1 INTRODUCTION

Supply chain is a network of facilities that supports procurement of materials, transformation of materials into intermediate & finished goods and distribution of finished products to customers. Successful supply chains manage flow of materials (downstream), fund flow (upstream) and information flow (in both streams) to provide high level of product availability to customers while keeping the costs low.

1.1 DEFINITION OF SUPPLY CHAIN MANAGEMENT

The Global Supply Chain Forum defines Supply Chain Management (SCM) as “The integration of key business processes from end user through original suppliers that provide products, services and information that add value for customers” (Lambert D et al., 1998). SCM involves all business processes from original supplier to the end customers including demand management, procurement, manufacturing flow management, order fulfillment, product development, Customer Relationship Management (CRM), customer service management, commercialization and returns.
1.2 ELEMENTS OF SUPPLY CHAIN

The elements of supply chain are: Purchasing, Operations & Distribution (Joel D. Wisner et al., 2005). The important processes under these elements are given in figure 1.1.

![Suppliers Chain Diagram]

**Figure 1.1 Processes under Supply Chain Elements**

In real-world businesses, the processes under supply chain elements are handled by different people working under different department heads in isolation, operating the processes with specific departmental objectives of cost control or saving material and other resources.

Several researches revealed that collaborative and cooperative businesses lead to success of both the companies involved. But still, each stake holder: supplier,
manufacturer, wholesaler & retailer all work in silos. As a result of reluctance to information sharing, there is uncertainty in demand planning. Disability in developing the attitude of shared vision among trading partners, hurdles in implementing and practicing corporate culture among supply chain partners lead to failure in building stronger links (genuine supply chain partnerships). Collaborative demand forecasting is mostly absent and the firms try to push what they produce in to the market (especially in Indian context).

1.3 NEED FOR INTEGRATION OF SUPPLY CHAIN ELEMENTS

In the present business scenario, a combination of several forces such as globalization, propagation of product variety, shortened product life cycles, etc., compelled companies to achieve greater coordination and collaboration among supply chain partners in an approach called supply chain integration to stay competitive in the business. For effective SCM, data integration, financial flow management, supply-demand matching, collaborative forecasting, information sharing and goods movement synchronization through efficient transport scheduling are some of the best practices.

As a new way of doing business, firms must realize the strategic importance of planning, controlling and designing a supply chain in an integrated approach to gain
synergy of inter-functional and inter-organizational integration and coordination across the supply chain elements.

Integrated Supply Chain Management (ISCM) is a process oriented integrated approach to procure, produce and deliver products & services to customers. Its scope includes management of sub-suppliers, suppliers, internal operations, trade customers, retail customers and end users. It includes managing material, information and fund flows. The interactions among different entities of a generic supply chain in ISCM are shown in figure 1.2.
1.4 COMPLEXITIES ASSOCIATED WITH INTEGRATION OF ELEMENTS

An organization can be a member of more than one supply chain and its position in each supply chain can also vary. For example, a company can be a components supplier in one supply chain and could be an assembly manufacturer in other supply chain. Given this complexity of supply chains that a company could be involved, D.M. Lambert & S.J. Garcia Dastugue (2003) suggested that companies should evaluate which business partner is critical to the company interest and have different degree of integration based on the criticality to the business.

The benefits of managing inter-functional and inter-organizational coordination can be demonstrated more transparently when exact data is available. Managerial issues involving real-world supply chain problems such as organizational resistance to change, inter-functional and inter-organizational conflicts are the major barriers for joint production planning, dynamic demand forecasting, profit sharing, team oriented performance measurement, CRM, information sharing, real time communication, inventory ownership (Hokey Min & Gengui Zhou, 2002) and technical compatibility.
The lack of mutual trust, lack of understanding on shared vision and silo mentality causes individual firms to work in isolation without considering the interests of their trading partners. Privacy problems and trade secrecy impose limitations on data interchange among the trading partners. From performance measurement point of view, there are several precincts in terms of non-availability of data on cross-border transactions, the question of promptness in data interchange across organizational boundaries, lack of clarity on attribution of performance indicators to specific organization or process due to over lapping of jurisdictions. All these practical problems enforce severe restrictions and serious limitations on integration of supply chain elements.

