4 OVERALL DELIVERY PERFORMANCE ASSESSMENT

4.1 INTRODUCTION

Overall delivery performance can be defined as the level up to which products and services supplied by an organization meet the customer expectations. ODP includes supplier on-time and in full delivery, manufacturing schedule attainment, warehouse on-time and in full shipment and transportation provider on-time delivery. This is most important metric in supply chain management as it integrates the measurement of performance right from supplier end to the customer end.

In the present research work, the objective function is formulated in an integrated approach considering the contribution of suppliers, manufacturing firm, distributors and logistics providers in achieving the ODP. Also, the basis for benchmarking expected ODP and a total cost model to arrive at optimal expected performance level from each entity has been furnished.

4.2 METHODOLOGY

The framework explaining methodology for measuring and benchmarking ODP is furnished in figure 4.1.
Figure 4.1 Framework for measuring and benchmarking ODP
In level-2 of SCOR model, ODP has four elements.

a. Supplier on-time and in full delivery
b. Manufacturing schedule attainment
c. Warehouse on-time and in full shipment
d. Transportation provider on-time delivery

The working definitions of the elements of delivery performance are as follows:

1. Supplier on-time and in full delivery: It is the ratio of the number of purchase orders fulfilled by supplier(s) on-time (with flaw less match of quality, quantity and price as quoted in purchase order and invoice) and in full to the total number of purchase orders placed per period.

\[
\text{Supplier on – time and in full delivery} = \frac{\text{No. of purchase orders fulfilled on time & in full}}{\text{Total No. of purchase orders placed per period}} \quad -- \quad (4.1)
\]

2. Manufacturing Schedule attainment: It is the fraction of manufacturing schedules attained on-time and in full to total number of manufacturing schedules per period.

\[
\text{Manufacturing Schedule attainment} = \frac{\text{No. of mfg. schedules attained on time & in full}}{\text{Total No. of mfg. schedules per period}} \quad --- \quad (4.2)
\]
3. Warehouse on-time and in full shipment: It is the ratio of number of consignments dispatched to warehouse (B2B) or directly to the customer (B2C) as per customer commit date to the total number of customer orders per period.

\[
\text{Warehouse on-time and in full shipment} = \frac{\text{No. of customer orders delivered on time & in full}}{\text{Total No. of customer orders placed per period}} \quad (4.3)
\]

4. Transportation provider on time delivery: It is the ratio of number of times transportation provider (3PL) placed trucks on-time to the total number of times transportation facility is requested per period.

\[
\text{Transportation provider on-time delivery} = \frac{\text{No. of times trucks placed on time}}{\text{Total No. of times facility requested per period}} \quad (4.4)
\]

It can be observed that the four elements discussed above assume a value between 0 and 1. Now these variables are declared as follows:

Let

\[
\begin{align*}
P_s &= \text{Fraction of on-time and in full delivery of raw materials by supplier(s) per period} \\
P_m &= \text{Fraction of manufacturing schedules attained as per production plans per period} \\
P_w &= \text{Fraction of on-time and in full shipment of goods to warehouse(s) / to customer(s) per period and} \\
P_t &= \text{Fraction of on-time placement of trucks and delivery of goods by transportation provider(s) per period}
\end{align*}
\]
The ODP may be taken as the product of the above four factors treating each of them as probability of success in a sequence of stages.

\[
\text{Overall Delivery Performance (}\bar{P}_d\text{)} = P_s \times P_m \times P_w \times P_t
\] ------ (4.5)

### 4.2.1 Formulation of the model

Problem: To formulate a model to measure ODP of a supply chain and benchmark for improvement.

Model Assumptions:

(i) The success / failure of any aspect i.e., supplier(s) on-time delivery, manufacturing schedules’ attainment, on-time shipment to warehouse(s) / customer(s) and transportation providers’ on-time placement of trucks and delivery of goods, is independent of the others.

(ii) The terms \(P_s\), \(P_m\), \(P_w\) and \(P_t\) represents the performance levels of all potential suppliers, manufacturing units, warehouses and transportation providers.

\[
i.e., P_s = \prod_{i=1}^{n} Psi \quad \text{for ‘}n\text{’ potential suppliers.}
\]
Similarly $P_m$, $P_w$, $P_t$ may be estimated for given no. of manufacturing units, warehouses / customer segments and transportation providers.

