CHAPTER 4 SUPPLY CHAIN LOGISTICS AND MODEL BUILDING

In this chapter the factors that influence supply chain in automobile sector were identified from primary and secondary sources. From (a) literature review 35 factors and from (b) expert interview 17 factors (refer Appendix 2) were identified. Then variables for the research study are selected.

4.1 VARIABLES SELECTION

In this chapter, supply chain of incoming components in the automobile sector have been studied to bring about comprehensive causal factors that affect logistics cost of automobile products.

(a) Literature Review,

The table 4.1 lists all the 35 factors that are identified through literature review with regards to the total logical cost. These factors are grouped into three categories: transportation costs, inventory costs (including stationary and in-transit inventory) and other costs.
Table 4.1 Total Logistics Costs

<table>
<thead>
<tr>
<th>Transportation Costs</th>
<th>Inventory Costs</th>
<th>Other Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping distance</td>
<td>Delays in average transit time</td>
<td>Documentation</td>
</tr>
<tr>
<td>Unit freight rate</td>
<td>Variability in transit time</td>
<td>Packaging (cost &amp; type)</td>
</tr>
<tr>
<td>Shipping weight</td>
<td>Average item monthly demand</td>
<td>Sourcing</td>
</tr>
<tr>
<td>Shipping cost per mile</td>
<td>Average item value</td>
<td>Warehousing</td>
</tr>
<tr>
<td>Shipping rate per pound</td>
<td>Product value</td>
<td>Production costs</td>
</tr>
<tr>
<td>Truck load weight</td>
<td>Product demand for each assembly plant</td>
<td></td>
</tr>
<tr>
<td>Average item weight</td>
<td>Warehouse and material handling time</td>
<td></td>
</tr>
<tr>
<td>Number of items per ensemble</td>
<td>Inventory carrying charge</td>
<td></td>
</tr>
<tr>
<td>Product weight</td>
<td>Lot size</td>
<td></td>
</tr>
<tr>
<td>Product density</td>
<td>Demand rate</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Expected stock out</td>
<td></td>
</tr>
<tr>
<td>FOB</td>
<td>Order processing</td>
<td></td>
</tr>
<tr>
<td>Documentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity of transportation vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Currency exchange rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duties and taxation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation mode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(b) Expert interviews

Since the context of this study is specific to the case firm’s case, three teams comprising of 2 managers, 3 supervisors and 12 analysts from supply chain management division who manage transportation, inventory and warehousing operations were interviewed (unstructured interviews) to identify relevant factors impacting supply chain cost. The case firm has institutionalised continuous process improvement initiatives, and thus Six Sigma techniques and tools are widely implemented. The outcome is presented as a Cause and Effect diagram that depicts supply chain cost (Refer Figure 4.1).

![Supply chain cost Cause and Effect diagram](image)

Figure 4.1. Supply chain cost Cause and Effect diagram (fish bone)

The focus of study is on factors related to inbound logistics costs of auto components for assembly plant. Thus, the factors related to logistics costs and parts (automobile components) were chosen for this study. Further, two logistics-cost-related factors, freight mode (reason: road is fixed for domestic transport) and distribution channel (reason: relevant only for outbound logistics or fixed dealer networks), and two parts-related factors, number of parts (reason: fixed for the model under study) and minimum package quantity (reason: fixed based on consumption rate and shipping frequency), were not considered. The six important factors impacting inbound logistics cost were selected for further research. Those factors are Inbound logistics cost (Ic), Supplier distance (Sd), Part
Table 4.2 Description of Factors Selected for the Study

<table>
<thead>
<tr>
<th>Factors</th>
<th>Measurement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier distance</td>
<td>Kilometers</td>
<td>Distance between supplier location to assembly plant in south India</td>
</tr>
<tr>
<td>Part volume</td>
<td>Cubic meters/vehicle set</td>
<td>Volumetric measurement of part (auto component, includes packaging)</td>
</tr>
<tr>
<td>Cubic efficiency</td>
<td>Percentage</td>
<td>Percentage volume of parts (auto component) or packages stuffed per container</td>
</tr>
<tr>
<td>Material handling cost</td>
<td>USD/cubic meters</td>
<td>Incurred in the process of rearranging parts to achieve higher cubic efficiency per container shipment</td>
</tr>
<tr>
<td>Packaging type</td>
<td>Standard or nonstandard</td>
<td>Used for repacking parts (secondary packaging) to achieve higher cubic efficiency per container shipment</td>
</tr>
<tr>
<td>Inbound logistics cost</td>
<td>USD/vehicle set</td>
<td>Freight cost from supplier location to assembly plant in Western India</td>
</tr>
</tbody>
</table>

