Information Technology–Tool to Deal with Bullwhip Effect in Supply Chain Management

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ABSTRACT

Over the past decade, the traditional purchasing and logistics functions have evolved into a broader strategic approach to materials and distribution management known as supply chain management. This research reviews the literature base and develops the effectiveness of supply chain management using the modern practices of information technology. This research also discusses various supply chain management strategies that require complex decision making form time to time and to deal with variety of situations and huge amount of data. The use of modern information technology becomes an indispensable tool for designing and managing complex supply chain systems. In present research the implementation of management information system has also been explored.

Keywords: Bullwhip effect, Information Technology, Management information system, Supply Chain Management.

1. INTRODUCTION

Over the past decade, the traditional purchasing and logistics functions have evolved into a broader strategic approach to materials and distribution management known as Supply Chain Management (SCM). Supply Chain Management consists of network of organizations related to each other in different activities (like flow of material, information or finance) that produce value in form of product or service to satisfy customer. Supply Chain Management can be applied to large companies with several sites, covering large geographical area with the aim to satisfy large number of people with different types of products or services. In broad sense, supply chain management is inter-organizational supply chain which does different types of functions like marketing, production, procurement, logistic, finance, etc. The utmost need of governing supply chain management is to get competitive advantage; the organizations which apply supply chain management are able to optimize resources and hence improve its functions and survive in the market.

Supply Chain Management deals with competitiveness which can be improved by reducing cost, optimizing use of resources, increasing flexibility to deal with customer demand and frequent changes in customer demand, providing superior quality of products and services, utilizing information and communication technology. There are various facets of supply chain management. Besides competitiveness and customer service, strong integration between sub-functional departments within the organization and outside the organizations, i.e. network and inter-organization collaboration, is very much required to implement a successful and effective supply chain. Supply chain management should be process orientated and equipped with advance planning. It should also look into customer behavior, change in demand and technology, forecasting of finance, material, etc. Foundation of supply chain management includes purchasing, resource allocation and requirement, manufacturing of goods or services, logistics, marketing, finance, statistics and operational research, accounting, information technology, organizational theory, and so on.

Different authors have given the different definitions of supply chain management. Tan et al. defined it as a capability which is to enhance competitive advantage. Berry et al. defined supply

chain in terms of information and trust. Jones defined it as "An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users." Christopher defined it in terms of upstream and downstream operation. Another definition of supply chain management emerges from the transportation and logistics literature of the wholesaling and retailing industry, emphasizing the importance of physical distribution and integrated logistics. There is no doubt that logistics is an important function of business and is evolving into strategic supply chain management (*New and Payne, 1995*).

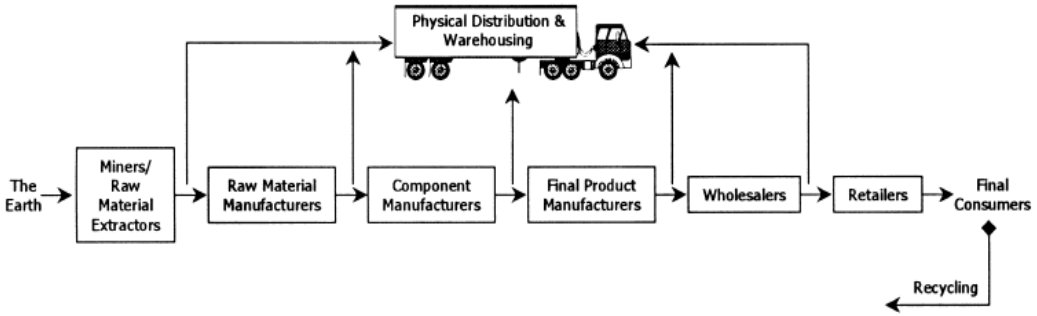

Fig. 1. Activities and firms in a supply chain. Source: New and Payne (1995).

As it can be noted from Figure 1, process integration in terms of information exchange plays very important role to make supply chain management effective. Information is to flow from customer to retailer, retailer to wholesaler and then wholesaler to manufacturer, this flow of information is termed as upstream information. On the basis of the information various activities like planning, manufacturing, distribution and marketing are performed to attain some functional objectives under system constraints.

