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Aligning supply chain collaboration using Analytic Hierarchy Process

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ABSTRACT

The significance of collaboration among supply chain members has been sufficiently stressed in the recent literature as a powerful tool for increasing accuracy of demand forecasts and for consequent cost reductions. Since it has been recognized that naïve forecasting is no longer cost efficient, Supply Chain (SC) members have found it very important to exchange relevant information that will help improve accuracy of demand forecasting. This information differs widely in terms of their characteristics. For example, some information (e.g. historic sales data) that is cheap to exchange may not contribute to a great increase in forecast accuracy. Similarly, some information may not be very reliable (e.g. demand forecast by individual SC members). In general, there is a trade-off in the kind of information required and the kind of information exchanged. This study analyses these trade-offs using an Analytic Hierarchy Process (AHP) model. The model is then implemented based on case studies conducted in two manufacturing firms. The AHP model ranks available information in terms of their contributions to improve forecast accuracy, and can provide vital clues to SC partners for preparing exchangeable data. From the case studies using AHP model, it was proved that using the preferred SC data, the firms could enhance forecasts accuracy. This in turn can help the firms to make decisions on SC collaborative arrangements for information exchange.

1. Introduction

In the past two decades, supply chain management has been recognized as a powerful business tool to survive in the competitive marketplace. Supply Chain (SC) operators have started considering the changing interests of consumers and their shifting loyalty whilst managing supply chain inventory, capacity and production, and delivery management. This is reflected in collaborative relationships between SC partners to avoid stock-outs and excess inventory [22,6]. Several collaborative SC tools such as Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR) are being increasingly adopted by SC operators to improve SC efficiency.

Some manufacturers practicing Supply Chain Collaboration (SCC) and advanced information integration with retailers have realised cost reduction and increased revenue [25]. Many researchers have discussed the role of supply chain information and quality of information in improving supply chain performance [18,19]. Information Sharing (IS) among partners facilitates flow of goods in the supply chain [6] and also helps to forecast demand more efficiently. However, the benefits of IS are highly dependent on the context and proper use of available information [34]. Forecast information quality may be lower for upstream members in the supply chain, especially for manufacture-to-order suppliers [18], but effective and efficient handling of available data will enhance the performance of supply chain and yield more benefits [23].

All available information may not be equally useful for the purpose of forecasting or decision making for all SC partners [27,34]. For instance, demand or transaction information may be more important to retailers than manufacturers, while product or inventory information may be more important to the latter. Yu et al. [48] showed that centralized IS benefits manufacturers more than retailers. They also suggested some incentives to retailers in order to encourage their participation in information sharing. Ovalle and Marquez [33] classified information into three types: product information, customer demand and transaction information, and inventory information. This classification varies widely depending on the firms involved in SCC. An exceptional level of service can be achieved through integrated information [24]. Although the benefit of IS is not necessarily the same to all SC members, it is perceived as one of the critical success factors for collaborative supply chains [22]. This paper refers to the information exchange among members of SC collaboration as 'Collaborative Information Exchange' (CIE), and it is discussed with regard to improving demand forecasts.

In contrast to the above literature, Småros [42] identified from case studies that manufacturers' initiative on establishing collaboration for IS and forecasting with downstream members such

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as retailers wholesalers and distributors is an uncommon practice. However, there is no systematic approach in the existing literature for identifying importance of IS under SC collaboration. This paper, through two exploratory case studies, tries to study and rank the information needs of manufacturing firms to improve forecast accuracy. This paper has two objectives:

- To identify and prioritize the information need in CIE to attain forecast accuracy. As mentioned earlier, various kinds of SC information have differing levels of importance to SC operators. This study attempts to develop a new AHP-based framework to arrive at the relative importance of this information by eliciting opinions from SC operators.
- To decide the level of collaboration in SC. Depending on the importance of information, some SCs may have to engage in very close collaboration, while some SCs may not need very close engagement. A framework is established to decide on the levels of collaboration using the AHP model.

The rest of the paper is organized as follows. The literature on evolution of information exchange in SCC is discussed briefly in Section 2. Research methodology is detailed in Section 3. Two case studies are briefly discussed in Section 4. Based on the case study observations, an AHP model is developed and analyzed in Section 5. The findings of AHP analysis are discussed in Section 6. The final section concludes with the research observations. This section also discusses scope for future work.

2. Evolution of collaborative information exchange (CIE)

In contrast to conservative SC practices, today's SC management is more transparent to SC operators. Healthy collaborative arrangements among SC partners are proving to be successful in many world-class businesses such as Wal-Mart, Sara Lee, Nabisco etc. [28]. In order to improve SC processes and to gain collaborative support from the other SC partners, several SC management practices such as VMI, Efficient Consumer Response, Continuous Replenishment, and Electronic Data Interchange have been suggested in the literature. In an attempt to introduce readers to the concept of information exchange in SC collaboration, two of the famous SC tools are briefly discussed (VMI and CPFR) below.

In VMI (developed in the mid 1980s), the customer's inventory and replenishment process are managed by manufacturer or supplier. However, SC visibility has not been found to be totally immune to the bullwhip effect [4]. This may be due to the fact that the information exchange is not highlighted much in VMI, except for inventory information [40]. Noran [32] proposed a decision framework with a step-by-step approach, incorporating knowledge of various elements of the organization. However, Noran did not discuss the role of information within the concept of collaborative network.