The objective is to maximize ODP ($P_d$). Since the objective function in equation (4.5) is non linear, a NLP model can be used to find an optimal solution to the problem. The problem is formulated with constraints as upper limits of performances expected from each entity as follows.

Maximize $P_d = P_s \times P_m \times P_w \times P_t$

Subject to

\[
\begin{align*}
P_s & \leq 1, \\
P_m & \leq 1, \\
P_w & \leq 1, \\
P_t & \leq 1, \\
P_s, P_m, P_w, P_t & \geq 0.
\end{align*}
\]

In reality, when supply chain philosophy has been adapted by a group of firms after mutual agreements on terms and conditions of strategic partnership, initially, the performance may not be much promising as per expectations. Also the investment on supply chain management will be significant but with little or no result. As the supply chain matures, the costs are controlled, performance levels will be improved. In such case, first of all we have to look at the current performance level and corresponding
costs so that the status of the firm(s) will be understood. Passing through successive sub-optimal stages in steps by benchmarking, the firm(s) along the supply chain can improve their performances for the benefit of all. In this regard, we need sub-optimal values for benchmarking. One of the most promising algorithms that provide sub-optimal solutions in a multi-stage optimization is dynamic programming approach.

**4.2.2 Solution of NLP model**

Dynamic programming is useful in making a sequence of interrelated decisions by systematically identifying optimal combination of decision alternatives under varying conditions. The above problem is a four-stage optimization problem. The recursive relations are very simple and the solution proceeds by identifying optimal values of the state variable at each stage. For simplicity, the values of each of the factors are taken in steps of 0.1 in the data range of 0 to 1.

Let \( S_i = \) State variable at stage ‘i’

\[ f_i (x_i) = \text{Stage variable} \quad \text{and} \quad f_i^* (x_i) = \text{Stage optimal} \]
The recursive relations are formulated for successive stages of the problem and are furnished as follows:

Recursive relations:

For stage: 1 \( f_1^* (x_1) = \text{Max} \{P_s\} \)  
\[ 0 \leq P_s \leq 1 \]  
\[ (4.6) \]

For Stage: 2 \( f_2^* (x_2) = \text{Max} \{P_m \times f_1^* (x_1)\} \)  
\[ 0 \leq P_m \leq 1 \]  
\[ (4.7) \]

For Stage: 3 \( f_3^* (x_3) = \text{Max} \{P_w \times f_2^* (x_2)\} \)  
\[ 0 \leq P_w \leq 1 \]  
\[ (4.8) \]

For Stage: 4 \( f_4^* (x_4) = \text{Max} \{P_t \times f_3^* (x_3)\} \)  
\[ 0 \leq P_t \leq 1 \]  
\[ (4.9) \]

The framework of dynamic programming approach to find ODP and backtracking to find benchmark values for optimal performance levels at different stages is given in the figure 4.2.
In first iteration, the suppliers' on-time and in full delivery is alone considered. In second iteration, fractions representing suppliers' on-time and in full delivery are multiplied by fractions representing manufacturing schedule attainment. In third iteration, the fractions representing the optimal combination for stages 1 & 2 put together are multiplied by fractions representing warehouse on-time delivery. In the last iteration, the optimal fractions up to stage 3 are multiplied by fractions representing transportation providers’ on-time delivery of trucks.
Calculations:

The Iterative solution of dynamic programming is given below:

Iteration: 1  
Recursive relation: \( f_1^*(x_1) = \max \{ P_s \} \)

<table>
<thead>
<tr>
<th>State Variable</th>
<th>S_1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Optima</td>
<td>f_1^*(x_1)</td>
<td>1</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Iteration: 2  
Recursive relation: \( f_2^*(x_2) = \max \{ P_m \times f_1^*(x_1) \} \)

<table>
<thead>
<tr>
<th>S_2</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_1^*(x_1)</td>
<td>1</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>P_m</td>
<td>1</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Optimal Solution: Stages - 1 & 2

