Impact of replenishment strategies on supply chain performance under e-shopping scenario

Abstract
With the development of Information and communication technologies (ICT), the supply chain performance and its management techniques have significantly transformed. The internet revolution has bought the surge in online shopping platforms attracting millions of small size manufactures to engage in the nascent business models. The research attempts to identify the factors influencing the supply chain performance for small size manufacturers under e-shopping scenario. The system dynamics simulation approach is attempted to assess the impact of replenishment strategies on supply chain performance indicators. The results reveal the existence of bullwhip effect in the e-shopping supply chains due to backlogged orders and management decisions. The comparison between two different inventory control strategies with replenishment patterns indicates that the target stock level method performs better over economic order quantity method under e-shopping scenario.

Keywords:
Supply chain performance, System dynamics, Replenishment strategies, Bullwhip effect, Simulation

1. Introduction
Information and communication technologies (ICT) are enhancing supply chain performance with improved efficiency and responsiveness (Huang et al., 2014). The Supply Chain (SC) performance is significantly boosted with the use of electronic portable devices. The revolutionary ICT has increased B2C and B2B transactions in E-Supply Chain Management (E-SCM) using Online Shopping Platform (OSP)
Though the benefits of E-SCM have long been analyzed (Cousins et al., 2008), there is still limited literature on the E-SCM for small businesses. Possessing the inherent advantage of information accessibility, E-SCM is mostly researched under the perspective of supply chain information sharing and collaboration (Giard and Sali, 2013; Kembro and Naslund, 2014). Organizations require both internal and external collaboration to construct a seamless and effective supply chain network. Limited available academic evidence reflects on the current trends of OSP-based business behaviors in relation to e-shopping supply chain performances. Disney et al. (2004) examined the bullwhip effect in four different E-SCM scenarios, where ‘e-shopping’ scenario was introduced for the first time. They also found that under E-SCM, bullwhip effect in a single echelon supply chain still exists contradicting the conventional theory that the most effective way to reduce bullwhip effect is to reduce supply chain echelons and improve the overall visibility (Lee et al., 1997; Giard and Sali, 2013). Vlachos et al. (2007) follows a system dynamics approach for development of an efficient capacity planning policies for the remanufacturing facilities in a closed loop supply chain network. In order to understand the complex behavior of the influential factors in the OSP, a closer inspection of e-shopping scenario is necessary. Following a System Dynamics (SD) modelling approach, the research aims to compare the supply chain performances for two replenishment strategies for small businesses operating online. The developed single-echelon SD model is run under different e-shopping scenarios to understand the overall behavior of supply chain performance indicators. The bullwhip effect, service level and inventory costs serve as primary indicators for evaluating supply chain performances under different set conditions.

The paper follows a systematic approach to the research. Next section provides a literature review on four building blocks of this research namely- E-SCM, supply chain performance measurement, system dynamics and inventory control strategies. Section 3 outlines the research methodology, followed by the design of system
dynamics model. In section 4, the simulation results are analyzed. Section 5 concludes with a discussion on findings and future research directions.

2. Literature review

There is evident research on E-SCM in the academic literature (e.g. Zhang et al., 2011; Kembro and Naslund, 2014). The academic literature has covered this topic under different names such as e-business, e-commerce, e-retail etc. with no accepted norm existing in the literature on the classification or difference (Gupta et al., 2009). The e-business impact on inventory levels (Rekik et al., 2015), pricing and delivery strategies (Huang et al., 2014) and sustainability (Mangiaracina et al., 2015) are being studied within the E-SCM context. An important factor that enables B2C type of e-business in current technology driven world is the prevalence of OSP. According to Huang et al. (2014), e-business facilitated with online transaction technologies will significantly improve supply chain performance by enhancing responsiveness and efficiency. The inventory cost and customer satisfaction both measure the extent to which efficiency and effectiveness can be achieved in the manufacturing process (Cousins et al., 2008). Customer satisfaction indicates the effectiveness of the response to customer demand in the supply chain (Gunasekaran et al., 2004). The simplest indicator of customer satisfaction is the fill rate, which is calculated as the fraction of orders that are delivered (Nahmias and Olsen, 2015). Supply chain performance can be evaluated through three dimensions: bullwhip effect, inventory cost and service level (Cachon and Terwiesch, 2009). Intensive research on the bullwhip effect over years shows increased focus on reducing its impact (Wang and Disney, 2016). Collaboration and information visibility are critical to overcome bullwhip effect and inventory instability (Costantino et al., 2014). Bayraktara et al. (2008) examined the bullwhip effect under E-SCM environment to predict seasonal order swing as a measure to reduce the effect in supply chain network.

