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GLOBAL SUPPLY CHAIN NETWORK: INTERMITTENT DEMAND, COLLABORATION MODEL AND INVENTORY CONTROL

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Keywords: *Forecasting accuracy, Collaboration models, Intermittent demand, slow movers, change management, obsolescence, inventory control, order fulfillment, inventory costs, performance Measurement, stochastic models.*

ABSTRACT

A fundamental aspect of supply chain management in many industries especially for automotive sector, is The inventory control of the products which have intermittent customer demand, it isessential for many organizations since its complexity makes it difficult to evaluateoverall performance, from customer demand to delivery and order fulfillment, Our research will contribute to the overall improvement of logistics flexibility by evaluating the effects of accurate forecasting on inventory control and performance improvement.

This paper discusses the various aspects of several researchers over slow moving inventory. Slow moving item constitute a large volume of firm items. The decision over the liquidation of some quantity of an on-hand stock slow moving items is an unpredictable one. Due to over stock situation, managing the slow moving or obsolescent items is the main problem for several industries.

The inventory control of the products which have intermittent demand is essential to many organizations, since excess inventory leads to high holding costs and stockout can have a great impact on operations performance. The difficulty in assessing good strategies for the management of these items lies in their specific nature. Since intermittent demands are highly stochastic and have a large percentage of zero values, the estimation of the lead time demand distribution is particularly intricate.

As part of a systematic approach we will start our research by a state of art to have an overview about the current studies on intermittent customer demand and inventory control especially for slow movers, phase in/out items, spare parts in order to evaluate the impact on the overall global supply chain of the company XYZ and its entire performance. Then a modified Markov chain model (MMCM) has been proposedfor modeling and estimating intermittent demand data, motivated by a case study (customer random behavior, slow mover and spare part control…).

The performance of Markov model and the other stochastic models have been compared by accuracy, Measures to show their effectiveness for more forecasting accuracy, customer fulfillment and inventory control of the products. The various strategies involving in the slow moving inventory like optimal level, forecasting and obsolescence are discussed. Further research on the slow moving inventory areas are suggested in this paper.

INTRODUCTION

Problematic description:

One of the most critical issues of inventory management is Customer demand (intermittent demand, request for change in product, process or phase in / out). Variation in demand increases the difficulty of determining the precise amount of inventory both to avoid stockout and to satisfy the customer fill rate. The inventory control problem is getting complicated by the fact that demand is uncertain or the variation of demand is highly volatile.

The most important factor that makes the demand volatile is the sequence of market changes and uncertainty reflected by customer demand , in one hand customer increase or decrease, change request of product , phase in/ phase out and in other hand The products which are not demanded very frequently, mostlyhave high percentage of zero demand. As consequence of this intermittent demand or customer changes lead to many inventory issues Such as increased consumption of raw materials and subassemblies or decreased consumption drives to slow moving items which are also referred to inventories that have a slower turnover ratethan the average turnover for

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the entire inventory. These items are classified aslumpy which means that there is great variability among the non-zero values. Theslow-moving demand with a large proportion of zero values is described as intermittent.

Many practical systems such as manufacturing and inventory systemsapplications are mostly used to model categorical data sequences. The paper aims to find out whether appropriate choice of collaboration model will enable the required inventory control leading to improved business outcomes and SCM KPI. Results indicate that firms that focus on flexibility, quality, and delivery should develop strategic collaboration with suppliers & customers to achieve market and innovation improvement. Cost- and quality-focused firms should develop operational collaboration to achieve resource efficiency. The model allows to understand the right alignment of external suppliers and customers being pursued to for key performance development and continuous improvement insight.

The research will follow in four sections:

1. S
tate of art:
1.1- The Intermittent customer demand and inventory control.
1.2- Research Background.
1.3- Synthesis of the current related research and the state of art knowledge**.**

2. T
he global supply chain network of manufacturing industry.

3. To validate the proposed mixed collaboration model for diversification of demand and inventory control.
The case study applied on the company XYZ in the automotive sector for the following purposes:
3.1- Proposal of a mixed collaboration model for the global supply chain for diversification of demand and inventory control.
3.2- Proposal of a mixed collaboration model for the global supply chain for diversification of demand and inventory control.
3.3- Model of Improved QFD.
3.3.a) Specific Procedures of Supplier Selection.
3.3. b) Build a Model of Supplier Selection Based on Improved QFD.

4. The final section covers a global overview about supply chain collaboration models: Limitations and Future Research.

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1. State of art

The Intermittent customer demand and inventory control.

In the literature, inventory management and demand forecasting are traditionally treated as independent problems. Most inventory papers ignore forecasting altogether and simply assume that the distribution of demand and all its parameters are known, while most forecasting papers do not evaluate the stock control consequences of employing different forecasting methods. The interactions between forecasting and stock control are analyzed in this paper for items with intermittent demand. The choice of forecasting method is shown to be an important determinant of the customer service that can be obtained from a given level of inventory investment.

The problem of slow moving parts in particular was initially investigated by Whitin and Youngs . Operations research methods have been continuously applied to inventory management problems after the World War II . Ever since 1915 work has progressed for smooth and continuous demand control of various stock keeping units, however it is not applicable for slow moving items. The main problem of the slow moving products is the lack of historical data .For Industry producing different types of products, large quantity of the items are typically slow moving items. These items should have intermittent demand character and uncertainty about the lead time. It is difficult to predict the reorder point of the slow moving items which results in the increased carrying costs. To avoid this problem, firm must know the manufacturing quantity and retention period of the inventory .Due to over stock situation, managing the slow moving or obsolescent items is the main problem for manufacturing, distribution and retail industries.. Every item should liquidate before the salvage value otherwise it will become obsolete. Effective inventory control method for slow moving items could be developed and implemented in order to improve the customer service and to reduce production, inventory and holding costs . A regular review reorder based inventory control system was inappropriate for slow moving items. In many periods the demand rate leads to zero replenishment level. Selecting the right periodic inventory system and determining how to forecast future demands of slow moving item is a major problem.

Forecasting for items with intermittent demand has received far less attention, even though such items typically account for substantial proportions of stock value and revenues. Intermittent demand items dominate service and repair parts inventories in many industries (including the process industries, aerospace, automotive, IT and the military sector), and they may constitute up to 60% of total stock value (Johnston, Boylan, & Shale, 2003). A survey by Deloitte (2011) benchmarked the service businesses of many of the world's largest manufacturing companies with combined revenues reaching more than $1.5 trillion; service operations accounted for an average of 26% of revenues. Thus small improvements in management of intermittent demand items may be translated to substantial cost savings; it is also true to say that research in this area has direct relevance to a wide range of companies and industries. In addition, intermittent items are at the greatest risk of obsolescence, and case studies have documented large proportions of dead stock in many different industrial contexts (Hinton, 1999; Syntetos, Keyes, &Babai, 2009; Molenaers, Baets, Pintelon, &Waeyenberg, 2010). Improvements in forecasting may be translated to significant reductions in wastage or scrap with further environmental implications.

Intermittent demand series are difficult to forecast because they usually contain a (significant) proportion of zero values, with non-zero values mixed in randomly. When demand occurs the quantity may be highly variable (Cattani, Jacobs, &Schoenfelder, 2011). Meanwhile the economic order quantity formula is the best well known one in inventory theory in which the demand should be uniform and lead time is constant. In this case shortages are not considered. In the case of slow moving items the demand seems to be fluctuating.

