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Bullwhip Effect Mitigation in Trading System: A System Dynamics Approach

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***Abstract*— This paper deals with the modelling and simulation in the business of packaging where products are stocked based on forecasting and inventory policies. The model refers to the stochastic demand between the manufacturer, retailer and customers. The main objective of this paper is to reduce the Bullwhip Effect and enhance the efficiency of supply chain. The key variables of study are Supplier ordering rate, Supply line, Acquisition rate, Shipment rate, Backlog, Inventory, and Indicated orders. The results depict that lead time has to be brought down to four weeks, in the trading industry under consideration, if there has to be a drastic reduction in Bullwhip Effect. Accordingly, suggestions are made to reduce lead time through root cause analysis.**

Index Terms*- *Supply Chain Management, Bullwhip Effect, Stochastic Demand, Supply Line and Inventory.

I. Introduction

Supply Chain Management is now becoming an important aspect of an organization as there is an increasing concern to improve efficiency of the supply chain, in order to compete in the globalized market. Also, diversification is another feature of globalization that demands an increase in the efficiency of supply chain. The leveraging of linkages within the supply chain has its origin since Porter's value chain models that identified the importance of exploiting both intra and inter firm linkages [1]. In recent years the concept has now been used more to gain competitive advantage in the present globalized era. Both practitioners and theorists are equally involved in identifying the leverage points so as to enhance the efficiency of supply chain and increase the effectiveness of their overall business. On the other hand, the area has grown to such an extent that indeed, several definitions of supply chain management refer explicitly to the entire supply chain from acquisition of basic raw materials to the consumption of finished products [2]. Having realized the importance of enhancing the efficiency of supply chain, this paper specifically focuses on the delay and its associated parameters in order to mitigate the Bullwhip effect. The Stock Management Model developed by Sterman [3] forms the basis of the supply chain model developed in this research.

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II. Literature Review

The field of Supply Chain Management (SCM) has grown by leaps and bounds since the past decade, owing to its importance in materials, productions and operations management. Accordingly, several definitions of SCM have emerged out based on the context, among which, Stevens [4] has given an elaborative working definition of supply chain as a system whose constituent parts include material suppliers, production facilities, distribution services, and customer linked together via the feed-forward flow of materials and feedback flow of information. The dynamic behaviour of supply chain has been studied extensively by a group of researchers starting with the pioneering work of Forrester [5] in using System Dynamic models to demonstrate demand amplification in supply chain (otherwise known as Bullwhip effect). A small variance in the demands of the downstream end customer may cause dramatic variance in the procurement volumes of the upstream suppliers via the Bullwhip effect under condition that the distortions of demand related information exists among the members of supply chain [6]. Way back in 1984, Professor Sterman from MIT Boston designed the beer game which proved the existence of the Bullwhip effect [7]. The results pointed that the cause of Bullwhip effect lay in the fact that the player failed to recognize that the beer supply chain was a system with each part of it interconnected with the orders. That was why they couldn't reasonably perceive the complex information feedback with delays in the system. In 1997, Towill [8] identified the causes of Bullwhip effect and the corresponding solutions, from the perspective of cybernetics by integrating Forrester's System Dynamics point of view and the theory of multistage information flow. The Bullwhip effect induces inefficiencies in capacity utilization, sourcing, distribution, revenue generation and its realization at the macro level. Managing Bullwhip effect is predominantly a strategic initiative not a tactical one [9]. De Souze et al., [10] have studied in detail the impact of seven causal factors on the dynamic performance of a generic supply chain simulation in order to reduce critical parameters influencing dynamics and worked on coordination dynamics in networking organizational structure. Their results show that reduction of coordination dynamics is an alternative solution to structural reengineering e.g., shortening manufacturing and transportation lead times. There is comparatively lesser research undertaken on the study of the influence of acquisition delay particularly based on the demand forecast of trading items. This paper is specifically focused on studying the effect of acquisition delay on the system performance with an objective of reducing the Bullwhip effect.