Ever-increasing SC demands have led to the invention of CPFR, another SC management tool, which incorporates planning, forecasting and replenishment under a single framework [17]. In recent literature, the benefits of SC collaboration and IS have been exposed through case studies conducted in European companies [42,13]. By obtaining demand information from downstream members, manufacturers can reduce SC costs [34]. Knowledge of demand information can reduce the inventory cost of both suppliers and customers [19,27,12,9] and help planning future business plans and promotions [37]. Sharing demand information along with inventory status among SC partners can help achieve elevated reduction in inventory cost and obsolescence [6,31].

In CPFR, demand forecast is a collective effort of all of the participating members of SC. A mathematical model developed by Aviv [2] captured the benefit of sharing local forecasts, particularly for products of shorter lead time. Depending on forecasting capabilities, the benefits of IS range from basic inventory reduction to higher profit earnings. In certain cases, readily available historical order data can reduce variance in demand forecast if it is used efficiently [34]. Knowledge of recent Point-Of-Sale data (POS) can improve forecast of promotions and new products [42]. POS data- and market data-sharing were found to be influential in achieving forecast accuracy in an augmented CPFR model developed by Chang et al. [10]. More detailed literature on the value of information sharing in SC was discussed by Li et al. [29]. In recent literature, Cao and Zhang [8] considered impact of SCC in company performance; While, Ramanathan et al. [35] discussed various performance metrics for evaluating collaborative SCs.

Although CPFR has been considered to be a better SC tool than VMI [40], recognizing the type of IS among SC members in order to build more visibility is a big challenge [4]. Ryu et al. [38] evaluated demand information sharing methods in supply chains. Almost all of the articles in the literature have concentrated on particular SC information, such as inventory or sales, but have not considered all of the available information. In this paper, the information need in CIE is identified and ranked through appropriate case studies.

Two exploratory case studies were conducted in manufacturing firms to examine the nature of CIE practices. In this exploratory study, an attempt was made to identify the type of information used in improving forecast accuracy under manufacturer-initiated SC collaboration. The two firms differed in terms of their capabilities (technical/communication and forecasting) to contribute to CIE. The first firm had high levels of technical capabilities to enable CPFR implementation but chose to work on pilot projects on CIE for the past two years. The other company was interested in CIE but had no immediate plans for a collaborative SC program such as CPFR. However, both companies have been employing demand forecasts as the basis for their long- and short-term planning. By analyzing these two firms for collaborative information exchange, the importance of different varieties of supply chain information for improved demand forecast accuracy was identified and ranked. The approach of the present paper includes two case studies and the AHP technique, explained in the next section.

3. Research methodology

A case study approach was adopted as this is an ideal methodology when exploratory in-depth understanding is needed [45]. Using our initial interactions with relevant officials of the case companies, we first identified various factors influencing their decisions to participate in CIE. We then obtained the opinions on the performance of the companies in terms of the identified factors using semi-structured interviews with four high level officials of these companies. We used these opinions in the implementation of the AHP model [21,3].

The case study approach was organized in two phases:

i) In the first phase, an attempt was made to explore the current collaboration practices (particular to CIE) of the case company with other SC partners. The author visited the case companies personally to better understand their relationship with other SC members. The emphasis in this phase was more on understanding the information used by the firms to create their demand forecast.
ii) In the second phase, interviews were conducted with a view to developing a structured procedure to facilitate a deeper understanding of the informational requirements for CIE. The case

study observations were put into a structured modeling methodology, namely an Analytic Hierarchy Process (AHP) model. The AHP model then served as a tool to prioritize the importance of information in CIE, and hence to decide the level of collaboration with other SC members.

3.1. Case study

Initially pilot case studies were conducted with three manufacturing firms to understand their current practices on CIE and to check the appropriateness of the selected cases in achieving our research objective [47]. Three firms were selected—a manufacturer of textile materials (TexCo), a manufacturer of packaging materials (PackCo) and a manufacturer of flame-proof electrical equipments. The names of the firms were not disclosed to maintain confidentiality. The case-study approach included field visits and semi-structured interviews with dependable officers and decision-makers responsible for sales, forecasting and CIE. Interviews were conducted with departmental chiefs of four major operations namely, purchase, logistics, production and IT. We also interviewed two forecasters and four planning officers responsible for production and replenishment. We interviewed 10% of the total employees of about 100. The questions for interview were kept provisional, and were updated on completion of each stage of case study [45]. This approach has helped us to capture more points on CIE specific to each firm.

All three case companies were global exporters, and we categorized as manufacturing companies. The product demand pattern and forecasting procedure of the firms were analyzed to better understand various factors influencing CIE. TexCo and PackCo used a similar set of information in CIE (see Section 4.3) and both companies valued CIE to a great extent to improve their demand forecasts. However, the third case company did not consider using information on promotional sales, local forecasts and discount sales. Hence, TexCo and PackCo were selected for further study to achieve the objective of this research [47]. It was hoped that useful insights on IS would be generated by comparing and contrasting the results from these two case studies. The case study information was checked for its validity through key informants of the company, then a multi-criteria decision analysis tool called the AHP was employed for further analysis.

3.2. The Analytic Hierarchy Process (AHP)

The AHP is one of the tools widely used in deriving valid argumentative decisions like supplier selection [46,15,43] and machine-tool selection. Wang et al. [46] used the AHP in supplier selection by matching product characteristics with supplier characteristics. Many authors suggested using AHP in decision making models. For example, Barker and Zabinsky [3] and Vadde et al. [44] used AHP for decisions on reverse logistics and product recovery. Melón et al. [30] used AHP model for evaluating innovative educational projects. Ramanathan and Ramanathan [36] suggested the use of AHP for dealing with qualitative judgments in DEA.