When we look at the processes under each supply chain element shown in figure 1.1, some of them are interdependent and some of them are independent. Also, a number of companies are involved in each of the business processes. There exist complex relationships among trading partners at different levels and different echelons in a supply chain due to wider variations in their financial status and technological capabilities. The optimization of particular objective in the interest of one particular firm or a small group of companies may lead to loss for other firms involved in the process. For example, when a focal firm is interested in achieving high level of product availability and supply chain flexibility, it is forced to maintain high levels of inventory upstream. If Vendor Managed Inventory (VMI) system is adopted, the vendors of components or intermediate parts have to be more cautious in meeting the changing requirements of the focal firm. Also, it is hard to get relevant
information on activities across the organizational boundaries for most of the processes of interest in supply chain as the companies may not maintain such data.

All these factors have been considered while formulating objectives of present research work. While selecting objectives of present research, due consideration is given to availability of data, extent of integration possible, impact on overall supply chain performance and affordability of the models to real time supply chains in Indian context.

The processes and performance indicators that are integrated in formulating present research objectives i.e., maximizing Overall Delivery Performance (ODP), minimizing Cash-to-Cash (C2C) cycle time (by optimizing payment and collection periods for minimum penalty), studying the impact Inventory Turnover Ratio (ITR) on C2C cycle time and developing a framework for shareholder facing performance measures are furnished in figure 1.3.
Figure 1.3 Performance indicators integrated in objectives of present research
1.5 SUPPLY CHAIN PERFORMANCE MEASUREMENT

In today’s economy, the battlefield is shifting from individual company performance to supply chain performance. For efficient SCM, performance measurement is vital as it directs the firms towards competitive edge by providing guidelines for improvement. Researches revealed that less than 10% of the companies are going outside their four walls to track the performance of supply chain activities of vendors, logistics providers, distributors and customers.

Basically, SCM starts with identification of trading partners who have interest in shared vision, mutual trust, Collaborative Planning Forecasting & Replenishment (CPFR) and good customer-supplier relationship. After identification of such partners, the firms can form strategic relationships that could make profits to all the firms along the supply chain. There is a famous saying “You can’t improve what you can’t measure”. Control of processes in a supply chain is crucial in improving performance and can be achieved, at least in part, through measurement.

We need performance measures (or metrics) which supports global supply chain performance improvements rather than narrow company specific or functional specific metrics which inhibit supply chain-wide improvements. Most of the companies have not succeeded in maximizing their supply chain’s potential because
they have often failed to develop the performance measures needed to fully integrate
their supply chain to maximize effectiveness and efficiency.

Each entity in a supply chain has its own influence on the overall performance. The extent of cooperation and coordination among different entities (suppliers, distributors, logistics providers and the focal firm) determines the level of integration as well as success of the supply chain as a whole.

1.6 GAPS IN INTEGRATED SUPPLY CHAIN PERFORMANCE MEASUREMENT

It has been identified from earlier researches that the objectives were of limited scope in a particular industry setup. The most important supply chain performance metrics: ODP, C2C cycle time have not been analyzed in an integrated approach. Though, some contributions on delivery performance have been published in various journals, the scope lack in a systematic procedure to measure and benchmark the performance expected from each entity. On the other hand, very limited work has been done on means of reducing C2C cycle time. The earlier researches were limited to determination of accounting ratios as means for indicating organizational financial performance. So far, no mathematical model is developed to optimize C2C cycle time by minimizing payment deferral period in the interest of
minimizing penalty to all entities i.e., a firm, its suppliers and distributors in an integrated approach. Also, the effect of ITR on C2C cycle time as well as on working capital management is not dealt with by earlier researchers.

