academic publications address theoretical issues and their practical implications, trade publications are mainly concerned with practical issues. Academic publications take various forms such as (i) theoretical and conceptual model development, (ii) empirical surveys, (iii) studies on 3PL relationships and partnerships, (iv) supplier evaluation and selection, (v) role and use of information systems and technologies, and (vi) case studies of 3PL companies. Most of the academic research is based on empirical surveys. Langley et al. (2007, 2008) conduct longitudinal surveys of 3PL users wherein they observe persisting gaps between expectations of users and achievements of service providers in terms of value-added service offerings, green supply chain initiatives, deployment of IT and security concerns. While shippers mostly outsource relatively commoditized services such as transportation and warehousing, they still maintain skepticism in outsourcing customer-focused and more strategically-oriented services that may directly affect revenue streams, and hence prefer to keep these services in-house. With regard to green supply chain initiatives, shippers would be willing to share the additional costs, if any, equitably with service providers. However, in practice, it is observed that in many cases shippers pass on the entire cost burden to service providers (Blanchard, 2008). Service providers are also not able to meet the expectations of shippers in terms of deployment of IT and security measures after security requirements have been made more stringent for international shipments.

Surveys from the perspectives of 3PL users are available in abundance in literature. However, 3PL provider surveys are comparatively less in number. Lieb and Butner (2007) and Lieb (2008a) conduct longitudinal surveys of large North American 3PL providers that capture the dynamics of the North American 3PL industry as pricing pressure and low margins, globalization of operations, expectation of increased breadth of service offerings, large-scale consolidations, recruitment and retention of employees, and branding of services. The industry is very much competitive and the margin is low since, as mentioned before, shippers prefer to outsource relatively commoditized services and keep customer-centric, more value-added services in-house. In order to overcome this problem, service providers need to differentiate and customize service offerings (Anonymous, 2008; Hannon, 2008), and provide one-stop solutions to shippers by offering a wide array of value-added services and global reach. This necessitates large-scale acquisitions and alliances such as the takeover of TNT Logistics and Eagle Global Logistics by Apollo Management and rechristening the merged entity CEVA logistics, one of the top 5 global logistics providers by gross revenue (Quinn, 2008). However, each and every 3PL provider may not be up for mergers and acquisitions. For them, partnering with other 3PL providers and acting as a fourth-party logistics (4PL) provider or Lead Logistics Provider (LLP) make more sense in terms of providing a single point of contact to shippers and offering one-stop solutions to all their logistical requirements (Trunick, 2008). Recruiting and retaining skilled
logistics professionals remain a contentious issue. For example, C.H. Robinson hires people who are customer-focused and proactive. The Senior Management spends a lot of time with the new recruits and existing employees as well. The employees go through continuous training and are empowered to take decisions on behalf of the Management (Anonymous, 2008). 3PL companies need to put in a lot of efforts in branding exercises, and differentiate in terms of their products/services and projecting themselves environment-friendly. The important differentiators identified by Lieb and Lieb (2008) are company’s IT capability, geographic coverage, breadth of services and non-asset approach. Many top global 3PL companies such as Exel Logistics (taken over by DHL in 2005), Keystone Dedicated Logistics, Logistics Management Solutions and Transplace are asset-free (Anonymous, 2008; Penton Media, 2008). A study of Hong Kong 3PL providers also found that a combined strategy of cost and differentiation performed best with respect to financial performance, followed by a pure differentiation strategy, which in turn outperformed a pure cost-based strategy (Yeung et al., 2006).

Recently a lot of attention has been attracted by 3PL activities in the Asia-Pacific region, so much so that Langley et al. (2008) and Lieb (2008b) have been including this region in their longitudinal surveys since the last few years. While both acknowledge entry of foreign players and high growth potential of 3PL markets in this region, inadequate infrastructure and inconducive regulatory structures are identified as major impediments. In addition, Lieb (2008b) finds similarities in industry dynamics with global 3PL markets such as pricing pressure, demanding customers, pressure to internationalize operations and shortage of management talent. Within the Asia-Pacific region, India seems to have the highest growth rate as 10 major global players operating in this region have projected the maximum growth of their revenues from India while revenues from other countries in this region have been projected to grow marginally or even decline. The problems identified in Indian 3PL are the lack of modern transportation infrastructure, long turnaround times, high transportation costs, congestion, toll and other local taxes. The only survey (Mitra, 2006) of Indian 3PL providers concurs with the findings of Lieb (2008b). It also identifies the fragmented nature of the market and the lack of awareness among Indian shippers as some of the major roadblocks. However, the survey also projects a growth rate of over 20% of the Indian 3PL industry, which was estimated to be USD 1 billion in 2004, as the Indian GDP is growing at a steady rate and the market is going to mature through consolidations once foreign 3PL players set up shops in India by acquiring or partnering with existing 3PL providers.

For detailed surveys of the 3PL literature, readers may refer to Maloni and Carter (2006), Selviaridis and Spring (2007), and Marasco (2008).

The current paper is the second survey of Indian 3PL providers. It puts the Indian 3PL industry in the perspectives of the 2004 survey (Mitra, 2006). It also brings out similarities and dissimilarities between the Indian 3PL market and the mature and largest 3PL market, i.e., North America based on an earlier survey (Mitra & Bagchi, 2008). In many conceptual and survey papers (Ashenbaum et al., 2005; Maloni & Carter, 2006; Mentzer & Kahn, 1995), rigour of research on 3PL has been emphasized. It is highlighted that more efforts should be put in to build theory, constructs and conceptual frameworks, which may be the foundation for subsequent empirical studies (Marasco, 2008). In an effort to this effect, a survey of North American 3PL providers (Mitra & Bagchi, 2008) was done in 2006 to explore underlying relationships among several important variables such as key success factors and performance metrics through interdependence techniques and dependency relationships. Part of the questionnaire for the 2006 survey was utilized in the current survey of Indian 3PL providers to compare between the Indian and North American 3PL industries, and generate learnings for Indian 3PL companies, shippers and the government. Literature shows that there have been comparisons among countries...
in terms of 3PL usage. However, as far as 3PL providers are concerned, there has been only one paper (Wang et al., 2008) so far that compares 3PL providers of Hong Kong with those of Mainland China. The study mentions the comparison between the 3PL industries of Mainland China and the U.S., a mature 3PL market, as a possible direction for future research. In this perspective, the current survey of Indian 3PL has two major contributions: (a) comparing between the states of the Indian 3PL industry in 2004 and 2008, and (b) comparing between the 3PL industries of India and North America with respect to some key industry variables. The research methodology has been drawn from an earlier survey of North American 3PL providers (Mitra & Bagchi, 2008). It is expected that the results of the survey would provide valuable managerial insights to Indian 3PL firms, foreign 3PL firms contemplating entry into the Indian market and the government.

The rest of the paper is organized as follows. Research objectives and methodology are presented in the next section, followed by the analysis of survey results and discussion on survey results. Then managerial implications are presented, and the paper is concluded with directions for future research.

**RESEARCH OBJECTIVES AND METHODOLOGY**

The primary objectives of this research were, as mentioned before, to

- a. Assess the changes in the Indian 3PL industry since the earlier survey in 2004 (Mitra, 2006), henceforth referred to as the 2004 survey, and
- b. Compare between the 3PL industries in India and North America, based on Mitra and Bagchi (2008), henceforth referred to as the 2006 survey, to generate valuable insights for industry personnel and the government.

In order to achieve the above-mentioned objectives, a survey of Indian 3PL providers was conducted to capture the following:

- a. Demographic information about the respondents
- b. Respondents’ perceptions of importance of various key success factors and their companies’ achievements with respect to these factors to identify gaps, if any
- c. Respondents’ perceptions of their companies’ achievements with respect to various performance metrics and dependency relationships with the key success factors
- d. Respondents’ perceptions of the industry size, growth rates, problems and prospects
- e. Respondents’ growth strategies

In particular, the following research questions were addressed.

- a. Do 3PL firms of various types have different perceptions of importance of the key success factors? If so, how are the rankings of the key success factors different across various types of 3PL firms and what are the implications for logistics managers?
- b. Are there significant gaps in perceptions between the expectations and achievements with respect to the key success factors for various types of 3PL firms? If so, what are the learnings for logistics managers?
- c. What are the significant relationships between the performance metrics and the key success factors? In other words, which key success factors are determinants of which performance metrics and what are the implications for practicing managers?

To address the first research question, it was required to carry out a cluster analysis of the responses of 3PL firms based on their perceptions of importance of the key success factors. Different clusters would then give different rankings of the key success factors.
based on their perceived importance. The second research question would be addressed by performing z-tests (or t-tests, depending on the sample size of the cluster) on the differences of perceptions of 3PL firms of the actual firm performance and the desired firm performance for each key success factor. Finally, to address the third research question, an ordered logit model would be run and a canonical correlation analysis would be carried out to identify significant relationships among the performance metrics (criterion variables) and the key success factors (predictor variables).

Data for the survey and subsequent analysis were collected from two sources: primary and secondary. Primary sources were the respondents and data collection was through a mail survey. Secondary sources were articles published in academic and trade journals. Variables for the questionnaire were obtained from secondary sources such as the extant 3PL literature. The questionnaire was limited to two pages in order to ensure a reasonable response rate, a copy of which is reproduced in the Appendix for reference. For perception-related questions, a 5-point Likert scale was used where “1” represented “very low” and “5” represented “very high”. The questionnaire was administered to some selected 3PL providers in a pilot study to assess its practicality and relevance. A few modifications were made before the final version of the questionnaire was accepted.

The Indian 3PL industry is in its early stage of development and there is little official information available in the public domain. The author had to contact industry sources, and refer to business dailies and the Internet to identify potential 3PL respondents. About 200 3PL providers were identified in the process each of whom was sent a questionnaire along with a covering letter, addressed to the CEO, and a self-addressed envelope. Every two-three weeks thereafter, e-mail reminders were sent and prospective respondents were also contacted over phone. The survey was done in the first half of 2008 and after all the efforts, 42 filled-in, and usable, questionnaires were received registering about 20% response rate. A check for nonresponse bias in survey data was made by the method suggested by Armstrong and Overton (1977) and no nonresponse bias was found. The survey data were collated in Microsoft Excel, and analyzed using the statistical package “Stata”. Details of the analysis are presented in the next section. Finally, about 15 respondents were contacted over phone and e-mail to validate some of the survey results.

ANALYSIS OF SURVEY RESULTS

The survey data are presented in the following sequence: profile of the respondents, respondents’ perceptions of problems, prospects, industry size and growth rates, respondents’ growth strategies, and respondents’ perceptions of the key success factors and performance metrics.

Location and Coverage

71.43% responses were received from Mumbai, National Capital Region (NCR) and Chennai with Mumbai topping the list with 33.33% responses. 50% of the respondents have geographic coverage limited to India only while 50% cover India and abroad. Within India, South, West and North are covered by 78.57%, 78.57% and 76.19% respondents, respectively, while East, Central India and North-East are covered by only 52.38%, 45.24% and 23.81% respondents, respectively. Among the respondents having geographic coverage abroad, 80% cover the Asia-Pacific region, 70% cover Europe, 65% cover North America and Middle East, 50% cover Latin America and 45% cover Africa.