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In this paper the works of various researchers have been summarized and categorized into three levels for analysis which are Optimal stocking level, Forecasting and Obsolescence of a slow moving inventory items and concluded with various issues.

The figures below shows the various works on slow moving inventory, from the graph it is observed that more researchers have concentrated on identification of optimal stocking level of slow moving inventory in various industries followed by forecasting and obsolescence. Due to over stock situation, managing slow moving inventory is a main problem in the industry. To avoid this atmosphere, many of the researchers have been attempted their research work on optimal stocking level of slow moving inventory compared to other problems.

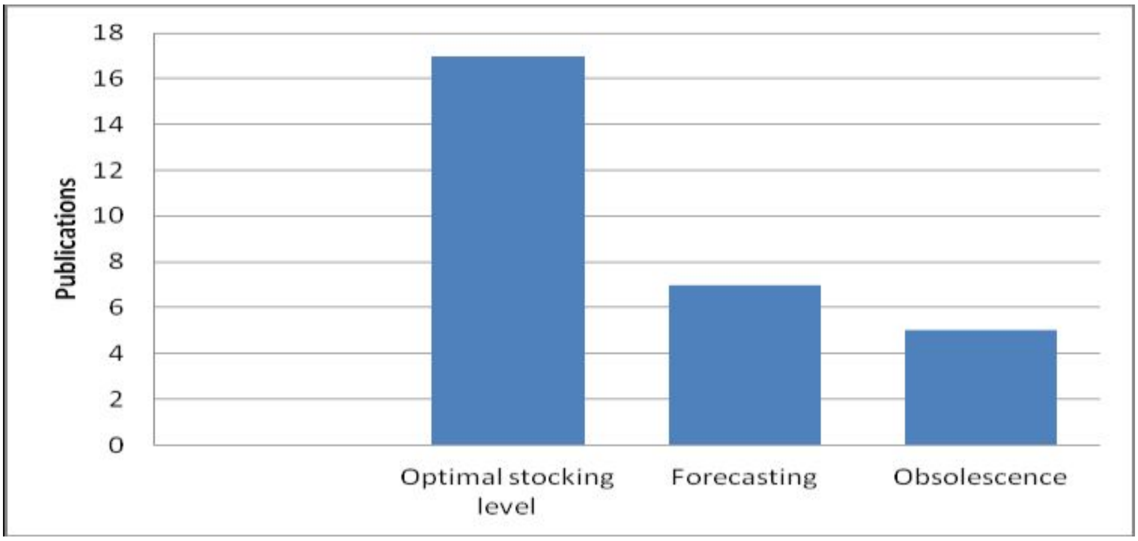

Fig. 1.Various works on slow moving inventory

Research Background

Two parametric methods, simple exponential smoothing (SES) and Croston's (1972) method with corrections by Rao (1973), are widely used to forecast intermittent demand. SES forecasts the mean level of demand for both non-zero and zero demand periods, treating them in the same way, while Croston makes separate forecasts of the mean level of non-zero demand and the mean inter-arrival time (time between demand occurrences). Croston assumes that the distribution of nonzero demand sizes is normal, the distribution of inter-arrival times is geometric, and that demand sizes and inter-arrival times are mutually independent. Shenstone and Hyndman (2005) challenge these assumptions and show that Croston's method is inconsistent with the properties of intermittent demand data. The primary problem is that Croston's method assumes stationarity, while any possible model underlying the method must be non-stationary. Furthermore, the underlying model must be defined on a continuous sample space that can take on either negative or positive demand values, something that is inconsistent with the reality that demand is always non-negative.

Despite its theoretical shortcomings, Croston's method has been successful in empirical research (see the review in Gardner, 2006) and is widely used in practice. Both Croston and SES are available in demand planning modules of component based enterprise and manufacturing solutions (e.g. Industrial and Financial Systems – IFS AB) and in integrated real-time sales and operations planning processes (e.g. SAP Advanced Planning and Optimisation).

Many improvements to Croston's original method have been published, including Johnston and Boylan (1996), Snyder (2002), Syntetos and Boylan (2005), Shale, Boylan, and Johnston (2006), and Teunter, Syntetos, and Babai (2011). The Syntetos and Boylan method (known as the SBA method for Syntetos-Boylan Approximation), is the only Croston improvement that has substantial empirical support. Although Croston claims that his method is unbiased, Syntetos and Boylan (2001) show that the opposite is true and present an improved method that corrects for bias (Syntetos& Boylan, 2005). The SBA method was tested by Eaves and Kingman (2004) using a sample of more than 11,000 monthly repair parts demand series from Royal Air Force

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(RAF) inventories. The results varied somewhat depending on the degree of aggregation of the data (weekly, monthly, quarterly) and the type of demand pattern (ranging from smooth to highly intermittent). However, in general the SBA method was more accurate than SES and the original Croston method. Another study by Gutierrez, Solis, and Mukhopadhyay (2008) reaches similar conclusions. In the empirical study below, all three parametric alternatives are tested: SES, Croston's original method, and the SBA method.

Given the parametric point forecasts, a demand distribution is needed to set inventory levels. Both the Poisson and Bernoulli processes have been found to fit demand arrivals, i.e. the probability of demand occurring (Dunsmuir & Snyder, 1989; Willemain, Smart, Shockor, &DeSautels, 1994; Janssen, 1998; Eaves, 2002). Regarding the size of demand when it occurs, various suggestions have been made for distributions that are either monotonically decreasing or unimodal positively skewed. With Poisson or Bernoulli arrivals of demands and any distribution of demand sizes, the resulting distribution of total demand over a fixed lead time is compound Poisson or compound Bernoulli, respectively. Compound Poisson distributions are simpler and have empirical evidence in their support (e.g., Boylan &Syntetos, 2008). In this empirical study, demand is modeled with the Negative Binomial Distribution (NBD), which performed well in the empirical study by Snyder, Ord, and Beaumont (2012). The NBD is a compound distribution in which the number of demands in each period is Poisson distributed, with random demand sizes governed by a logarithmic distribution.

As the data become more erratic, the true demand size distribution may not conform to any standard theoretical distribution, and it may be that non-parametric approaches (that do not rely upon any underlying distributional assumption) may improve stock control. Numerous bootstrapping methods are available to randomly sample (with or without replacement) observations from demand history to build a histogram of the lead-time demand distribution. Alternative bootstrapping methods are found in Efron (1979), Snyder (2002), Willemain, Smart, and Schwarz (2004, hereafter WSS), Porras and Dekker (2008), Teunter and Duncan (2009), Zhou and Viswanathan (2011), and Snyder et al. (2012). The most robust bootstrapping method appears to be that of WSS, a method patented earlier by Willemain and Smart (2001).

In a large empirical study, WSS claims significant improvements in forecasting accuracy over both SES and Croston's estimator. However, Gardner and Koehler (2005) criticize this study because the authors do not use the correct lead time demand distribution for either SES or Croston's method, and they do not consider published improvements to Croston's method, such as the SBA method (see Willemain et al., 2005, for a rejoinder).

One empirical study, by Teunter and Duncan (2009), Using a sample of demand series for military spare parts, Teunter and Duncan compare the inventory and service tradeoffs that result from forecasting with the same parametric methods tested below. They also test a simple bootstrapping method in which they sample lead time demand with replacement to estimate mean and variance, which are then fed into a normal distribution to set stock levels. Reliance on the normal distribution defeats the purpose of bootstrapping, which does not require a distributional assumption.