Cheng and Li [11] attempted to use the AHP in supply chain resource allocation by prioritizing information. The AHP technique was also been applied in the SC to find the relative importance of performance and coordination mechanism [1]. Although the literature included some studies on prioritizing SC risk factors or performance indicators [41,7], to our knowledge this paper is the first to propose the use of AHP for prioritizing supply chain information for the purpose of forecasting and collaboration. AHP was developed by Saaty in 1980 (a brief description of AHP is available in Appendix 1). We have conducted this AHP study with the case companies by engaging participants in group discussions. Most of the employees of the focal companies and seven representatives from SC partnering companies participated in this AHP study. This approach directed us to obtain the most commonly agreed score. In this study, numbers of participants for the interview and AHP questionnaires are well within the recommended samples representing the whole population [45,39].

4. Case study analysis

4.1. Study 1—TexCo

TexCo, a textile manufacturing company, is operating globally under fierce competition. In order to gain competitive advantage, the firm believed in technological advancement, and used SAP for inventory management, forecasting, production planning and scheduling. The use of advanced communication, such as the latest mobile communication tools (e.g. Blackberry PDAs) by all employees in marketing and sales division helps the company to obtain sales data from the downstream partners. The capability of using Information Technology (IT) in CIE seemed influential in building the firm's demand forecast. Though the firm was involved in various information exchange projects with their downstream customers, it struggled to identify the importance of information obtained through CIE in improving forecast accuracy.

The firm employed differing levels of collaboration with its customers depending on the information needs. For customers (retailers and wholesalers) with irregular orders and for relatively new customers (constituting about 30% of its total customer base), the firm simply used the readily available order information for the purpose of forecasting. For more established customers with more reliable sales records (forming about 70% of its customer base), the firm was involved in more elaborate collaborative arrangements. At this level of collaboration, CIE included sales data, promotional information and inventory data to reduce inventory cost and to improve production planning. Any change to government policy on imports and exports affected the firm's business to a certain extent, and hence this information was passed on to the downstream members, which in turn affected its planning.

If detailed sales data was not readily available, the firm collected other data related to sales such as seasonal, and discount sales information. The obsolescence costs were believed to be avoided with prior knowledge of seasonal data. The competitors' product information was useful at the time of new product introduction and market boom, but this data is more expensive to obtain. The competitors' information was obtained through third-party information providers. The historical sales data and inventory data were also used to verify and update the forecasts, productions and replenishments from time to time. An individual local forecast made by each customer played a vital role in creating the final forecast of TexCo. The inventory position of customers was also monitored periodically to update the forecast. All of the information used by the company was weighed by its forecast analysts for its importance with regard to a cost-benefit analysis. TexCo related the reliability of the information with cost of obtaining data. The company was working hard to maximize the use of CIE to improve forecast accuracy.

4.2. Study 2—PackCo

PackCo is a packaging material manufacturer selling products globally. The company has a special manufacturing division for producing Jumbo bags for orders from many industries such as petrochemical, mineral, dyeing and natural food material (pharmaceutical). PackCo deals with more than one hundred customers and nearly 40% of customers are exporting their products in the

Jumbo bags only. One of the reasons of the company's global operations is its attractive eco-friendly recycling policy. The company also produces 'Filling & Discharging machinery' which is used for filling and discharging of Jumbo Bags. These machines are manufactured with technical collaboration from another UK company.

PackCo used almost all of the data types described for TexCo for the purpose of forecasting, but their priorities for using this information were somewhat different. This was mainly due to the fact that PackCo's products were not often sold directly to end users. Most of the customers of PackCo were original equipment manufacturers of electrical and electronic products. PackCo was using relatively less advanced communication and information technology (phone and fax) compared to TexCo. Nevertheless, it was working progressively to achieve technical excellence. PackCo was still in its infancy in deciding the CIE for its forecasting purposes.

4.3. CIE-relevant information

Based upon the interactions with the officials of both case companies, a list of CIE-relevant information currently being used either partly or fully to improve forecast accuracy was complied. The list is given below.

- Daily/weekly sales
- Order
- Local forecast
- Competitors' information
- Inventory
- Sales promotion
- Seasonal sales
- Historical sales
- Government policy on export and production
- Discount sales

4.4. Factors influencing CIE

Increasing SC cost is one of the primary concerns of all SC operators. Both of the firms used cost-benefit analysis as a basis to decide CIE. The cost of obtaining data was not a serious issue for TexCo, but it was an important consideration for PackCo. The value (benefit) of any information in CIE is weighed on its usability. The usability of the SC information is its role in various SC processes, such as planning, forecasting, production and replenishment. TexCo had high IT support to integrate all information into their forecasting process, whereas PackCo depended heavily on their forecast experts and their relative judgments. The accuracy of forecasting not only depends on the information but also on forecast capability [26] and efficient use of CIE. Moreover, the quality of information decides the success of SC collaboration through improved forecast accuracy [18]. To achieve a responsive SC, the information needs to be actionable [28]. Although reliability and action-ability of the information were considered equally valuable by both the companies, these two measures were not included specifically in their decision-making processes of CIE. Hence, reliability and action-ability were considered as additional criteria to be tested in further analysis. All of these factors were combined together to form five important criteria influencing CIE: cost, usability, reliability action-ability, and forecast capability. These five basic factors of CIE are defined as follows:

Cost: Cost refers to the cost of obtaining sales related data from other SC partners. The case study company needs to express their preferred choice of information with respect to cost of securing data.

Usability: The usability of information is related with the possible inclusion and use of information in various SC process. In other words, usability represents the importance (or role) of information in the SC processes.