Information exchange within supply chain is main pillar to make it successful and effective. If either desired information or in-flow of information is having any error then it causes a big problem. The problem in deformation of the information while it goes upstream in supply chain is termed as **Bullwhip effect**. Any fluctuation in demand at customer end results in big deviation at manufacturer end. Even it has been seen that if demand is constant it gives a distorted picture to the manufacturer about the quantity to produce.

Suppose for a particular period, demand of a certain product is not known to retailer, then retailer would have high stock in order to overcome the uncertainty and the same information is passed to the wholesaler and then to the manufacturer. In that case manufacturer would produce the product in more quantity than it must have produced. So the inventory level becomes high only due to lack of information of demand at retailer's end. Higher inventory results in blocking of working capital for the firm. begins (towards improving performance for the entire supply chain). This stage can be characterized as the back-bone of the database, where successful strategies are also constructed using case-based reasoning, in order to transform the whole data into a database legible to the system—so that past successful decisions are transformed as knowledge for future use.

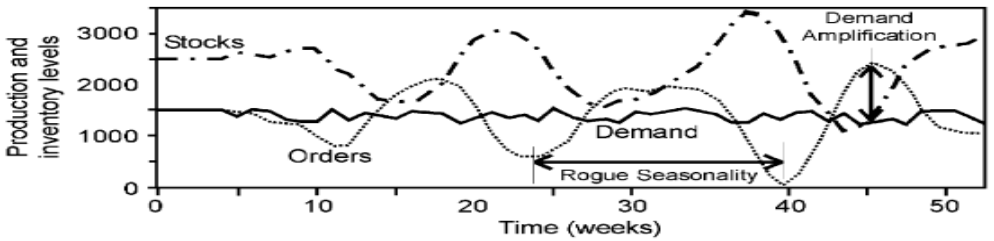

Fig.2 Demand amplification of time series to be viewed through the 'filter' lens
Source: Berry and Towill 1995

The blocking of working capital reduces the operational efficiency of the firm. When the number of supply chain increases, the complexity becomes larger and the aggregate inventory becomes much higher. This aggregate inventory results in loss of opportunity cost, reduces the required efforts, integrity and flow of information between partners.

According to the study of *R. Metters* (1997), the retailer's end cost of carrying inventory of product for a year equals at least 25 percent of what they pay for the product. Two-week inventory reduction represents a cost savings nearly equal to 1 percent of sales or the average retailer profit equals about 2 percent of sales so saving is enough to increase profit by 50 percent. Campbell soup found that after it introduced the program, profit of its product grew twice as compared to earlier profit.

Procter and Gamble (P&G) is the company which named this phenomenon as bullwhip effect after seeing the great variation between the order they are producing and actual sales of the product "pampers diapers." They observed that diaper with uniform demand created a wave of changes up the supply chain due to very minor changes in demand. HP also found great variability in the sale of printers; HP found it difficult to fulfill the orders on time and in order to meet the time it resulted in the increase in cost. Studies of apparel and grocery industry have shown a similar phenomenon in order as they move upstream in supply chain from retail to manufacturing. Nearly in all types of companies bullwhip effect has been observed like Campbell soup in consumer product IBM and Motorola in electronics, General Motors in automobiles and Eli Lilly in pharmaceuticals, etc. Over the last decade or so supply chain management has emerged as a major tool for the growth of business and it has encountered a rapid development so the traditional ways to manage the business have been phenomenally changed. Face to face management, on-paper ordering system, manual tracking and accounting system are obsolete and out-of-date systems now which are rarely used generally in small-scale organizations only. New tools and trends include website management and live databases, e-purchases, e-market, e-communication like email, fax have taken over the above-mentioned old systems. These tools and techniques surely provide edge over the traditional stated tools.

These changes are more evident in the industrial markets where the technologies have been applied to enterprise resource planning (ERP) and supply chain functions (procurement, inventory control, logistics), resulting in startling cost reductions, enhanced efficiencies, and remarkable increase in profit across industries *Soloner & Spence*.