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Tableau 1.3: Synthesis of the current related research and the state of art knowledge

Auteur	Keywords	Issue	Description	Result	Reference
UmayUzunogluKocer	Forecasting, Intermittent, Lead time, Markov chain model, Transition probability	Intermittent demand and inventory control	The intermittent demand pattern is irregular, the estimation of the lead time demand is challenging. A modified Markov chain model has been proposed for modeling and estimating intermittent demand data, The performance of markov model and the traditional methods have been compared by accuracy measures. The results reveal that the proposed method is a good competitor or even better than other methods.	As a result, although higher order Markov chain models are mostly used to model categorical data sequences, the characteristics of the intermittent data enable us to use this method to obtain accurate forecasts. For the intermittent demand structure the sequence of demand is critical as well as the percentage of zero values and the mean of non-zero demands. Modified Markov chain model makes possible to forecast both the sequence and the values of demand. The accuracy measure r, which measures the consistence, was computed as 0.50 on the average for the forecast values. In this case we can conclude that the forecast values reflect the real data pattern well and can be used for effective inventory management.	[1] E. A. Silver, Operations research in inventory management: A review and critique, Operational Research, vol.29, pp.628-645, 1981. [2] T. R. Willemain, C. N. Smart and H. F. Schwarz, A new approach to forecasting intermittent demand for service parts inventories, International Journal of Forecasting, vol.20, pp.375-387, 2004. [3] E. Ferrari, A. Pareshi, A. Regattieri and A. Persona, Statistical management and modeling for demand of spare parts, Springer Handbook of Engineering Statistics, vol.3, pp.905-929, 2006. [4] E. Porras and R. Dekker, An inventory control system for spare parts at a refinery: An empirical comparison of different re-orders point methods, European Journal of Operational Research, vol.184, pp.101-132, 2008. [5] W. Ching, E. Fung and M. Ng, A higher order Markov chain models for categorical data sequences, Journal of Operational Research Society, vol.54, pp.291-298, 2008.
Aris A. Syntetos M. ZiedBabai Everette S. Gardner, Jr.	Inventory management; Operations forecasting; Time series methods	Forecasting Intermittent Inventory Demands: Parametric Methods and performance Measurement	Intermittent demand items dominate service and repair parts inventories in many industries, research in forecasting such items has been limited. A critical research question is whether one should make point forecasts of the mean and variance of intermittent demand with a simple parametric method such as simple	The WSS method of bootstrapping does have advantages, most notably the ability to simulate demand values that have not appeared in history. However, it is questionable whether the WSS method is worth the considerable added complexity. Parametric methods are simpler, 18 and the simplest method of all, SES, performs well. In the electronics data, SES produces fewer backorders than WSS at all	Babai, M.Z., Ali, M., &Nikolopoulos, K. (2012). Impact of temporal aggregation on stock control performance of intermittent demand estimators. OMEGA: international Journal of Management Science, 40(6), 713-721. 20 Boylan, J.E., &Syntetos, A.A. (2008). Forecasting for inventory management of service parts. In D.N.P. Murthy, & K.A.H. Kobbacy (Eds.), Complex system maintenance handbook.

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			exponential smoothing or else employ some form of bootstrapping to simulate an entire distribution of demand during lead time. The aim of this work is to answer that question by evaluating the effects of forecasting on stock control performance . Tradeoffs between inventory investment and customer service show that simple parametric methods perform well, and it is questionable whether bootstrapping is worth the added complexity	levels of inventory investment. Parametric methods require less computing power, which is important when demands for very large numbers of SKUs have to be forecast. Parametric methods also require less specialist knowledge and thus are more transparent and more resistant to potentially damaging judgmental interventions. An alternative strategy to deal with intermittent demand patterns is to aggregate demand in lower-frequency time buckets thereby reducing the presence of zero observations.	London: Springer Verlag, 479-508. Brown, R.G. (1959). Statistical forecasting for inventory control. New York: McGraw-Hill. Cattani, K.D., Jacobs, F.R., &Schoenfelder, J. (2011). Common inventory modelling assumptions that fall short: Arborescent networks, Poisson demand, and single echelon approximations. Journal of Operations Management, 29(5), 488-499.
Thomas R. Willemain Charles N. Smart Henry F. Schwarz	Accuracy; Bootstrapping; Croston's method; Exponential smoothing; Intermittent demand; Inventory; Spare parts; Service parts	Forecasting intermittent demand for service parts inventories	A fundamental aspect of supply chain management is accurate demand forecasting. We address the problem of forecasting intermittent (or irregular) demand, i.e. random demand with a large proportion of zero values. This pattern is characteristic of demand for service parts inventories and capital goods and is difficult to predict. We forecast the cumulative distribution of demand over a fixed lead time using a new type of time series bootstrap. To assess accuracy in forecasting an entire distribution, we adapt the probability integral transformation to intermittent demand. Using nine large industrial datasets, we show that the bootstrapping method produces more	We compared exponential smoothing and Croston's method with the bootstrap on the basis of the uniformity of observed LTD percentiles. For each of the nine industrial datasets, we compared the three methods using lead times of 1, 3 and 6 months. The results of the accuracy comparisons. We analyzed the logarithms of the chi-square values using fixed-effects ANOVA, with forecasting method, lead time, and company as factors: 1. The bootstrap method was the most accurate forecasting method. 2. Despite its ability to provide more accurate estimates of mean demand per period, Croston's method had no statistically significant advantage over exponential smoothing at forecasting the entire LTD distribution; in fact, Croston's method was slightly less accurate at every lead time. 3. The accuracy of the bootstrap method decreased	Bagchi, U. (1987). Modeling lead-time demand for lumpy demand and variable lead time. Naval Research Logistics, 34, 687 – 704. Bier, I. J. (1984). Boeing commercial airplane group spares department: simulation of spare parts operations. Detroit, MI: ORSA/ TIMS Joint National Meeting. Bookbinder, J. H., &Lordahl, A. E. (1989). Estimation of inventory re-order levels using the bootstrap statistical procedure. IIE Transactions, 21, 302 – 312. Buffa, E. S., & Miller, J. G. (1979). In 3rd ed, Production –inventory systems: Planning and control. Homewood, IL: Irwin. Bu¨hlmann, P., &Ku¨nsch, H. R. (1995). The blockwise bootstrap for general parameters of a stationary time series. Scandinavian Journal of Statistics, 22, 35 – 54.