Reliability: This factor refers to the accuracy of the information and the reliability of the source from which the information is obtained.

Action-ability: Action-ability refers to the speed with which the company can react to the information obtained.

Capability: Capability refers to the forecast capability of the company on using the particular information effectively to get maximum benefit.

The hypothetical approach by decision makers to forecast their demand in the case study companies looked beneficial when appropriate information was used. As the case companies were not clear on whether to use all the information, of its relative importance in forecasting, a certain amount of risk was involved in their decision making. This ambiguity led to considering other alternatives in validating the importance of CIE. The use of AHP, an intuitive method in process of decision analysis, was felt to be appropriate for decision making on collaborative arrangement, where there were many criteria involved in the decision tree. In precise, using this suggested approach, if a company is clear on what information will help them to make demand forecasts, the decision maker will establish different levels of collaborative arrangement to obtain SC information from other SC partners.

5. An AHP model for CIE

The first phase of the case study analysis in the previous section presented details on various types of information for CIE and various criteria to evaluate this information. In this section, an AHP model with three levels was developed in order to synthesize the information and criteria in a structured framework. The AHP model is shown in Fig. 1. The first level of the AHP model is the primary goal of the analysis. The goal is to estimate the relative importance of information exchanged among SC members. The second level includes the criteria used to analyze the goal. On the basis of the discussion in the previous section, five criteria – cost, usability, reliability and action-ability and forecast capability – are included in the model. As discussed in the previous section, under CIE, ten different types of information are exchanged. This information is considered as the decision alternatives of the AHP model in level 3. The decision made in level 3 will be instrumental in setting up collaboration with various SC partners.

5.1. Implementing the AHP model

Each type of information included in CIE is weighed against cost, usability, reliability, action-ability and forecast capability. In the process of obtaining opinion through interviews, the definition of these factors was conveyed to the interviewees.

5.1.1. Pair-wise comparison of decision criteria

Pair-wise comparison of each criterion in terms of main goal (importance of information in CIE) was obtained using expert opinions. Tables 1a and 1b represent the collective opinions of the decision authorities and corresponding consistency check.

The pair-wise comparisons of the five factors (criteria) obey the consistency condition of being less than 0.10. Hence, it can be claimed that the pair-wise analysis of decision criteria is consistent with respect to the given goal [39].

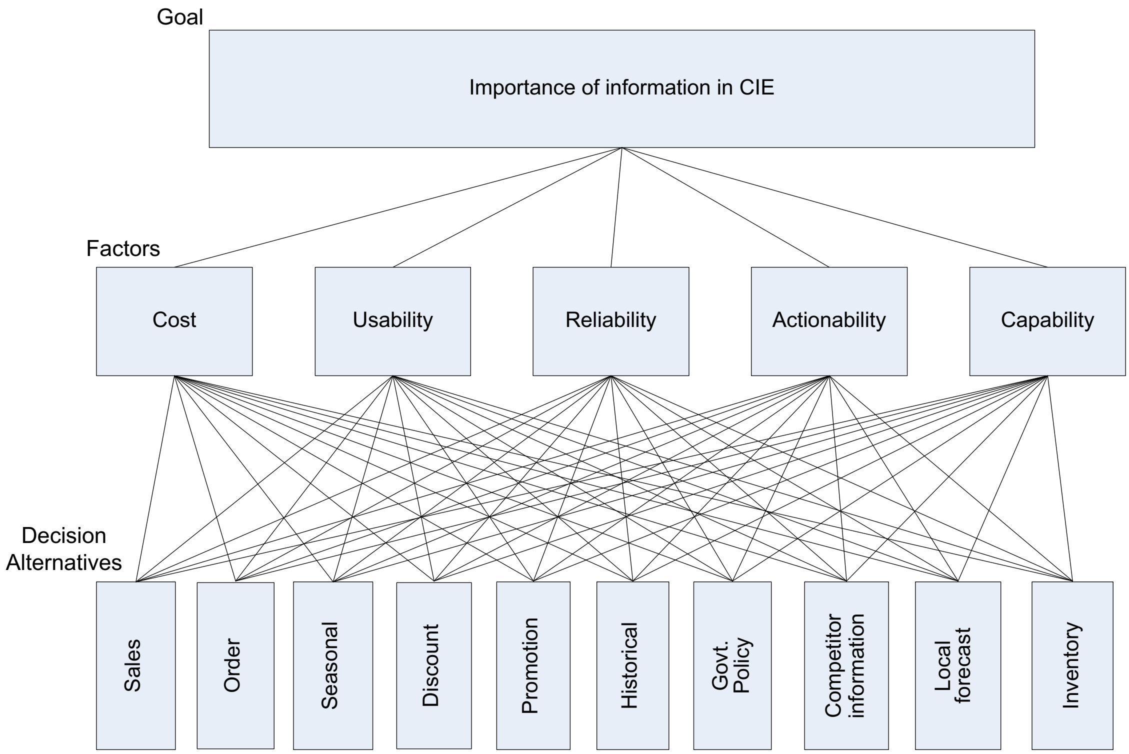

Fig. 1. Critical information need hierarchy model—AHP model for CIE.

Table 1a
Pair-wise comparison of criteria with respect to the goal—TexCo.

TexCo	Cost	Usability	Reliability	Action-ability	Capability
Cost	1	1/5	1/2	1/6	1/3
Usability	5	1	3	1	4
Reliability	2	1/3	1	1/4	1/5
Action-ability	6	1	4	1	4
Capability	3	1/4	5	1/4	1
λ_{max}=	5.3913				
C.I.=	0.0978				
C.R.=	0.0873				

Table 1b
Pair-wise comparison of criteria with respect to the goal—PackCo.

