Sales and Operations Planning in Company Supply Chain 
Based on Heuristics and Data Warehousing Technology

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Abstract - Traditional sales and operations planning (S&OP) focus on coordination in sales, production and inventory. The most obvious drawback is to manipulate various operational data during the planning meeting. To improve existing manual process of balancing between demand and supply, the integrated architecture of S&OP in supply chain based on Data Warehousing (DW) technology has been presented, which includes three layers: Data transformation layer with extracting raw operational data from business information systems, middle layer with planning solving engine provides the heuristics of decision mechanisms and top layer provides an interface for managers to connect simulations of the desired scenarios. In this paper, we focus on designing multi-dimensional model and heuristics for S&OP. It is anticipated that planning effort and time will reduce.

Keywords: Data warehouse, Architecture, S&OP

1 Introduction

A supply chain of company is characterized by two types of flows: The forward physical flow that integrates the functions of procurement, production, distribution and sales to satisfy the final customer demands, and the backward information flow that allows each member to effectively acquire sharing data from downstream members. The flows integration is usually made by enterprise information system based on Enterprise Resource Planning (ERP). Before the company supply chain can be implemented, sales and operations planning (S&OP) that encompass balance of supply capability and demand for each product group in the global context have to be carried out to evaluate the cost and benefit of each solution.

S&OP is a tactical-based integrated planning process that plans total solution from several different functional units, and it is performed to ensure the aligned plans supporting the business strategic goal [1]. From the definition of APICS, S&OP should integrates procurement, production, distribution and sales into a cross functional plan. It is a routine process that plans a horizon about 12 to 18 months. Nowadays business consultants and information system developers advocate that S&OP should be incorporated into supply chain planning context. They regard S&OP as a planning pillar that not only conducts vertical integration but also supports coordination between members in the supply chain [2]. Clearly, applying decision-wide information into S&OP is necessary. However, ERP merely serves to effectively integrate the operational data of processes and activities from the suppliers to the customers. It excludes decision support information from operational databases. Recent conventions in practice present the trend of gathering data from ERP database, and then translating into planning data for S&OP manually. The way of collecting planning data maybe cause the concern of immediacy and changeability.

To remedy the aforementioned problems of data integration, data integration technologies have experienced explosive growth in the last few years, and data warehousing has played a major role. A data warehouse that supports managerial decision making is a repository of data taken from operational systems of business [3][4]. Ahmad et al.(2004) developed a prototype DSS based on data warehousing technology for site selection problem. The DSS help user to select site from the list of available ones [5]. Combes and Rivat (2008) proposed a data warehouse environment to support decision-making process for productivity improvement and marketing strategy for multinational companies. The environment help user who need identify necessary information and knowledge for decision-making process [6]. From the perspectives of integration between S&OP and DW, S&OP is vital in a company supply chain environment where data warehouse (DW) is becoming an essential part of information provider. The core of DW is multi-dimensional model which comprises a fact table and a set of dimension tables connected to the fact table around the periphery.

A multi-dimensional model enables user to reap useful information for decision making. Up to the present, there is no complete and consistent design methodology available for designing a data warehouse. Furthermore, business planners and researchers on S&OP make efforts in definition [7], planning procedures [1][8] and case implementation [9]. Few researches have addressed the data model problem in S&OP aspect.

The aim of our research is to fill in the gap of S&OP by presenting a planning architecture that represents the data warehousing technology and heuristics to effectively support planning. The rest of the paper is organized into four sections.
Section two proposes planning architecture according to consideration of decision support. Based on the architecture, the dimensional model of data warehouse and heuristic based on planning mechanisms are developed to fulfill the analysis demand. Section three describes how we implement the proposed framework. Finally, analysis and conclusions are then provided.

2 The system architecture of S&OP

A basic planning logic flows of S&OP is: evaluating the monthly demand based on forecasting data and monthly capacity; identifying the unit cost of production, distribution and inventory; balancing the demand and the capacity to output the practical plans with sales, production and inventory. In general, the result of S&OP should fit in with the managerial concerns. For example, minimize the total cost or maximize the profit is the common practice for planning objective. Fig. 1 shows the proposed architecture of S&OP. There are three layers:

The data layer provides functions of data transformation. Data are identified from databases of operational systems and other external sources. Afterward those are extracted, transformed and loaded (ETL) into data warehouse. Once the data are stored in the data warehouse, then multi-dimensional models become effective.