Two widely used inventory replenishment strategies are Economic Order
Quantity (EOQ) and Target Stock Level (TSL). EOQ is one of the most fundamental order patterns providing optimal size of fixed orders that minimizes the total inventory cost (Beamon, 1998; Sterman, 2000). While TSL is a periodic replenishment strategy under which a fixed order review interval is approached (Giannoccaro et al., 2003). The research trend in replenishment strategies probe into the impact and operability under different scenarios of dynamic re-order quantity or reorder interval. Maximum storage requirement and finished goods inventory level can be achieved by the dynamic adjustment of the replenishment strategy for the seasonal products (Grewal et al., 2015). Within E-SCM context, Yang et al. (2014) revealed that collaborated order quantity benefits both manufacturers and distributors with credit period and quantity discount achieved. Eruguz et al. (2014) conducted research using TSL policy into reorder interval and target stock level optimization within complex supply chain network. The comparative research by Tsou (2013) testified that under dynamic target inventory level TSL (JIT model) performs better with lower order cost, while EOQ policy has better performance with higher order cost or higher rate of stock shortage.

Within E-SCM research, there is an evident lack in the research synthesizing e-shopping supply chain with supply chain performance and associated behavioral analysis (Huang et al., 2014). To overcome this gap, series of SD simulations are conducted in the research. The paper illustrates online shopping platforms and their behaviors under different inventory replenishment conditions. The simulation study conducted in this paper is particularly applicable to the small businesses- the main entity in the online shopping market.

3. **Model Development**

In order to identify the relationship between e-shopping supply chain performance and its influencing factors, SD modeling approach is followed. SD simulation is conducted using *VensimPLE*©, a continuous event simulation platform. SD modelling follows a three step approach (Sterman, 2000). The first step
conceptualizes elements of e-shopping supply chain into the computer model. Manufacturer, customer demand, supplier behaviors and supply chain activities are embedded into SD model at this stage through a casual loop diagram and its corresponding stock and flow diagram as seen in Fig. 1 and Fig. 2 respectively. In Fig. 1, the colored box variables are the key variables targeted for the observation (e.g. service level, BWE, inventory cost). Other box variables such as supplier, manufacturer, backlogged orders are core variables not under direct observation. Remaining dependent/independent variables are also shown in the feedback loop to represent the complex relationship of different variables in the supply chain network.

The next step is to run the simulation to identify potential influencing factors and to draw inferences from the analysis. All the variables shown in the causal loop diagram are consolidated in Table 1 with their associated cause and effect. Customer demand is generated as a primary data through the use of random function that randomizes the outcome under controlled normal distribution. The stochastic data is generated with the help of control variables available within the simulation platform. The SD model has considered following input values for different variables: Unit cost of product = £50, Ordering cost = £10, Holding cost per unit = £10, Holding rate = 20%, forecasting error =10 units/week. The simulation is run for 260 weeks with a time step of 1 week. The hypothesized business type is a small business selling identifiable products online. Under above set assumptions, lead-time is only considered during the replenishment products are transported from supplier factory to the manufacturer’s warehouse. Lead-time from manufacturer to customers is not considered in the simulation. Three dependent variables selected to be observed are bullwhip effect, inventory cost and customer service level.