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			accurate forecasts of the distribution of demand over a fixed lead time than do exponential smoothing and Croston's method.	with lead time, which is to be expected; however, the bootstrap remained the most accurate of the three methods even at a lead time of 6 months. 4. Lead time had little effect on the accuracy of exponential smoothing and Croston's method. This surprising result might be caused by offsetting factors: accuracy should decrease with lead time, but the normality assumption should improve as more demands are summed. 5. the bootstrapping approach to forecasting intermittent demand is a powerful new option, we recognize that there remain several difficulties and unsolved problems.	
Ulrich Küsters Holger Kömm	Agriculture ARIMA modelsGARCH modelsMixture modelsPrice forecasting Time seriesVolatility forecasting Zero-inflated models	Forecasting zero-inflated price changes with a Markov switching mixture model for autoregressive and heteroscedastic time series	The weekly changes in prices of several German milk-based commodities exhibit not only traditional patterns such as mean dependence and volatility clustering, but also a high frequency of zero changes that cannot be explained by well-known ARIMA-GARCH models. We therefore develop a new mixture model which combines the elements of zero-inflated models that are common in micro-econometrics and intermittent demand forecasting with a traditional ARIMA(1,1,0)-GARCH(1,1) model. We describe the model components, the data generation processes, the maximum likelihood estimation techniques, and the generation of	a new mixture model developed thatcombines the elements of zero-inflated models that are common in micro-econometrics and intermittent demand forecasting with a traditional ARIMA(1,1,0)-GARCH(1,1) model. We describe the model components, the data generation processes, the maximum likelihood estimation techniques, and the generation of forecasting distributions and point forecasts by resampling techniques. The model is applied to a low frequency weekly time series of skimmed whey powder (SWP). Competing sub-models are compared using the Akaike information criterion (AIC).	Christoffersen, Peter, (1998), Evaluating Interval Forecasts, International Economic Review, 39, (4), 841-62 Hyndman, Rob and Anne B. Koehler, (2006), Another look at measures of forecast accuracy, International Journal of Forecasting, 22, (4), 679-688 Lee, Lung-Fei, (1999), Estimation of dynamic and ARCH Tobit models, Journal of Econometrics, 92, (2), 355-390 Pesaran, M and Allan Timmermann, (1992), A Simple Nonparametric Test of Predictive Performance, Journal of Business & Economic Statistics, 10, (4), 561-65

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			forecasting distributions and point forecasts by resampling techniques. The model is applied to a low frequency weekly time series of skimmed whey powder (SWP). Competing submodels are compared using the Akaike information criterion (AIC). Furthermore, in addition to the evaluation of the out-of-sample forecasting performance, several coverage and independence tests are also computed.		

2. The global supply chain network of manufacturing industry.

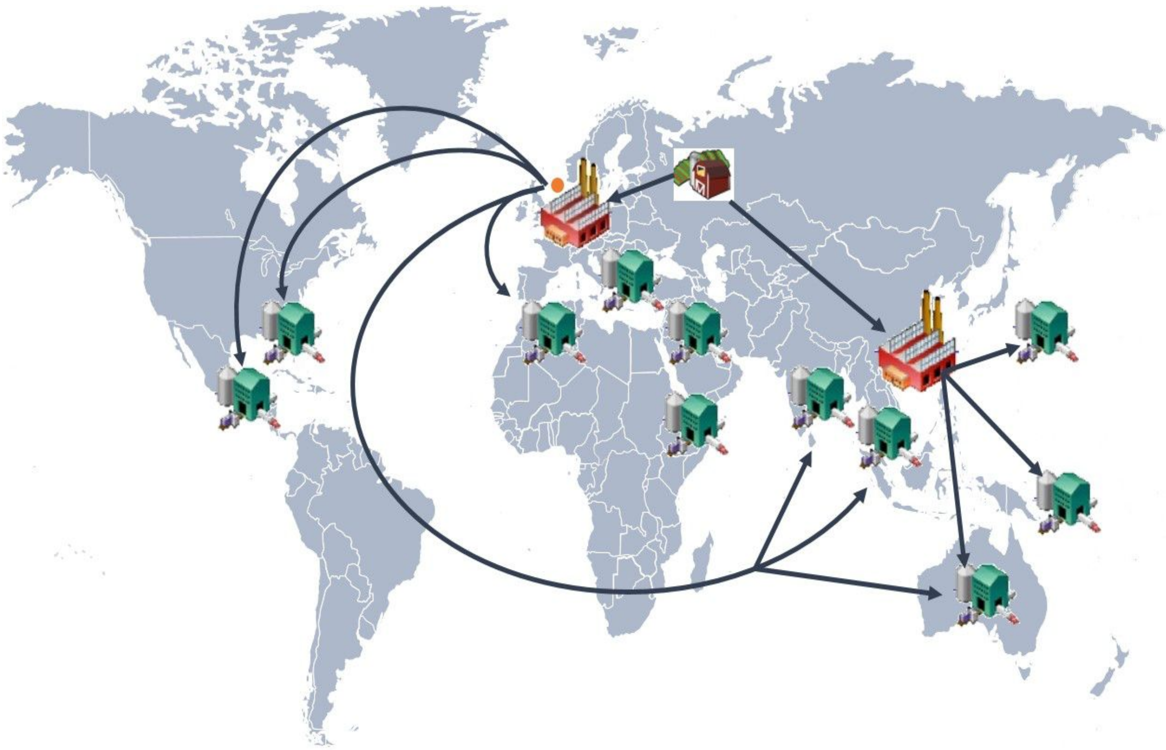

Fig.2:Example of global supply chain network in manufacturing industry.

With manufacturers throughout the world confronted by increasing prices for fuel, natural resources and raw materials, the need for process optimization and efficiency has come into sharp focus. Production has become spread ever more widely around the globe. This trend will only intensify in the manufacturing industry; this trend is driving increased complexity in supply chains, as identified in a recent study by APICS and Michigan State University. Today, a product moves from manufacturer to supplier to distribution center, and on to the

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retailer, before eventually reaching the end customer, often crossing multiple borders in the process. This complexity demands an agile and transparent supply network which provides clear visibility of a product's whereabouts and other crucial information.
For manufacturers to optimize processes and retain a competitive edge, we must take a deep analysis on customer behavior and market changes and new technologies tendency.
One of the most important factor that makes the demand volatile is the sequence of market changes and uncertainty reflected by customer demand is The *PPCM (Product and Process Change Management)* describes and regulates the flow of product and process changes of products, which are in serial production. The change requests are incorporated either external (customer or supplier) or applied internally by various departments. Before a change can be implemented, the change request is checked on the feasibility of technical and monetary aspects. When a customer disposes a change requests corresponding tenders takes place.
And there is two types of changes:

- ***Internal change:*** All changes, which are started by internal departments. These can be customer relevant but don't have to.
- ***External change***: All changes, which are started by external customers or by the direct suppliers of the customer.

Overview of the PPCM process:
Below an overview about the PPCM(Product and Process Change Management) process:

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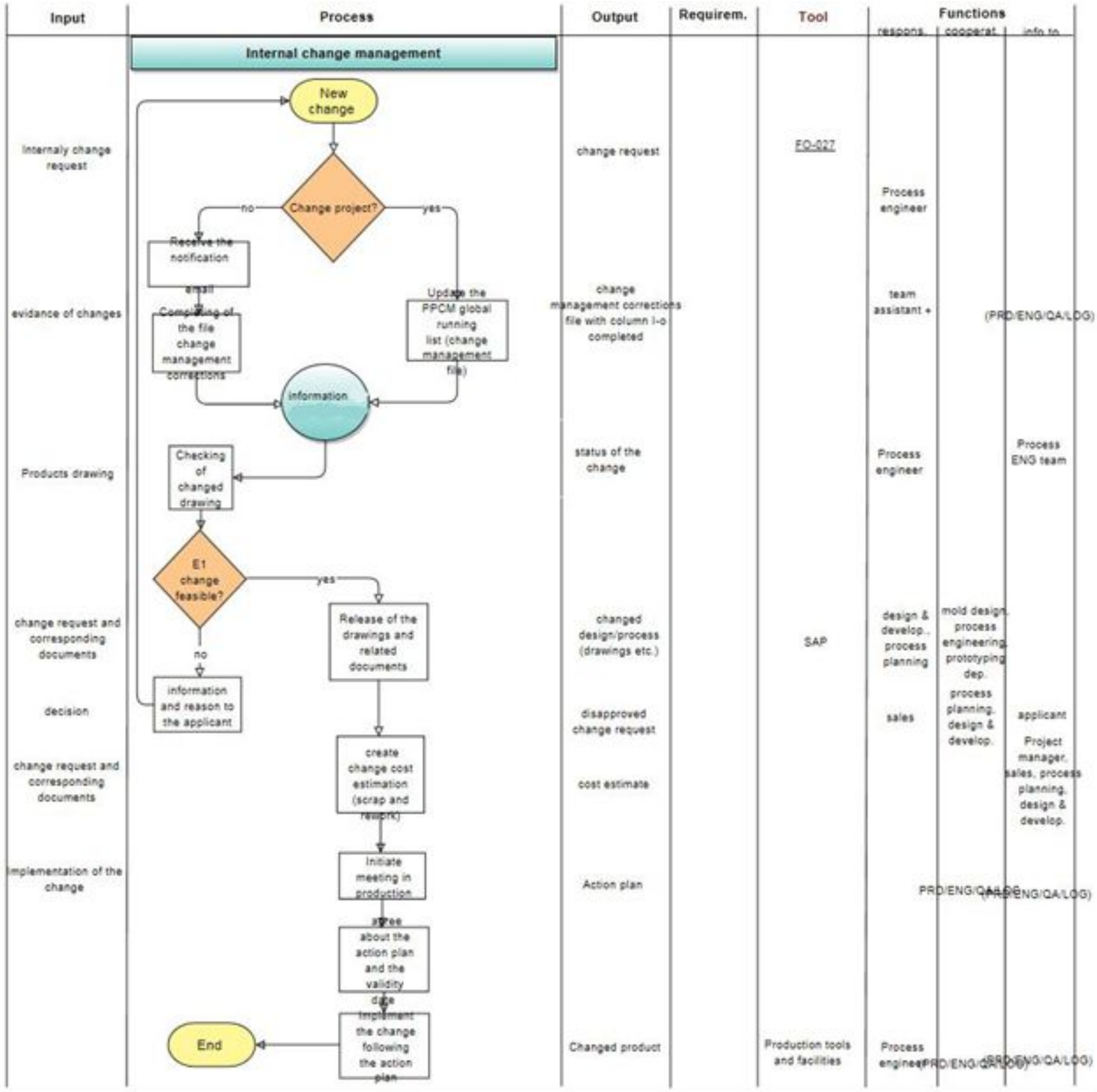

Fig.3: Overview about the PPCM (Product and Process Change Management) in manufacturing industry

3. To validate the proposed mixed collaboration model for diversification of demandand inventory control.

- **The case study applied on the company XYZ in the automotive sector for the following purposes:**

To define parameters impacting the inventory control.

One of the crucial element that determine the key performance index on supply chain is the inventory control which is directly impacted by the customer intermittent demand which is relevant to talk about the *PPCM (Product and Process Change Management).*
Moreover to have an overview about the impact of the product and process changes this is requested by internal or external customer / supplier affecting:

- The product design.
- Change of the product drawing.
- Change in the production process.
- Change of the technical or functional use of the product: (length, ergonomic, life cycle…).
- The phase in of new article and the phase out of old one.
- Finished good component changes.
- *BOM (Bill of material)* change.
- Change of supplier/ customer product.

The list of the above parameters drive to many consequences and effects that directly impact the global supply chain key performance especially the inventory control such as :
a) Increased stock value of slow moving parts.
b) The increased stock value of the run out / obsoleted articles
c) The decreased demand of the old articles.
d) The overlapping order between the new and old article.
e) Increased stock leftover of the old article after change implementation.
f) High scrapping value of the old article.

Excessively gathered stocks consist of either obsolete parts, which currently are not used or any further customer demand of this article, and the ones which are excessively gathered, i.e. not adjusted to the level of use. A high level of slow movers or obsoleted parts which are maintained in enterprises are frequently not justified economically since this stock corrode or shelf life but, most of all, freeze capital. The main reasons of the occurrence of excess and obsolete inventory, below an overview about stock evolution of slow movers due to customer change from high runner article to slow mover one, and this change drive to the below status which affect directly the stock level value:

- <u>*Increased stock value of slow moving parts.*</u>

Belowan overview about slow moving stock evolution, impacted by customer product change, during one year observation period.

	M 01	M 02	M 03	M 04	M 05	M 06	M 07	M 08	M 09	M 10	M 11	M 12
Stock Value €	€ 412.351	€ 454.712	€ 641.201	€ 658.412	€ 800.147	€ 974.125	€ 1.087.412	€ 1.148.723	€ 1.247.819	€ 1.472.310	€ 1.523.178	€ 1.563.108

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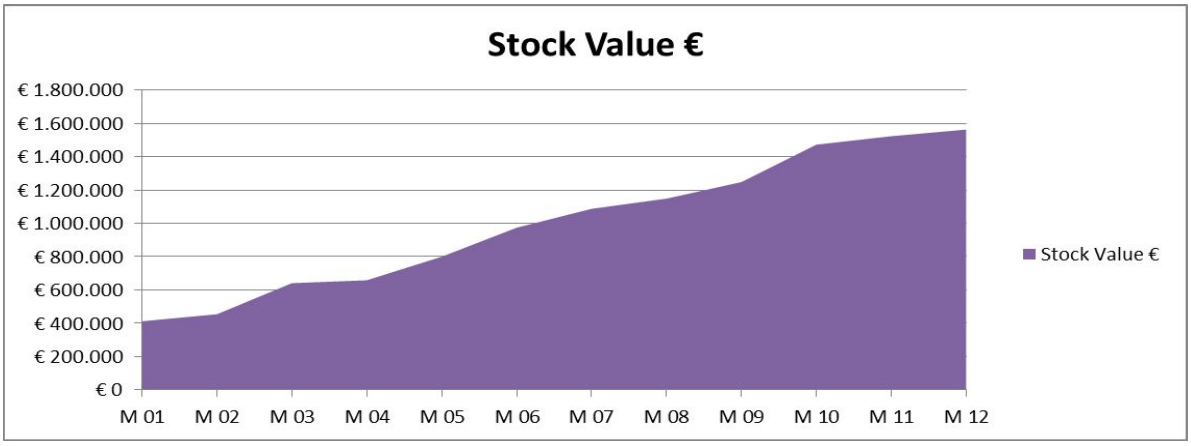

Fig.4: Slow movers stock evolution during one year observation period.

This study case shown that the customer change product is directly impact the global stock inventory of the company XYZ, due to the decreased demand of the old articles which increased the slow moving stock value compared to the company XYZ regular stock.

- *The stock evolution of run out parts / obsoleted parts:*

Belowan overview about run out or obsoleted parts, impacted by customer product change, during one year observation period.

Basing on the figures below we could conclude that the customer change product is directly impact the global due to the run out/ obsoleted parts of the old articles which increased the obsolete stock value compared to the regular stock.