4.1.1 Supplier distance

There is a huge impact imposed on the transportation/freight cost due to supplier distance. This factor plays a prominent role in the logistics cost and impact variable costs such as fuel, maintenance and labour. Though global supply chain model ensure the companies leverage the lower cost manufacturing, transportation managers face significant challenges in terms of ensuring the products being delivered at long distances and right locations without delay. In company's revenue, the cost spent on transportation is somewhere between 5-6% and contributes to overall products costs majorly. When the transportation is managed effectively, the cost to company is reduced and its supply chain process gets efficient.
The cost and time estimation in transportation is a difficult process due to various factors such as volatile fuel prices, unavoidable delays and longer lead times with suppliers. Due to this difficulty, companies incur enormous inventory costs.

Supplier selection and the facility location are the two main criteria that needs to be given top priority in order not only to reduce the transportation overheads but also in ensuring the right product reaching the right location as per the committed time.

**4.1.2 Part volume**

Part Volume includes the load volume and the transport cost and unit of weight decreases when load volume increases i.e., inversely proportionate. Part Volume occurs due to the reason that the fixed cost in delivery and pickup in addition to administrative costs that are scattered over additional volume. Say, for example, when there is high volume part, then it occupies huge space that considerably affects the number of components being shipped, type of packaging, handling cost and cubic efficiency. When the part volume is high, then the impact on the logistics cost is also higher.

**4.1.3 Cubic efficiency**

The logistics cost is predominantly influenced by the loading capacity of transportation vehicles. Cubic efficiency is nothing but the efficiency with which the container space is utilized for goods transportation. The industry’s biggest challenge is how a manufacturer and their relevant TPL (i.e., Third-Party Logistics) providers successfully optimize the pickups between a supplier and several manufacturing plants in a holistic manner. This challenge can be overcome with the knowledge on cubic efficiency or by better vehicle fill that usually reduces the transportation costs in turn the logistics cost.
4.1.4 Handling cost

Wang, J., and Zhang, N. [71], in the application on automated warehouse logistics in the manufacturing sectors, stressed the importance of warehouse enabled with automated supply chain in order to reduce the handling cost. The handling cost, usually affected by the manner in which the products are consolidated during transport and during their storage, has a substantial impact on the logistics cost. The handling costs cover the expenses on manpower and equipment during loading and unloading processes. In case if there is special packaging required for efficient cubic efficiency, then the handling cost is affected.

4.1.5 Packaging type

From the literature, it can be inferred that the logistics cost can be recovered through proper packaging designing. “The redesign means a lot more product on each pallet, which means fewer pallets need to be shipped and handled”. Thus, packaging practices and logistics cost is significantly related.

Packaging exerts a substantial impact on the expenditures incurred and productivity of logistics process. The purchase of packaging material and material disposal constitute packaging type. In our model the packaging type consists of four variants:

- Standard pallets
- Nonstandard pallets
- Nonstandard trolleys
- Special bin

The type of packaging and empty return management are the areas that are gaining interest in logistics. As the return flow of containers must match the trucks leaving the plant, their movement is now very much under logistics purview.

The elements of the theoretical framework are developed from literature review, and best-suited constructs (factors) are identified through unstructured interviews with case firm’s
supply chain management team. This approach is more suitable for case study approach as it enables development of more relevant constructs from representing the unit of analysis. The theoretical framework with hypothetical constructs reflects causal interrelationships.

4.2 THE HYPOTHETICAL MODEL BUILDING

The above six hypothetical constructs, namely, Inbound logistics cost (Ic), Supplier distance (Sd), Part volume (Pv), Cubic efficiency (Ce), Material handling cost (Hc) and Packaging type (Pt), were selected to develop hypothetical model. The case firm’s third-party logistics partner provides logistics services that include warehousing and transportation. The logistics process includes collection of parts from suppliers through milk run model from three hubs in north, west and south India. Since cubic efficiency is a
critical factor for transport operational performance, the case firm and third-party logistics partner jointly evolved frequency of consolidation plan for line hauling operations. To increase cubic efficiency, secondary packaging practice was introduced with nonstandard packaging material. The outcome was expression of \( I_c \) as a function of \( S_d, P_v, P_t, H_c \) and \( C_e \). Since the TPL (i.e., Third-Party Logistics) partner is involved in logistics operations involvement, the supply chain analysts from Case Firm monitored the performance metrics. Thus, the constructs \( P_t, H_c \) and \( C_e \) were considered to be intervening among \( S_d, P_v \) and \( I_c \). The outcome is hypothetical structural model illustrated in Figure 4.4. A total of 12 hypotheses were tested on the relationships between the six factors.