**Fig. 1.** Causal loop diagram for inventory replenishment in supply chain network**

**Table 1** List of variables and associated cause and effects**
3.1. Causal loop diagram

In the model, the manufacturer directly receives orders from end customers through OSPs. Orders in each period are calculated as the sum of two parts: customer demand and the backlogged orders that reflect the sum of unfulfilled orders for a given period. During each time-step, manufacturer will prioritize to fulfill the back-orders before new customer demand is fulfilled. For each period, the ratio of the fulfilled orders to simultaneous customer demand is calculated as the service level. Since the simulation model considers single echelon in the supply chain model, backlogged orders are considered as the major trigger to the bullwhip effect. After the delivery of orders by the manufacturer, replenishment orders are placed with their suppliers based on TSL or EOQ pattern. Under EOQ strategy, manufacturer will make a replenishment order with a fixed quantity, when stock level reaches the re-order point (ROP). Whereas in the TSL scenario, a variable-quantity replenishment order will be generated after a fixed review interval. For the modelling purpose, it is assumed that the manufacturer is small-sized and suppliers can always satisfy the replenishment requests. Hence the frequency of replenishment orders and inventory holding by the manufacturer altogether contributes to the overall inventory cost. Customer demand is randomly generated by the normal distribution function in the simulation platform. Developed stock and flow diagram in Fig. 2 illustrates the system behaviors, indicating the binary relationships among variables.

**Fig. 2. Stock and flow for inventory replenishment in supply chain network**

3.2. System dynamics modeling

The SD model for a single echelon supply chain network structure is adapted following the work of Campuzano and Mula (2011, pp. 62-65). Extensive study on SD approach for supply chain simulations was found to be a good starting point for identifying core variables and parameters influencing supply chain performance. The SD model discussed in the paper serves different research targets and hence adapted
to suit the research requirements. Three primary performance indicators and facilitating functions are controlled in the simulation: service level, accumulated inventory cost and order delivery. Service level is calculated by dividing the difference of flow of products to customers and backlogged orders with customer demand, indicating how much of the customer demand is fulfilled in each time step (Equation 4.1). In this case, service level is identified as an auxiliary variable with two main functions involved. IF THEN ELSE function is applied to avoid the situations, when service level is less than zero. XIDZ function is adopted to define a 100% service level, when no customer demand is generated in a given time period.

\[
\text{Service level} = \text{IF THEN ELSE} (\text{Flow of products to customers} \geq \text{Backlogged orders}, \text{XIDZ} ((\text{Flow of products to customers} - \text{Backlogged orders}), \text{Customer demand}, 1) * 100, 0)
\]  

(Equation 4.1)

The accumulated inventory cost indicates the sum of inventory costs at the start of the simulation (Equation 4.2). The inventory cost in the simulation is divided into two parts: inventory holding cost and ordering cost. Holding cost and order cost are calculated as seen in equation 4.2. Above equations are based on standard inventory management concepts (e.g. Vollmann et al., 1993).

\[
\text{Accumulated inventory cost} = \text{No of delivery orders} \times \text{Order cost} + \text{Holding cost per unit} \times \text{Manufacture}
\]  

(Equation 4.2)

In the EOQ scenario, a replenishment order is made when the sum of inventory of manufacturer and products delivered to the manufacturer is less than the simultaneous order amount (Equation 4.3). IF THEN ELSE is selected to define the trigger of a replenishment order: 1 is counted whenever a replenishment order is made otherwise 0 is counted.

\[
\text{Delivery order (EOQ scenario)} = \text{IF THEN ELSE} ((\text{Manufacture} + \text{Products delivered to Manufacturer} - \text{Orders}) < (\text{Customer demand} \times \text{Lead time} + \text{Safety stock}), 1, 0)
\]  

(Equation 4.3)

In the TSL scenario, fixed order interval strategy is applied and hence the
delivery order is manipulated with ‘PULSE TRAIN’ function to imitate the order patterns, under which a fixed order-review interval is adopted from initial time to the end.

\[ \text{Delivery order (TSL scenario)} = \text{PULSE TRAIN (INITIAL TIME, 1, Review interval, FINAL TIME)} \]  \hspace{1cm} (4.4)

Function adopted to calculate bullwhip effect is derived from the work of Lee et al. (1997) and applied by Disney et al. (2004).