Internet acting as an enabling force for the improvement in supply chain management offers efficiency and cost reduction in business processes across industries as well as nations. By allowing real-time communication among supply chain participants, networks can practice integrated forecasting, where it is possible to modify raw material orders to meet demand in real time, thus reducing the costs of stock outs or conversely costs associated with holding, and it is more beneficial in case of "perishable" inventory *Briant.*

2. LITERATURE REVIEW

Supply chain management has received attention since the early 1980s, yet conceptually the management of supply chains is not particularly well understood, and many authors have highlighted the necessity of clear definitional constructs and conceptual frameworks on supply chain management (*Saunders, 1995, 1998; New, 1995; Cooper et al., 1997; Babbar and Prasad, 1998). Saunders (1995)* warns that pursuit of a universal definition may lead to unnecessary frustration and conflict, and also highlights the fragmented nature of the field of supply chain management, drawing as it does on various antecedents including industrial economics, systems dynamics, marketing, purchasing and inter-organizational behavior. The scientific development of a coherent supply chain management discipline requires that advancements be made in the development of theoretical models to inform our understanding of supply chain phenomena. As an illustration, the application of *Forrester's (1961)* industrial dynamics model applied to supply chains (the Forrester Effect, also known as bullwhip effect or whipsaw effect) exemplifies such a model. Its value lies in the ability to aid understanding of the actions of materials flow across a chain, and has provided a basis for further advancement of understanding supply chain dynamics (for example, see *Sterman, 1989; Towill, 1992; Van Ackere et al., 1993; Lee et al., 1997). Cooper et al. (1997)* support this view, pointing to the fact that whilst supply chain management as a concept is a recent development, much of the literature is predicated on the adoption and extension of older, established theoretical concepts.

Forrester (1961) initiated analysis of this variance amplification phenomenon i.e. the bullwhip effect. His work has inspired many authors to develop business games to demonstrate the bullwhip effect. The well-known Beer Game originated from MIT at the end of the fifties and *Sterman (1989)* reports on the major findings from a study of the performance of some 2000 participants. *Kaminsky and Simchi-Levi (1998),* developed a computerized version of the beer game. There is certainly no lack of empirical evidence from real-world supply chains. *Lee et al. (1997a, b)* identify five major causes of the bullwhip effect: demand signal processing, non-zero lead times, order batching, supply shortages and price fluctuations. Of these *Disney and Towill (2003b)* consider lead time and demand signal processing to be of particular importance. Remedies include synchronizing capacities and lead times *(Lee et al., 1997; Towill, 1997),* increased coordination among companies *(Metters, 1997),* vendor-managed inventory *(Disney and Towill, 2003b)* and including demand variability in pricing decisions. In terms of management science techniques, *Yao and Dong-Qing (2001)* indicates that demand forecasting and ordering policies are two key methods of controlling the bullwhip effect.

The emphasis of information sharing in supply and its criticality is discussed by various authors. *Balsmeier and Voisin, Jones, Mentzer et al., Novack et al., Yu et al.,* all have worked on the importance of information sharing in supply chain management, whereas other authors like *Berry et al., Chizzo, Holmberg, Mason-Jones and Towill, Metters* have given importance to information quality that refers to the accuracy, timelines, adequacy, and credibility of information exchanged.

The rest of the study is organized as follows. Section 3 explores the role of information technology in SCM and later on in section 4 a framework of management information system is suggested that deals with the implementation of system to counter bullwhip effect. Section 5 and 6 contains the conclusion and future scope of paper.

3. INFORMATION TECHNOLOGY IN SCM

It has become clear that an individual firm can no longer flourish in business, rather it is the entire network that moves raw materials through production and, ultimately, to end users, which are the nexus of marketplace success. This entire network is termed as SCM. In essence, new rules of competition dictate that single firms are no longer the generators of economic worth, but it is the entire network of firms involved in the delivery of goods and services to end users that

create market value. In response, a trend towards partnership sourcing has emerged, which is characterized by a long-term commitment to supply chain relationships and a cooperative integrated approach to business processes *Roberts*. Various authors defined SCM differently and emphasize on role of information technology in supply chain. *Scott and Westbrook* and *New and Payne* describe supply chain management as the chain linking each element of the manufacturing and supply process from raw materials to the end user, encompassing several organizational boundaries that require information flow from downstream to upstream.