Age and Employee Base

More than half the respondents started their 3PL operations in 2000 or later, which shows the young age of the Indian 3PL industry. While 66.67% respondents have 300 or fewer
employees, 25.64% respondents have 1000 or more employees, showing the fragmented nature of the industry.

**Financials**

As far as financials are concerned, 33 firms disclosed revenue figures. The gross 3PL revenues of these 33 firms in 2006-07 were Rs. 4836 crore (~ USD 1 billion). Out of these, 8 firms (24.24%) grossed Rs. 4438.23 crore, i.e. 91.78% of the total turnover of these 33 firms in 2006-07, which again indicates the fragmented nature of the Indian 3PL industry. As far as growth figures are concerned, the combined revenue of respondent firms grew 27.38% in 2006-07 over last year and is projected to grow by 24.59% in 2007-08 over 2006-07. The Compounded Annual Growth Rates (CAGR) of individual firms had a wide range with small and medium firms growing at faster rates than large firms.

Between the 2004 and 2008 surveys, there were 18 common respondents, out of whom CAGRs (1999-2000 through 2003-04 from the 2004 survey and 2004-05 through 2006-07 from the 2008 survey) for 12 respondents could be computed, which showed no significant difference in growth rates by a paired-sample t-test at 5% level of significance.

No significant correlation was found between firms’ revenues in 2006-07 and globalization.

**Ownership of Assets**

Among the respondents, 17.07% own assets (vehicles, warehouses, material handling equipment etc.), 31.71% outsource to third parties and the rest 51.22% both own and outsource assets. As far as managed warehouse space is concerned, 31 respondents provided data. It has been observed that 61.29% of them manage warehouse space less than 50,000 sq. ft. and at the same time 25.81% of them have warehouse capacities more than 800,000 sq. ft. again indicating the wide division between small and large firms.

**Services Offered and Industries Served**

Among the services offered, warehousing tops the list with 83.33% respondents offering this service, closely followed by transportation (80.95%), freight forwarding (78.57%) and customs clearance (73.81%). These 4 services also happen to be the top revenue earners for the respondent firms. Table A1 in the Appendix indicates the major services and the % of respondents offering them. Considering services, except transportation and warehousing, as value-added services, it was observed that respondents offered, on an average, 7.71 value-added services No significant correlations were found between the number of value-added services and firms’ revenues in 2006-07, and also between the number of value-added services and firms’ globalization.

Among the top three industries/sectors served by the respondent firms, Engineering/Industrial is at the top with 47.62% respondents mentioning it as one of the major revenue earners, followed by Automotive (35.71%), Computer/Electronics (23.81%), Textile/Apparel (21.43%) and Chemical/Fertilizer (21.43%). Table A2 in the Appendix lists the industries/sectors and the % of respondents mentioning them as top revenue earners. It may be observed from the table that the contribution of Retail is insignificant since currently only 5% of the Retail sector is organized. Globally, 70% of the logistics cost is accounted for by Retailing. As the organized Retail sector in India grows and the government allows Foreign Direct Investment (FDI) in Retail, it is expected that the contribution of Retail to 3PL revenues would increase.

**Problems and Prospects**

Respondents indicated government control, bureaucracy and lengthy documentation procedures as the major impediment to the growth of 3PL in India with 78.57% of them marking it as either “important” or “very important”. Other “important” or “very important” factors
highlighted by the respondents as threats to the Indian 3PL industry are poor transportation and communications infrastructure (76.19%), high costs of operations and low margins (73.81%), lack of skilled manpower (73.81%), and lack of trust and awareness among Indian shippers (61.91%).

Among the factors that are deemed to fuel the growth of 3PL in India, 92.86% respondents marked government investments and public-private partnerships (PPP) in development of infrastructure (highways, Special Economic Zones, logistics hubs etc.) as either “important” or “very important”. Other factors that are perceived to be “important” or “very important” by the respondents are increasing awareness towards 3PL (83.33%), increasing government support and conducive policies (80.95%), globalization and more Foreign Direct Investment (FDI) in the Indian 3PL industry (76.19%), and consistent GDP growth resulting in more demand for 3PL services (73.81%).

Estimates of Industry Size and Growth Rate

With regard to the size of the industry, respondents provided varying estimates, like in the 2004 survey, from tens of crores to several thousand crores of rupees. However, considering the industry size of Rs. 5000 crore (slightly more than USD 1 billion) estimated in the 2004 survey and 20% annual growth rate, the current estimated industry size would be about Rs. 10,000 crore (slightly more than USD 2 billion). The average industry growth rate estimated by the respondents is 17.52% which is likely to be exceeded by 63.63% respondents. The estimated cumulative growth rate (24.59%) of respondent firms in 2007-08 also exceeds the estimated average industry growth rate. A z-test at 5% level of significance validated the hypothesis that the Indian 3PL industry would grow by at least 18% per annum in coming years.

Growth Strategy

Among the growth strategies, “Alliances” was mentioned by majority (73.81%) of the respondents, followed by “Direct Investments” (64.29%) and “Acquisitions” (45.24%). Merely 16.67% respondents mentioned “Mergers” as one of their growth strategies.

Key Success Factors

Respondents were asked to rate 10 key success factors based on their perceived importance levels and firms’ achievements. Considering respondents and factors as independent variables and factor importance ratings as the dependent variable, a two-way ANOVA without replication showed significant differences among both respondents and factors at 5% level of significance, indicating differences in perceptions of the importance of key success factors among the respondents. Subsequently, the k-means nonhierarchical cluster analysis method was applied to the data with many possible numbers of clusters and starting seeds in order to form groups of similar respondents. In each trial for each cluster, treating respondents and factors as independent variables and factor ratings as the dependent variable, a two-way ANOVA without replication was performed to check if there were significant differences among respondents and factors at 5% level of significance. After several trials, it was possible to come out with 4 stable clusters where there were significant differences between clusters but no significant differences among respondents within clusters. Unfortunately, cluster compositions did not throw any light on grouping dimensions. Cluster 1 consisted of 31 respondents whose responses seemed to be very much “realistic” in the sense that these were not biased in either direction on the rating scale. Cluster 2 had 3 members, who were “very optimistic” in their responses, marking almost all factors “very high”. The 7 respondents of Cluster 3 were “conservative” in their responses, marking around “average”. Finally, Cluster 4 had only 1 member, who was “extremely pessimistic” in his response and marked most of the factors “very low” (This may be due to confusion at the time of marking responses, which could not be verified). However, for the purpose of ascertaining the
importance of key success factors, only Cluster 1 responses were taken into consideration. It was observed that breadth of services and customer focus were given the most importance, 96.77% respondents having marked them as either “high” or “very high”, followed by availability of skilled manpower (93.55%), investment in information systems (90.32%) and integration of supply chains (90.32%). Table A3 in the Appendix shows the key success factors and the % of Cluster 1 respondents marking them “high” or “very high” in terms of importance ratings.

Next, for each respondent and each factor, the difference between the company rating and importance rating is computed to check if this difference is significant. Surprisingly, the average differences for all factors turned out to be negative, and excepting customer focus and 3PL experience, the differences for all other factors turned out to be significantly negative (at 5% level of significance) indicating gaps between firms’ achievements and expectations with respect to these factors.

### Performance Metrics

Respondents were asked to rate 10 metrics based on their firms’ performance. The objective was to establish dependency relationships among the performance metrics and key success factors as dependent and independent variables, respectively. Since ratings for both the performance metrics and key success factors were on an ordinal scale, the ordered logit (or ologit) model was applied for every dependent variable and the set of 10 independent variables. The same exercise was carried out for the entire set of respondents (41 in number) and Cluster 1 respondents (30 in number since one member did not mark his responses for the performance metrics) to check if there were any differences between the outcomes of the aggregate set and the subset (Cluster 1) of respondents, who were “realistic” in their ratings of the key success factors. Table 1 shows the statistically significant (at 5% level of significance) independent variables for an overall model fit, types of relationships and p-values against each performance metric for the aggregate set and the subset (Cluster 1).

It may be observed from Table 1 that there are quite a few differences between the outcomes of the aggregate set and the subset (Cluster 1). Breadth of services appears as a significant, positively related independent variable for year-on-year growth in revenues, year-on-year growth in cargo and on-time delivery performance for the aggregate set while it is conspicuously absent in any of the performance metrics for the subset. Internationalization of operations bears a significant, positive relationship with reducing inventory levels and a significant, negative relationship with on-time delivery performance for the aggregate set while it is also absent in any of the relationships for the subset. The positive relationship between internationalization of operations and reducing inventory levels is the same as was observed in the 2006 survey, possibly indicating the transfer of ownership of inventory and existence of inventory more in the form of sea freight than in the form of land transportation and storage. Another reason may be that as firms become more and more globalized, there is a shift towards providing more value-added services than transportation and warehousing, though it may not be true for Indian service providers since no significant correlation was found between the number of value-added services offered and global reach of sample respondents. The negative relationship between internationalization of operations and on-time delivery performance may be attributed to the increased shipping lead time and the lack of global reach of Indian service providers. Customer focus has strong positive relationships with on-time delivery performance for the aggregate set and customer satisfaction for both the aggregate set and the subset. This is quite intuitive and needs little explanation.

Focus on industries, on the other hand, bears strong negative relationships with year-on-year growth in cargo, return on investments (ROI) and geographic reach for the aggregate set while it does not appear in any of the relationships
Table 1. Significant dependency relationships among the performance metrics and the key success factors

<table>
<thead>
<tr>
<th>Performance metrics</th>
<th>All clusters (41 responses) Aggregate set</th>
<th>Cluster 1 (30 responses) Subset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Independent variable</td>
<td>Type of relationship</td>
</tr>
<tr>
<td>Revenue growth</td>
<td>Breadth of services</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Investment in asset</td>
<td>-</td>
</tr>
<tr>
<td>Profit growth</td>
<td>Integration of supply chains</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Integration of supply chains</td>
<td>+</td>
</tr>
<tr>
<td>Cargo growth</td>
<td>Focus on industries</td>
<td>-</td>
</tr>
<tr>
<td>ROI</td>
<td>Focus on industries</td>
<td>-</td>
</tr>
<tr>
<td>ROA</td>
<td>3PL experience</td>
<td>+</td>
</tr>
<tr>
<td>Reducing inventory</td>
<td>Internationalization</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Skilled manpower</td>
<td>+</td>
</tr>
<tr>
<td>On-time delivery</td>
<td>Breadth of services</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Internationalization</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Focus on customers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Investment in information system</td>
<td>-</td>
</tr>
<tr>
<td>Customer satisfaction</td>
<td>Focus on customers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Investment in information system</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Integration of supply chains</td>
<td>+</td>
</tr>
<tr>
<td>Customer acquisition</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Geographic reach</td>
<td>Focus on industries</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Investment in information system</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Skilled manpower</td>
<td>+</td>
</tr>
</tbody>
</table>

for the subset. The reason may be that unlike in developed countries in North America and Europe, the industrial output in India is lower, and the 3PL market is ill-developed due to the lack of awareness among Indian shippers and various other reasons. Therefore, focusing on specific industries would not ensure higher returns, growth and geographic reach in the Indian market, at least in the initial period of growth of 3PL. Once the market is adequately...
developed and industries generate substantial volumes of business, then probably limiting one’s offerings to some select industries may also lead to growth and expansion of business.

