A Theory and Tools for Collaborative Demand-to-Supply Management in the SCM Age

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Abstract. *In recent years, the collaborative demand-to-supply management which strategically supplies products to the market so as to maximize profit is a critical role for establishing a sustainable company. However, sales sector and production sector, respectively, do not always work together for corporate-wide optimization. In the most case, sales sector is responsible for maximizing sales. On the other hand, production sector is responsible for minimizing production cost. In the SCM age, this situation causes to produce excess inventory as well as long order fulfillment time. For the collaboration of both sectors, a strategic demand-to-supply map has been developed. The map consists of a row for demand speed and a column for the smoothing factor, and the respective elements indicate the indices in economics and reliability on collaboration. This paper presents a theory and an effective planning tool, called the planner, for the collaborative demand-to-supply management based on the strategic demand-to-supply map. The planner consists of demand forecasting, aggregate planning, strategic map, production scheduler, and progressive analysis. The effectiveness of the planner is demonstrated using a numerical example. In addition, this paper shows that the planner is useful not only for supporting the collaborative demand-to-supply management but also the systematic training and education for staffs at sales department and production department. This paper also presents the potential areas of future development on the collaborative demand-to-supply management and the planner.*

Keywords: *Collaborative demand-to-supply management, Aggregate planning, Strategic map, Production scheduler, Sustainable company, Progressive analysis*

1. INTRODUCTION

In the so called “mass-production and mass-consumption age”, because of long-term product life cycle and increasing demand, most companies had recognized inventory as corporate valuable asset. In such a situation, managing a balance of demand plan and supply plan in order to avoid excess inventory and to improve corporate profit had not been a critical issue. Strong demand could absorb excess inventory in the most case.

However, today’s competitive and unforeseeable market requests shorten product lifecycle and increasing product variety. Therefore the excess production against market demand makes excess inventory that needs disposal cost to put it into correct inventory level. In the Japanese beverage industry, for example, each company introduces approximately 100 new products into the market every year. However, only two to three products can remain in the market until the next year. The inventory of out-of-market products can be dead stock which is considered as nonperforming asset. In this market situation, companies have gradually recognized inventory reduction as a management issue to increase corporate profit. Inventory

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reduction, however, can cause out of stock, and therefore less sale opportunity.

In the circumstances, Supply Chain Management (SCM), which is defined by Smith-Lev *et al.* (2007) as “Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufactures, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize, to systemwide costs while satisfying service level requirements” has been widely spread around the world since 1990’s. One of the goals of the SCM is to improve the return of asset which can be attained by reducing inventory as well as increasing sales opportunity. The successful implementation of the SCM needs collaborative decision making among different sectors, such as sales, production, distribution, retail, and so on. (In this paper, a sector means a part or a division in a company.)

In the most case, however, each sector has a different goal, and therefore each sector’s strategy to attain each goal cannot always optimize corporate profit. Especially, traditional sales sector’s strategy and production sector’s strategy tend to interfere each other in today’s market situation. Sales sector makes strategy to increase sales, therefore requests products supply based on the expectation of the highest possible demand forecast. This is a reasonable strategy in sales sector to minimize sales loss because of stock shortage, and maximize sales volume. On the contrary, production sector makes strategy to minimize production cost. Therefore production sector tends to produce products in larger lot size. Larger lot size production can cause excess inventory level as well as stock shortage under sudden demand change situations because long lead time production cannot response demand change quickly. A simplified mechanism of excess inventory and stock shortage at the same time under independent sector strategies is depicted in figure 1.

As stated in the above, maximization of corporate profit cannot always attain based on the sales sector strategy and the production sector strategy which are made independently for each sector’s goal. It is obvious that both sales and production sectors need collaborative work for making a strategy to maximize corporate profit.

Namely, most companies have been recognized the collaborative demand-to-supply management, which strategically supplies products to the market based on a collaborative strategy with sales sector and production sector so as to maximize profit, as a critical role for implementing successful SCM and for establishing a sustainable company in today’s market situation (Cyber Concurrent Management Research Group 2004). (In this paper, the collaborative demand-to-supply management is also called the demand-to-supply management, hereafter. In addition, strategy indicates a set of parameters to form plans including sales plan and production plan in this paper.)