Fig.5: Stock evolution of run out parts / obsoleted parts during one year observation period

- *Stock Overview :*

The below figures shown that the global stock includes:

	Stock ratio
Regular stock	77%
Stock without demand within 365 days	12%
Slow mover > 365 days	8%
Obsoleted parts	3%
Total stock	100%

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Fig.6: The global stock overview during one year observation period

The impacted stock by customer change products of slow moving, obsoleted parts and articles without demand within 365 days, are representing more than 20 % of the global stock of the company XYZ during one year observation period.

This amount of stock leaded by many parameters:

- The production overproduction of the old version of the article.
- The lack of communication between different supply chain actors.
- The inaccuracy of customer forecasts.
- The customer volatility.
- The customer / supplier change request in firm zone agreement…

Proposal of amixed collaboration model for the global supply chain for diversification of demand and inventory control

With the economic globalization and diversification of demand, the lifecycle of product is becoming increasingly shorter and the uncertainty of market is increasingly higher. The supply chain collaboration refers to mutual coordination and endeavor by supply chain enterprises in order to improve the overall competitiveness of supply chain. In the supply chain collaboration, the supplier selection is the key issue.

Currently, the research methods regarding supplier selection mainly include ABCcost method, linear planning method, AHP, fuzzy comprehensive evaluation method, neural network method, TOPSIS method, DEA method, principal component analysis method, grey comprehensive evaluation method, integrated application of these methods, and so on. The shortcoming of these methods lies in that they do not take customer demand into the supply chain consideration, and it is therefore a must to start from the customer demand so as to build a reasonable, effective model of supplier selection.

a) E-collaboration tools for new-product development :

Numerous firms reported how successfully they use the e-collaborative tools in evaluating new products at different stages. These tools reduce the design time because firms evaluate and modify their new designs faster and can make changes more rapidly and earlier in the NPD (new-product development) process without changing the product design repeatedly. The electronic collaboration in GVTs (global virtual teams) helps firms bring together information located in various parts of the world. On the other hand, it can remove the socialization aspects of human communication. To compensate, some studies recommend that GVTs meet face-to-face at the early stages of the NPD project so they can build better relationships, develop trust and establish common understanding which will later improve their performance.

Different types of technologies support e-collaboration among the GVT members. Examples of e-collaboration technologies are websites, instant messaging, groupware including e-mail, databases, discussion arenas, bulletin boards and calendars, videoconferencing, weblogs and Wikis. It is accepted that there is a large selection of e-collaboration tools which require that the team members are proficient in a new kind of literacy – relating todocument formats such as forms, graphs, charts and maps and also visual representations such as images, graphics, and video and audio presentation of information.

In the context of new-product development, several functional teams are involved and a vast number of technologies ensure efficient interactions between them. With the advent of Web-based tools, collaborative engineering encompasses technical and social aspects of product development.

Technologies such as CAD systems or other systems that facilitate communication and coordination are critical to the integration of partners in the product-development process.

Collaborative engineering encourages design teams involved in a relationship to create and maintain joint processes, but also to develop decision-making models that focus on knowledge transfer and management.

These challenges have pushed firms to adopt different e-collaboration tools for communication, but also for dedicated tasks such as document-sharing,project management and technical communication.

b) Determinants of the use of e-collaboration tools :

While a significant body of research on the benefits of e-collaboration toolsis steadily increasing, one of the areas that requires more research attentionis the understanding of the determinants of use of e-collaboration tools.

Examined team effectiveness in terms of relationship between technology use, primary choice of communication medium and group conclusions. They also looked at how structural characteristics such as tasks, organizational culture and team characteristics interacted with technology. Their findings suggest that a global team's most effective use of technology will be shaped by the dimensions of the team'stask and its context. Inprevious work, showedthat the benefits of using a more complex medium increased as the tasks became morecomplex. Other research on GVTs has mostly focused on the role of cultural diversity and its influence on teams' communication patterns.

Other characteristics such as differences in language, traditionand cultural values may make effective communication more difficult Training is another issue that has been suggested as supporting the performance of GVTs, most notably in communication usingelectronic media.

c) Performance improvements derived from e-collaboration tools:

E-collaboration tools bring people together to work on interdependent tasks without taking into account the geographic, temporal or organizational barriers.

The teams' members are assigned according to their knowledge, skills and abilities. This certainly allows an organization to enrich the pool of its resources at a more effective cost.

Furthermore, since the pool of knowledge is more diversified, interactions between team members with different professional and cultural backgrounds foster creativity, since creativity mainly happens as a direct result of interaction.

Because of the global distributed nature of business today and the technical advancements of e-collaboration tools, organizations with global teams can react in a more responsive way all over the world. While e-collaboration tools offer all these benefits, a good understanding of these tools is necessary for the management to ensure effectiveness. A team's extent of virtualness (its use of e-collaboration tools) depends on the nature of the task, the technological resources and members' skills and capabilities. Because global VTs live and work in different countries, cultural diversity, language differences and varying IT sophistication become important variables to consider while studying the use of e-collaboration tools.

In the context of complex product development, there is a significant level of product and engineering data, process uncertainty and frequent engineering changes. Firms are actively seeking more sophisticated e-collaboration tools to effectively manage product engineering, thus enabling them to control design and engineering and measure progress during the development process. Product lifecycle management (PLM) seems to be a powerful tool supporting this endeavor. PLM is an approach that supports both engineering data (drawings, project plans and part files) and the product-development process during the total product life-cycle. Product data is accessible to different GVT members, allowing them to effectively collaborate, which leads eventually to a shorter development cycle and reductions in time and cost for organizations. Although attempted to measure the impact of e-collaboration on the performance of individual firms acting along the different modes of a supply chain, the measurement of supply-chain performance is plagued with difficulties and our common understanding of such measures remains incomplete.

Model of Improved QFD:
QFD is an important comprehensive planning tool, which converts customer demandinto the technical requirement of each link in production while the house of quality is the major tool for such series of conversions, and thus the application of QFD method here mainly means that of the house of quality.

For improvement of core competitiveness of supply chain, the core enterprises alwaysneed to outsource some parts, which requires the enterprises to make a choice between different suppliers supplying the parts of the same kind; however, the traditional methods often cannot combine customer demand in the supply chain, enabling the whole evaluation system to lose its target, especially the personalized customer demand requesting modern manufacturing enterprises to respond rapidly, and the customer demand therefore needs to be combined as the supplier is selected. Therefore, the improvement of traditional house of quality must be done.

The supplier selection model based on improved QFD is obtained through tailoring,adding and deepening by the restructured house of quality according to the demand in supplier selection on the basis of traditional house of quality, as shown in Fig. below:

	Evaluation and selection index system	
Customer demand	Relation matrix	Customer demand weight
	Weight of index	
Supplier	Score	Total score

Fig.7: The model of supplier selection based on improved QFD.

In this research, the technical demand is to be replaced by the index system of supplier selection. The elements in the relation matrix is generally marked with four common symbols including ⊙, ○, △ and × to represent the relation between customer demand and index system of supplier selection: strong correlation, intermediate correlation, week correlation and no correlation. Furthermore, the technical competitiveness evaluation module in traditional house of quality is replaced by evaluation module of supplier.

a) Specific Procedures of Supplier Selection :

- **Build a Comprehensive Evaluation Index System of Supplier Selection :**

At first, starting from various demands of customers of core enterprises, classify purchase materials in 80/20 principle (Pareto Principle) taking into consideration cost of purchase materials, supply risk and importance and enthusiasm of supplier and then classify the suppliers.