Like in the 2006 survey, 3PL relationship does not appear in either the aggregate set or the subset. It may be inferred that 3PL relationship is a necessary but not sufficient criterion for success of a 3PL firm. 3PL experience, on the other hand, has a strong positive relationship with return on assets (ROA) for the aggregate set, but strong negative relationships with year-on-year growth in revenues and year-on-year growth in profits for the subset. With experience, asset utilization possibly improves and hence the first outcome. The second one relates to the finding of the 2006 survey and is explained in the following way. In the initial years of a firm’s existence, the absolute revenues and profits are low; however, growth rates may be very high if the firm succeeds in a high-growth market. As the firm ages, its percentage growth may taper off, even decline, though the absolute revenues and profits may be substantial. This is caused due to the saturation effect, and is not specific to the 3PL industry.

Investment in assets has a strong negative relationship with year-on-year growth in revenues. In the 2006 survey also, investment in assets bore a negative relationship with geographic reach. This may be due to the fact that there may be many asset-free firms, which register high growth rates. Alternatively, if a firm invests heavily into assets, it may have very little funds available for expansion and growth of business. Therefore, as far as possible, a firm needs to maintain a minimum level of quality assets and outsource the rest, especially when assets are available in abundance at competitive rates in fragmented markets such as India.

Investment in information systems, surprisingly, has strong negative relationships with on-time delivery performance and customer satisfaction, and a strong positive relationship with geographic reach for the aggregate set. On the other hand, investment in information systems bears strong positive relationships with customer acquisition and geographic reach for the subset. Negative relationships between investment in information systems and some of the performance metrics are counter-intuitive since in today’s world, availability and utilization of information have become absolutely essential for success in every sphere, more so in the context of information-intensive 3PL services. However, a glance at the data provided by the respondents points to the fact that Indian firms are short of investments in information systems, and this is also validated by the significant negative gap between firms’ achievements and expectations of information-readiness.

Availability of skilled logistics professionals bears strong positive relationships with geographic reach for the aggregate set, and reducing inventory for both the aggregate set and the subset. As already noted, Indian firms have under-investment in information systems and hence the over-reliance on skilled manpower for expansion and inventory management, especially because this kind of services becomes exceptionally labour-intensive in the absence of a proper information system. Integration of supply chains has strong positive relationships with many a performance metric for either set, year-on-year growth in profits and customer satisfaction for the aggregate set, and year-on-year growth in revenues/profits/cargo and ROA for the subset. As in the 2006 survey, integration of supply chains proves to be a very important predictor variable.

In the ordered logit model, the relationship is one-to-many, i.e., one dependent variable is taken at a time and its relationship with one or more independent variables is established. We also performed canonical correlation analysis, which considers all dependent and independent variables simultaneously and establishes an overall dependency relationship. Using various combinations of pairs of linear composites from the criterion (dependent) and predictor (independent) variables, a pair was found to be maximally correlated at 5% level of significance.
for each of the aggregate set and the subset. Table 2 shows the canonical correlation coefficient, F-statistic, p-value and significant dependent and independent variables for each set.

All canonical loadings and cross-loadings were found to be significantly positive, indicating positive relationships among the dependent and independent variables. It may be observed from Table 2 that breadth of services, investment in information systems, skilled manpower and integration of supply chains prove to be the most important key success factors for 3PL firms. However, as already noticed, with respect to each of these factors, there have been significant negative gaps between respondent firms’ performance and expectations, which gives an indication to Indian 3PL firms to take appropriate steps and bridge these gaps on an urgent basis.

**DISCUSSION ON SURVEY RESULTS**

This section first presents comparisons between the current state of the Indian 3PL industry and its status in 2004. Next, it compares between the Indian and North American 3PL industries.

**Comparison with the 2004 Survey**

As far as the location of headquarters is concerned, NCR, Mumbai and Chennai remain at the top of the list since most of the business is generated in North, West and South, with East, Central India and North-East still lagging behind in terms of volumes. Global reach of Indian service providers has definitely expanded with increasing coverage in almost all parts of the world. The Indian 3PL industry still remains very young and fragmented in terms of distributions of both employee base and revenues generated. The industry growth rate also remains in the range of 18-20%. With respect to ownership of assets, services offered and industries served, there has not been any significant change. The only noticeable thing is that freight forwarding and customs clearance activities have increased a bit, maybe due to the expanding global reach of Indian service providers as noted above.

With regard to the problems facing the Indian 3PL industry, the top two concerns remain as the inadequate transportation/storage/communications/bureaucratic infrastructure and the lack of awareness among Indian ship-

**Table 2. Significant dependent and independent variables in canonical correlation analysis**

<table>
<thead>
<tr>
<th></th>
<th>All clusters (41 responses)</th>
<th>Cluster 1 (30 responses)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate set</strong></td>
<td></td>
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<tr>
<td>Canonical correlation coefficient</td>
<td>0.67</td>
<td>0.85</td>
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<tr>
<td>F-statistic*</td>
<td>1.76</td>
<td>2.36</td>
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<tr>
<td>p-value*</td>
<td>0.0349</td>
<td>0.0052</td>
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<td><strong>Subset</strong></td>
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<tr>
<td>Dependent (criterion) variables</td>
<td>Revenue growth</td>
<td>Revenue growth</td>
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<td></td>
<td>Profit growth</td>
<td>Profit growth</td>
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<td></td>
<td>Reducing inventory</td>
<td>Cargo growth</td>
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<td></td>
<td>Customer satisfaction</td>
<td>ROA</td>
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<td></td>
<td>Geographic reach</td>
<td>Reducing inventory</td>
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<tr>
<td>Independent (predictor) variables</td>
<td>Breadth of services</td>
<td>Customer acquisition</td>
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<tr>
<td></td>
<td>Investment in information system</td>
<td>Geographic reach</td>
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<tr>
<td></td>
<td>Skilled manpower</td>
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<tr>
<td></td>
<td>Integration of supply chains</td>
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</tbody>
</table>

* F-statistics and p-values correspond to Wilks’ lambda. Other tests, namely Pillai’s trace, Lawly-Hotelling trace and Roy’s largest root, were also found significant.
pers. The encouraging factors for the industry are development of infrastructure, increasing awareness towards 3PL, globalization and FDI in 3PL, and consistent growth of GDP and hence more demand for 3PL services, as was also observed in the 2004 survey. Regarding the estimates of industry size, and industry and company growth rates, the responses are also very similar to those of the 2004 survey.

Therefore, based on the outcome of the survey, it can be concluded that there has not been much change in the profile of respondents, except increasing revenues and expanding global reach and related activities.

Comparison with the 2006 Survey

North American 3PL firms are definitely bigger in size and more globalized compared to their Indian counterparts. There is a significantly high correlation between revenues earned and the extent of globalization for North American firms indicating that as a firm grows in size, it becomes more globalized. However, no such correlation was found for Indian firms since many relatively bigger firms had their operations limited to India only. The average number of value-added services offered by North American firms is also higher than that offered by Indian firms. There are high correlations between revenues earned and the number of value-added services offered and also between the extent of globalization and the number of value-added services offered by North American firms, indicating that as a firm grows in size and becomes more globalized, the bouquet of value-added services offered by it also expands. Such correlations are absent in the sample of Indian firms probably because of the limited number of value-added services offered by them. The percentage of asset-free Indian firms is more than that of North American firms probably because of the fragmented Indian transport market and abundance of assets available at competitive rates.

With respect to the key success factors, there is a clear difference in responses of different sizes of North American firms, indicating differences in perceptions. However, no such difference in responses, based on size or any other dimension, was observed in the case of Indian firms. As far as the commonality of responses is concerned, both North American and Indian firms accorded high importance to customer focus, investment in information systems and availability of skilled manpower, and both assigned medium to low importance to internationalization of operations, focus on industries, 3PL relationship, 3PL experience and investment in assets. On the other hand, while North American firms considered breadth of services and integration of supply chains as having medium and medium to low importance levels, respectively, their Indian counterparts perceived these factors as very highly and highly important for success, respectively. This may be due to the reason that North American firms have more breadth of services and integration of supply chains than Indian firms, and hence perceive customer focus, investment in information systems and availability of skilled manpower as more important than breadth and integration. For North American firms, there are significant gaps in expectations and achievements with respect to internationalization, availability of manpower and integration of supply chains while Indian firms seem to underperform with respect to all but customer focus and experience.

In the overall dependency relationships among the performance metrics and key success factors, breadth of services, investment in information systems, availability of skilled manpower and integration of supply chains prove to be very significant predictor variables for both North American and Indian firms. On the other hand, internationalization of operations, customer focus and industry focus are significant for North American firms, but not so for Indian firms because, as mentioned before, Indian firms are less globalized, and due to the nascent state of the industry and inadequate volumes, focusing on customers and specific industry verticals would not ensure enough revenues, profits and growth at least in the initial period. 3PL relationship, 3PL experi-
ence and investment in assets do not appear in the dependency relationships for either North American or Indian firms. While 3PL relationship and experience deem to be necessary but not sufficient conditions for success, investment in assets can be minimized subject to availability of the same in the market at competitive rates.

With respect to growth strategies, responses of North American and Indian firms are similar. While alliances and direct investments are the preferred choices of expansion, other less traveled routes for growth are acquisitions and mergers.

**MANAGERIAL IMPLICATIONS**

The survey provides useful insights for logistics managers and the government. Although the Indian 3PL industry is in its early stage of development, it has high growth potential. The annual logistics cost in India is estimated to be 13% of GDP (Mitra, 2006), and based on the World Bank estimate of India’s GDP in 2008, i.e. USD 1232.7 billion (http://www.worldbank.org), the annual logistic cost would be around USD 160 billion. India’s logistics costs are high compared to those of developed countries such as the U.S. and Germany where annual logistics costs are less than 10% of their respective GDPs. Therefore, there are opportunities for the Indian logistics sector to reduce costs and make the prices of its products more competitive in domestic and international markets. Also, considering the estimated Indian 3PL industry size to be USD 2 billion, the size of the industry is about 1.25% of the annual logistics cost, indicating high potential for the industry that is already growing at a healthy rate of 18-20% per annum.