Supply chain management focuses on how firms utilize their supplier's processes, information technology, and capability to enhance competitive advantage *Farley* and the coordination of the manufacturing, logistics, and materials management functions within an organization *Lee and Billington*. When all strategic organizations in the value chain 'integrate' and act as a single unified entity, performance is enhanced throughout the system of suppliers.

Mason-Jones and Towill speak of a "seamless supply chain," where everyone in the supply chain gets the most recent market sales data. Utilization of this information improves the responsiveness of the supply chain and reduces the bullwhip effect. *Gullu* demonstrates that information sharing in a two-echelon allocation model results in lower order-up-levels and diminished system costs. Lee et al. echo the same. With one supplier and multiple identical retailers, *Fisher* find that supply chain costs are around 2.2 percent reduced on average with complete information, with a maximum difference of about 12.1 percent. *Mitra and Chatterjee* illustrated this point through numerical examples.

Process integration in terms of information exchange plays very important role to make supply chain management effective. Information is to flow from customer to retailer, retailer to wholesaler and then wholesaler to manufacturer, this flow of information is termed as upstream information. On the basis of this information various activities like planning, manufacturing, distribution, and marketing are performed to attain some functional objectives under system constraints.

Information exchange within supply chain is main pillar to make it successful and effective. If either information is not correct or in-flow of information is having any error it may cause a big problem and results to bullwhip effect. Bullwhip effect results in blocking of working capital, reduces the operational efficiency of the firm. When the number of supply chain increases, the complexity becomes more and the aggregate inventory becomes much higher, resulting in the loss of opportunity cost. Increase in members also reduces the required efforts, integrity and flow of information between partners.

The use of internet and information technology helps to reduce the bullwhip effect upto a certain extent, the process is known as continuous replenishment that helps manufacturer to have a smooth flow of material through the supply chain. One good example is Campbell Soup which implements this program. Modern technology electronic data interchange is used in the company that links the retailer and the company; everyday retailer electronically informs the company about the sales and inventory in the distribution center, then Campbell uses that information to forecast the demand. Later on making the use of the supplied information company ships the required replenishment in the afternoon of the same day. This reduces retailer's inventory and distortion of the information.

By using the information technology one can increase the sales upto twice thus increasing the profit by 50 percent *Fisher*. Also it helps to reduce inventory level and smoothens the entire supply chain management. SCM deals with competitiveness which can be improved by reducing cost, optimizing use of resources, increasing flexibility to deal with customer demand and frequent changes in customer demand, providing superior quality of products and services by the proper and effective utilization of information and communication technology.

Extant research has demonstrated the necessity of two-way inter-organizational communication for successful supplier relationship. Effective inter-organizational communication can be characterized as frequent, genuine, and involving

personal contacts between buying and selling personnel. *Newman and Rhee*, in their case study, found that many supplier product problems were due to poor communication. Poor communication was a fundamental weakness in the interface between a buying firm and its supplier.

Today we need IT at every stage and every point of SCM. Due to IT a very effective communication can be established that is very cheap and universally acceptable. The strength of inter-organizational systems is been particularly crucial with respect to enabling of the process transformation needed to create effective networks. Information technology also enhances supply chain efficiency by providing real-time information regarding product availability, inventory level, shipment status, and production requirements *(Radstaak and Ketelaar)*. It has a vast potential to facilitate collaborative planning among supply chain partners by sharing information regarding demand forecasts and production schedules that dictate supply chain activities. In particular, the goal of these systems is to replace inventory with perfect information. Thus, the indicators of this construct are conceptualized to denote the presence of electronic transactions and communication in various forms between the supply chain partners.

In a case study with Hindustan Oil Company, *Ravichandran* has shown that the performance of organization was increased remarkably well after implementing the package Enterprise Resource Planning (ERP), the performance parameters studied were demand planning, data warehouse (reduce mal distribution and lost sale), vendor manage inventory (improve response time), etc.