III. CONSTRUCTION OF THE MODEL

The model developed refers to the supply chain of an MNC based in India, whose products are imported from a manufacturing plant in Netherland. The company has an annual turnover of about one hundred thousand US$. The model (Fig. 1) is based on the forecasted demand quantity. Forecasting has been carried out for the sum of the items for A and B category under the ABC analysis for sales value. The items under C category are ignored, as they do not influence the sales figures significantly. The basis for the model is Sterman-Business Dynamics Stock Management Model [3]. The three components of the model are: Inventory control, Ordering process, and Order fulfillment. The influencing factors are Supplier ordering rate, Supply line, Acquisition rate, Indicated orders, Backlog, Order shipment rate and Inventory. Other influencing factors such as price fluctuation, currency fluctuation, quality of the product are considered extraneous to the study, whereas, mitigation of Bullwhip effect is the focus of this research.

Inventory control: The market demand calculations are stochastic based and Gaussian function is assumed for demand variation. Demand is formulated as white noise with normal distribution. The Change in demand is considered to be stochastic. The Inventory adjustment is controlled by the gap between desired and current inventory levels.

Ordering process: Ordering is based on the minimum value of Available capacity and Indicated order. Indicated order in turn is dependent on Adjustment for supply line and Desired delivery rate which is the sum of Forecast order rate and Adjustment for inventory.

Order fulfillment: It is based on Order shipment rate and is given by the minimum of Desired shipment rate and Maximum order shipment rate.

IV. SIMULATION RESULTS AND ANALYSIS

The model was simulated for 60 weeks with Demand as stochastic with a Normal delay (most likely delay time) from supplier varied as 3, 4, 5, 6 and 7 weeks. The influence on Supply line, Inventory, and Backlog were analysed. The initial values of Demand, Supply line, Inventory and Backlog were taken as 360, 500, 1000 and 600 products for the starting week, based on real-life data of the company.

Stochastic Demand – It is a general trend (Fig. 2a) of demand for a product. Even though it declines over a period of time depending upon the market, it keeps regaining periodically.

Supply Line – By the 4th week, the increase in Normal delay from the supplier being increased from 3 to 7 weeks would increase the supply line from 1700 to 2500 products and the fluctuations are sinusoidal (Fig. 2b). It is also clear that the increase in Normal delay from the supplier would increase the settling time of the Supply line.

Inventory – By the 4th week, the Inventory level falls down from 528 to 311 for an increase in Normal delay from the supplier being increased from 3 to 7 weeks (Fig. 2c). Again, the trend is sinusoidal fluctuations with longer time for settlement with the increase in Normal delay from the supplier.

Backlog – By the 4th week, the value falls down to 460 products and would increase to 578 for an increase in Normal delay from the supplier (3 to 7 weeks) (Fig. 2d). Initially, Backlog falls down for the first two weeks along with the initial Inventory, after which, Backlog increases abruptly as the Normal delay from the supplier increases (3 to 7 weeks).

V. IMPLICATIONS AND SUGGESTIONS

It is clear from graphs (figure 2) that the shorter the lead time, the lesser will be the Bullwhip effect. The simulation graphs indicate that the Normal delay from the supplier should not exceed one week, beyond which, Supply line gets piled up, Inventory level falls down drastically and to regain stability it overshoots the threshold value and stabilizes at around 800 units, when the Backlog increases to about 450 units, which means the overheads increase continuously.

This has lead to Root cause analysis of Normal delay from the supplier (Fig. 3). Supplier stock out is mainly due to inaccurate forecasting, which is due to lack of mechanisms available to strengthen supplier commitment. This is in turn, because of inadequate performance analysis procedure available at the supplier end. In addition, information delay is found to be the other factor causing delay, which is due to lack of feedback between the supplier and the distributor, and information asymmetry which may be due to lack of control mechanism and standardization procedure available. Finally, another factor of concern is transportation delay, which is due to the delay in departure time of the ship or other logistical issues. Improper documentation and delay of transportation from port to warehouse is mainly due to lack of communication between transporter and warehouse authorities which needs to be rectified.

Suggestions for lead time reduction are:

1. *Logistics:*

- Value-added services: It is essential for ports as a part of a logistics chain to provide value added services such as playing the role of distributors or developing continuous replenishment or cross-docking activities.
- Physical integration of multimodal systems and operations: Ports are bi-directional logistics systems. They receive goods from ships to be distributed to land (road/rail) and inland waterway modes and vice versa. This requires a high level of co-ordination, inter-connectivity and inter-operability capabilities within the port system with which the supplier and trader has to align.