The structure model was deduced on the assumption of endogenous variables such as \( I_c, P_t, H_c \) and \( C_e \), where their respective error terms are considered as unobserved exogenous variables. \( S_d \) and \( P_v \) were assumed as observed exogenous variables. Measures of observed variables are extracted from enterprise resource planning system from April 2013 to April 2014 (12 months). The ranges of measurements are presented in Table 4.4.

![Figure 4.3. Inbound logistics cost control hypothetical model](image-url)
H1: Supplier distance positively affects inbound logistics cost.

H2: Parts volume positively affects inbound logistics cost.

H3: Supplier distance positively affects packaging type.

H4: Supplier distance positively affects material handling cost.

H5: Supplier distance positively affects cubic efficiency.

H6: Parts volume positively affects packaging type.

H7: Parts volume positively affects material handling cost.

H8: Parts volume positively affects cubic efficiency.

H9: Packaging type positively affects inbound logistics cost.

H10: Material handling cost positively affects inbound logistics cost.

H11: Cubic efficiency positively affects inbound logistics cost.

H12: Supplier distance and parts volume impact each other.

Table 4.3. Range Measures of Variables in the Model

<table>
<thead>
<tr>
<th>S.No</th>
<th>Logistics cost Factors</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Logistics cost</td>
<td>USD ( 0 to 8.74 )</td>
</tr>
<tr>
<td>2</td>
<td>Part Volume</td>
<td>Cubic ( 0 to 1.34 )</td>
</tr>
<tr>
<td>3</td>
<td>Supplier Location</td>
<td>KMs ( 0 to 2000 )</td>
</tr>
<tr>
<td>4</td>
<td>Packaging Cost</td>
<td>USD 0 to 3</td>
</tr>
<tr>
<td>5</td>
<td>Cubic Efficiency</td>
<td>% ( 0 to 0.8)</td>
</tr>
<tr>
<td>6</td>
<td>Handling cost</td>
<td>USD ( 0 -15 )</td>
</tr>
</tbody>
</table>
Note: Since the Case Firm is a Multinational company, all the costs i.e., logistics costs, packaging costs, handling costs etc., are shown in USD since it is tracked and reported so.

Somuyiwa [68], in her work on logistics cost, established the cost equation for transportation with the “volume of goods” and “distance over which the goods are carried”.

Xu and Zhao [69] highlights the significance of logistics cost in the supply chain. Thus, we establish a significant relationship and association between logistics cost and supply chain cost.

The logistics process is defined by Guirong [70] as “According to the needs of users, transfers auto parts from suppliers to OEMs with the smallest cost. It mainly includes transportation, storage, packing, loading, unloading, and sales and information processing etc.”

There is a need for companies to manage both their costs and performance in logistics since a low-cost transportation path need not necessarily to be the fastest path. The logistics cost usually is the charges incurred during transportation such as train travel, air travel, ocean transport and trucks. The logistics cost also includes the warehousing space, packaging, material handling, fuel cost, tariffs and duties. It is possible for a company to reduce the costs and increase efficiency by employing an efficient supply chain and systematic logistics procedures. Otherwise, a company that has poor logistics or no systematic procedures fail to meet the customers’ demands and expectations, thus leads to business closure.

4.3 STRUCTURAL EQUATION MODELLING

In marketing, Structural equation modelling (SEM), a tool that is used to analyze multivariate data, is deployed for appropriate theory testing Bagozzi [61]. SEM models are way beyond the usual regression models that represent a number of independent, dependent variables along with hypothetical latent constructs that may be the clusters of observed variables. It provides a way to evaluate a set of relationships between observed
and latest variables as a whole and it allows theory testing to be done even if it is not possible to conduct the experiment at all. Due to this characteristic, SEM model became ubiquitous in all social and behavioral sciences (e.g. MacCallum [62]). Baumgartner and Homburg [63] reviewed the usage of SEM in marketing research.

In the past two decades, the evolution of SEM is noteworthy from being just a statistical technique for small group to the most established and valid tool for broader scientific public. Though the analysis is huge, the price offered for such analysis is questionable. The review provided an overview about SEM, the ideas behind it, its potential applications and about the current software. Further, this study also discussed about the possible pitfalls that could be avoided along with the drawbacks which are in-built. These insights help the researcher choose whether to include SEM in their research or not. An internet survey findings on “State of the Union Address” among the SEM users and their usage discussed various questions such as the models that are to be preferred and the software to be favored in current psychological research. This review comes with an SEM first-aid kit that helps the reader. In this review, typical problems and possible solutions are addressed and the readers are guided with the most-expected support. This study is an initiative to help the novice readers on how to use SEM and make the advanced reader criticize themselves on the SEM limitations.