\[ \text{Bullwhip effect} = \frac{\sigma^2_{\text{replenishment orders}}}{\sigma^2_{\text{customer demand}}} \]  \hspace{1cm} (4.5)

Other critical functions used for constructing the SD model are listed in the following section. Variable ‘Manufacture’ measure the inventory level of manufacturer at each period. With an initial amount of 50 units, in each period manufacturer inventory will vary as the products gets delivered to the manufacturer and customers.

\[ \text{Manufacture} = \text{Flow of products delivered to manufacturer} - \text{Flow of products to customers}, \text{ (Initial value}=50 \text{ units}) \]  \hspace{1cm} (4.6)

The flow of products to customer indicates that, if the inventory held by the manufacturer exceeds the current order (Backlogged orders + Customer demand), all orders will be fulfilled, otherwise the manufacturer inventory will be cleared. Furthermore, in both EOQ and TSL scenarios, backlogged orders will be fulfilled based on the priority.

\[ \text{Flow of products to customer} = \text{INTEGER (IF THEN ELSE ((Manufacture-Orders) >= 0, Orders, Manufacture))} \]  \hspace{1cm} (4.7)

\[ \text{Products delivered to manufacture} = \text{DELAY FIXED (FLOW OF PRODUCTS FROM MANUFACTURER, MANUFACTURER LEAD TIME, 0)} \]  \hspace{1cm} (4.8)

\[ \text{Backlogged orders} = \text{INTEGER (IF THEN ELSE ((Manufacture-Orders) >=0, 0, IF THEN ELSE (Flow of products to customers) >= Backlogged orders))} \]
orders, Customer demand+ Backlogged orders-Flow of products to customers, Customer demand)) - Backlogged orders delivered) (4.9)

The backlogged orders are calculated at the end of each time step.

Backlogged orders delivered= INTEGER IF THEN ELSE (Flow of products to customers>=Orders, Backlogged orders, IF THEN ELSE (Flow of products to customers>=Backlogged orders, Backlogged orders, Flow of products to customers)) (4.10)

Replenishment orders (EOQ scenario) = INTEGER IF THEN ELSE (Manufacture + Products delivered to Manufacture - Orders< (Customer demand * Lead time + Safety stock), Order quantity, 0)) (4.11)

Under the EOQ scenario, the replenishment order is generated when the ROP is achieved. The ROP is calculated as (Customer demand * Lead time + Safety stock). Whenever the manufacturer inventory is less than the amount of ROP, a replenishment order with the amount of order quantity, or EOQ, will be generated. The EOQ is calculated following standard inventory management theory as:

\[ EOQ = \sqrt{\frac{2 \times \text{Annulaized customer demand} \times \text{order cost}}{\text{holding rate} \times \text{unit cost}}} \] (4.12)

While under the TSL scenario, replenishment order quantity is determined by the difference between TSL and the sum of manufactured inventory plus due-in stock (Equation 4.13 and 4.14). Once a review interval is approached, a replenishment order will be generated for the supplier.

Replenishment orders (TSL scenario) = PULSE TRAIN (INITIAL TIME, 1, Review interval, FINAL TIME) * Order quantity (4.13)

Order quantity = INTEGER IF THEN ELSE (Target Stock Level - Manufacture
"Due-in stock" >= 0, Target Stock Level – Manufacture - "Due-in stock", 0)  

\[ \text{Due-in stock} = \text{Flow of products from supplier} - \text{Products delivered to manufacture} \]  

\[ \text{Target stock level (Only in TSL scenario)} = \text{Mean of customer demand} \times (\text{Lead time} + \text{Review interval}) + \text{Safety stock} \]