Lancioni et al. surveyed 1000 US firms that were members of the Council of Logistics Management regarding their application of Internet technologies within their supply chains. Their study, "Strategic Internet Trends in Supply Chain Management", shows that beyond cost reductions, the use of the internet within the supply network increases productivity and profits for participating firms. Internet allows firms to customize service solutions for their customers, which enhances the overall value and competitive position throughout the supply chain network. Internet is acting as a source of huge amount of information and big scope of communication. By means of internet an organization can link up with global market, in which some of them are acting as benchmark for the future growth of organization. From the past decade or so the use of internet is acting as a revolution in SCM.

It has been illustrated that the role of information technology has been an area of study for many researchers in supply chain management. This is an era of customer relationship management, enterprise resource planning, decision support system, etc. An effective supply chain management without the use of information technology is nearly out of imagination. The role of information technology cannot be accurately estimated as it covers very wide area in supply chain management.

4. MIS FRAME WORK TO DEAL WITH BULLWHIP EFFECT

In the present study it has been illustrated that how the use of information technology results in mitigating the bullwhip effect. Bullwhip effect can be identified as a problem which results due to certain events. The methodology can be categorized into following four stages:

1. Identification of the events which result in bullwhip effect
2. Assessment of bullwhip effect due to these events
3. Implementation of remedial action.
4. Optimization

4.1 Identification of the events which results in bullwhip effect

This is first stage of bullwhip effect where bullwhip effect is identified by the use of quantitative models like a ratio of variance in order and the variance in demand. The other model can be the difference in variance of order to the variance in demand or any other method based on the events.

The backbone of this process is based upon the monitoring of various key performance indicators (KPIs) related to the performance of supply chain. The level of an in-stock inventory, production throughput, capacity utilization and delivery lead times are some of the indicators that can be used

to identify an abnormal situation that may lead to the bullwhip effect. The actual values of those KPIs are monitored within a specific time frame and are compared with predefined values that are described either in an agreement among partners, or unofficially when the type of relationship does not require an agreement. Statistical tests can identify significant deviations between the actual and the pre-defined values. In case a significant deviation is identified, an alarm is triggered by the monitoring agent.

4.2 Assessment of bullwhip effect due to these events

This is a stage where corrective actions are taken to mitigate the bullwhip effect on the basis of the factors identified in previous stage. The analysis takes into consideration a wide range of criteria such as the probability of occurrence of the event, the bullwhip level and its impact, and it prioritizes the impact according to the outcome of this process.

In conjunction with the outcome of the bullwhip assessment, a description for the level of the impact (e.g. no impact, minor impact, medium impact, or serious impact) and the level of probability for the occurrence of the event (e.g. very unlikely, improbable event, moderate event, probable event, very probable, etc.) can be given. This process is executed by root cause identifier software, which is incorporated in the learning module of the disruption management agent. Through the monitoring of crucial indicators like delivery time and production output, the potential causes of the triggered alarm can be identified. For instance, in case of a significant delivery delay, the root cause identifier will initiate a process to trace the cause of this delay.

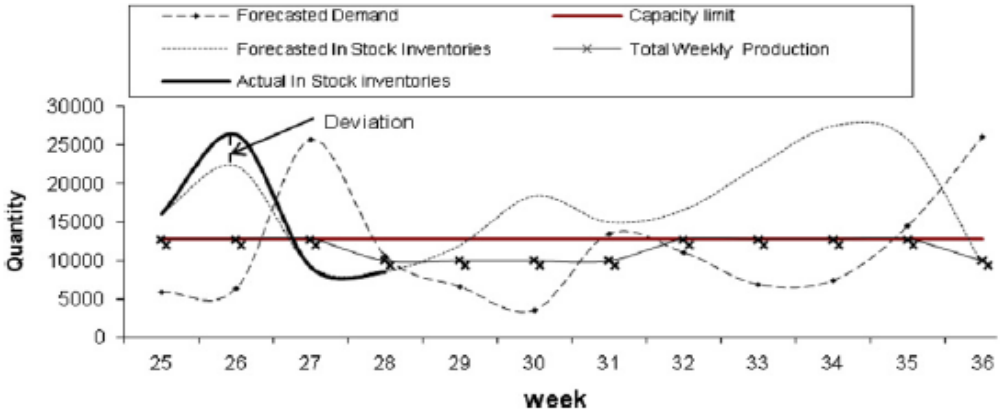

Fig. 3. Production plan monitored through key performance indicators.
Source: Illustration by author.