Similarly, from shareholders’ perspective also, very limited work has been done in developing means of presenting supply chain performance in financial terms to assess the effect of renovation (in terms of integration) on supply chain management.

1.7 MOTIVATION FOR THE PRESENT RESEARCH

Earlier researches were focused on certain Key Performance Indicators (KPIs) that would lead to improved performance of the focal firm which may in turn lead to sub-optimal performance of the successive echelons of trading partners. This motivated me to concentrate on certain performance indicators among the supply chain elements in an integrated approach that would lead to improved performances of all the firms involved in the process.

The present research work is an attempt to evaluate the supply chain performance in an integrated approach and providing guidelines for benchmarking to
improve performance of individual firms along the supply chain in operational and financial perspectives.

In operational perspective, ODP has been selected as a supply chain performance measure. ODP is not a single variable. It depends on factors such as on-time procurement of raw materials, manufacturing schedule attainment, on-time shipment to warehouse and on-time truck placement by logistic provider. All these activities does not attribute to a single firm. Suppliers, warehouses / distributors, logistic providers are all involved along with the manufacturing firm in achieving prompt delivery to the customers.

Hence, an integrated approach is required to measure the current ODP taking into account, the core capabilities of trading partners and select optimal benchmark values to initiate improvements in performances of different entities involved in this process.

In financial perspective, the metric C2C cycle time is considered. Especially in working capital management, it could be observed that one or few companies take advantage of credit period by operating their business with other’s money. The strategy of “late payments and early collections” may be beneficial for one firm but not for its suppliers and customers. This will weaken supply chain relationships in the
long run. While formulating strategic alliances with supply chain trading partners, the firms must negotiate regarding the terms and conditions of payment that will be acceptable for both the parties. Here is an attempt to develop a mathematical model to calculate optimal collection & payment periods that are acceptable and beneficial to trading partners along a supply chain.

Similarly, there is need to develop a framework for assessing performance of a supply chain from shareholder’s perspective as shareholders are also interested in reviewing of the performance of a firm and its supply chain in order to know the effect of integration on the supply chain management process. Hence, a framework is developed to assess the performance of a firm and its supply chain from shareholders’ perspective.

1.8 OBJECTIVES OF RESEARCH

The objectives of present research work are as follows:

1. To develop a mathematical model for benchmarking expected levels of performance from each entity (i.e., supplier(s), manufacturing firm(s) and transportation provider(s)) by measuring the ODP of the supply chain in an integrated approach.
2. To develop a mathematical model for identifying the optimal payment period (to suppliers) and collection period (from distributors/customers) that would minimize C2C cycle time as well as total cost of working capital of a supply chain (in terms of penalty to all entities i.e., a firm, its suppliers and distributors).

3. To study the effect of ITR on C2C cycle time and working capital management.

4. To develop a framework for analyzing a firm’s performance from shareholders perspective to study the impact of integration on supply chain management.

1.9 FRAMEWORK AND EXTENT OF RESEARCH

For the present research, the working definitions of performance indicators of ODP, C2C cycle time and shareholder facing performance measures have been taken from Supply Chain Operations Reference (SCOR) model (Supply Chain Council Inc., Version 7.0, 2005).
Considering the elemental performances in terms of suppliers on-time delivery, manufacturing schedule attainment, warehouse on-time shipment and logistic providers’ on-time truck placement, the ODP is optimized by formulating a non linear objective function and solved by dynamic programming approach using Microsoft Excel spreadsheet. For benchmarking, the stage wise optimum of dynamic programming solution is used. The ODP of a supply chain is measured and the supply chain is classified as one of the four categories: Best in class, Advantage, Median and Major opportunity. Using the optimal table of dynamic programming solution, the next benchmark performance level for the supply chain can be selected and the expected performance levels for different entities can be fixed. In supplement to the dynamic programming model, a total cost model is developed to identify optimal expected performance level associated with minimum total cost.