Though there are studies available, introductory SEM books (e.g. Hoyle [64]) do not have a simple, accurate and direct definition for SEM. Kaplan and Haenlein [65] proposes that “structural equation modeling can perhaps best be defined as a class of methodologies that seeks to represent hypotheses about the means, variances and covariances of observed data in terms of a smaller number of ‘structural’ parameters defined by a hypothesized underlying model”. Keeping aside the problem of using the terms ‘structural’ and ‘model’ which needs clarification, this definition puts forth some important features such as “SEM represents a multitude of techniques under one umbrella” and this can be explained through concepts and typical examples in a comprehensible manner.
LISREL models (Linear Structural Relations) is the other name for Structural Equation Models. Here, the term ‘structural relation’ denotes SEM core concept i.e., handling the relationships among the latent variables. These relations are generally formulated by linear regression equations and expressed in a graphical format, path diagrams using arrows. Being flexible, SEM deals with both single, simple, multiple linear regressions as well as with a system of regression equations.

Wright [66], a geneticist, defined Structural Equation Modelling (SEM) as a statistical technique that can be used to evaluate the causal relations with the combination of qualitative causal assumptions and statistical data. Referring to the figure 4.2, SEM models allow both confirmatory and exploratory modelling i.e., SEM models suit both theory testing and development. The confirmatory modelling that usually begins with a hypothesis is represented through causal model. The concepts which are utilized in the model must be operationalised so that the relationships are allowed to be tested between the concepts in the model. The SEM model is evaluated against the data measured in order to find out the ability of the model to fit the data. The model which contains the causal assumptions are usually filled with falsifiable implications and these can be evaluated using data. A, B and C are three variables or constructs and the below figure indicates the relationship among three variables

![Figure 4.4. Simple SEM model](image)

With an initial theory, through specification of a corresponding model, the SEM can be used inductively. This is followed by the value estimation of free parameters with the help of data. Usually, the initial hypothesis needs to be adjusted for model evidence. SEM is
usually used to explore in the context of exploratory factor analysis as in psychometric design. The SEM has strengths such as it has the ability to construct latent variables i.e., variables which could not be directly measured, but can be estimated as a model from different measured variables, which can be predicted as latent variables. This enables the researcher to capture the non-reliability of the measurement in the model explicitly, thus in theory, it accepts the structural relations among the latent variables to be estimated in an accurate manner. The special cases of SEM are represented through regression, path analysis and factor analysis.

In Structural Equation Modelling, the missing variables represent the qualitative causal assumptions in every equation and further it also represents the vanishing covariances among other few error terms. The above mentioned assumptions can be tested in experimental studies whereas it must be confirmed in observational studies judgmentally.

The empirical framework is developed using Structural Equation Modelling (SEM) approach to evaluate the predictive ability of each construct defined in the theoretical framework. It integrates measurement (factor analysis) and structural (path analysis) approaches. Its applications include causal modelling or path analysis, “Confirmatory Factor Analysis (CFA)”, “second-order factor analysis”, “covariance structure models” and “correlation structure models” Alavifar [60]. Various popular programs include LISREL, EQS, MPLUS, R, Smart PLS, Stata SEM, SAS and Amos in SPSS.

4.3.1 Logistics cost: model building

Measures of variables are extracted with the help of management information systems team from enterprise systems. The observed variables thus operationalise the hypothetical constructs and empirical level. The error terms are represented as latent variables. Thus, the evaluation model considers only observed variables. Unlike statistical tests like Analysis of Variance (ANOVA) and Multiple Regressions (MR) that determine individual effects, SEM provides a higher perspective of the analysis by evaluating entire model. It
also requires large sample size and thus makes it possible to have highly significant results. It provides better estimates of magnitude of effects or effect size for observed variables than ANOVA and MR techniques Kline [67]. Figure 4.3 provides the steps to develop an SEM. Specification of hypothetical SEM model can be made in three formats: path analysis, confirmatory factor analysis and structural regression. Path analysis enables specification and testing of structural models with a priori assumptions about observed variables. Confirmatory factor analysis evaluates hypotheses about relationships between indicators and factors specified in the measurement model. The structural regression model enables analysis of both structural component and measurement component. Since structural regression model enables analysis of both structural and measurement components specified, this is chosen as an approach to test hypotheses and analysis.

SPSS AMOS is selected to develop and test structural regression model. This programme provides easy to use graphical user interfaces and generates results that can be used to verify reliability and validity of the empirical model.

In the next chapter, the hypothetical model is converted to SEM