In the demand-to-supply management, sales sector and production sector work together to decide integrated demand and supply strategy in the company. To support the demand-to-supply management, we have developed steps and mechanisms for making a demand-to-supply plan. In addition, we have developed a PC-based decision support software, which applies the steps and mechanisms, called the demand-to-supply management planner. (The demand-to-supply management planner is called the planner, hereafter.)

In this paper, we explain a model of collaborative decision making between sales sector and production sector as well as the planner. A numerical example of the planner is demonstrated. In addition, we apply the planner as a tool for training and education to implement the demand-to-supply management successfully in practice. Because the collaborative work of sales and production sectors for making a demand-to-supply plan is relatively a new practice in the most company, it is necessary to prepare training and education system to educate staffs who understand the importance and also have skills of the collaborative work. In this background, we developed an education system on the demand-to-supply management. In this paper, we describe the system as well as evaluation of a trial class which applied the system with graduate students. Finally, we propose future development topics on the demand-to-supply management in the SCM age.

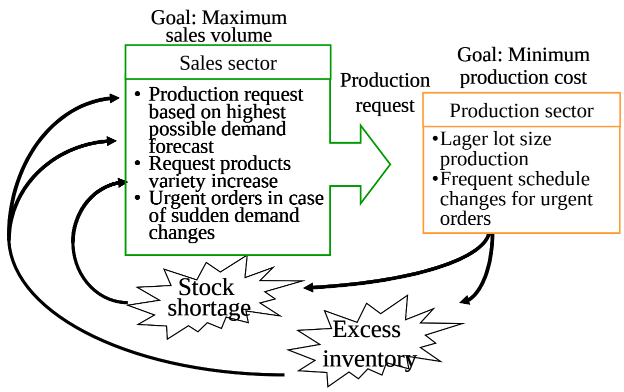

Figure 1: A simplified mechanism of excess inventory and stock shortage under non-collaborative strategies

2. DEMAND-TO-SUPPLY MANAGEMENT PROBLEM

In today’s ordinary companies, sales sector decides the sales strategy which maximizes corporate wide sales volume, and production sector decides the production strategy which minimizes production cost. Then, in order to avoid lose of sales opportunity from stock shortage, sales sector’s strategy tends to take forecast under the highest possible demand. On the other hand, production sector’s strategy tends to take large-lot size production to reduce production cost. It cannot follow unexpected demand fluctuations because of the longer production lead time.

In a stable demand situation, independent strategies of sales sector and production sector can lead corporate-wide profit optimization as a result. However, in today's unstable and unforeseeable market situation, local optimization in each sector may lead loss of sales opportunity and increase inventory cost (Matsui *et al.* 2006).

To make a rational demand-to-supply management strategy from a corporate-wide standpoint and to increase corporate profit in today's unstable and unforeseen market situation, the demand-to-supply management where both sales and production sectors work together with sharing information, as shown in figure 2, is necessary.

As shown in figure 2, the collaborative demand-to-supply management strategy is made based on information from sales sector and production sector. The planed collaborative strategy is returned to sales sector and production sector as feedback information to update each sector's strategy and to form each sector's plan.

Since the middle of 1990, ERP (Enterprise Resource Planning) (Monk and Wagner, 2008) has been widely spread as corporate core information systems. ERP is a software application which fully integrates core business functions, including transaction processing, management information, and so on. Most ERP packages, for example, can apply financial management, human resource management, marketing, sales, production management, and so on. Each ERP package has an original business process, unified enterprise database, and implementation methodology. The business process is a standard process which ERP provide as the best practice to optimize the company. In other word, implementing an ERP is to reform the company based on the business process the ERP provides. However, most ERP packages have not included the concept of the demand-to-supply management. Although they are useful to integrate corporate information, they have almost no mechanism for collaborative decision making among different sectors.

Most companies have recognized the importance of the demand-to-supply planning problem in today's market situation. However, in fact, sales sector and production sector still do not collaborate well each other (Matsui and Fujikawa, 2005). In addition, research and practice are not enough to provide tools and methodologies applicable to the collaborative demand-to-supply management.