Many global 3PL providers, who came to India primarily to satisfy the needs of their overseas customers, are now heavily investing in physical assets, getting licenses and also extending their network. DHL’s acquisition of Blue Dart, FedEx’s acquisition of Prakash Airfreight Pvt. Ltd., TNT’s acquisition of Speedage Express and tie-up with Elbee Services, and UTi Worldwide’s acquisition of Indair Carriers are testimonies to this trend. Even Private Equity (PE) players are showing a lot of interest in Indian logistics firms (Lieb, 2008b). Indian shippers are also becoming more and more aware of the benefits of logistics outsourcing. In the 2004 survey, it was observed that shippers put a lot of emphasis on selection of 3PL providers, who were asset-based. However, this trend has changed and shippers are accepting 3PL firms without asking questions on ownership of assets and subcontracting systems, opined one of the respondents. In fact, as mentioned before, there are many top global 3PL providers, who are asset-free. From a 3PL point of view, it is best to share assets of dedicated asset owners, who are big and state-of-the-art, on a pay-per-use basis, opined the same respondent. The survey indicates that the global reach of Indian 3PL firms has increased with corresponding increases in related activities. However, according to one freight forwarder respondent, it is not necessary to go global to provide global services. Any freight forwarder today may join a freight forwarding association by which it is connected to the globe. The same has also been echoed by Schoenfeld (2008).

Two of the most important dynamics of the Indian logistics sector are pricing pressure due to demanding customers and high costs of operations. Due to the global recession, freight rates all over the world have dropped significantly. Shippers are demanding the shortest transit times and most competitive air/sea freight rates. This, coupled with fluctuations in fuel prices and rising costs, is affecting the already low margin of 3PL firms. In order to overcome this problem, thrust should be on cost-efficient transportation, value-added service offerings and differentiation. Substantial fuel costs can be saved through multi-modal transportation by railways and waterways, given the large railway network, inland waterways and vast coastal lines. Multi-modal transportations also add flexibility in loading/unloading, introduce economies of scale, and result in savings to the tune of 4-6% (Thuemer, 2008). In addition to redesigning transportation networks, 3PL firms...
should also strive for offering more value-added services and differentiating vis-à-vis competitors. However, the survey finds that firms lag both in terms of breadth of services and key differentiators identified by Lieb and Lieb (2008). Apart from breadth of services, investment in information systems, availability of management talent and integration of supply chains were identified by the survey as significant predictor variables for performance metrics. However, the survey also finds that there are significant gaps between firms’ expectations and achievements with respect to these variables, which should be seriously looked into by logistics managers in order to decide on allocation of scarce resources. One respondent mentions that Indian logistics companies are going through vertical integration and extending the portfolio of services. As regards information systems, respondents argue that shippers demand latest technologies, but consider these as part of the standard service package and are not willing to compensate for investments made. Availability of skilled manpower is a global problem; however, in India this problem is more acute for domestic players as they are unable to match the offers made by multinationals. The shortage of manpower is going to be mitigated to some extent as the supply of workforce would be augmented due to the recession and manpower would be available at reasonable costs. Integration of supply chains, i.e. selling supply chain solutions to clients’ customers and suppliers, is yet to take off in a big way in India because of its early stage and shippers’ unawareness and unwillingness towards logistics outsourcing. However, respondents have acknowledged high importance levels for integration, which is going to develop with time.

From the shippers’ point of view, there is already growing awareness towards the benefits of logistics outsourcing. Shippers have to place more trust on and confidence in service providers, involve 3PLs in the planning process (Hannon, 2008; Thuermer, 2008) and outsource more customer-centric, value-added activities besides the regular activities of transportation and warehousing. Also, shippers should be willing to pay for the value-added services and investments of service providers in information systems and technologies. It is the responsibility of service providers to make their cost structures transparent so that shippers get a fair idea of their margins.

As far as the government is concerned, there is much to be desired in terms of infrastructure, procedures, documentations and taxation systems. Road networks are inadequate leading to long turnaround times for vehicles, draft availability at some of the major ports is constrained restricting the size of ships coming into the harbors, there is port congestion due to the lack of modern warehousing facilities and slow and cumbersome customs procedures, and overall there are bureaucracy, red tapes, lengthy documentation requirements, multiple check posts, numerous taxes such as toll tax, sales tax, octroi etc. and interstate issues that cause substantial delays in shipments. These issues have been raised many times and the government is aware of these. Albeit slow, steps are being taken to mitigate these problems. Constructions of the golden quadrilateral project, East-West, North-South corridors and a dedicated rail freight corridor are some of the initiatives that are expected to ease the load on the existing infrastructure. Allowing private investments in inland containerized transportation three years back would increase the percentage of containerized freight from a meager 47% where globally 80% of the freight is moved in containers. Also, there are plans to invest in public-private partnerships (PPP) in airports, seaports, roads, refrigerated transportation and warehousing facilities, hubs and Special Economic Zones (SEZ). The import policy has become liberal and customs clearance has been made easier. Electronic Data Interchange (EDI) is being implemented in many areas to make paperwork simpler and faster. Implementation of a uniform Value-Added Tax (VAT) structure is expected to address the multiple taxation system, check post delays and interstate issues. However, the entire process is extremely slow, and the industry is still reeling under cumbersome procedures and complex tax structures. The government
has to seriously look into this and expedite the process of modernization. After all, growth in the logistics sector would lead to growth in GDP and generate employment.

Industry bodies and associations also have a significant role to play in this context. They are the intermediaries between the 3PL industry and government. On behalf of the industry, they can lobby with the government for policies conducive to growth, economic incentives, cheap financing etc. They can increase the awareness of 3PL by periodically organizing workshops/seminars/conferences and bringing shippers, service providers, government representatives and other stakeholders under the same umbrella for interactions and exchanges of thoughts and experiences. According to one respondent, there are not many tailor-made courses in India for imparting technical and managerial skills to logistics professionals. The industry bodies and associations can collaborate with universities and institutions to offer short-term and long-term courses to suit the needs of the industry.

DIRECTIONS FOR FUTURE RESEARCH

The current survey intended to assess the state of the Indian 3PL industry and compare it with that in 2004 based on a previous survey. A comparison of the Indian and North American 3PL industries was also made based on an earlier survey of North American 3PL providers. The survey provides significant insights to logistics managers, and makes recommendations to the government and industry bodies for facilitating growth of 3PL in India. To the best of the author’s knowledge, there has not been any study so far comparing the Indian 3PL industry with that of North America, the most developed 3PL market, for benchmarking. It is expected that the survey would provide valuable inputs to the Indian 3PL industry to assess where it stands and where it has to be.

The survey was done based on 42 responses. Ensuring a better response is difficult in the present situation as the Indian 3PL industry is still in its infancy and the market is fragmented with a handful of serious players (Only 1% of the Indian logistics sector is organized). Future studies may look into the issue of response rate. As pointed out by Marasco (2008), future research should be more devoted to theory building, constructs and conceptual frameworks development. More focus interviews and case studies should be conducted to complement the body of knowledge on 3PL (Maloni & Carter, 2006; Selviaridis & Spring, 2007). Also, there should be single, combined studies on 3PL users and providers to get the perspectives from both sides to assess the expectations of 3PL users and achievements of 3PL providers (Maloni & Carter, 2006). Finally, more comparative studies between Asian countries such as India and China can be the possible topics for future research.

REFERENCES


ENDNOTES

1 National Capital Region refers to the capital of India, New Delhi and its adjoining area

2 Rs. 1 crore = Rs. 10 million and USD 1 ~ Rs. 48-49 (January, 2010)

3 a form of tax levied by the local authority

Subrata Mitra is a Professor of Operations Management at the Indian Institute of Management Calcutta (IIMC), Kolkata, India. Prof. Mitra is a Fellow (Ph.D.) of IIMC. He has over thirteen years of experience in industry and academics. He has research interests in inventory control, logistics and supply chain management, and has published in international journals such as European Journal of Operational Research, Omega, Journal of the Operational Research Society, Asia Pacific Journal of Operational Research and Supply Chain Forum: An International Journal. Prof. Mitra is a past Fulbright Senior Research Fellow, and he serves on the Editorial Review Board of the Journal of Supply Chain Management.
APPENDIX

Table A1. Major services and % of respondents offering them

<table>
<thead>
<tr>
<th>Service</th>
<th>% of resp.</th>
<th>Service</th>
<th>% of resp.</th>
<th>Service</th>
<th>% of resp.</th>
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</thead>
<tbody>
<tr>
<td>Warehousing</td>
<td>83.33</td>
<td>Break Bulk Ops.</td>
<td>45.24</td>
<td>Import/Export Mgt.</td>
<td>35.71</td>
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<tr>
<td>Transportation</td>
<td>80.95</td>
<td>Cargo Insurance</td>
<td>45.24</td>
<td>NVOCC</td>
<td>33.33</td>
</tr>
<tr>
<td>Freight Forwarding</td>
<td>78.57</td>
<td>Packaging/Labeling</td>
<td>42.86</td>
<td>Inventory Mgt.</td>
<td>30.95</td>
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<tr>
<td>Customs Clearance</td>
<td>73.81</td>
<td>Distribution</td>
<td>38.10</td>
<td>Order Processing</td>
<td>28.57</td>
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<tr>
<td>Freight Consolidation</td>
<td>57.14</td>
<td>Reverse Logistics</td>
<td>38.10</td>
<td>Payment Collection</td>
<td>28.57</td>
</tr>
<tr>
<td>Freight Brokerage</td>
<td>47.62</td>
<td>Consulting Services</td>
<td>38.10</td>
<td>Vendor Mgt.</td>
<td>21.43</td>
</tr>
</tbody>
</table>

Table A2. Industries/Sectors and % of respondents mentioning them as top revenue earners

<table>
<thead>
<tr>
<th>Industry</th>
<th>% of resp.</th>
<th>Industry</th>
<th>% of resp.</th>
<th>Industry</th>
<th>% of resp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering/Industrial</td>
<td>47.62</td>
<td>Textile/Apparel</td>
<td>21.43</td>
<td>FMCG</td>
<td>14.29</td>
</tr>
<tr>
<td>Automotive</td>
<td>35.71</td>
<td>Chemical/Fertilizer</td>
<td>21.43</td>
<td>Food/Beverages</td>
<td>14.29</td>
</tr>
<tr>
<td>Computer/Electronics</td>
<td>23.81</td>
<td>Retail</td>
<td>16.67</td>
<td>Pharmaceuticals</td>
<td>11.90</td>
</tr>
</tbody>
</table>

Table A3. Key success factors and % of respondents marking them “high” or “very high”

<table>
<thead>
<tr>
<th>Key success factor</th>
<th>% of resp.</th>
<th>Key success factor</th>
<th>% of resp.</th>
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<tbody>
<tr>
<td>Breadth of Services</td>
<td>96.77</td>
<td>Internationalization</td>
<td>83.87</td>
</tr>
<tr>
<td>Customer Focus</td>
<td>96.77</td>
<td>Investment in Asset</td>
<td>77.42</td>
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<tr>
<td>Skilled Manpower</td>
<td>93.55</td>
<td>3PL Experience</td>
<td>74.19</td>
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<tr>
<td>Investment in Info. Sys.</td>
<td>90.32</td>
<td>3PL Relationships</td>
<td>67.74</td>
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<tr>
<td>Integration of SC</td>
<td>90.32</td>
<td>Industry Focus</td>
<td>58.06</td>
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Table A4. Questionnaire for “A survey of Indian 3PL providers”