In the case of inability on behalf of the local supply chain partner to deliver the order, the root cause identifier will label this incident as probable delay risk.

All such incidences can be stored in a managed information system. This managed
information system act as a resource to calculate probability for future events and to predict the impact of bullwhip effect on the basis of past observations.

Mathematical models like regression analysis, variance, etc. can be used to predict the bullwhip effect on basis of which financial losses can be predicted.

$$\begin{aligned} &Expected\ cost \\ &= cost\ to\ mitigate\ bullwhip\ effect \\ &+ expected\ loss\ due\ to\ bullwhip. \end{aligned}$$

where expected loss due to bullwhip is given by

$$\begin{aligned} &Expected\ loss\ of\ bullwhip \\ &= prob.of\ occurence\ of\ bullwhip \\ &\times\ loss\ due\ to\ bullwhip \end{aligned}$$

4.3 Implementation of remedial action

After the assessment of bullwhip effect, events due to which bullwhip effect occurred are identified. These events are then recorded which act as observation for future assessment. The selected corrective actions are transferred again to the built-in simulator, where the optimization process begins (towards improving performance for the entire supply chain). This stage can be characterized as the back-bone of the database, where successful strategies are also constructed using case-based reasoning, in order to transform the whole data into a database legible to the system—so that past successful decisions are transformed as knowledge for future use.

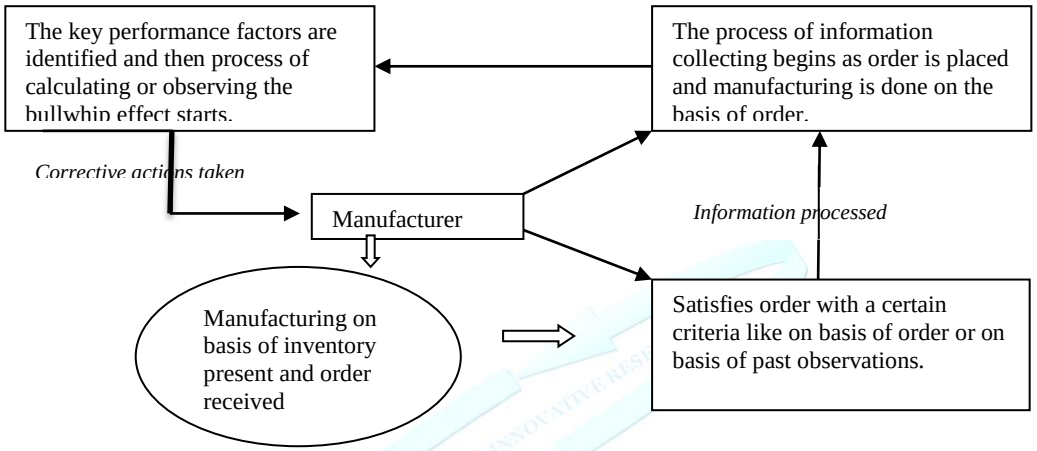

Fig 4. Illustration of management information system for bullwhip effect. Source: Author.

4.4 Optimization

After the assessment of the bullwhip effect and the implementation of corrective actions, now it is the time to optimize the supply chain efficiency in presence of bullwhip effect. Bullwhip effect is a phenomenon which surely occurs in supply chain management at some point of time or the other.