PackCo	Cost	Usability	Reliability	Action-ability	Capability
Cost	1	3	2	1/2	3
Usability	1/3	1	4	1/2	3
Reliability	1/2	1/4	1	1/4	1
Action-ability	2	2	4	1	3
Capability	1/3	1/3	1	1/3	1
λ_{max}=	5.3111				
C.I.=	0.0778				
C.R.=	0.0694				

The AHP results have shown that action-ability is a crucial decision criterion for CIE. Both firms conferred equal importance (local weight is around 0.36) to having actionable data to improve their SC (refer to Fig. 2). The reliability is another criterion viewed equally by both the case companies, but local weight (0.08) was not as high as that for action-ability. The cost of obtaining data seemed important for PackCo. with local weight 0.28, but the same was not influential for TexCo (weight 0.05). As discussed earlier, this is not a surprising result, given the fact that TexCo had already installed some infrastructure for information interchange and hence cost was not considered an overriding factor. Usability of information in the SC processes was another criterion viewed differently by these two firms. The textile manufacturing firm's intention of using the information in planning and forecasting is reflected through AHP weight of 0.34, compared to PackCo's local weight of 0.20 with respect to criteria 'usability'. The criterion called 'forecast capability' was strongly supported by TexCo, with local weight of 0.16; but PackCo did not give much importance for the forecast capability, and its local weight was 0.08.

5.1.2. Pair-wise comparison of decision alternatives explained

The next step in the AHP application involves rating decision-alternatives with respect to the criteria. In third AHP model, there are ten alternatives, represented by the ten CIE-relevant information points discussed earlier. AHP methodology requires the alternatives to be compared pair-wise with respect to each criterion. All of the required pair-wise comparisons from the case companies were collected.

The local weight of each decision alternative (information) in CIE with respect to the five criteria is shown in Fig. 3. Customers of TexCo and PackCo sent their sales data at the end of every day, every week, or on a monthly basis in line with their collaborative agreement. TexCo's enhanced IT capability supported the SC planning and forecasting, and hence usability of sales data was found to be more with local weight of 0.0598, compared to PackCo's 0.0494. The cost of obtaining sales data was high for TexCo, and hence sales data in CIE was not preferred in terms of cost (with weight 0.0350).

Order data was readily available with the firms and hence acts as a basic key reference for simple demand forecast. PackCo's basic forecasting and communication facility strongly supported the use of order data and try to make use of the order data in forecasting. In this case, forecast capability did not seem to be an obstacle to use order data in CIE.

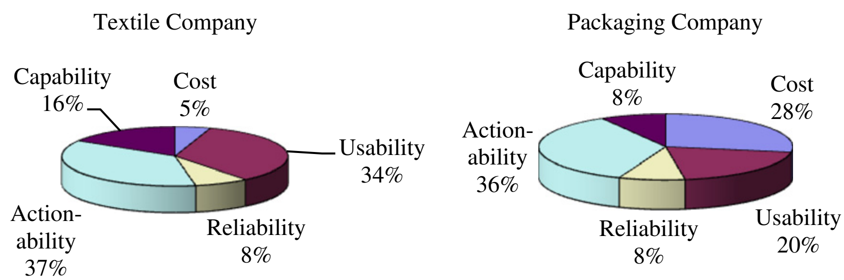

Fig. 2. Importance of various criteria in CIE.

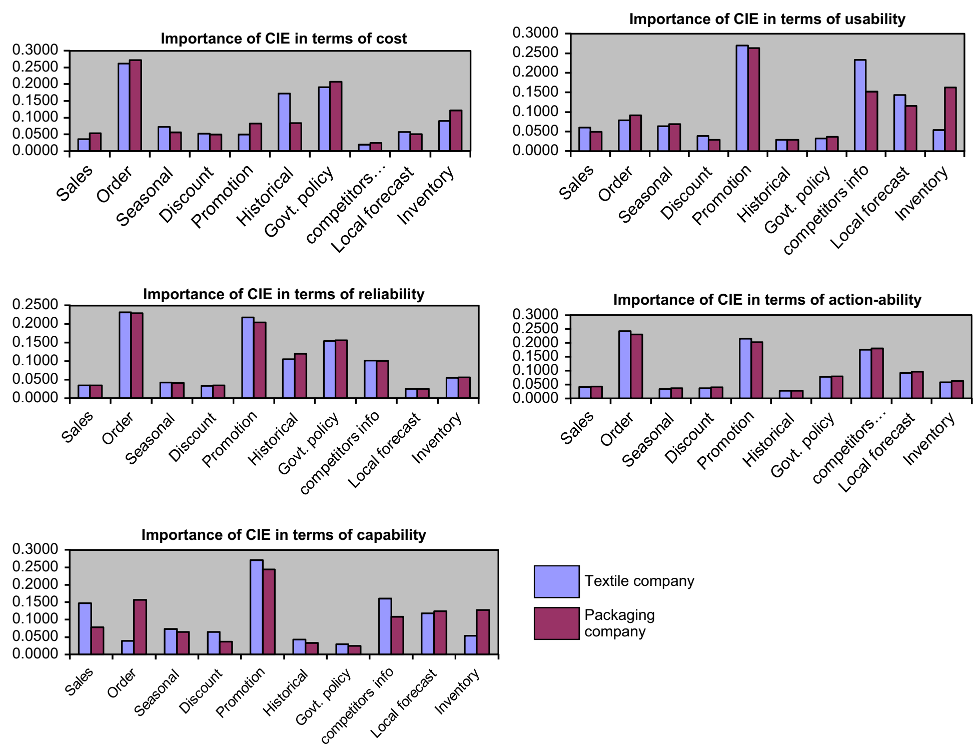

Fig. 3. Importance of CIE in terms of decision criteria.