In financial perspective, optimal collection and payment periods associated with minimum penalty are calculated for current values of payables and receivables by formulating the problem as a Linear Programming Problem (LPP) with an objective of minimizing total penalty. The LPP is solved using TORA software. Data required to analyze the objectives of research has been collected from Amara Raja Batteries Limited (ARBL). Analysis of primary data has been carried out and results are tabulated. The effect of ITR on C2C cycle time is also analyzed in case of ARBL. The performance of ARBL supply chain is assessed from shareholder’s perspective in the light of renovation in supply chain management.
1.10 LIMITATIONS AND JUSTIFICATION OF THE RESEARCH

The present research work is limited to evaluation of ODP of a firm and its supply chain in an integrated approach and providing benchmark values for improvement in elemental performances. In financial perspective, the scope is limited to find the optimal combination of payment and collection periods, payment deferral period that ensures minimum penalty to trading partners as well as minimizes C2C cycle time and providing basis for benchmarking to improve the individual performances in working capital management. In shareholders’ perspective, the contribution covers only formulation of a framework to evaluate the impact of renovation on supply chain management from stakeholder’s point of view.

In Indian scenario, the inherent difficulties in getting relevant data on cross border transactions entail the researchers to limit their scope to one-echelon supply chain transactions only. Hence, at this juncture it is admitted that the scope of present research is also limited to one-echelon supply chain only. But the ideology can be extended to successive echelons also in a generic sense.

The present research is an attempt to measure important performance indicators in integrated set up considering suppliers, distributors, transportation providers and the firm. The results clearly indicate that there is wide scope for supply
chains to improve their core competencies in terms of delivery performance and fund flow management by using the methodology presented in this thesis. This research is a step towards identifying opportunities for reallocation of pooled benefits to all entities by optimization.

1.11 ORGANIZATION OF THE THESIS

The thesis is organized into eight chapters. Definitions of supply chain and SCM, a brief note on elements of supply chain, need for integration of supply chain elements has been presented. The complexities associated with integration, need for supply chain performance measurement and gaps in earlier performance measurement systems have been addressed. Motivation for present research work, objectives of research, frame work and extent of research, limitations and justification of the research have been furnished in this Chapter.

In Chapter two, critical review of literature has been carried out in the light of integration of supply chain elements. Barriers for integration and expected benefits of integration have been addressed. Earlier contributions on supply chain performance measurement relevant to the present research objectives have been presented considering interdisciplinary nature of SCM.
In **Chapter three**, the framework for data acquisition and brief note on data requirement for the present research work is presented. The primary data required for analysis collected from SCM division and annual reports of ARBL is presented.

In **Chapter four**, Methodology to assess ODP of a firm and its supply chain in an integrated approach has been presented. The problem is formulated as Non-Linear Programming (NLP) model and is solved by dynamic programming approach to find benchmark values for expected performance levels for each entity in ODP. A total cost model has been developed to find the optimal performance of each entity and empirical analysis is carried out to check the validity of the total cost model.

In **Chapter five**, the focus is on minimizing penalty to all entities and shortening C2C cycle time. LPP approach to find optimal payment and collection periods that will minimize C2C cycle time; simultaneously minimizing penalty to all entities along the supply chain is described. Also, considering ITR as a supply chain performance measure, its impact on C2C cycle time has been analyzed.

In **Chapter six**, a framework for assessing performance of a supply chain from shareholder’s perspective is presented. The data collected from annual reports
of ARBL is analyzed. The reflection of renovation on SCM is studied in terms of financial metrics.

Chapter seven contains discussion on results of analysis, managerial implications and impact of selected metrics on overall supply chain performance.

In Chapter eight, Conclusion and direction for future scope of research have been presented.

Finally, references and appendices are presented after Chapter eight. In appendices, appendix – A includes screen shots of LPP formulation and solution in optimizing payment deferral period to minimize C2C cycle time using TORA for different objective function coefficients as well as different right hand side values of constraints. Appendix – B includes results of sensitivity analyses of payment deferral period from financial year: 2000 – 01 to 2008 – 09. Appendix – C includes copies of articles published in international journals.