<table>
<thead>
<tr>
<th>State Variable</th>
<th>S_2</th>
<th>1</th>
<th>(1,2)</th>
<th>2</th>
<th>(2,3)</th>
<th>3</th>
<th>(3,4)</th>
<th>4</th>
<th>(4,5)</th>
<th>5</th>
<th>(5,6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Optima</td>
<td>f_2^*(x_1)</td>
<td>1</td>
<td>0.9</td>
<td>0.81</td>
<td>0.72</td>
<td>0.64</td>
<td>0.56</td>
<td>0.48</td>
<td>0.36</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Similarly, the calculations for subsequent iterations can be carried out. The calculations for four iterations are carried out in Microsoft Office EXCEL spreadsheet as shown in figure 4.3. The stage wise optimal results have been furnished in table 4.1.
Figure 4.3 Spread sheet showing solution to dynamic programming problem
Table 4.1  Stage optima for delivery performance

<table>
<thead>
<tr>
<th>Iteration:1</th>
<th></th>
<th>S_1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage Optima</td>
<td>f_1^* (x_1)</td>
<td>1</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Iteration:2</th>
<th></th>
<th>S_2</th>
<th>1</th>
<th>1,2</th>
<th>2</th>
<th>2,3</th>
<th>3</th>
<th>3,4</th>
<th>4</th>
<th>4,5</th>
<th>5</th>
<th>5,6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>State Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage Optima</td>
<td>f_2^* (x_2)</td>
<td>1</td>
<td>0.9</td>
<td>0.81</td>
<td>0.72</td>
<td>0.64</td>
<td>0.56</td>
<td>0.49</td>
<td>0.42</td>
<td>0.36</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Iteration:3</th>
<th></th>
<th>S_3</th>
<th>1</th>
<th>1,2</th>
<th>1,2</th>
<th>2</th>
<th>2,3</th>
<th>2,3</th>
<th>3</th>
<th>3,4</th>
<th>3,4</th>
<th>4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>State Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage Optima</td>
<td>f_3^* (x_3)</td>
<td>1</td>
<td>0.9</td>
<td>0.81</td>
<td>0.729</td>
<td>0.648</td>
<td>0.576</td>
<td>0.512</td>
<td>0.448</td>
<td>0.392</td>
<td>0.343</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Iteration:4</th>
<th></th>
<th>S_4</th>
<th>1</th>
<th>1,2</th>
<th>1,2</th>
<th>1,2</th>
<th>2</th>
<th>2,3</th>
<th>2,3</th>
<th>2,3</th>
<th>3</th>
<th>3,4</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>State Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage Optima</td>
<td>f_4^* (x_4)</td>
<td>1</td>
<td>0.9</td>
<td>0.81</td>
<td>0.729</td>
<td>0.6561</td>
<td>0.5832</td>
<td>0.5184</td>
<td>0.4608</td>
<td>0.4096</td>
<td>0.3584</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.2.3. Classification of levels for benchmarking ODP

The final iteration of dynamic programming problem provides optimal and sub-optimal values for benchmarking ODP. The current ODP of a firm and its supply chain is measured by multiplying the fractions representing suppliers’ on-time and in full delivery, manufacturing schedule attainment, warehouse on-time and in full shipment and transportation providers’ on-time delivery of trucks. The present performance may fall between any two values in the ranges specified for different classes of performance, i.e., best in class, advantage, median or major opportunity. The classes of performance and corresponding range for ODP are given in table 4.2.

Table 4.2 Classification of performance levels for benchmarking

<table>
<thead>
<tr>
<th>S.No</th>
<th>Performance Class</th>
<th>Range for ODP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Best-in-class</td>
<td>80 % – 100 %</td>
</tr>
<tr>
<td>2</td>
<td>Advantage</td>
<td>60 % – 80 %</td>
</tr>
<tr>
<td>3</td>
<td>Median</td>
<td>40 % – 60%</td>
</tr>
<tr>
<td>4</td>
<td>Major Opportunity</td>
<td>Less than 40%</td>
</tr>
</tbody>
</table>
After assessing the performance of supply chain as a whole, the next benchmark level of expected ODP can be selected from stage - 4 optima in table 4.1. Moving back from stage - 4, the combinations of expected performances at different stages could be benchmarked. For example: suppose that the current overall delivery performance is between 0.6 and 0.8, it is in “ADVANTAGE” class. In order to achieve “BEST-IN-CLASS” performance for entire supply chain, the firms must work together to fix up norms for expected performance levels by different companies involved in the business. Now, the problem of fixing norms can be resolved considering costs associated with maintaining a desired level of performance by each entity as discussed in the following section.