4. Simulation findings

4.1 EOQ analysis

The service level measures the percentage of fulfilled customer demand for each time period (Equation 5.1). In first round of simulation, the effect of lead-time (LT) on service level is computed while keeping all other inputs constant. Lead-time injects its influence into the system by affecting replenishment behaviors, changing order quantities and order frequencies. Holding all other variable constant, extension in lead-time will reduce the order frequency and increase safety stock. In Fig. 3, mark ‘LT1’ indicates the lead-time is set as 1 week; ‘LT2’ indicates a 2 week’s lead-time and similarly LT3 and LT4. Although manufactures usually require shorter lead-time from suppliers, there is a noticeable increase in the service level when lead-time is increased. Based on 5 years (260 weeks) simulation, the service level of 1-week lead time supply chain falls below 50% several times; while the service level fluctuation in supply chains with 2-week, 3-week and 4-week lead-time were less frequent (Fig. 3). It can be deducted that as the lead-time increases, the service level gets stabilized with less fluctuations in the EOQ based replenishment strategy. The main reason behind this phenomenon is believed to be reduction in the backlogged orders. Fig. 3 shows that the frequency and total amount of the backlogged orders are reduced with the
increase in lead-time mainly due to increase in safety stock. Supply chain with a 4-week lead-time possesses a safety stock of 25 units, while that number for 1-week is 13 units. The safety stock provides better buffering to the customer demand variation and improves the service level, even though it increases average inventory level (Fig. 4).

**Fig. 3. Service level and causal factors under different EOQ lead-time conditions**

In order to observe the behavior of the order quantity, three sub-indicators namely- Holding Rate (HR), Order Cost (OC) and Unit Cost (UC) are examined as the influencing factors to determine its effect over the service level. The impact of holding rate on the service level is tested while keeping all other variables as constant (LT3, OC£10, UC£50). Four rounds of simulation runs were conducted with different holding rate setting-10% (Marked as HR01), 20% (HR02), 30% (HR03), and 40% (HR04). It can be observed that massive service level swing exists in Fig. 5 and hence it can be concluded that holding cost increase will lead to increased fluctuations in the service level.

**Fig. 4. Impact on EOQ inventory level and other causal factor for varying lead time**

**Fig. 5. Impact on EOQ service level for varying holding rates**

Observations into backlogged orders, replenishment orders and inventory level further proves that ordering cost change possess very little effect on the above variables. Further research, such as regression analysis and relativity analysis is required to validate these findings. The impact of unit cost is examined by keeping all other variables constant (LT3, OC £10, HR20%). Massive service level fluctuations (SL=0%) were witnessed in all five simulations for variable unit cost from £25 to £125. It is observed that the fluctuations in the service level increases when unit cost increases, making it more volatile.
In practice, it is unwise to maintain a high service level with excessive inventory or replenishment orders due to associated holding and ordering costs. Inventory cost performance for variable lead times is observed with other control variables set constant. It is observed that the increase in the lead-time exaggerates the inventory cost. These results compliments with the conventional knowledge that with the increase in service level there is a trade-off in the inventory cost burden. It is also observed that the replenishment orders of shorter lead time are more equally distributed over time. However, for longer lead time conditions such as LT 4, 10 replenish orders are needed in a row from week 2 to week 11. The result of this behavior is significant, where no more orders comes (products delivered to manufacturer) in the next 8 weeks which means a maximum holding period for certain inventory is two months, which significantly increases the holding cost. This brings to another finding that in the EOQ scenario, lead-time increase will amplify inventory cost by rising average inventory holding period.

There is positive relationship between holding rate and accumulated inventory cost as observed in Fig. 6 (a) and complies with the existing inventory theory. However, the cost differences between 30% HR (HR03) and 40% HR (HR04) and that between 60% HR (HR06) and 80% HR (HR08) are not as significant as the difference between 10% and 20% HR. It can be inferred that, as the holding rate increases, manufacturer tend to arrange more replenishment order rather than holding extra inventory. The inventory level also exhibits the similar variation pattern. The lower holding rate increases the sensitivity of both inventory level and inventory cost. Another target parameter examined in the EOQ order quantity influencing the inventory cost is the unit cost. The decomposition of inventory cost reveals that with the increase in unit cost, the inventory with manufacturer becomes more stabilized at a lower level and hence poses little impact on the overall inventory cost.