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<tr>
<td>1. Name of the company:</td>
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<td>2. Location of HQ:</td>
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<td>3. Geographic coverage (Please √):</td>
<td>Only India □ India and abroad</td>
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<td>4. Year of starting 3PL operations:</td>
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<td>5. Number of employees in India:</td>
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<td>6. Please list below the 3PL revenues and % contributions of the domestic 3PL market for the last 4 years. Year 3PL revenue (Rs. crore) Contribution of the domestic market (%)</td>
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<td>7. Asset base (Please √):</td>
<td>Owned □ Outsourced □ Both 8. Managed warehouse space (sq. ft.):</td>
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<td>8. Managed warehouse space (sq. ft.):</td>
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<td>9. Please √ one or more of the following services offered by your company. Also, please rank the top 3 services. □ Transportation □ Warehousing □ Freight forwarding □ Customs clearance □ Import/export mgmt. □ Fleet management □ Freight brokerage □ Freight consolidation □ Inventory mgmt. □ NVOCC □ Port operations □ Break bulk operations □ Order processing □ Order fulfillment □ Vendor management □ Packaging and labeling □ Distribution □ After sales support □ Payment collection □ Assembly/Installation □ Trade finance □ Cargo insurance □ Reverse logistics □ Consulting services</td>
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<td>10. How much importance will you give to the following factors for success in the 3PL industry? Also, how will you rate your company with respect to these factors? (1: Very low, 2: Low, 3: Average, 4: High, 5: Very high) Factor importance</td>
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<td>11. How will you rate your company with respect to the following performance criteria? (1: Very low, 2: Low, 3: Average, 4: High, 5: Very high) Factor importance</td>
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<td>12. Please note below the top three industries/sectors served by your company.</td>
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<td>13. How much importance will you give to the following factors for low 3PL growth in India so far? (1: Not at all important, 2: Less important, 3: Moderately important, 4: Important, 5: Very important) Factor importance</td>
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<td>14. How much importance will you give to the following factors for opportunities and growth of 3PL in India? (1: Not at all important, 2: Less important, 3: Moderately important, 4: Important, 5: Very important) Factor importance</td>
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<td>15. Please indicate below your estimates for the following: Factor importance</td>
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<td>16. Please √ one or more of the following growth strategies appropriate for your company. □ Direct investments □ Mergers □ Acquisitions □ Alliances</td>
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Name of the respondent: _____________________ Designation: _______________ E-mail: _______________

Signature: _________________________________ Date: _____________________
An Improved Lightweight RFID Authentication Protocol

Xiaowen Zhang, College of Staten Island - CUNY, USA
Zhanyang Zhang, College of Staten Island - CUNY, USA
Xinzhou Wei, New York City College of Technology – CUNY, USA

ABSTRACT

This study extends the vulnerability analysis of a RFID authentication protocol and offers solutions to security weaknesses through enhanced measures. Vajda and Buttyan (VB) proposed a lightweight RFID authentication protocol, called XOR. Defend, Fu, and Juels (DFJ) analyzed it and proposed repeated keys and nibble attacks to the protocol. In this paper, we identify the source of vulnerability within VB’s original successive session key permutation algorithm. We propose three improvements, namely removing bad shuffles, hopping the runs, and authenticating mutually, to prevent DFJ’s attacks, thereby significantly strengthening the security of the protocol without introducing extra resource cost.

Keywords: Authentication Protocol, Radio Frequency Identification (RFID), Random Permutation, RFID Authentication, XOR Protocol

1. INTRODUCTION

As a consequence of the massive deployment of Radio Frequency Identification (RFID) systems in a variety of applications, security and privacy issues are still paramount concerns. Some consumer rights protection organizations, like CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering), are against the use of RFID (CASPIAN, 1999).

In general, a RFID system consists of three kinds of components: RFID tags (or transponders), RFID readers (or interrogators), and backend computer servers. An RFID tag is a tiny microchip embedded with a radio frequency antenna. It is capable of emitting the identification and other information for the tagged item. A reader is another electronic device located between tags and backend server. A reader receives information from or sends information to a tag, which in turn communicates with (updates) the backend server. A backend server runs application software, hosts databases, and processes tag information received from a reader. It communicates with readers through wireless or wired connection on one end and with the enterprise network infrastructure on the other end. The wireless communication links between tags and readers are considered the most vulnerable part in terms of security and privacy threats. As documented in the literatures (Avoine, 2005; Juels, Pappu...
2. ORIGINAL XOR PROTOCOL AND REPEATED KEYS ATTACK

The original XOR protocol by VB (Vajda & Buttyan, 2003) is a challenge-response protocol as shown in Figure 1. Under the following assumptions: (1) the readers and tags initially share a piece of secret key $k^{(0)}$, (2) both reader and tag are capable of calculating a permutation $\Pi$ (given soon), and (3) reader and tag maintain a synchronized counter $i$ to indicate the current run of authentication, the challenge-response process at the $i$th run can be described as follows:

**Reader -> Tag:** $a^{(i)} = x^{(0)\oplus} k^{(0)}$

// Reader picks a random number $x^{(i)}$, calculates $k^{(0)}$, then sends a challenge $a^{(i)} = x^{(0)\oplus} k^{(0)}$ to Tag.

**Tag -> Reader:** $b^{(i)} = x^{(0)\oplus} k^{(0)}$

// Tag calculates $k^{(i)}$, extracts the challenge $x^{(i)}$ by $k^{(0)} a^{(i)}$, then sends a response $b^{(i)} = x^{(0)\oplus} k^{(0)}$ to Reader. Following that, the Reader verifies the Tag, because only the Tag knows $k^{(0)}$.

Here $k^{(0)} = \prod(k^{(i-1)})$, and $\Pi: \{0, 1\}^n \rightarrow \{0, 1\}$ $n$ is a permutation starting from the initial secret key $k^{(0)}$. That is, $k^{(1)} = \Pi(k^{(0)}), k^{(2)} = \Pi(k^{(1)}), \ldots, k^{(i-1)} = \Pi(k^{(i-2)}), k^{(i)} = \Pi(k^{(i-1)}), \ldots$. Because $x^{(i)}$ is random, so are $a^{(i)} = x^{(0)\oplus} k^{(i)}$ and $b^{(i)} = x^{(0)\oplus} k^{(i)}$. If the $x^{(i)}$ is truly random, no information about the secret $k^{(0)}$ is revealed from the communication.

Suppose $n = 128$ bits as key length, the algorithm for the permutation $\Pi$ is as follows:

- Step-1: At the run $(i-1)$th iteration, the session key $k^{(i-1)}$ is split into 16 bytes, then we cut each byte into two nibbles of 4-bit each. Following that, we concatenate all left nibbles $k_{0L}^{(i-1)}, k_{1L}^{(i-1)}, \ldots, k_{15L}^{(i-1)}$ to form $k_L^{(i-1)}$, concatenate all right nibbles $k_{0R}^{(i-1)}, k_{1R}^{(i-1)}, \ldots, k_{15R}^{(i-1)}$ to form $k_R^{(i-1)}$.
- Step-2: At the run $(i)$th iteration, the right half key $k_R^{(i)}$ is a permutation of $k_R^{(i-1)}$ controlled by $k_L^{(i-1)}$: i.e., swapping the $0$-th and the $k_{0L}^{(i-1)}$-th, the $1$-st and the $k_{1L}^{(i-1)}$-th, ..., the $15$-th and the $k_{15L}^{(i-1)}$-th nibbles of $k_R^{(i-1)}$.
- Step-3: The left half key $k_L^{(i)}$ for run $(i)$ is a permutation of $k_L^{(i-1)}$ controlled by $k_R^{(i-1)}$ in the similar nibble swaps.
- Step-4: Finally the next run session key $k^{(i)}$ is obtained from rearranging (interleaving) the half bytes of $k_L^{(i)}$ and $k_L^{(i)}$, i.e.,


**Figure 1.** A simple example (S: Split, P: Permute, M: Mix). It shows how the session keys \( k^{(i-1)} \), \( k^{(i)} \), and \( k^{(i+1)} \) are developed. We underline the numbers that are always on the right halves. This demonstrates that the left half session key always stays on the left, and the right half always stays on the right.

\[
k^{(i)} = k^{(i)}_{0.L} \mid k^{(i)}_{0.R} \mid \ldots \mid k^{(i)}_{15.L} \mid k^{(i)}_{15.R}, \text{ here the symbol “|” represents concatenation.}
\]

**Observations:** The problem in the above process is the step-4 of the permutation. This step adds a perfect shuffle to \( \Pi \). No matter what we do out-shuffle
\[
k^{(i)} = k^{(i)}_{0.L} \mid k^{(i)}_{0.R} \mid \ldots \mid k^{(i)}_{15.L} \mid k^{(i)}_{15.R}, \text{ or in-shuffle}
\]
\[
k^{(i)} = k^{(i)}_{0.R} \mid k^{(i)}_{0.L} \mid \ldots \mid k^{(i)}_{15.R} \mid k^{(i)}_{15.L}, \text{ after some number of shuffles the sequence will return to the original order (Morris, 1998). That is the culprit why this permutation suffers from short cycles, as DFJ (Defend, Fu & Juels, 2007) identified. And this vulnerability makes the protocol susceptible to their repeated keys attack.}

Based on experiments performed by DFJ (Defend, Fu & Juels, 2007), given an initial key \( k^{(0)} \), the successive session keys \( k^{(1)}, k^{(2)}, \ldots, k^{(10,000)} \), which are generated by the permutation \( \Pi \), cycle after an average of 68 sessions. They also found that about 32% of session keys have cycle 1, and all of tested session keys eventually repeat themselves and only one thousandth of keys have the maximum cycle of 36. Let \( c \) represent a cycle, then \( k^{(i)} = k^{(i+c)} \).

Suppose \( k^{(i)} = k^{(i+2)} \), under the adversary model for the repeated keys attack (Defend, Fu & Juels, 2007), an eavesdropper, Eve is able to form a valid response without knowing \( k^{(0)} \) or
x(i). She calculates e(i-2) = a(i-2) ⊕ b(i-2) = k(i-2) ⊕ k(0). Since k(i) = k(i-2), she calculates a(i) ⊕ e(i-2) = (x(i) ⊕ k(i)) ⊕ (k(i-2) ⊕ k(0)) = x(i) ⊕ k(0) = b(i), therefore she can impersonate a valid tag, as shown in Figure 2.

3. IMPROVEMENTS TO XOR PROTOCOL

In this section we propose three improvements to the original XOR protocol, namely removing bad shuffles, hopping the runs, and authenticating mutually.