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There are various comprehensive evaluation indexes of supplier. This paper comprehensivelyreflects the traditional indexes such as quality, date of delivery, price and service with combination of quantitative and qualitative principles, along with such indexes as supply flexibility of suppliers, enterprise culture and environmental protection level that embody core competitiveness of enterprises.

The index system is divided into two classes, where the first-class index is divided into quality index, price index, delivery index, enterprise comprehensive index and production capacity index. According to the different emphases to evaluating indexes, the items in first-class index can be future subdivided, as shown in Figure below:

Fig. 8: The index system of supplier selection.

- **Obtain Customer Demand in Supply Chain:**

To obtain customer demand is the key in QFD process. The core enterprise in supplychain considers part of suppliers as its "virtual factory" and hands over its parts or componentscompletely to the supplying enterprises for production. With competition andchange of market, the customer-directed demand of the core enterprise will unceasinglyupdate and change, and therefore make demands to the suppliers in supply chain.

Through investigation, the common table of customer demand is shown in Figure below:

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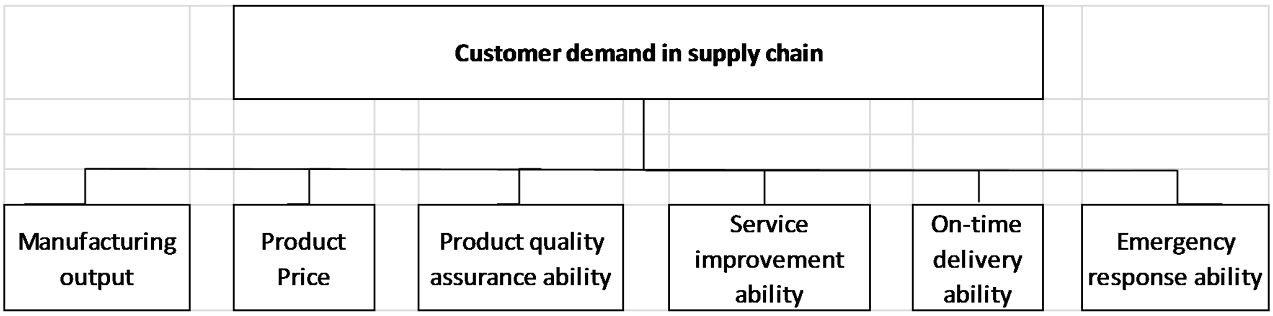

Fig. 9:The Table of Customer Demand

b) Build a Model of Supplier Selection Based on Improved QFD:

- **Formulate a Relation Matrix:**

In accordance with the above established model of supplier evaluation and selectionbased on improved QFD, formulate the two dimensional table of relation matrix betweencustomer demand in supply chain and evaluation index of supplier, and useseparately the symbols of ⊙, ○, △ and × to represent the relevant relations betweeneach evaluation index and different customers.

- **Determination of Importance of Customer Demand:**

The importance of customer demand is an extremely important quantitative index inQFD. The quantitative grading on each demand can show the importance of each demandto customers. The writer recommends adopting AHP method to quantize theimportance of customer demand and then determine the absolute importance mi ofeach customer demand.

- **Importance Conversion:**

The importance conversion means to convert the importance of customer demand (weight) to the weight of each evaluation index by use of the corresponding relations established by the house of quality. The weight of each evaluation index mjis obtained through direct multiplying of the weight of customer demand and numerical values of ⊙, ○, △ and × by use of independent collocation method. The numerical values of ⊙, ○, △ and × therein are generally represented by "⊙:○:△:×=5:3:1:0".

- **Calculate Corresponding Index Weight:**

Calculate the weight of customer demand αi (i.e. the relative importance of each customer demand in supply chain) of i component, where mi represents the absoluteimportance of each customer demand and n represents number of item of customerdemand.

$$\alpha_i = \frac{m_i}{\sum_{i=1}^{n} m_i}$$

Calculate the weight of each evaluation index mjthrough the pertinence relation between each evaluation index and the element of customer demand based on theweight of customer demand αi, namely:

$$m_j = \sum_{i=1}^{n} a_i \cdot r_{ij}$$

Where rij is the pertinence relation between customer demand and each evaluation index represented by "⊙:○:△:×" separately representing "5:3:1:0".

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Divide the grading of each evaluation index into several grades, and use βijrepresent the grade value, and thus the final total evaluation grade of each supplier is:

$$Sum = m_j \cdot \beta_{ij}$$

- **Select the Best Supplier:**
After analysis of the above procedures, keep the total valuation scores of all suppliers in order from high to low, and the enterprise with the highest score is the best supplier.

Meanwhile, such evaluation model can also enable the enterprise to make comparison with the model enterprise in higher weight of customer demand to facilitate the
Enterprise's improvement.

- **Application and Discussion:**
At present, the automobile industry has formed its complete supply chainsystem of supply – manufacture - sales – service. Taking a certain Automobile XYZ for example, it now needs to evaluate 6 suppliers providing dashboard, which are separately set to be A, B, C, D, E and F.

Use RS theory to normalize customer demand, obtain the importance Di of each customer demand in Fig. 2, being respectively 7, 44, 21, 21, 5 and 2, and then use the equation (1) to calculate the relevant importance of customer demand, being respectively 0.07, 0.44, 0.21, 0.21, 0.05 and 0.02, as shown in Table 1.

Establish an expert group in special charge of evaluation on suppliers, discuss and determine the degree of correlation rij between each evaluation index and customer demand, represented by "⊙, ○, △, ×". If the score ⊙between the evaluation index I1 and customer demand D1 is obtained, then rij=5; use the equation (2) to get the first evaluation index:

$$m_1 = \sum_{i=1}^{6} a_i \cdot r_{i1} = 5 \times 0.07 + 3 \times 0.21 + 1 \times 0.21 + 5 \times 0.02 = 1.29$$

Similarly, the weights of other 22 evaluation indexes can be obtained.

Divide each index into seven grades, respectively representing very good, good, above average, general, below average, poor, very poor whose corresponding scores are 0.75, 0.50, 0.25, 0, -0.25, -0.50 and -0.75. The expert group gives the score βijconsidering the concrete situation of 6 suppliers, e.g. the indexes of A Factory are individually 0.75, 0.25, 0.5, 0.75, 0.25, 0.75, 0.5, 0.25, 0.25, 0.5, -0.75, 0.5, -0.25, 0.5, 0.5, 0.25, -0.5, 0.25, 0.25, 0.25, -0.5, 0.5 and 0.25. By use of the equation (3),

Sum(A)= mj.β1 j = 9.3. Similarly, the scores of the other 22 evaluation indexes can be figured out, and the scores of the other 5 suppliers are individually 12.04, 4.15, 1.69, 6.78 and 7.25. See Table 1 for details.

As seen from the above calculations, the total score of supplier B is the highest, which is 12.04, suggesting that supplier B can better satisfy all demands in supply chain. In the meantime, the highest total score in quality index, price index, delivery index, enterprise comprehensive index and production capacity index shows that such supplier is more advantageous in those aspects.