**Fig. 6 (a).** Impact of holding rate on EOQ accumulated inventory cost**
**Fig. 6 (b).** Impact of holding rate on on TSL inventory cost **
4.2 TSL analysis and comparison

It is difficult to conduct the entirely unbiased comparison when two strategies and parameters are different. For conducting a comparative study, a constant 3-week lead-time is set as a control variable to compare the performances of two different scenarios. Under the fixed review intervals (R10), the increase in lead-time will improve the service level. To quantify the different manufacturer behavior responding to the lead time when their review interval is determined, Review Ratio (RR) is set as a variable. RR is defined as the percentage of review interval to the lead-time (Moon and Choi, 1998). For example, In 3-weeks LT with a RR of 0.5 will possess a review interval of 1.5 weeks. Fig. 7. indicates the service level variation with different review ratios when LT is set as 3-week.

**Fig 7. Impact on TSL service level for varying review interval**

It can be noticed that with the increase in RR, the service level gets improved. In the TSL scenario, a 0.5 review ratio (R05) possesses most volatile service level, however service levels at higher RR’s such as R10, R15 and R20 are stabilized at 100% (Fig. 7). By comparing the results from different EOQ scenarios, it can be inferred that when review ratio exceeds 1.0, TSL provides better service level (refer to Fig. 6 (a) and 6 (b)). The simulation on service level and inventory cost performance is conducted for a comparative study. The results indicate similar inferences drawn from the EOQ scenarios: longer lead-times will increase inventory cost; order cost has little impact, while holding cost per unit affects significantly on the inventory cost as seen in Fig. 6 (b).

For the inventory cost comparison, both scenarios are set with the following parameters: Lead-time 3 weeks, Unit cost £50, Order cost £10, Holding cost £10 (HR in EOQ is 20%), Forecast error 10units/week, Service level 90% (z-score 1.26). Average inventory cost for TSL replenishment strategy with different review interval
(R05, R10, R15, R20) is £172,317 and that for EOQ simulation under LT3 is £206,020. It can be inferred from above inventory cost numbers that the TSL strategy possess a cost advantage over EOQ strategy in the e-shopping supply chains. However further research with more sophisticated analysis methods is necessary to validate above findings.

4.3 Bullwhip effect in TSL and EOQ

In this section, effect of both strategies on the bullwhip effect is observed. The bullwhip effect increases with increase in the lead time in both EOQ and TSL scenarios as evidenced in Fig. 8. Categorized views of the bullwhip effect in TSL and EOQ scenarios are presented in Fig. 9. In the TSL scenario, bullwhip effect exhibits a positive relationship with a review ratio or review interval. Whereas, in the EOQ scenarios, it increases with order cost and decreases with unit cost and holding rate (Fig. 9).

**Fig. 8. Impact of lead time on bullwhip effect in TSL and EOQ scenario**

**Fig. 9. Impact of causal factors in TSL and EOQ scenario **

The simulation results in both TSL and EOQ scenarios confirmed the existence of bullwhip effect in the e-shopping supply chains. Lead-time influences the inventory cost and service level in both scenarios. In the EOQ strategy unit cost, holding rate variations contribute mostly to the inventory cost and service level performances; while order cost has very little impact on the overall performance. In the TSL scenario, review interval is the key element affecting both service level and inventory cost. It is evident that the managerial decisions influence on the different ordering patterns leading to drastically different supply chain performances. The TSL strategy shows preferable results with improved cost performance and improved service level for RR greater than 1.0. The comparative study is based on the simulation results and further research in this direction is necessary to validate these findings.
5. Conclusion and discussion

Using SD simulation, the influencing factors of supply chain performance under different e-shopping scenario are examined. Simulation results confirmed that the bullwhip effect exists in all e-shopping scenarios. It is found that the TSL strategy reflects less bullwhip effect than the EOQ strategy, while holding all other variables constant. Under EOQ strategy lead-time, order cost, unit cost and inventory holding rate all contributes to the bullwhip effect. Increase in the lead-time and order cost exaggerates the bullwhip effect, while increase in the unit cost and inventory holding rate reduces it. In the TSL scenario, same as the results from the EOQ scenario, lead-time also possesses a positive relationship with the bullwhip effect. This effect is exaggerated when review ratio is increased. Service level varies under EOQ strategy when lead-time, unit cost and holding rate changes, in spite the order cost has little influence on the service level. Existing literature suggests that shorter lead-time will provide better supply chain performance. However, through the simulation it is suggested that the longer lead-time will improve service level by increasing the safety stock and general inventory level. Unit cost and holding rate influence the service level in the opposite direction: when these two variables are increased, the service level is reduced. Moreover, it is also found that the order cost has little impact on the service level, however further investigation is necessary to validate these findings.