4.2.4 Estimating optimal performance level (total cost model)

Every firm along the supply chain can use this simple method to estimate the performance of its suppliers, internal operations, logistics providers, warehouses / distributors in terms of fractional success in achieving overall delivery performance. For each entity in the supply chain, i.e., a firm, its supplier, distributor and transporter, norms must be fixed while negotiating contracts. A firm can rank the entities depending on their past performances and form strategic alliances with only reliable parties. Every time, the benchmark should be revised with mutual agreement on terms and conditions of supply for smooth flow of materials along the supply chain with enhanced delivery performance to customers. Firms can carry out trade-off
analysis while negotiating on definite level of performance expected from their
counterparts considering the costs associated with maintaining desired level of
performance and cooperation expected among the parties for effective achievement of
the targeted performance level. But achieving desired level of delivery performance
is associated with costs namely:

(a) Supply chain management costs to maintain desired level of delivery
performance. This cost \( C_d \) (associated with operating business activities to
achieve desired level of performance) is directly proportional to ‘\( P \)’.
Where \( P = \) performance level expected.

(b) Penalty associated with loss of sale or goodwill due to deficiency in
delivery performance of the entity. This cost \( C_p \) associated with loss of
sale or good will due to deficient delivery performance is proportional to
\((1-P)/P\).

Mathematically,

\[
C_d \propto P
\]

\[
C_d = K_d \times P \tag{4.10}
\]

Where \( K_d = \) slope of the delivery cost line.

Also, we have \( C_p = 0 \) when \( P = 1 \)

\[= \infty \text{ when } P = 0\]
Hence, we can take

\[ C_p \propto \frac{(1 - P)}{P} \]

\[ C_p = K_p \frac{(1 - P)}{P} \]

-----------------------------------

(4.11)

Where \( K_p \) = Penalty cost coefficient.

Total Cost \( TC = C_d + C_p \)

\[ = K_d \cdot P + K_p \cdot \frac{(1 - P)}{P} \]

-----------------------------------

(4.12)

The mathematical validity of equation (4.12) can be checked as follows:

For minimum total cost, the first order derivative of equation (4.12) should vanish. The resulting equation will give an expression for optimal performance level.

\[ \frac{\partial(TC)}{\partial P} = K_d - \frac{K_p}{P} \]

-----------------------------------

(4.13)

For \( \frac{\partial(TC)}{\partial P} = 0 \), \( P = \sqrt{\frac{K_p}{K_d}} \)

-----------------------------------

(4.14)

Equation (4.14) gives an optimal performance level for a combination of \( K_p \) & \( K_d \).

Also \( \frac{\partial^2(TC)}{\partial P^2} = \frac{2K_p}{P^3} > 0 \) and hence the total cost function is convex.

The relationship between performance level and associated costs are shown in the figure 4.4.
4.2.5 Effect of learning on delivery performance

As discussed earlier, initially the SCM costs will be significant but with little or no improvement. But as the supply chain matures, with the learning effect, the cost slope will come down. Assuming penalty cost curve to remain the same, decrease in
slope of SCM cost (delivery related cost) line; the minimum total cost tends to shift towards right indicating increase in optimal value of $P$ but at a some what lesser total cost. The effect of learning has been explained graphically as shown in figure 4.5.

![Total Cost Lines](image)

**Figure 4.5 Variations in total cost & performance level with slope of $C_d$ line**

The graph clearly shows that decrease in delivery related SCM cost slope leads to improved performance as well as minimum total cost. An empirical analysis has been carried out in the next section in support to the total cost model discussed in this section. Creating a learning index utilizing learning rate metrics can be helpful for firms wishing to benchmark their supply chain’s customer interface effectiveness (Thomas J. Kull, et al., 2007).
Let us consider the following expression similar to that of Belkaoui (1986) for learning index:

\[ P_n = P_o n^\alpha \quad \text{------------------ (4.15)} \]

Where \( P_n \) = Performance after ‘n’ transactions

\( P_o \) = Initial Performance level

\( \alpha \) = Learning index

\[ \alpha = \log \Phi / \log 2 \]

\( \Phi \) = Learning rate; \( 0 \leq \Phi \leq 1 \).