3.1 Removing Bad Shuffles

In step-4 of the original VB’s permutation algorithm, we don’t interleave nibbles of k_{L}^{(i)} and k_{R}^{(i)} to create k^{(i)}. Instead, we just simply concatenate k_{L}^{(i)} and k_{R}^{(i)} to form k^{(i)}, i.e., k^{(i)} = k_{L}^{(i)} || k_{R}^{(i)}. In this way we remove the out-shuffles from the permutation, therefore, the short cycles disappear, and the DFJ’s repeated key attack is prevented, and the security is improved. And we argue that without the out-shuffle step, the permutation [\Pi] is a Knuth shuffle¹, i.e., an algorithm for generating a random permutation of a finite set. In the case of 128-bit key length, there are two finite sets with 16 nibbles (0 ~ F in hexadecimal) each. The operation [\Pi] to the left and right nibble sets (k_{L}^{(i)} and k_{R}^{(i)}) will provide 16! permutations each. Theoretically, there are 16!×16! (> 2^{88}) in total.

Here is an example to illustrate how the permutation [\Pi] without out-shuffles works. We use a pseudo-random key generation program to create a 128-bit k^{(0)} in hexadecimal as: C3 47 3F BB 8D B4 C1 E0 5F 4C 2D 8B 2B A6 BD 98, then split it into left and right nibble sets as:

\[
\begin{align*}
    k_{L}^{(0)} & : C 4 3 B 8 B C E 5 4 2 8 2 A B 9, \\
    k_{R}^{(0)} & : 3 7 F B D 4 1 0 F C D B B 6 D 8.
\end{align*}
\]

Then under the control of k_{L}^{(0)}/k_{R}^{(0)}, we permute k_{L}^{(i)}/k_{R}^{(i)} to obtain k_{L}^{(i)}/k_{R}^{(i)} as follows:

\[
\begin{align*}
    k_{L}^{(1)} & : 4C 98 BA 2B 52 84 CB E3 and \\
    k_{R}^{(1)} & : BD 1B C7 3D 4B 60 DB FF.
\end{align*}
\]

k^{(i)} is the concatenation of k_{L}^{(i)} and k_{R}^{(i)} as:

\[
\begin{align*}
    k^{(1)} & : 4C 98 BA 2B 52 84 CB E3 BD 1B C7 3D 4B 60 DB FF.
\end{align*}
\]

The second run starts from k^{(1)} : 4C 98 BA 2B 52 84 CB E3 BD 1B C7 3D 4B 60 DB FF. Again we split it into left and right nibble sets as:

\[
\begin{align*}
    k_{L}^{(2)} & : 4 9 B 2 5 8 C E B 1 C 3 4 6 D F, \\
    k_{R}^{(2)} & : C 8 A B 2 4 B 3 D B 7 D 8 0 B F.
\end{align*}
\]

Then controlled by k_{L}^{(1)}/k_{R}^{(1)}, we permute k_{L}^{(2)}/k_{R}^{(2)} to obtain k_{L}^{(2)}/k_{R}^{(2)} as follows:

\[
\begin{align*}
    k_{L}^{(2)} & : 1B 5E 8C 2B 4C 3D 64 9F and \\
    k_{R}^{(2)} & : 28 BC 7D 0B AB BD 43 8F.
\end{align*}
\]

k^{(i)} is the concatenation of k_{L}^{(i)} and k_{R}^{(i)} as:
\[ k^{(2)} : 1B \ 5E \ 8C \ 2B \ 4C \ 3D \ 64 \ 9F \ 28 \ BC \ 7D \ 0B \ AB \ BD \ 43 \ 8F. \]

And so on so forth, we can obtain \( k^{(3)} \), \( k^{(4)} \), \( k^{(5)} \), … as follows:

\[ k^{(3)} : 04 \ A5 \ 6B \ 88 \ 24 \ 3B \ 27 \ 19 \ FD \ CB \ 38 \ 4D \ FB \ BD \ CE \ CB, \]
\[ k^{(4)} : 23 \ 4F \ 06 \ 1C \ BC \ 82 \ CF \ 49 \ B5 \ DD \ 48 \ BB \ BD \ B7 \ 8E, \]
\[ k^{(5)} : 18 \ 0B \ D4 \ 8B \ 42 \ BB \ B3 \ C4 \ 3C \ 6F \ 58 \ 9B \ EC \ D7 \ 2F \ DA. \]

**Observations:** the permutation \( \prod \) does not create the new nibbles (hexadecimal symbols), instead it just moves all existing nibbles around by each run. If an ideal pseudo-random key generator is used during the initial key generation, within \( k^{(0)} \) nibbles (0 ~ F) should be uniformly distributed and unbiased. Theoretically, the random permutation \( \prod \) can guarantee \( 16! \times 16! \) permutations for a 128-bit sequence. However, if the distribution of 16 nibbles is not uniform (as the above example shows the frequencies of the 16 hex symbols are: 0(1), 1(1), 2(2), 3(2), 4(3), 5(1), 6(1), 7(1), 8(3), 9(1), A(1), B(6), C(3), D(3), E(1), F(2)), the total number of permutations is less than \( 16! \times 16! \), but still a huge number.

In practice, before installation of a \( k^{(0)} \)’s to a tag, this \( k^{(0)} \) should be tested to make sure it can be used to generate enough numbers \( (5 \times 16! \) is already big enough) of session keys without repetition. This procedure is used to eliminate weak keys. If the key length is 128-bit, there are in total \( 2^{128} \) key\( ^{(0)} \)’s. Even there is only one good strong key among every one hundred keys, the total number of strong keys is about \( 2^{121} \), which is huge.

For curiosity, we carried out an experiment with a 128-bit key length, similarly as in Defend, Fu and Juels (2007). We generated 1000 different \( k^{(0)} \)’s, and from each \( k^{(0)} \) we permuted 10,000 times to generate session keys \( k^{(1)}, k^{(2)}, \ldots, k^{(i-1)}, k^{(i)}, k^{(i+1)}, \ldots, k^{(10,000)} \) and put them into a file. We obtained 1000 such files with each containing 10,000 session keys. Our experiment results show that there is no repeat session key within these 1000 files. So the repeated keys attack is prevented.

### 3.2 Hopping the Runs

The purpose of making the session keys hop is so that the next session key does not have to be the immediate successor of the current session key. This makes the nibble attack (Defend, Fu & Juels, 2007) much harder, if not impossible.

Here is how the nibble attack (Defend, Fu & Juels, 2007) works. Starting from run \( i \), the attacker Eve builds a table over the following number of runs. Two columns are the challenges and responses between Reader and Tag, i.e., a’s and b’s. The next column is the xor’ed result of the previous two columns, i.e., \( a^{(i)} \oplus b^{(i)} = k^{(i)} \oplus k^{(0)} \).

The last column is the xor’ed result of two of consecutive rows from the fourth column, which will give us the xor’ed result of two consecutive session keys. As observed, when a nibble of this last column becomes 0, the corresponding nibble of the session key \( k^{(0)} \) becomes known. This is because in the original permutation case, the two continuous session keys are

\[
\begin{align*}
k^{(i)} &= k^{(i)}_{0,L} | k^{(i)}_{0,R} | \ldots | k^{(i)}_{15,L} | k^{(i)}_{15,R}, \\
k^{(i+1)} &= k^{(i+1)}_{0,L} | k^{(i+1)}_{0,R} | \ldots | k^{(i+1)}_{15,L} | k^{(i+1)}_{15,R},
\end{align*}
\]

If Eve detects that the second nibble of \( (k^{(i+1)} \oplus k^{(0)}) \) is “0000”, then she has \( k^{(i+1)}_{0,R} = k^{(i)}_{0,R} \).

Since \( k^{(i+1)}_{0,R} \) is obtained by swapping 0-th and \( k^{(i)}_{0,R} \)-th elements of \( k^{(i)}_{0,R} \), if \( k^{(i+1)}_{0,R} = k^{(i)}_{0,R} \) then \( k^{(i)}_{0,R} \) swaps with itself. That means \( k^{(i)}_{0,L} = 0 \).

From the fourth column of Table 1, Eve knows that the first nibble of \( (k^{(0)} \oplus k^{(0)}) \) is the \( k^{(0)}_{0,L} \). Likewise, if the 18-th nibble of \( (k^{(i+1)} \oplus k^{(0)}) \) is “0000”, then she has \( k^{(i+1)}_{8,R} = k^{(i)}_{8,R} \). Since \( k^{(i+1)}_{8,R} \) is obtained by swapping 8-th and \( k^{(i)}_{8,R} \)-th ele-

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ments of \( k_r^{(i)} \) if \( k_r^{(i+1)} = k_{s,R} \), then \( k_r^{(i)} \) swaps with itself. That means \( k_{s,L}^{(i)} = 8 = (1000)_2 \). From the fourth column of Table 1 Eve knows that xor’ing the 18-th nibble of \((k(0) \oplus k(0))\) with “1000” is the \( k_{s,L}^{(0)} \). Gradually, all other nibbles of \( k(0) \) could be obtained by the attacker in this way.

In the permutation without out-shuffles situation (see section 3.1), two consecutive session keys are

\[
k^{(i)} = k_{0,L}^{(i)} \mid k_{0,R}^{(i)} | \cdots | k_{8,L}^{(i)} | \cdots | k_{15,L}^{(i)} \mid k_{15,R}^{(i)}
\]

\[
k^{(i+1)} = k_{0,L}^{(i+1)} \mid k_{1,L}^{(i+1)} | \cdots | k_{15,L}^{(i+1)} \mid k_{15,R}^{(i+1)} \mid \cdots | k_{5,R}^{(i+1)} \mid \cdots | k_{8,R}^{(i+1)} \mid \cdots | k_{15,R}^{(i+1)}
\]

Now the nibble attack only applies to gain two nibbles of \( k(0): 17\)-th and 32-th nibbles. If the first nibble of \((k(i) \oplus k(0))\) is “0000”, then she has \( k_{0,L}^{(i+1)} = k_{0,L}^{(i)} \). Since \( k_{0,L}^{(i+1)} \) is obtained by swapping 0-th and \( k_{0,R}^{(i)} \)-th elements of \( k^{(i)} \), if \( k_{0,L}^{(i+1)} = k_{0,L}^{(i)} \), then \( k_{0,R}^{(i)} \) swaps with itself. That means \( k_{0,R}^{(i)} = 0 \). From the fourth column of Table 1, Eve knows that the 17-th nibble of the \((k(i) \oplus k(0))\) is the 17-th nibble of \( k(0) \). We have similar argument for gaining 16-th nibble of \( k(0) \). If \( k_{15,R}^{(i+1)} = k_{15,R}^{(i)} \), then \( k_{15,L}^{(i)} = 15 = (1111)_2 \). So the 16-th nibble of \( k(0) \) is the xor’ed result of 16-th nibble of \((k(i) \oplus k(0))\) and “1111”. All other nibbles of the \( k(0) \) will not be easily recovered by observing “0000” nibbles seen in the last column of the Table 1. In Table 1, in the original XOR protocol, hopping offsets \( h_0, h_1, h_2, \ldots \) are all 0’s, i does not update. With the hopping the runs, these offsets \( h_0, h_1, h_2, \ldots \) are functions of current session keys, e.g., \( h_0 = h(k^{(i)}) \).