Under the TSL strategy, service level is improved when review ratio or lead-time increases. Hence the inference is made that under e-shopping scenario, it is important for the decision makers to adopt fixed review interval strategy (order-up-to, OUT) than fixed order quantity replenishment strategy. Though online purchasing platform is becoming a prevalent channel for small manufactures to do their business, the main research stream on e-shopping or e-business is still focusing on large companies with complex supply chain. In the paper, small manufacturer’s behavior and factors influencing supply chain performances is studied. The SD simulation study was inspired by the prevalence of online shopping platform, especially the ones spurred
trillions of transactions in China. Small businesses are drivers for this increasing phenomenon. However, as mentioned in the paper the scarcity in the field of small business under e-shopping scenario constrained the simulation. Understanding the e-shopping scenario for small manufacturers is believed to be valuable to the current body of knowledge in the e-business. It is believed that the inferences made will support in the future research on micro-supply chain behaviors within e-business. Supply chain decision-makers need comprehensive models to increases the profitability of the whole network (Georgiadis et al., 2005). The research has significant implications for the decision-makers in small businesses using online platforms. The insights drawn guides supply chain Managers into making appropriate replenishment decisions based on volume and environment of the business. For small businesses, it is better to follow TSL strategy with fixed order review intervals or order-up-to (OUT) strategies, rather than EOQ with fixed order quantity strategies while making replenishment planning.

Due to the functional constraints, it is difficult to implement comprehensive quantitative analysis to validate the findings. Validation of the findings is lacking due to scarcity of existing case studies in the field of small-business under the OSP context. The research can be validated with the use of different modelling approach to SD to check for consistency in the results. Variables beside the target observation parameter are controlled stable, when inspecting specific relationship between two target variables to attain internal validity. Primary data such as customer demand is generated through input-controlled functions and the assumptions are set based on the researcher’s experience. The future research can consider dynamic customer behaviors under promotions and customer delivery delay to generate further insights. Advanced EOQ and TSL models are also expected to change the overall behavior of the influencing factors. The research discussed in this paper can be explored further by testing the findings on multiple small businesses for additional insights. Investigating the trade-offs and sensitivity between inventory cost and service level
under different replenishment strategies within e-business are other challenges to explore.

References


**Additional reading**


# LIST OF TABLES

**Table 1** List of variables and associated cause and effect

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Cause</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier</td>
<td>Indefinite availability to respond to the orders made by the manufacturer.</td>
<td>Replenishment orders</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Measures the inventory level of manufacturer at each period.</td>
<td>Supplier, Orders</td>
<td>Inventory cost, Order frequency, Backlogged orders, Orders</td>
</tr>
<tr>
<td>BWE</td>
<td>( \frac{\sigma^2_{\text{replenishment orders}}}{\sigma^2_{\text{customer demand}}} )</td>
<td>Replenishment orders, Customer demand</td>
<td>Safety stock</td>
</tr>
<tr>
<td>Service level</td>
<td>Indicates how much of the customer demand is fulfilled in each time step.</td>
<td>Products delivered to customer, orders</td>
<td>Safety stock</td>
</tr>
<tr>
<td>Inventory cost</td>
<td>Indicates the sum of inventory costs from the beginning of the simulation.</td>
<td>Replenishment orders, Order cost, Order frequency, Manufacturer, Holding cost</td>
<td></td>
</tr>
<tr>
<td>Backlogged orders</td>
<td>Indicating the unsatisfied customer demand at each time period.</td>
<td>Manufacturer, Lead time, Customer demand</td>
<td>Orders</td>
</tr>
<tr>
<td>Replenishment orders</td>
<td>In the EOQ scenario, a replenishment order is made when the sum of inventory of manufacturer and products delivered to manufacture is less than the simultaneous order amount.</td>
<td>Manufacturer, Lead time, Orders, Safety stock, Order quantity</td>
<td>Supplier, Inventory cost, BWE</td>
</tr>
</tbody>
</table>