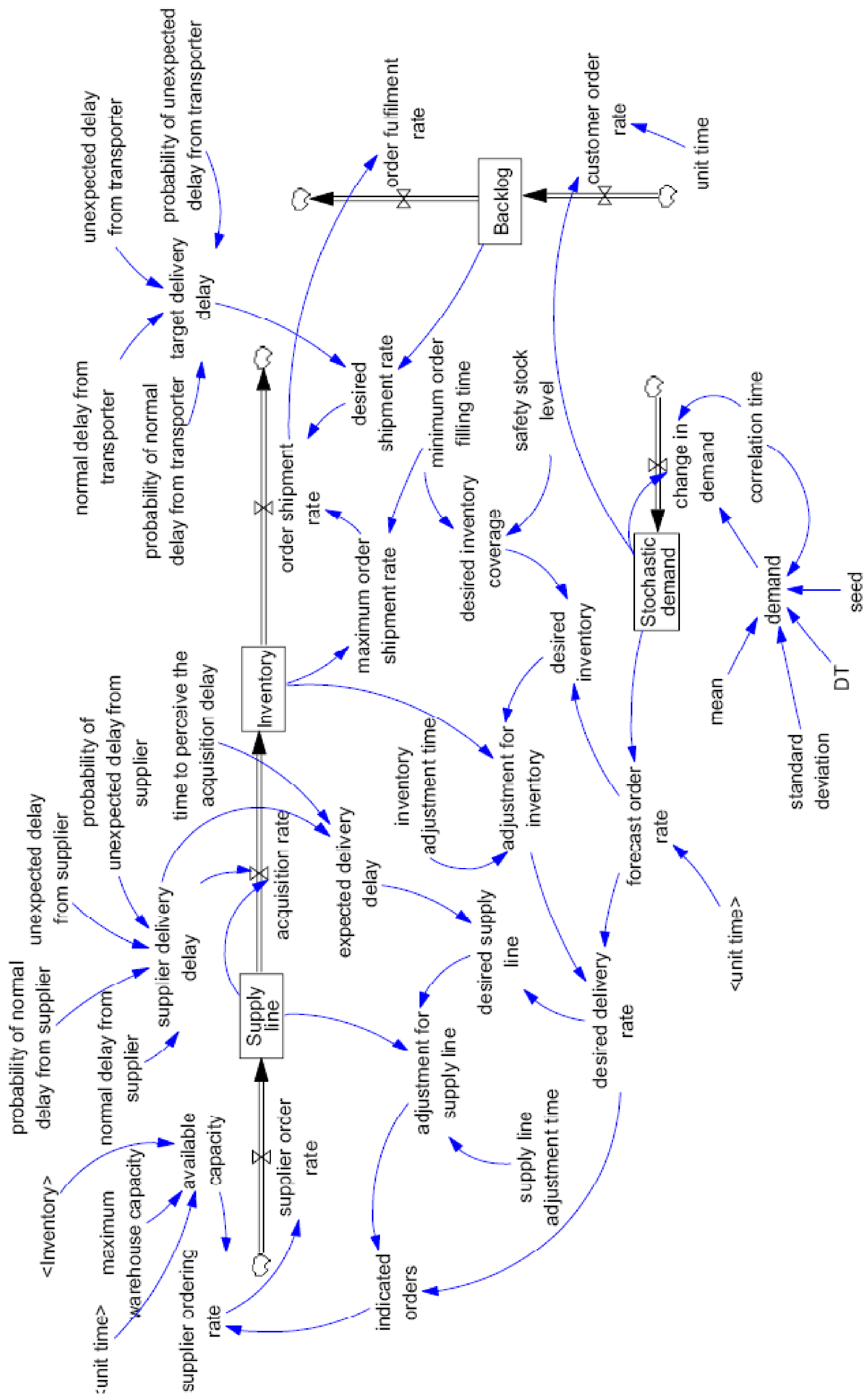

Fig. 1: Stock and flow diagram of trading system model

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- Supply chain integration practices: Integration practices are evaluated by the port authorities regularly, and accordingly they organize activities, processes and procedures. This results in frequent procedural changes, which can cause delay if there is a communication lag. Hence, the supplier and the trader need to develop a mechanism to be aware of these changes and take timely actions.
- Documentation procedure as per government policies and norms need to be professionally managed to save time.