The hopping function is simply defined as a resulting nibble by performing XOR of the first eight nibbles of the current session key. For instance, the hopping offset

\[
h_0 = h(k^{(i)}) = \sum_{m=0}^{7} k_m^{(i)}
\]

where \( k_m^{(i)} \) is the m-th nibble of the session key \( k^{(i)} \). It is noted that this hopping_offset formula could be changed to a simple hash operation.

With hopping the runs mechanism embedded in the XOR protocol, even when attacker Eve finds “0000” nibble in the last column of the Table 1, she has no way of knowing hopping offsets except through the brute force of guessing. Therefore the nibble attack is prevented.

This improvement makes the nibble attack impossible. Meanwhile it may slow down the calculation speed a little bit, since the next session key is not just one iteration of the permutation, it is (hopping_offset +1) iterations. Note, the “+1” is just to prevent repeat session keys in case of hopping_offset equal to 0.

### 3.3 Authenticating Mutually

In general, a 3-pass mutual authentication protocol works as follows. Both parties, Alice and

---

**Table 1. Nibble attack table**

<table>
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<tr>
<th>run</th>
<th>hop</th>
<th>a</th>
<th>b</th>
<th>a ⊕ b = c</th>
<th>c(i+1) ⊕ c(i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>h0 = h(k(i))</td>
<td>x(i) ⊕ k(i)</td>
<td>x(i) ⊕ k(0)</td>
<td>k(i) ⊕ k(0)</td>
<td>undefined</td>
</tr>
<tr>
<td>i+h0+1</td>
<td>h1 = h(k(i+h0+1))</td>
<td>x(i+h0+1) ⊕ k(i+h0+1)</td>
<td>x(i+h0+1) ⊕ k(0)</td>
<td>k(i+h0+1) ⊕ k(0)</td>
<td>k(i+h0+1) ⊕ k(i)</td>
</tr>
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<td>i+h0+1</td>
<td>k(i+h1+1)</td>
<td>x(i+h1+2) ⊕ k(i+h1+2)</td>
<td>x(i+h1+2) ⊕ k(0)</td>
<td>k(i+h1+2) ⊕ k(0)</td>
<td>k(i+h1+2) ⊕ k(i+1)</td>
</tr>
<tr>
<td>i+h1+1</td>
<td>k(i+h2+1)</td>
<td>x(i+h2+3) ⊕ k(i+h2+3)</td>
<td>x(i+h2+3) ⊕ k(0)</td>
<td>k(i+h2+3) ⊕ k(0)</td>
<td>k(i+h2+3) ⊕ k(i+2)</td>
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Bob, have a piece of shared secret key $k$. Alice initiates the first pass by sending a challenge $F_k(R_A)$, in which $F_k$ is one kind of encryption (or cryptographic hash) function controlled by $k$, and $R_A$ is a random number chosen by Alice. Bob responds with $F_k(R_A+R_B)$ in the second pass, where $R_B$ is a random number chosen by Bob. In this second pass, Bob is authenticated by Alice, because only Bob is able to extract the random number $R_A$. In the third pass, Alice acknowledges Bob by sending $F_k(R_B+R_A)$ back. In this final pass, Alice is authenticated by Bob, since only Alice is able to restore $R_A$ with their shared secret $k$.

In the RFID system, mutual authentication is very important. Without it, a reader and a tag could be out of synchronization for further communication. Due to this reason, challenges and responses between a reader and a tag have to keep changing in order to avoid traceability. The XOR protocol is a 2-pass protocol. That is, only the tag is authenticated by the reader and the reader is not authenticated by the tag. We need add a third pass to make it become a mutual authentication protocol as shown in Figure 3.

We use the hopping to run XOR protocol, where we change the next session key index as $i + \text{hopping_offset} + 2$ (in stead of “+1” in Improvement-II) in order to leave a middle permutation for the acknowledge message $c(i)$ of the third pass. That is, $c(i) = x(i) \oplus k(i + (h + 2)/2)$, where $h$ is the hopping_offset, and $(h + 2)/2$ takes the greatest integer less than or equal to $(h + 2)/2$.

In the first pass, a reader sends a challenge $a(i) = x(i) \oplus k(i)$ to a tag. In the second pass, the tag responds the reader by sending $b(i) = x(i) \oplus k(0)$. Only the legitimate tag is able to extract the challenge $x(i)$ and create the response $b(i)$. By receiving $b(i)$, the reader authenticates the tag. In the third pass, the reader sends $c(i) = x(i) \oplus k(i + (h + 2)/2)$ back to the tag. Because only the legitimate reader knows $x(i)$ and is able to generate $k(i + (h + 2)/2)$, and send $c(i)$. After receiving $c(i)$, the tag knows it comes from the right reader. So the tag authenticates the reader.

4. CYCLE COMPARISON EXPERIMENT

In this section, we provide results that compare the cycles of session keys from VB’s original XOR algorithm, and the XOR algorithm without the bad shuffle. For a 128-bit key, there are 16 symbols (0 ~ F). The total number of random permutations is $16! \times 16!$, which is a huge number. It is not practical to do an exhaustive test with our limited computing resources. Instead, we tested two short cases: 4-symbol (0 ~ 3) and 8-symbol (0 ~ 7). This experiment provided us with the opportunity to compare these two algorithms under the same conditions for a small permutation data set. It also provided empirical proof that our improvement can significantly reduce the risk of DFJ’s attack by increasing the difficulty or cost of carrying out DFJ’s attack. We measure the difficulty of DFJ’s attack by...
the number permutation cycles it takes for a successful attack.

For the 4-symbol situation, each symbol can be represented in two bits. The key consists of two sets of those 4 symbols, and the key (and session key) length is 2×4×2, which is 16 bits, or 2 bytes. In an ideal case, the number of random permutations for concatenated two sets of 4-symbol is 4!×4! (= 576).

For the 8-symbol situation, each symbol can be represented in three bits. The key consists of two sets of those 8 symbols, and its length is 3×8×2 bits, i.e., 6 bytes. In an ideal case, the total number of random permutations for concatenated two sets of 8-symbol is 8!×8!, which is equal to 1,625,702,400. The testing results are given in Table 2. Shorter cycles for the XOR without bad shuffle result from biased distribution of symbols in the initial keys (i.e. weak initial keys). For more details of the experiment, please see Zhang, Zhang and Wei (2009).

For the 48-bit session key situation, the average cycle is 9,482. This is because we limit our runs to 10,000, which is less than 8!×8!. Otherwise, the average should be much large.

We performed an experiment to stretch test the cycle with the initial key C3473FBB8DB4C1E05f4C2D8B2BA6BD98. It runs up to 200,000,000 session key without repeating.

### 5. CONCLUSION

In this paper, we identified the weaknesses in the XOR authentication protocol proposed by Vajda and Buttyan. We made three improvements to this protocol: removing bad shuffles, hopping the runs, and authenticating mutually. By these improvements, the XOR protocol is greatly strengthened to resist the repeated keys and nibble attacks proposed by Defend, Fu, and Juels. Our improvements to the XOR protocol do not introduce extra resource cost. The storage resource needed for the XOR protocol is only 128-bit plus some temporary storage for permutation use. The improved protocol is suitable for majority low-cost RFID system application scenarios.

### REFERENCES


<table>
<thead>
<tr>
<th>Number of different initial keys</th>
<th>16-bit key</th>
<th>48-bit key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of session keys generated from each initial key</td>
<td>500</td>
<td>10,000</td>
</tr>
<tr>
<td>Shortest average cycle of the original XOR algorithm</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>Shortest average cycle of the XOR without bad shuffle</td>
<td>22</td>
<td>9,482</td>
</tr>
</tbody>
</table>

Table 2. Cycle testing results for two XOR algorithms


**ENDNOTE**

1 “Knuth shuffle is to the identity permutation or any other any permutation, then go through the positions 1 through n-1, and for each position i swap the element currently there with an arbitrarily chosen element from positions i through n, inclusive. It’s easy to verify that any permutation of n elements will be produced by this algorithm with probability exactly 1/n!, thus yielding a uniform distribution over all such permutations.”

Xiaowen Zhang is an Assistant Professor at Department of Computer Science, College of Staten Island / The City University of New York (CUNY), U.S.A. He received a PhD in electrical engineering from Northern Jiaotong University, China, and a PhD in computer science from the City University of New York, U.S.A. His research interests include cryptography, information security and privacy, RFID, and wireless communication.

Zhanyang Zhang is an Associate Professor at Department of Computer Science, College of Staten Island / CUNY, U.S.A. He received his PhD in Computer Science from the City University of New York, U.S.A. His research interests cover wireless ad-hoc and sensor networks, underwater acoustic networks and RFID. Prior join CUNY, he was a member of technical staff (MTS) at Bell Labs/Lucent Technologies and worked on 3G wireless networks and data security.

Xinzhou Wei is an Associate Professor at Department of Electrical Engineering and Telecommunications Technology, New York City College of Technology / CUNY, U.S.A. He received his Ph.D. in computer science from the City University of New York, U.S.A. His research interests include public key cryptography, network security, digital signal processing, and image processing.
Research of Supply Quality Control and Optimization Under Multi-Period Dynamic Game

Jun Hu, Zhejiang Gongshang University, China
Yulian Fei, Zhejiang Gongshang University, China
Ertian Hua, Zhejiang Gongshang University, China

ABSTRACT

To control quality in supply chain, this paper presents multi-period, dynamic game models in principal-agent theory, which are opposite to static, single period game models. The research comes from industrial practice and the conclusions are more operational and feasible in theory. Finally, the research is applied into two famous companies in different industries and shows good effectiveness.

Keywords: Dynamic Game, Game Models, Multi-period, Quality Control, Supply Chain Contract

1. INTRODUCTION

From “Magdala Red Accident” in 2005 to “Sanlu Milkpower Accident” in 2008 and “OMP Accident” in 2009, there have being many food accidents since 2000. Control and management of quality in food supply chain has been paid more and more attention by people. At present, quality management in supply chain will threaten not only single company but also industrial development. Pasternack (1995) set forth quality management in supply chain. From view of incentive and restraint mechanism, supply chain contract is new field in quality control and management, in which quality is managed and controlled through quality provisions. Some researchers pay the role of incentive to quality management and quality contract becomes one approach to control and manage quality in supply chain. As illustrated, there are many academic and practical researches to quality management from view of incentive and restraint.

Here, we should explain some definitions. Firstly, there are two kinds of contracts: supply chain contract and supply chain quality contract. So-called supply chain contract is meant traditional contract in supply chain, in which main variables are price and quantity while quality is neglected or fixed. And supply chain quality contract is a kind of supply chain contract, in which main variables quality, price, quantity and other related variables while quality interacts...
with other variables. Secondly, there are two kinds of models: one is structural model and another is economic and quantificational model or called game theory. Structural model depicts transaction process and information flow between supplier and buyer, in which information of variables such as price, volume and quality are passed down to next and how these variables change. Economic and quantificational model is called the game theory, which includes many variables, formula, algorithm, mathematics and constructed based on principal-agent theory.

There have been many supply chain quality contract models. For example, there are some parameters such as price, quantity, revenue, quality level, sampling level, penalty and incentive in these models. Although there are some achievements in the contract research, these models have some disadvantages such as static, single period, simple structure and lack of operation. So, there are many things to manage supply chain quality in the future.