The packaging materials were produced for orders from other manufacturers or retailers. Hence, the demand for the packaging materials was heavily dependent on customers' product and demand fluctuations. Some packaging materials meant for summer are not used in rainy seasons. The demand for special winter packs is quite high only before or during winter. Hence, the knowledge on impact of seasonal fluctuation in demand was deemed more useful by PackCo, with local weight of 0.07, compared to TexCo's 0.06. However, PackCo's forecast capability (local weight 0.0652) of using seasonal data was still not as high as TexCo's. This shows that PackCo necessitated recuperating its forecast capability to use seasonal data.

The case study has revealed that the discount data was used by TexCo in the case of delayed orders and for improvements in product design. For PackCo, the discount sale was nothing but an end-of-life sale. For PackCo, products' end-of-life was known through its inventory, as every pack had its expiry date, and hence the company could react quickly. With respect to AHP analysis, the action-ability on the discount data is equally preferred by both firms with a weight of around 0.04. However, the forecast capability of using the discount data was highly likely for TexCo, with a local weight of 0.0647 (refer to Fig. 3).

The promotions-related information was highly preferred by both firms. The local weight for promotional information in terms of usability by TexCo and PackCo was 0.27 and 0.26, respectively, but the reliability of promotional plans for PackCo was lower than that of TexCo.

The historical data related to sales, inventory or any other information was not considered highly valuable in CIE as it is not as beneficial, and the data is costly to obtain. Instead, the firm's own historical data is used for the purpose of forecasting. The information on government policy was not considered as influential as other data in CIE. Though some changes in the government policy have a minor impact on the demand, it does not directly affect the demand pattern significantly. Both firms preferred to know government data, because the cost of obtaining this data is very low. The usability is not very high, and hence more forecast capability is not required to analyze this information.

As the cost of obtaining competitors' information is very high, the preference to include this information in the SC decision making was not favoured by the firms. Nonetheless, TexCo was confident in its forecast capability (local weight 0.16) and the related usability (local weight 0.23) of using competitors' information.

In both case firms, the local forecast was observed by the customers individually based on their demand and this forecast figure was passed on to the suppliers. TexCo was collaborative with their customers over the past several years to obtain local forecasts. It is evident from the past history that the usability of local forecasts had a positive impact in improving the forecast accuracy. Both firms claimed that they had high forecast capability to use the local forecasts (local weight is around 0.12). Inventory data was more important for PackCo than TexCo in terms of usability. The local weight of 'usability' was more than double for PackCo with a score of 0.16, compared to TexCo's 0.05.

Although generalization of results based on AHP analysis is difficult, to reduce the amount of uncertainty of results, we included two focal companies and at least seven supply chain partners of these two companies. We have considered the collective opinions from interviews and the results of AHP analysis for further discussion.

6. Findings and discussion

6.1. Findings

The results of AHP analysis have been discussed with the case study companies and the reasons behind each result have been justified with their comments. Generally, the importance of data have been analyzed on the basis of their impact on forecasting accuracy. In practice, other factors affecting CIE are not directly dealt at the time of decision making. However, the results of AHP analysis has helped the firms to revisit their decisions on IS with their SC partners.

In the initial stage of the case study, sales data and discount data were not found to be an integral part of CIE for PackCo but they were found to be important for TexCo. The results of the analysis have also supported the same observation. This was due to the fact that the products of shorter shelf life need to be more reactive to the market [28]; hence the textile products have required both the sales and the discount sales data for forecasting the demand. Final priorities (refer to Table 2) of CIE were considered a combination of all the criteria. The discount data were designated as the least preferred data for TexCo with the rank of ten. Meanwhile, readily available order data was used effectively in both the firms. PackCo used its readily available order data in the first instance for the purpose of forecasting, which is highly preferred with a maximum weight of 21%.

The seasonal sales information was preferred equally by both firms at the time of non-availability of other sales data. Promotional sales information was found to be highly beneficial for TexCo, even if the cost involved in promotions is high. Historical data is not highly preferred by both the firms, and was ranked ninth. The basic reason for its lower popularity was that the historical data did not make much impact in improving the forecast, and incurred more cost in administration and data maintenance. However, historical data is seldom used for forecasting if it is owned by the firms. Usually, government policy on import, export, the use of raw materials, and any other specific changes is passed on to the firms through suppliers and customers, hence the basic communication between SC members will suffice to update this information.

A competitor's information is another costly input to use in forecasting, but TexCo might risk their attractive business opportunities in the absence of competitors' information. The choice of competitor's information in CIE was ranked second by TexCo. Involvement of the third parties in this exercise seemed to inflate the cost of obtaining competitors' information. Meanwhile, the anticipated usability of competitors' information seemed to be higher than the cost incurred. PackCo preferred to obtain competitors' information, with the final weight of 0.1190 (ranked third). Local forecast was found beneficial for both companies, irrespective of the cost involved. The final priority of the local forecasts was 0.1047 and 0.0839 for TexCo and PackCo, respectively. Tracking the customers' inventory was found useful to PackCo with the final weight of 0.103. At the same time, TexCo updated their database with sales and discount information; hence inventory position was not deemed important for its demand forecasting and its final weight was 0.0575.