2. *Increased information velocity*

- Establishing systems to provide appropriate information to supplier on materials usage and providing forecast reports frequently as a feed-forward loop.
- Maintaining undistorted and updated information through Management Information System.

3. *Supplier-trader relation building programmes*

These programmes should focus on sharing of best practices, discussing common problems and possible solutions, sorting out specific delay points, and familiarizing with information and communication tools.

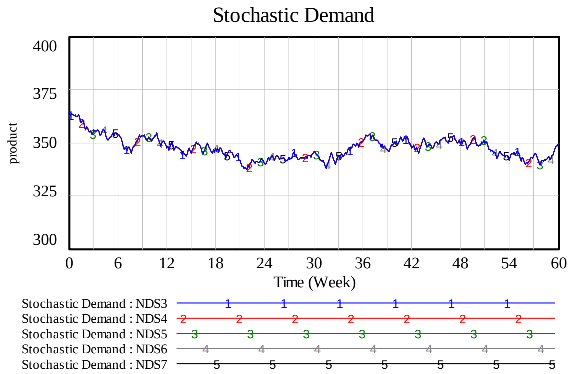

Fig. 2a: Effect on stochastic demand

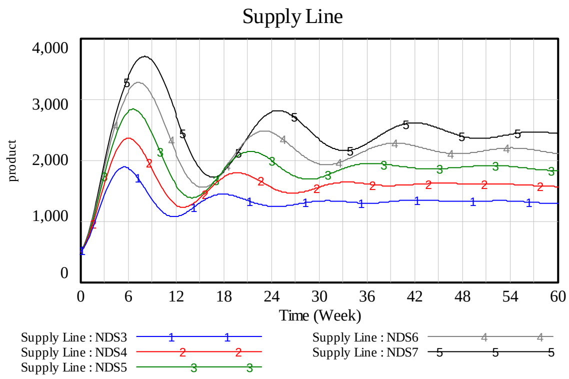

Fig. 2b: Effect on supply line

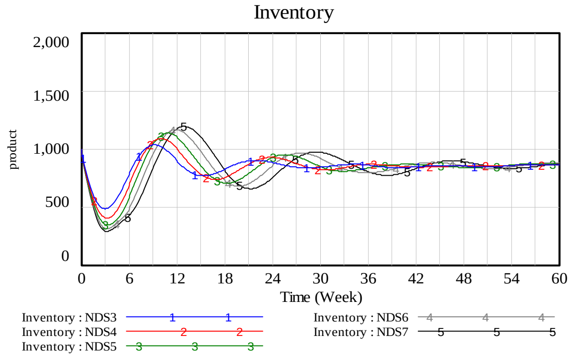

Fig. 2c: Effect on inventory

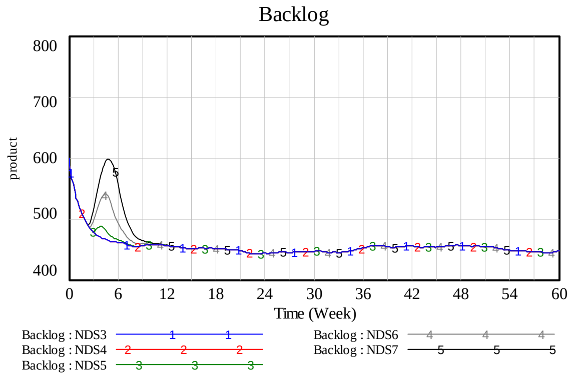

Fig. 2d: Effect on backlog

VI. CONCLUSIONS

The main focus of this research was to study the influence of lead time on Bullwhip effect. Modelling and simulation delineated the fact that the shorter the lead time, the lesser will be the Bullwhip effect and sooner will be the stabilization of the system. Reducing lead time is a constant endeavour in any trading business, as it involves multiple variables. In this paper, root cause analysis has been carried out to identify the factors affecting lead time and implications have been drawn to eliminate or minimize the same. Some important factors identified were delay in transportation, lack of standardization & system control, and erroneous documentation.