In the TSL scenario, fixed order interval strategy is applied hence replenishment order is made at fixed rate.
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
<th>Associated Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation of customer demand</td>
<td>Auxiliary variable fixed at 20 units.</td>
<td>Customer demand</td>
</tr>
<tr>
<td>Customer demand</td>
<td>Demand generated by customer at each time period.</td>
<td>Mean of customer demand, Standard deviation of customer demand, Orders, Backlogged orders, BWE</td>
</tr>
<tr>
<td>Orders</td>
<td>Indicates the sum of simultaneous customer demand and backlogged orders.</td>
<td>Customer demand, Backlogged orders, Manufacture</td>
</tr>
<tr>
<td>Mean of customer demand</td>
<td>Auxiliary variable set at 15 units/week.</td>
<td>Customer demand, Replenishment orders</td>
</tr>
<tr>
<td>Orders, Backlogged orders</td>
<td>Backlogged orders delivered are set as auxiliary variable created to avoid infinite accumulation of backlogged orders.</td>
<td>Lead time, Backlogged orders delivered, Manufacture, Costumer demand</td>
</tr>
<tr>
<td>Holding cost</td>
<td>Indicates the cost of inventory in stock.</td>
<td>Inventory cost</td>
</tr>
<tr>
<td>Order frequency</td>
<td>Indicates how often manufacture makes replenishment order to the supplier.</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Order cost</td>
<td>Indicates the cost for each replenishment order made by manufacturer.</td>
<td>Inventory cost</td>
</tr>
<tr>
<td>Lead time</td>
<td>Indicates the time lag from replenishment orders are made till the orders are delivered. Fixed at 3 weeks.</td>
<td>Backlogged orders, Replenishment orders, safety stock</td>
</tr>
<tr>
<td>Safety stock</td>
<td>Indicates buffer stock to avoid lost sales/other uncertainties</td>
<td>Lead time, Service level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Replenishment orders, Order quantity</td>
</tr>
</tbody>
</table>
Fig. 1. Causal loop diagram for inventory replenishment in supply chain network
Fig. 2. Stock and flow for inventory replenishment in supply chain network
### Service level across different lead times

<table>
<thead>
<tr>
<th>LT</th>
<th>Average</th>
<th>Stdev</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1</td>
<td>93.12656127</td>
<td>18.9180963</td>
</tr>
<tr>
<td>LT2</td>
<td>98.01061808</td>
<td>11.24280603</td>
</tr>
<tr>
<td>LT3</td>
<td>98.64514654</td>
<td>10.51911443</td>
</tr>
<tr>
<td>LT4</td>
<td>99.66354885</td>
<td>4.645826416</td>
</tr>
</tbody>
</table>

**Fig. 3.** Service level and causal factors under different EOQ lead-time conditions

### Inventory level across different lead times

<table>
<thead>
<tr>
<th>LT</th>
<th>Average</th>
<th>Stdev</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1</td>
<td>34.54615385</td>
<td>15.32636537</td>
</tr>
<tr>
<td>LT2</td>
<td>57.87692308</td>
<td>22.57925223</td>
</tr>
<tr>
<td>LT3</td>
<td>78.64514654</td>
<td>30.70752528</td>
</tr>
<tr>
<td>LT4</td>
<td>99.19230769</td>
<td>37.77296456</td>
</tr>
</tbody>
</table>

**Fig. 4.** Impact on EOQ inventory level for varying lead time
Fig. 5. Impact on EOQ service level for varying holding rates

Fig. 6 (a). Impact of holding rate on EOQ accumulated inventory cost
**Fig. 6 (b).** Impact on TSL inventory cost for varying holding rate

**Fig. 7.** Impact on TSL service level for varying review interval
**Fig. 8.** Impact of lead time on bullwhip effect in TSL and EOQ scenario

**Fig. 9.** Impact of causal factors in TSL and EOQ scenario