From the results of the AHP analysis (refer to Table 2), it is clear that although both firms uses similar types of information for their planning and forecasting, they attached different priorities to the information. From this table, it is clear that TexCo preferred to use current data from their customers as it uses advanced technology for information sharing and forecasting (namely Blackberry and SAP). Hence, the firm preferred to have a high level of collaboration with customers. The forecast accuracy of textile products in the past three years was consistently in the range of 60–70%. However, PackCo claimed only 50–55% forecast accuracy. However, PackCo preferred to use the available data (order data) as it did not have the technical capability to obtain electronic sales data. PackCo seldom obtained details of promotions from retailers. Currently, they do not maintain higher levels of collaboration with the customers for CIE due to the cost involved. Both firms used their judgements in establishing a collaborative relationship with their partners based on the priorities of CIE and forecasting capabilities.

6.2. Further discussion

Collaboration between manufacturer and customers aims to have more flexible SC to react quickly to any changes in the demand. The information extent and intensity decides the degree of integration among SC partners [5]. The level of collaboration is generally based on the interdependency of each other in SC. Though CIE is instrumental in attaining collaborative forecasting accuracy, it widely varies depending on the use of information with respect to various criteria such as cost, reliability, actionability, forecast capability and usability. Every company should establish different levels of collaboration with partners based on their information need for CIE. The given AHP model in this paper

Table 2
Final priorities of CIE for TexCo and PackCo.

TexCo	Final weight	Rank	PackCo	Final weight	Rank
Promotion	0.2336	1	Order	0.2078	1
Competitors' information	0.1759	2	promotion	0.1852	2
Order	0.1546	3	Competitors' information	0.1190	3
Local forecast	0.1047	4	Govt. policy	0.1085	4
Govt. policy	0.0680	5	Inventory	0.1035	5
Sales	0.0647	6	Local forecast	0.0839	6
Inventory	0.0575	7	Historical	0.0517	7
Seasonal	0.0527	8	Seasonal	0.0512	8
Historical	0.0452	9	Sales	0.0496	9
Discount	0.0430	10	Discount	0.0396	10

can be used as basis for decision analysis of information need from each SC partner.

Interviews with top management personnel in the case companies revealed that the information from SC members may not be sufficient to sustain competition in volatile markets and hence the firms need to avail other information related to market and competitor from external sources. This led to conceptualizing the idea of forecasting information needs (refer to Fig. 4). Both the case companies have been contacted periodically to understand the forecast accuracy during the period of our study (30 months). Based on SC information needs of the company, the SC collaboration on IS can be precisely defined in three different levels to better understand the decision alternatives of CIE.

The basic level of collaboration [14] can be classified as preparatory communication level of collaboration. In the preparatory level, members of the SC can exchange order data and government policy. Sometimes this preparatory level may also require historical background details for new customers. Collaborative arrangement at this level may not require more investment in new technology set-up. The next level of collaboration is one step forward to preparatory level, which is called progressive level of collaboration. This supports the current existing collaboration and encourages further expansion in the partnership. The exchange of local forecast with reference to their forecast (such as seasonal data, discount sales data etc.) is essential. Use of standardised procedure in forecasting by all the members involved in CIE will improve the forecasting accuracy, and any discrepancy in a forecast figure can also be identified. However, the collaborating firms in this level need a considerable investment in new technology to gain access to CIE. The final and advanced level of collaboration needs to be futuristic collaboration. In addition to the progressive level data exchange, futuristic level will encourage CIE on promotions and all sales related data. An advanced technology is found essential to have futuristic collaboration as it includes more data transfer at this level, which attracts more investment.

7. Observations, conclusions and scope for future research

Demand uncertainty is instrumental in bringing all the SC members under one collaborative network. The varying demand makes planning, forecasting and a replenishment a complicated task. Timely information from retailers on product sales to manufacturers and then to suppliers will prepare them to serve for an unexpected demand situation: *companies should use demand indicators to improve forecasts and institute a system for tracking forecasting errors* [16]. To obtain timely information, investment in information technology is a crucial phenomenon for any SC decision maker. The importance of information in the process of CIE will decide the appropriate level of collaboration. The case study analysis presented in this paper has helped identify five factors influencing CIE, namely cost, usability, reliability, action-ability and forecast capability. With respect to these factors, various kinds of collaborative information used for forecasting were prioritized using the AHP model. Observations based on the case studies and the results of AHP analysis can be summarized as follows:

Observation 1. Prioritizing the information needed to enhance forecasting accuracy should be in line with the collaborative arrangement. This could avoid unwanted overload of information and also could reduce the cost of CIE.

The manufacturer using CIE for their forecast needs to identify the type of information they require and then try to prioritize information based on various criteria relevant to their business. This is essential to remove any *non-value adding* practice [20]. Once the

Level of collaboration	Information need: Supply chain members	Information need: Third party information providers
Preparatory Collaboration	Government policy (export & import, use of raw material etc.,) Order data Historical sales data	Back ground of collaborating company
Progressive Collaboration	Preparatory level information need + Local forecast (LF) Reference to LF • Seasonal • Historic • Inventory • Discount • Overall sales Inventory update	Competitors information & Market data
Futuristic Collaboration	Progressive level information need + Promotion information • Type of promotion • Period POS data	Competitors information & Market share, Sales trend etc.,

Fig. 4. Information need and level of collaboration in CIE.

collaborative information is hierarchically arranged the manufacturer can think of possible alternatives to improve existing collaboration or establish a new initiative to adopt appropriate collaboration (such as VMI or CPFR) to support their information need. This would help relating their investment policy on technology with the level of collaboration. From the case studies, it is clear that the use of appropriate communication technology reduces the ambiguity and increases the ability of handling more information in the process of forecasting. Incremental cost of technology may be compensated by improved benefits of SC. The information based culture was found to be one of the *enablers* and resources of collaboration [4]. Businesses with a less complicated demand structure can have preparatory or progressive collaboration; otherwise, it is better to have futuristic collaboration.