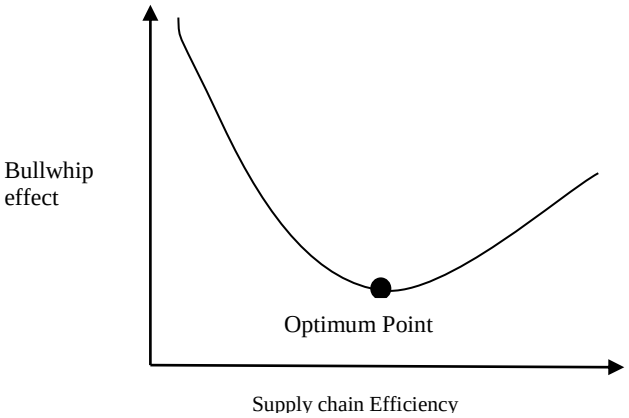

Fig. 5. Relationship between the supply chain efficiency and bullwhip effect. Source: illustration by author.

It is a effect which can be minimized but can't be completely eliminated, for example pricing strategy may result in bullwhip effect by acting as a cost for manufacturer but may not be suitable for retailer hence to optimize the supply chain efficiency it is very much required that a balance tradeoff should be maintained between the bullwhip effect and supply chain efficiency. This can be illustrated using Fig. 5. The internal structure of the event management module including database management system and the bullwhip management process is illustrated in Fig. 6. It can be seen in the figure that learning takes place when the cause for an alarm is identified and a rectification strategy is proposed.

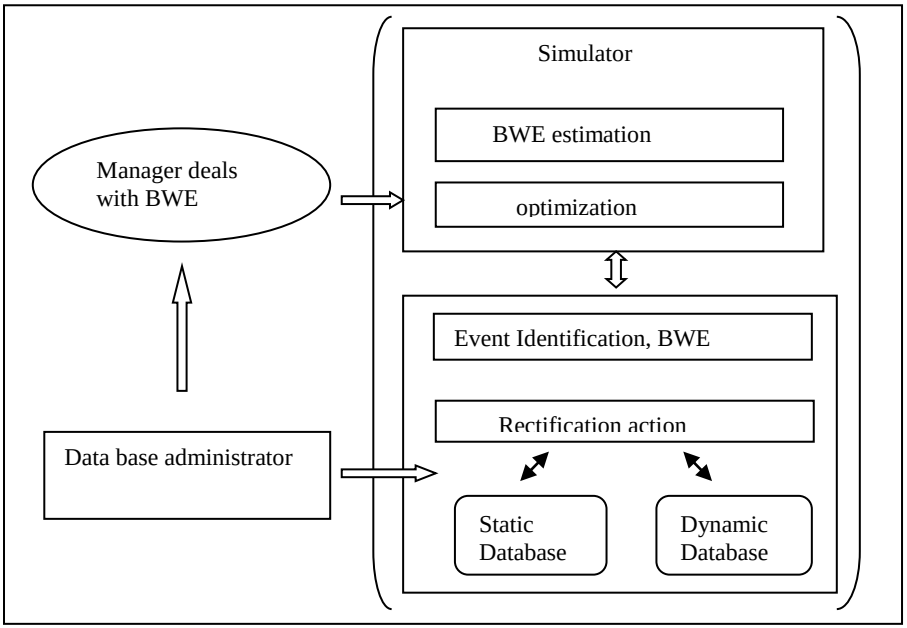

Fig. 6. The internal structure of the event management module.Source: Author.

5. CONCLUSION

It has been demonstrated that IT is an essential ingredient for business survival and it improves the competitiveness of firms. As a result of the literature review, we can see that IT has a tremendous influence on achieving an effective SCM. Integrating the supply chain activities is driven by the need to streamline operations to achieve quality service to customers. There are many research articles on IT in SCM, but there is a lack of critical review of the literature with the objective that brings out the pertinent factors that would influence the successful application of IT in SCM. In this study, an attempt has been made to review the literature on IT in SCM and to develop a framework for the development and implementation of IT in SCM. The emphasis is given to develop a framework which can deal with the dynamic behavior of supply chain management known as bullwhip effect.

6. FUTURE SCOPE

The present study deals with the area of applicability of information technology in supply chain management. In the future research metrics can be developed by which the importance of information technology can be expressed in terms of quantitative analysis.

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