While benchmarking, learning rate may also be used to fix up norms for trading partners.

**Specimen Calculation:**

Let \( P_o = 0.65 \)

\( n = 100 \)

For \( P_{100} = 0.75 \), the value of learning index should be \( \alpha = 0.01609 \).

For different values of \( P_n \) (which is greater than \( P_o \)), the learning indices are calculated and presented in table 4.3.
Table 4.3 Learning indices for different values of Pn and ‘n’

<table>
<thead>
<tr>
<th>Pn</th>
<th>No. of Transactions (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>0.70</td>
<td>0.01609</td>
</tr>
<tr>
<td>0.75</td>
<td>0.03107</td>
</tr>
<tr>
<td>0.80</td>
<td>0.04509</td>
</tr>
<tr>
<td>0.85</td>
<td>0.05825</td>
</tr>
<tr>
<td>0.90</td>
<td>0.07066</td>
</tr>
<tr>
<td>0.95</td>
<td>0.08241</td>
</tr>
<tr>
<td>1.00</td>
<td>0.09354</td>
</tr>
</tbody>
</table>

4.3 ODP OF ARBL SUPPLY CHAIN

The firm produces industrial and automotive batteries of different capacities (Amp-hrs). The major raw materials lead and lead alloys (contributing about 74% of total material cost) are sourced from Australia and Korea. Among the other materials, separators contribute about 8.8% of the total material cost. In the present research work, the potential suppliers of these materials are only considered. The contribution of major raw materials in total material cost is presented in the form of pie diagram as shown in figure 4.6.
Table 3.1 provides aggregate performance of supplier(s) in terms of fractional on-time delivery. The data furnished was on quarterly basis for simplifying analysis. The data regarding manufacturing schedule attainment consolidates the performances of IBD, Automotive Batteries Division (ABD), power systems division and precision parts division. The aggregate quarterly data is furnished in table 3.2. The data regarding on-time and in full shipment to retail outlets as well as different customer segments such as railways, power sector, solar sector, telecom and automotive sectors put together aggregated on quarterly basis and is presented in table 3.3. Similarly, the data regarding transportation providers’ on-time delivery to different customer segments / retail outlets have been furnished in aggregate on quarterly basis in table 3.4. ODP of the firm and its supply chain is calculated using equation (4.5) and the results are furnished in table 4.4.
**Specimen Calculation:**

The values of $P_s$, $P_m$, $P_w$ and $P_t$ have been taken from tables: 3.1 to 3.4 for the first quarter of the year 2004–05.

$$P_s = 0.8133,$$

$$P_m = 0.9601,$$

$$P_w = 0.7485,$$

$$P_t = 0.61$$

The ODP of ARBL Supply Chain in the first quarter of the year 2004–05 is calculated as follows:

$$P_d = 0.8133 \times 0.9601 \times 0.7485 \times 0.61$$

$$= 0.3565$$

Similarly, the ODP is calculated for all quarters from FY: 2004–05 to 2009–10 and furnished in table 4.4.
Table 4.4 ODP of ARBL supply chain (quarterly)

<table>
<thead>
<tr>
<th>Year</th>
<th>1st Quarter</th>
<th>2nd Quarter</th>
<th>3rd Quarter</th>
<th>4th Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 – 05</td>
<td>0.3565</td>
<td>0.3042</td>
<td>0.3725</td>
<td>0.5004</td>
</tr>
<tr>
<td>2005 – 06</td>
<td>0.5434</td>
<td>0.4528</td>
<td>0.6081</td>
<td>0.6981</td>
</tr>
<tr>
<td>2006 – 07</td>
<td>0.6646</td>
<td>0.6196</td>
<td>0.6142</td>
<td>0.6623</td>
</tr>
<tr>
<td>2007 – 08</td>
<td>0.7009</td>
<td>0.6128</td>
<td>0.6269</td>
<td>0.7425</td>
</tr>
<tr>
<td>2008 – 09</td>
<td>0.7114</td>
<td>0.6933</td>
<td>0.6058</td>
<td>0.6623</td>
</tr>
<tr>
<td>2009 – 10</td>
<td>0.6632</td>
<td>0.6405</td>
<td>0.6388</td>
<td>0.6831</td>
</tr>
</tbody>
</table>

The graph shown in figure 4.7 indicates that the mean / median performance is in between 0.6 to 0.8 in the past four years. Also, it is observed that the seasonal variations were mostly reduced in the financial year 2009 – 2010.