Observation 2. Investment in collaborative information technology plays a supportive role in CIE and forecast accuracy.

The ability of using appropriate information in the flow of CIE is made possible through enhanced technological advancement [25]. The observation made by Småros [42], that 'investment in collaboration technology is not a key obstacle to large-scale forecasting collaboration,' may be true for CIEs with relatively less variety of data. If a manufacturer intends to use all the data related to sales, order, local forecast and inventory, the magnitude of data handling in different aspects of business will be a complicated task and hence a higher level of technical support is essential.

The observation by Småros [42] on investment in collaboration technology is not valid in the two cases analyzed in this paper. PackCo very much understood the need for their lack of potential in handling huge and wide data sets and hence preferred to upgrade their technology to have efficient forecasting. TexCo upgraded their technology recently, and hence are confident in using all the relevant available data. TexCo also showed their interest in obtaining sales related information from their customers, as it would help to improve forecast accuracy irrespective of its direct relevance to profit contribution.

The observations and results of the two case studies were used to prioritize the SC information. Then a framework was developed that uses the priority information to decide an appropriate level of SC collaboration. It is believed that the framework developed in this paper will be useful for firms that are involved in CIE for forecasting to prioritize the value of information before investing in collaboration or technology. For instance, if promotional information is more valuable than order information in forecasting, then the firm can invest more in collaboration or technology to obtain the particular information.

This paper has suggested using AHP to identify the importance of each of the SC information. Using the most preferred information in demand forecasts, the accuracy of demand forecast can be enhanced. This is evident from the case company that improved the forecast accuracy in recent years. This research is based on two cases of manufacturing companies. To make the findings of these case results into a more generalized study, a greater number of cases need to be analyzed relating many types of manufacturers. This will help drawing a conclusion on the type of information need in CIE depending on the type of product. The case companies claimed their sustained forecast accuracy for the period of 2 years after using the most preferred SC information. In this line, our research can be extended through more empirical studies by collecting forecast and actual demand details for the past few years from companies involved in collaboration. As collaborative information exchange and forecast are very recent topics in the manufacturing sector, this empirical research will be a milestone.

To sustain a competitive edge in the marketplace, manufacturers need to know sales data and promotional plans from downstream members. Meanwhile, the relationship with the supplier is also equally important for a manufacturer to get raw materials on time so as to deliver goods to retailers at an agreed upon period. Research on the inclusion of suppliers in CIE and their impact in the demand forecasts could be a new perspective of looking at SC collaboration.

Appendix 1

The Analytic Hierarchy Process (AHP)

AHP was developed by Saaty in 1980. AHP is considered as one of the most powerful tools of complex decision analysis. Briefly, AHP can be explained through four basic steps [49].

Step 1: The decision problem is divided into a hierarchy of interrelated decision elements in setting up the decision hierarchy. In a simple AHP model, level one is the goal of decision problem. Level two comprises a set of criteria to decide decision alternatives with respect to the goal. Decision alternatives are included in level three which is the last level.
Step 2: Decision elements are compared pair-wise by collecting opinion and then entered into a square matrix.
Step 3: Relative weights of decision elements are found through 'eigen value' method. Steps 2 and 3 are repeated to derive local weights of criteria with respect to the goal and to derive local weights of decision alternatives with respect to each criterion.
Step 4: A set of rating for the decision alternatives are arrived at by aggregating the relative weights of decision elements.

The AHP method assumes that the evaluator does not aware of weight attached with each decision element. Hence, it is not

Table A1
The scale of measurement and average random index (RI) values used in AHP analysis.
Source: Saaty [39].

Intensity of importance									
1							Equal importance		
3							Slightly more importance		
5							Strong importance		
7							Very strong importance		
9							Highest possible importance		
2,4,6,8							Intermediate values		
Reciprocals of above non-zero numbers							Reciprocal effect of the above opinions		
Size of square matrix	1	2	3	4	5	6	7	8	9	10
Average RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

possible to produce the pair-wise relative weights of matrix A accurately. Then matrix A may have inconsistencies and which need to be check for. $AW=\lambda_{\max}W$ is true for all AHP models. Where, A is the observed matrix of pair-wise comparison, $\lambda_{\max}$ is the largest eigenvalue of A (where $\lambda_{\max}\geq n$), n is order of the matrix A and W is its right 'eigenvector' such that $W=(w_1,w_w, w_3,...,w_n)^T$, defined using the matrix equation $AW=\lambda_{\max}W$.

The closer the value of computed $\lambda_{\max}$ is to n, the more consistent are the observed values of A. This concept of $\lambda_{\max}$ is further developed into consistency index (CI) and consistency ratio (CR). The established relationship among CI, CR and RI are explained through $\mathrm{CI}=(\lambda_{\max}-n)/(n-1)$ and CR=CI/RI. Where, RI is random index, randomly generated weights (refer to Table A1 for value of average RI). Generally, the pair wise comparison approach is less sensitive to judgmental errors. A consistency ratio of 0.10 or less is considered acceptable [39]. Otherwise, it is recommended that matrix A be observed again to resolve consistencies in pair-wise comparisons. Finally, rating of decision alternatives is made through aggregation of relative weights of all levels in order to achieve the objective of the undertaken decision problem. Generally, scales used in AHP analysis are in the range of +9 to 1 and their reciprocals (refer to Table A1).

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