Forecast order rate is based on Stochastic demand in this research, and hence, there is ample scope for considering other models such as trend analysis, multiple exponential smoothing, and regression analysis to estimate the Forecast order rate. Space limitation in the warehouse was a constraint for the trading firm chosen in this research, however, modeling and simulation may be performed to obtain ideal space requirement, rather than fixing it in advance as in the present case. Finally, this research considered the effect of lead time on Bullwhip effect and future researchers may fix the ideal lead time and simulate for the other variables which influence the Bullwhip effect.

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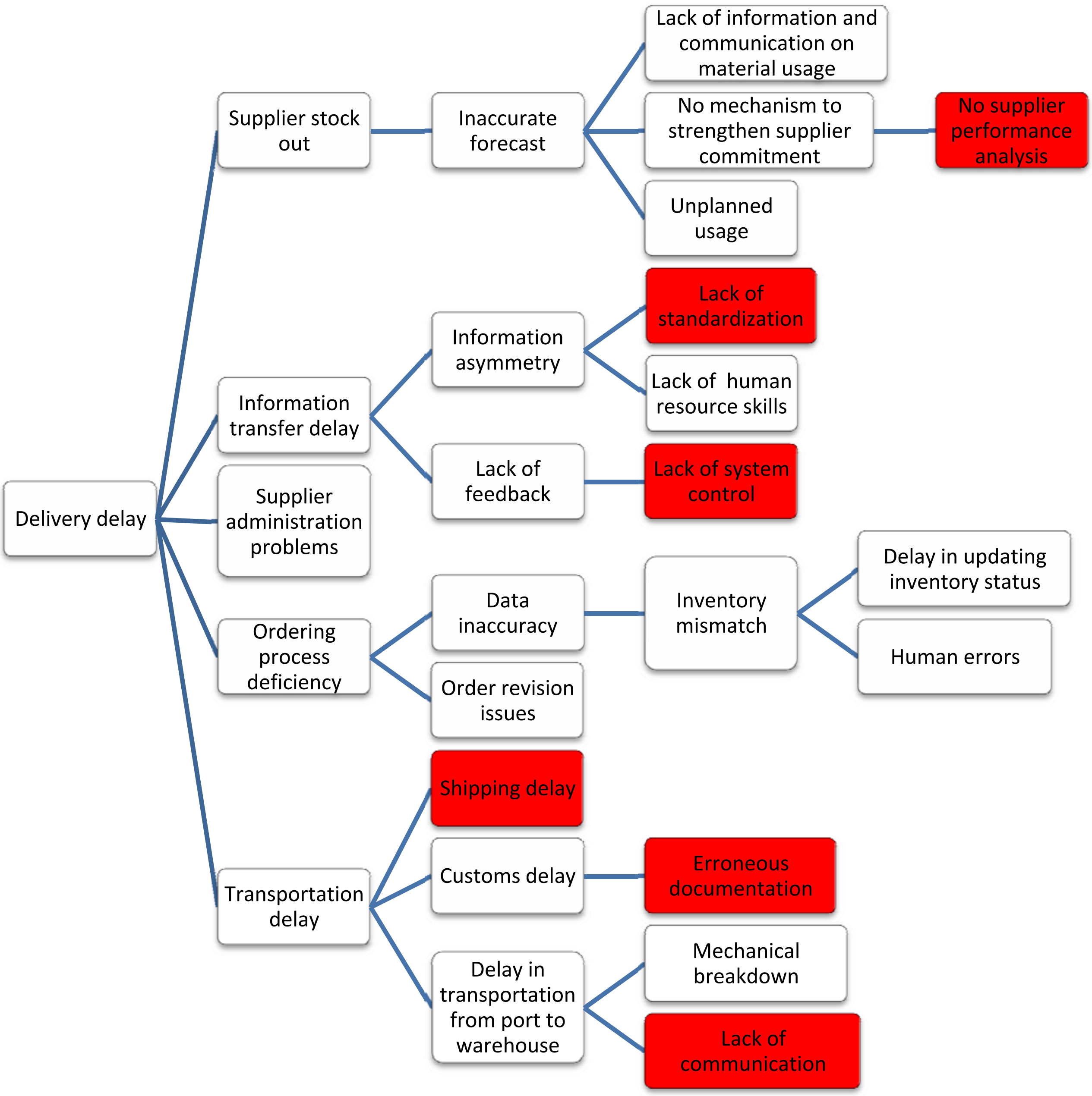

Fig. 3: Root cause analysis of delivery delay

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