The middle layer is in charge of mapping raw data to multi-dimensional model. First of all the extracted data must transform again under aggregations and projections, and then model designer determine which data attributes are treated as parameters or decision variables for S&OP. Finally, assign those data type to precise fact tables and dimension tables. All parameters are used to input in heuristics and the decision variables represent feedback of calculation result. The design logic of multi-dimensional model and heuristics will be introduced in the following section.

The top layer provides an interface for user to connect simulations of the desired scenarios with manipulation of decision variables stored in the data warehouse.

3 Methodology

During the S&OP process, managers want to get feasible plans under the planning objective of maximizing the overall profit within product revenue, production cost, distribution cost and inventory cost with following assumptions: Demand is defined such that each product is at least ordered by one customer. The unit costs of transportation, the fixed costs on plants and DCs and the sites capacities in every data set were extracted from ERP system. The product holding cost of a product over two periods is of the same level as its price reduction. Product refers to BOMs. The general steps of S&OP are:

- Demand Forecast calculation in the sales department in term of product groups;
- Execute calculation and capacity balancing for each plant by the planner and manager;
- Simulation of scenarios and feasible plans for the whole company supply chain;
- Modification of resource requirements and availabilities and feasible plans validation by the planner;
- Compare the scenarios and select the best plan in the monthly meeting.

Fig. 1 The integrated architecture for S&OP

3.1 Multi-dimensional Model for S&OP

Because of the planning scope cover the company supply chain, the dimensional model considers four fact tables including procurement, production, distribution and sales. The dimension tables are connected with the fact table by foreign keys. Fig. 2 shows the multi-dimensional model of S&OP. Every fact tables provides following foreign keys:

- Procurement fact table: product number, vendor number, time period,
- Production fact table: product number, plant number, time period,
• Distribution fact table: product number, path number, time period,
• Sales fact table: product number, channel number, time period.

The multi-dimensional model gives needed information to execute S&OP. With the model we query interesting reports between tables. For example, the SQL query concerning “Quantity of production per product group per plant and per planning period” is the following:

```
SELECT time_period_key, plant_key, product_key, SUM(product_produced_qty)
FROM Production_Fact, Time_Period_Dimension, Plant_Dimension, Product_Dimension
WHERE Production_Fact.time_period_key = Time_Period_Dimension.time_period_key,
   Production_Fact.plant_key = Plant_Dimension.plant_key,
   Production_Fact.product_key = Product_Dimension.product_key,
GROUP BY model_group, plant_name, time_period;
```

The result of the query is composed of cells that define attributes SUM (product_produced_qty). It is possible to change the level of aggregation such as Year/Month/Week on Time_Period dimension.

3.2 Planning Heuristics for S&OP

We develop a heuristic solution of resources allocation to solve the S&OP problem. The expectation is confirmed by the computational result. In what follows is the description of each heuristic procedure. The developed heuristic in this paper as shown in Fig. 3 aims to select a candidate from sets of material vendors, manufacturing sites, DCs and then decides the quantities of production, inventory subject to capacity restrictions of each stage in the supply chain. The S&OP heuristic uses detail procedure as follows:

![Heuristics flow chart of S&OP](image)

**Fig. 3 Heuristics flow chart of S&OP**

Step 1: Aggregate the total demand from orders. From a multi-tasking perspective, demands of the product in a period can be assigned to several planning periods according to the comparative forward planning cost of one product as compared with others. Sort the production priority for products which considers variable profit determined from the product price, transportation cost and inventory cost across planning periods. The heuristic pseudo code of Step1 as follows:
Step 2: Execute the capacity allocation according to the production priority, and allocate the product production quantity under the capacity constraint of manufacturing sites. Make the assignment of demand of the product p to manufacturing site f in priority order. Adjust capacity of the manufacturing sites, remove the order, and continue next order until all demands have been assigned to production, or all capacity have been utilized. Calculate the shortage of product demand in each period finally. The heuristic pseudo code of Step2 as follows:

```
//--- Step 2---
//---Calculate production quantity based on production quantity Qpft and demands Qmpt...
For i=1 to maxPRFpt, p++
If MAX(CAPpt, f) to max(f=0)
   Step (a) Consider product demand Qpft, available capacity CAPpt simultaneously to decide production quantity Qpft = MIN(Qpft, CAPpt / Wpf)
   If Qpft < CAPpt / Wpf
      CAPpt = CAPpt / Wpf + Qpft
   Dpt = 0
Else
   //If product demands are more than capacity, then update the demands gap
   Dmpft = Dpt - Wpf - CAPpt
   CAPpt = 0
   Break
   EndIf
EndFor
```