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Supplier \ Index	Quality index				Price index				Delivery index			Enterprise comprehensive index							Production capacity index					Weight of demand
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	I19	I20	I21	I22	I23	a_i
D1	⊙		⊙	○		⊙	○	△		⊙	○	○	⊙		○	⊙	△	○		⊙	⊙		△	0.07
D2		⊙	○		⊙		○		⊙		○		○		○				⊙			○		0.44
D3	○			⊙	△	○		⊙		△	△			○			△			○			○	0.21
D4	△	△	⊙		○		⊙				○	⊙			○			⊙		△	○		○	0.21
D5				△					⊙	△			⊙	△			○				△			0.05
D6	⊙		○		⊙	△		○				△				○			○		△		○	0.02
Weight of index m_j	1.29	2.83	2.78	1.41	3.14	1.00	2.58	1.18	2.45	0.61	2.37	1.28	1.92	0.68	2.16	0.37	0.43	1.26	2.26	1.19	1.05	1.33	1.39	Sum
Factory A	0.75	0.25	0.5	0.75	0.25	0.75	0.5	0.25	0.25	0.5	-0.75	0.5	-0.25	0.5	0.5	0.25	-0.5	0.25	0.25	-0.25	-0.5	0.5	0.25	9.3
Factory B	0.75	-0.5	0.75	0.25	0.5	0.5	0.25	0.5	0.5	0.75	0.5	-0.25	0.5	0.75	-0.25	-0.5	0.25	0.5	0.5	0.25	0.25	0.25	0.5	12.04
Factory C	0.75	0.5	0.25	-0.25	-0.25	-0.25	0.25	-0.5	-0.75	0.25	0.25	-0.5	0.75	0.25	0.5	0.25	0.25	-0.5	0.75	0.5	0.25	-0.25	-0.25	4.15
Factory D	0.5	0.75	-0.5	-0.5	-0.5	0.25	-0.25	-0.25	0.25	-0.5	0.25	0.25	0.25	0.5	0.25	-0.25	0.5	0.75	-0.5	0.25	0.75	-0.5	0.25	1.69
Factory E	0.75	0.25	-0.25	0.25	-0.25	0.5	-0.5	0.75	0.75	-0.25	0.5	0.5	-0.5	-0.5	0.75	0.25	0.75	0.25	-0.25	0.75	-0.75	0.75	0.75	6.78
Factory F	0.75	0.25	0	0.5	0.5	-0.25	0.75	0.25	-0.25	0.75	-0.25	0.75	-0.25	-0.25	0.25	0.5	-0.5	-0.25	0.25	-0.25	0.25	0.25	0.5	7.26

Fig.10: Table:The System of House of Quality for an automotive company XYZ.

Conclusion

The adoption of the improved model based on QFD to conduct the supply chain collaboration directed supplier selection overcomes the disadvantage that the customer demand is often ignored by the traditional methods in supplier selection. The model gives full consideration to the importance of customer demand in supply chain collaboration which enables the core enterprises to address the issue of supplier selection on purpose, reasonable and effectively selects appropriate suppliers in supply chain group and better copes with uncertainty of various customer demands in supply chain.

Limitations and Future Research

While the research has made significant contributions to research and practice, there are some limitations that need to be considered when interpreting the study findings.

First, because the number of observations is limited, the constructs were not revalidated in this research by splitting the observations as training and validation samples. This needs to be addressed in the future research. New data maybe collected to revalidate the measures developed here.

Second, a key respondent, namely the top manager, in an organization was elicited to respond to a set of complex issues on supply chain collaboration, culture, trust, IOS use, collaborative advantage, and firm performance, since the top management is arguably the most knowledgeable individual about those issues.

This may introduce common-method bias. The stability of the findings needs to be tested by generating data using multiple informants from within the organization, and using knowledgeable members of the organization. Third, the response rate of 6 %, even though comparable to similar studies, is considered low. A main reason of the low response rate is the length of questionnaire.

Because of the time constraint of top managers, they are unlikely to participate in lengthy surveys. This issue can be addressed in the future research by reducing the number of items in the questionnaire.

Fourth, data collection on both sides of the manufacturer-supplier dyad would alleviate concern about biased assessments. However, while collecting information about the same relationship from both sides of the dyad is advocated, it is very difficult to carry out in practice due to the operational difficulty and an adequate sample size.

This study has provided a useful starting point from which to examine the roles of IOS appropriation, collaborative culture, and trust in supply chain collaboration and has identified several variables of notable research and managerial significance.

As a result, there are a number of interesting areas in which future research could be undertaken to good effect. Since the usefulness of a measurement scale comes from its generalizability, future research should revalidate measurement scales developed in this research by using similar reference populations. Future research should

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also conduct factorial invariance tests. Generalizability of measurement scales can further be supported by factorial invariance tests. Using the instruments developed in this research, one may test for factorial invariance across different organization size, across organizations with different supply chain structure (such as organization's position in the supply chain, channel structure, and so on), and across industries. For example, an analysis of supply chain collaboration and its related constructs by industry would be very beneficial. Examining how they are used across different industries and what are the most common level of supply chain collaboration in each industry would help identify any industry-specific bias toward or against supply chain collaboration.

Future research should apply multiple methods to obtain data. The use of a single respondent to represent what are supposed to supply chain wide variables may generate some inaccuracy and more than the usual amount of random error.

Future research should try to use multiple respondents from each participating firm as an effort to enhance reliability of research findings. More insights will be gained by collecting information from both sides of the manufacturer-supplier dyad rather than just from one organization. Once a construct is measured with multiple methods, random error and method variance may be assessed using a multitreat multimethod approach.
Future research should examine the hypothesized structural relationships across industries. Assuming an adequate sample size in each industry, structural analysis may be done by industry. This would reveal either industry-specific structural relationships or invariance of structural relationships across industries. The same hypothesized structural relationships across countries can also be tested in the future research. This will allow the comparison of the level of collaboration among supply chain partners across countries, the identification of country-specific facilitating and inhibiting factors, and the generalization of common collaboration and outcome factors across countries.
Future studies can also examine the proposed relationships by incorporatingsome contextual variables into the model, such as organizational size and production systems. For example, it will be interesting to investigate how supply chain collaboration differs across organization size. It will also be interesting to examine the impact of production systems (e.g., make-to-order and make-to-stock) on supply chain collaboration and performance.

In this study, composite measures are used to represent each construct, and onlythe construct-level structural model is tested using LISREL. However, the nature of relationships among sub-constructs across different variables will be more interesting. For example, what components of collaborative culture have more impact o supply chain collaboration? What differing roles of three components ofIOS appropriation on supply chain collaboration? What dimensions of supply chain collaboration has more impact on collaborative advantage? By assessing these relationships at the sub-construct level, many alternative models can be explored and the findings will be more useful for decision makers.

While this study provided important insights into the determinants of supply chain collaboration, and of collaborative advantage, it did not shed much light on the change processes involved in the supply chain collaboration since time, and changes over time, were not explicitly modeled. However, research is needed at this level since supply chain partners learn from ongoing relationships and they modify business practices to better meet each other's needs to ensure the relationship remains adaptable and valuable (Min et al. 2005). In the future, other research designs such as longitudinal study and experimentation research can be conducted to help determine how collaboration-related factors and relationships change over time.

The model developed in the study does not purport to represent all the possible antecedents of supply chain collaboration. Future research can expand the current theoretical framework by incorporating new constructs. For example, one might include e-business and IS strategies into the existing framework.

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