2. LITERATURE REVIEW

Contracts and quality contracts in supply chain have been studied by overseas and domestic researchers for long time.

Corbett, Zhou, and Tang (2004) found that more suppliers get information about buyers’ cost structure, higher the value between supplier and purchaser become. Gurnani and Erkoc (2008) studied the distribution channel on the condition that demand is influenced by supplier’s quality and retailer’s promotion. When the cost of promotion is private, there are three types of contract: wholesale price contract, fixed fee contract under marginal cost and franchise contract. Manufacturers have different choice and costs under three contracts. Starbird (2001) studied that the relation among quality, quality cost and information and how to coordinate quality of supplier, sampling inspection of purchaser and penalty of bad quality between the risk-neutral supplier and risk-neutral purchaser. Reyniers (1995) studied that as to different sampling policy. Reyniers and Tapiero (1995) designed the contract model of price rebate and after-sale guarantee cost concerning quality of supplier, sampling policy of production and the finished product quality. Agrawal (2002) considered the choice of contract between an entrepreneur and a worker: in a situation where the worker cannot readily observe the outcome (such as profit or output) of their joint effort, while the entrepreneur cannot easily observe the effort supplied by the worker. On the basis of analyzing cost in supply chain, Rahim (2000) studied the quality cost of supply chain based on the principal-agent theory under asymmetric information. Agrawal (2002) demonstrated that the game model between supplier and manufacturer in two-echelon supply chain there are suitable incentive and penalty to meet first-best. It also analyses the relation among quality, late delivery and penalty.

In summary, there are more and more plentiful researches in supply chain quality contract. Based on sampling inspection mechanism, quality inspection, penalty and incentive, charge to quality lose are, quality management is coordinated through quality contract. But, those achievements have some disadvantages, such as single structure, ignorance to other factors of cooperation and standards.

3. RESEARCH BODY

3.1 Research Clue

As stated above, the previous researches in supply chain quality contract have been made achievements but have some disadvantages including single tool (mainly sampling), static, simple model (two period), ignoring electronic commerce and product market structure, participants’ attitude to risk and new means of supply chain quality management. So, the paper will put forward dynamic, multi-period model of quality control and optimization in supply chain under different environment after it screens and analyzes all characteristic of factors influencing quality.

Its clue is: firstly to find all factors which determine quality in supply chain and induce the characteristics in all factors. Secondly, it builds structural model and quantificational model (adding some variables such as cooperation and time) according to process of quality management in supply chain and influencing factors. Then, economic and quantificational models of quality control and optimization, which are based on dynamic and multi-period, are set up under different environments. After building all models, solutions can be obtained by use of backward induction method and multi-level programming. Finally, all conclusions of models are accepted by some typical companies and the models are modified.

3.2 Research Content

(1) Acquisition of factors and characteristics influencing quality control in supply chain.

Through investigation and analysis, we study industrial quality management in supply chain from the view of practice. The objects include key environment, technology, influencing factors and effects. Especially, we study industrial practice under different industries, product market structure, attitude to risk and electronic commerce. Through these works, factors and characteristics, which influence quality control in supply chain, are identified.

(2) Structural model of supply chain quality contract.

According to above analysis, structural model of supply chain quality contract is put forward, which is used to build quantificational model including all hypothesis. It explains regulation and essence of quality contract mechanism in supply chain, based on system theory.

(3) The game model of quality management in supply chain.

Followed on the step 1 and 2, we add up to two new variables of quality and time (q, t) and new controlling variables such as cooperation in supply quality contract models. Therefore, any dynamic, multi-period models can be designed under different environments.

For example, there are some game models with different stages or periods: single period and single stage, single period and multi-stages, multi-periods and multi-stages. There are some game models with different attitudes to risk: risk preference, risk averse and risk neutral. There are some game models with different means: option, revenue sharing, quantity discount and buyback contracts. There are some game models with different reputation: reputation signal and trust. There are some game models with different organization structure: traditional environment (many supplier vs. single manufacturer, single supplier vs. many manufacturers) and electronic commerce. There are some game models with different market structure: monopolistic competition, oligopoly, perfect monopoly and perfect competition.
This part studies supply quality contract in theory and is close to industrial practice. The method of research is the combination of theory and practice.

(4) Solution and data analysis.

Next to the above step 3, the paper applies backward induction method and multi-level programming to obtain solutions. At the same time, it will analyze the effect and feasibility of solution.

(5) Application

The paper takes electronic commerce Alibaba and traditional company-Shanghai VW as example and probes into their quality management in supply chain. Then, we look on the effect after they introduce the scheme of all models. Finally, industrial application will respond to the theory models.

3.3 Key Issues

There are many issues in the research, and the key issues include:

(1) Discovery of factor and characteristic influencing quality control in supply chain

In order to set up dynamic, multi-period game structural model of quality control in supply chain, we should know that: How and which factors influence quality control in supply chain? What characteristic are these factors and process of quality control? How do industrial companies filter these factors and eliminate the noise from data collected. All of above works is the basis and hypothesis of structural model.

(2) Acquisition of structural model and quantificational model of quality in supply chain

Supply chain quality multi-period, dynamic game models differ with structural models in traditional supply contract (such as Newsboys model). If adding some variables such as time and quality, game models of supply chain quality will respond to above change. What are the quantificational models under different environment according to structural models? And what are these quantificational models hypothesis?

(3) Building quality game model in supply chain

After obtaining structural models and quantificational models in supply chain, what are quality game models in supply chain under different environment condition such as product market structure, industrial attitude to risk, competition structure and electronic commerce? How are the game models built after considering industrial quality practice (such as cooperation and time)?

(4) Solution and data analysis

Multi-period models are difficult to get solution. Then, the next thing is how to select algorithm suitable to all models and how to value effect and feasibility of solutions.

(5) Example and Model modification

The research needs to be used in industrial companies. Then, we will apply the research into industrial companies and the theory models will be modified according to the companies’ practice.

4. RESEARCH SCHEME AND FEASIBILITY ANALYSIS

4.1 Basic Framework

The basic framework of the research is seen in Figure 1.

Figure 1 shows the framework of quality control and optimization research based on multi-period, dynamic game. It includes the body, clue and method of research.
4.2 Technology Route

(1) Step 1: Analysis of influencing factors and characteristics of quality control in supply chain.

The research method of step 1 is mainly based on investigation. After gathering all data widely, we will study quality management practices in industrial companies, such as regulation, process, means and effect. The emphasis is to factors and tools of quality control under different environment. Then, key factor and characteristics is obtained by use of statistics.

(2) Step 2: Acquisition of structural model of quality control in supply chain.

(3) Step 3: The game models of quality control in supply chain being constructed.

We will study the stability and the filtration on basis of analyzing key factors and characteristics. Then, structural models of quality control in supply chain are extracted by use of generalization and induction. Structural models and quantificational models are set up in system and dynamic theory.

On basis on quantificational models, we construct many game models under different environment based on principal-agent theory, mathematics and system theory, which add some variables such as time, quality and tools (cooperation, $C$ and standards, $S$) on Newsboy model.
(4) Step 4: Model solution and data analysis.

The solution is obtained by use of backward induction method and multi-period programming considering the characteristics of multi-period. The controlling variables of quality management in supply chain are extracted. The effect and feasibility of the research achievements are demonstrated (Matlab platform).

(5) Step 5: Example and model modification

Through quality practice of supply chain in traditional company, Shanghai VW and new industry, electronic commerce giant, Alibaba, the data of quality management in companies are studied and analyzed based on our research through Matlab. Finally, models are modification through demonstration analysis and contract models will be optimized.

5. CHARACTERISTICS AND INNOVATION OF RESEARCH

There are some innovations in the research:

(1) Influencing factors and characteristics of quality management in supply chain being filtrated.

Through investigation and analysis into supply chain practice, influencing factors and characteristics are obtained, which shows the rules and essence of quality management in supply chain.

(2) Structural model and quantificational model of quality control in supply chain being built suitable to industrial practice.

The research is based on traditional supply contract model (Newsboy model) and different static, single period supply quality contract. The structural model is multi-period and the quantificational models add many variables such as time, which exist loop system of quality control in supply chain.

(3) Supply contract model under different environment being built and optimization.

Quality control practice in supply chain under different environments is studied and contract models are constructed accordingly. Solution of all contract models are obtained by use of backward induction method and multi-level programming. The effectiveness and feasibility of solution analyzed.

(4) Theory combining with practice

The research is good at operation because the models include many practice variables, which exist in quality management of industrial companies. The research can upgrade quality management practice in supply chain. Finally, the models can be modified and rectified while theory and practice both develop deeply.

6. EXAMPLE

In a food supply chain, a manufacturer sells food to a retailer. The manufacturer decides its quality prevention, which can be hidden or observable. The manufacturer signs the contract with quality provisions, in which there are rewards and penalties of internal and external loss. After that, the retailer decides its quality valuation and quantity regarding the need in the market.

Through mining from quality data in supply chain, we find that many variables will change dynamically in the multi-period. When the transaction is one time between the manufacturer and the retailer, there is a combination of quality prevention and valuation between the manufacturer and the retailer. But when the transaction is many times in multi-period, and we suppose that every good transaction can bring both parties the reputation revenue, the quality valuation of the retail will decrease, that means its cost will decrease, and its revenue will
increase under certain other conditions (Figure 2). And the penalties of internal and external loss can decrease and the revenues of the manufacturer, the retailer and the total supply chain will increase under certain other conditions when good transaction increase (Figure 3).

7. CONCLUSION

The paper studies quality management in supply chain in dynamic, multi-period. Many factors influencing quality are mined from practice data in supply chain. The structural and game models under different environments are built based the principal agent. Solutions are obtained by use of backwards induction method and multi-level programming. Through the examples, we can know that good transaction will result in long-term reputation in both parties. And the cost of quality valuation will decrease and every party’s revenue will increase in supply chain due to dynamic, multi-period game. So, we can find that the total supply chain will
benefit from quality management of dynamic, multi-period cooperation.

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REFERENCE


Jun Hu is a lecturer at the College of Computer Science & Information Engineering, Zhejiang Gongshang University, China. He received his PhD in industrial engineering from Tongji University, China. His primary research interests are in strategy management, supply chain & logistics management and management theory.

Yulian Fei is a associate professor at the College of Computer Science & Information Engineering, Zhejiang Gongshang University, China. She received his PhD in management science and engineering from Zhejiang Gongshang University, China. Her primary research interests are in information management and dataming.

Ertian Hua is a professor at the College of Computer Science & Information Engineering, Zhejiang Gongshang University, China. He received his PhD in mechanical engineering from Shanghai University, China. His primary research interests are in product innovation management and mechanical theory.
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Editorial: Zongwei Luo
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         International Journal of Applied Logistics
         Email: eic.jal@gmail.com

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                  Customer Service
                  701 E Chocolate Avenue
                  Hershey PA 17033-1240, USA
                  Tel: 717/533-8845 x100
                  E-mail: cust@igi-global.com