Figure 4.7 Track sheet of quarterly ODP of ARBL
The mean (0.6564) or median (0.6396) ODP for the year 2009 – 10 lies in between 0.6 to 0.8. This indicates that the firm and its supply chain are in “ADVANTAGE CLASS” as per classes of performance given in table 4.2.

### 4.3.1 Benchmarking ODP

Suppose the firm and its supply chain aim at achieving best-in-class ODP, the next benchmark level of performance is 0.81. In order to achieve Best-in-Class ODP, the mean / median performance in any aspect should not be less than 0.9. Even, within the same class (Advantage) the next benchmark level is 0.729. To achieve this, the expected level of performance in any aspect should not be less than 0.9.

Hence, the firm and its trading partners must negotiate on maintaining desired levels of performance in a most coordinated and cooperative manner so as to improve the overall delivery performance.

### 4.3.2 Empirical analysis of total cost model

In general, the firms may not maintain relevant data on costs associated with inter-firm supply chain delivery performance. As data on penalty costs for non-
conformity in deliveries varies around 5% for customer segments of ARBL such as railways and telecom, it has been taken as 5% of the value of transaction. As delivery related supply chain management costs are not available, it is assumed as 12.5% of the value of transaction. An empirical analysis is carried out to check the validity of the total cost model discussed in section 4.2.3.

Example: 1 Let us consider that the value of transaction is Rs: 20 lacs. As the penalty cost coefficient $K_p = 5\%$ of the value of transaction, $K_p = \text{Rs: 100,000/-}$. Let the delivery related SCM cost be initially Rs: 250,000/- (i.e., 12.5 % of the value of transaction). When this cost is reduced in steps of Rs: 10,000/- the corresponding changes in total cost as well as the optimal delivery performance as a result of ‘learning effect’ are given in table 4.5.
Table 4.5 Improvements in performance level and total cost as a result of learning

<table>
<thead>
<tr>
<th>Cost Slope $K_d$ (Rs)</th>
<th>Optimum Performance Level</th>
<th>Optimum Total Cost (Rs)</th>
<th>Percentage Decrease in Total Cost</th>
<th>Percentage Increase in Performance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>250,000</td>
<td>0.6324</td>
<td>121367.77</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>240,000</td>
<td>0.6455</td>
<td>119468.67</td>
<td>1.565</td>
<td>2.071</td>
</tr>
<tr>
<td>230,000</td>
<td>0.6594</td>
<td>117593.02</td>
<td>1.570</td>
<td>2.153</td>
</tr>
<tr>
<td>220,000</td>
<td>0.6742</td>
<td>115743.94</td>
<td>1.572</td>
<td>2.244</td>
</tr>
<tr>
<td>210,000</td>
<td>0.6900</td>
<td>113927.54</td>
<td>1.569</td>
<td>2.344</td>
</tr>
<tr>
<td>200,000</td>
<td>0.7071</td>
<td>112132.71</td>
<td>1.575</td>
<td>2.478</td>
</tr>
<tr>
<td>190,000</td>
<td>0.7255</td>
<td>110385.98</td>
<td>1.558</td>
<td>2.602</td>
</tr>
<tr>
<td>180,000</td>
<td>0.7454</td>
<td>108696.16</td>
<td>1.531</td>
<td>2.743</td>
</tr>
<tr>
<td>170,000</td>
<td>0.7669</td>
<td>107085.10</td>
<td>1.482</td>
<td>2.884</td>
</tr>
<tr>
<td>160,000</td>
<td>0.7906</td>
<td>105546.21</td>
<td>1.437</td>
<td>3.090</td>
</tr>
<tr>
<td>150,000</td>
<td>0.8165</td>
<td>104123.97</td>
<td>1.348</td>
<td>3.276</td>
</tr>
<tr>
<td>140,000</td>
<td>0.8452</td>
<td>102835.19</td>
<td>1.238</td>
<td>3.515</td>
</tr>
<tr>
<td>130,000</td>
<td>0.8770</td>
<td>101725.09</td>
<td>1.080</td>
<td>3.762</td>
</tr>
<tr>
<td>120,000</td>
<td>0.9128</td>
<td>100833.02</td>
<td>0.877</td>
<td>4.082</td>
</tr>
<tr>
<td>110,000</td>
<td>0.9535</td>
<td>100226.77</td>
<td>0.601</td>
<td>4.459</td>
</tr>
<tr>
<td>100,000</td>
<td>1.0000</td>
<td>100000.00</td>
<td>0.226</td>
<td>4.877</td>
</tr>
</tbody>
</table>
The variation in optimal delivery performance for different values of $K_d$ are represented graphically and furnished in figures 4.8 to 4.23.