Step 3: Calculate the material requirements by way of the BOMs and estimate whether the supply capability of vendors is affordable in each periods. If the supply capability is overload with material requirements, the production plan needs to be modified to fit in with the material constraint. The heuristic pseudo code of Step3 as follows:

```
//--- Step 3---
//---Calculate procurement quantity Qmpt based on production quantity Qpft and supply constraint...
//Calculate the material requirements Dmt according to BOMs
For p=1 to max p, p++
For f=1 to max f, f++
   Dmt = Dmt + Qpft * BOMmp
EndFor
EndFor
```

Step 4: Consider the shortage of product demand and remaining capacity and materials in each period, and balance the shortage demand to remaining capacity from the perspective of forwarding planning. The available forward period in each product is restricted by inventory cost of product. The lowest inventory cost of product will be select to reallocate firstly. The heuristic pseudo code of Step4 as follows:
Step 5: Consider the distribution center-channel transportation cost and channel demands to find the lowest link and decide the amounts of products that will be shipped from distribution centers to channels. Next, Consider the manufacturing site-distribution center transportation cost and distribution center storage capacity to find the lowest link and decide the amounts of products that will be shipped from manufacturing sites to distribution centers. The heuristic pseudo code of Step5 as follows:

4 Results

To get the sales plan, production plan and inventory plan simultaneously, we use the proposed architecture to execute scenario simulation of S&OP. We perform a four factors experimental test to express the uncertainty of the environment. Site capacity, procurement cost, product inventory cost and product distribution cost are selected as key factors. Each key factor has low level and high level to combine different scenarios. The management meaning for the factors are as follows:

LC: Loose Capacity, the total demand at per planning period set to 75%~95% of total production capacities,

TC: Tight Capacity, the total demand at per planning period set to 95%~115% of total production capacities,

PCL: Lower procurement cost for components, the costs are set to the original component price,

PCH: Higher procurement cost for components, the added costs are correspond to variation in component price,

ICL: Lower product inventory cost, the costs are set to the original cost,

ICH: Higher product inventory cost, the added costs are correspond to reduction in product price,

TCL: Lower product logistics cost from sites and channels, the costs are set to the original cost,

TCH: Higher product logistics cost from sites and channels, the added costs are correspond to fluctuation in exchange rate.

TABLE I shows all 16 scenarios planning results with costs, revenue and profit. The differences in planning result are in response to the different planning environment respectively.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Factor combination</th>
<th>TREV</th>
<th>TMAT</th>
<th>TMAN</th>
<th>TINV</th>
<th>TPRO</th>
<th>TTRA</th>
<th>Profit</th>
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<tbody>
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<td>$1,960</td>
<td>$560</td>
<td>$540</td>
<td>$600</td>
<td>$600</td>
<td>$840</td>
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<td>2</td>
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<td>$840</td>
<td>$1,390</td>
</tr>
</tbody>
</table>

TREV: Total Revenue, TMAT: Total Material Cost, TMAN: Total Manpower Cost, TINV: Total Inventory Cost, TTRA: Total Transportation Cost.
5 Conclusions

We can acquire operation-related data through information platform such as ERP and figure up the operational planning of the firms as the decision-making support for manager. In this paper, we have proposed an integrated architecture to support S&OP with data warehousing and heuristic technology. The architecture for S&OP has following characteristics: integrating planning data by means of multi-dimensional model, improving S&OP by proposed heuristic algorithm, extending planning flexibility with scenario simulation.

The next step of our research concerns the optimization of the planning quality, to realize this we need to design decision model by means of mathematical planning technology.

6 References