[Note: In general, Total SCM costs are expressed as a % of Cost of Goods Sold which is about 5 – 10 % for best-in-class organizations. In this example delivery related SCM costs are alone considered for which industries may not maintain exclusive data. Hence, it is admitted that approximately higher value is taken.]

The graph plotted for the penalty costs at different performance levels in example: 1 is a polynomial curve satisfying the equation:

$$C_p = aP^2 + bP + c$$

with $R^2 = 0.897$ (more significant)

Where $a = 17874$; $b = -27066$ and $c = 99340$.

Similarly, for total cost;

$$TC = a_1P^2 + b_1P + c_1$$

with $R^2$ varying between 0.838 to 0.877 (more significant)

Where $a_1 = 17874$; $b_1 = -24566$ to -26066 (in steps of 1000 for reduction in $K_d$ by Rs: 10,000/-) and $c_1 = 99340$.

The more significant values of $R^2$ indicate that the selected costs ($C_p$ & $C_d$) are good predictors of optimal performance levels with varying cost slope $K_d$. 
Figure 4.8 Various Costs for $K_d = \text{Rs: 250,000 / -}$

Figure 4.9 Various Costs for $K_d = \text{Rs: 240,000 / -}$

Figure 4.10 Various Costs for $K_d = \text{Rs: 230,000 / -}$

Figure 4.11 Various Costs for $K_d = \text{Rs: 220,000 / -}$
Figure 4.12 Various Costs for $K_d = Rs: 210,000$

Figure 4.13 Various Costs for $K_d = Rs: 200,000$

Figure 4.14 Various Costs for $K_d = Rs: 190,000$

Figure 4.15 Various Costs for $K_d = Rs: 180,000$
Figure 4.16 Various Costs for $K_d$ = Rs: 170,000 / -

Figure 4.17 Various Costs for $K_d$ = Rs: 160,000 / -

Figure 4.18 Various Costs for $K_d$ = Rs: 150,000 / -

Figure 4.19 Various Costs for $K_d$ = Rs: 140,000 / -
Figure 4.20 Various Costs for $K_d = \text{Rs: 130,000 / -}$

Figure 4.21 Various Costs for $K_d = \text{Rs: 120,000 / -}$

Figure 4.22 Various Costs for $K_d = \text{Rs: 110,000 / -}$

Figure 4.23 Various Costs for $K_d = \text{Rs: 100,000 / -}$
The improvements in performance level and total cost with learning have been presented in the figure 4.6.

![Decrease in TC due to learning](image)

Figure 4.24 Decrease in Total Cost due to Learning

4.4 SUMMARY

In this chapter, an approach to measure the ODP of a supply chain has been presented. Dynamic programming model is used to find sub-optimal values for benchmarking expected performance levels of suppliers, manufacturing firms, warehouses and transportation providers. A firm can use benchmark values from the solution of dynamic programming problem (optimal iteration) given in table 4.1. The firms can also use learning indices for benchmarking expected performances as given in table 4.3 while negotiating with its supply chain partners.
The empirical analysis supports that the total cost model provides a basis for assessing optimal performance levels considering penalty cost and delivery related SCM costs. Also, it helps firms to benchmark expected performance levels of individual entities from overall supply chain perspective to achieve the desired overall delivery performance. The model also demonstrates the importance of learning and helps firms to gain competitive advantage by exercising control on costs associated with supply chain delivery performance.