Matsui *et al.* (2006) propose a demand-to-supply management planner using a strategic map which shows performance of each combination of sales and production strategies. The strategic map is developed using the theory of pair-matrix table (Matsui, 2002). Matsui *et al.* (2007) modify the planer so that the planner is applicable to a long-term business planning. The effectiveness of the application is demonstrated in a case study.

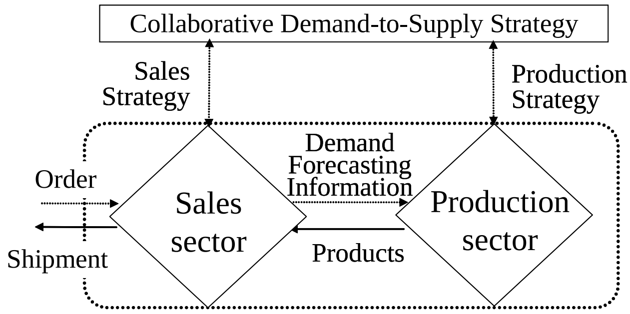

Figure 2: A two sector model of collaborative demand-to-supply problem

In this paper, the planner is expanded so as to select better strategy using production scheduling. In addition, a training and education system to educate demand-to-supply management staffs using the planner is developed.

3. OVERVIEW OF DEMAND-TO-SUPPLY MANAGEMENT PLANNER

In this section, we describe the demand-to-supply management planner (the planner) we developed for the collaborative demand-to-supply management.

The planner works to find the collaborative plan which maximize profit, called expected net return (*EN*). It consists of six major systems as shown in figure 3. Namely, the planner defines the future demand based on the historical demand data in certain terms, and designs a demand-to-supply strategic map (called the strategic map). The strategic map is a 2-dimension matrix consisting of a demand strategy axis and a supply strategy axis as explained at section 4.2 in this paper. The design of the strategic map defines the ranges of both axes. The aggregate planning makes an aggregate plan which minimizes expected cost (*EC*) of each combination of strategies. Because the expected return (*ER),* which can be defined by demand level, is already figured out on the map, the *EN* is obtained as *EN*=*ER*-*EC*. Then the planner selects a demand-to-supply plan, which maximizes the *EN* from the map. The selected plan is simulated in more detailed production conditions with production scheduling (Morton and Pentico, 1993), and modified the strategy to improve the accuracy of the plan if necessary. In addition, the plan is evaluated by progressive analysis. The planner returns the results of evaluation to the aggregate planning or the scheduling until an acceptable demand-to-supply plan by both sales sector and production sector is created.

In the planner, the demand forecasting is considered as a strategy which reflects sales sector intensions. On the contrary, the plan made by aggregate planning and scheduling is considered as a strategy which reflects production sector intensions. The strategic map is used to set in comparison of both sectors' strategies and to find the optimum plan. Namely, we use the map as a tool for collaborative demand-to-supply management. The progressive analysis is used to find the potential directions for collaborative works between both sectors.

In the following sections, functions and methodologies used in the planner is explained.

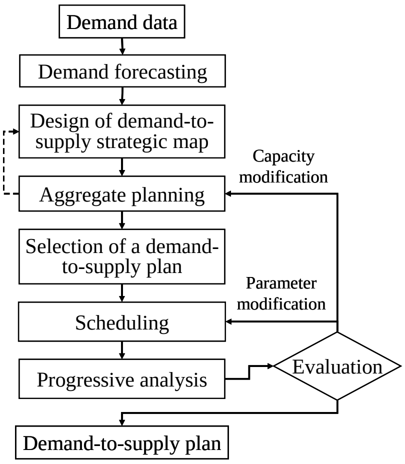

Figure 3: Steps of demand-to-supply planner

3.1 Demand Forecasting

The demand forecasting system in the planner forecast the monthly market demand regarding the target products from historical demand data. In the current version, the planner uses exponential smoothing method for demand forecasting. The numerical formula of the method is shown in section 4.

It is possible to take different demand forecasting approaches in the system, although the design of the demand-to-supply map may need to be modified.

3.2 Design of Demand-to-Supply Strategic Map

The strategic map represents the possible combinations of sales strategies and production strategies as shown in figure5. The map consists of a row for expected demand, which considered as a sales section strategy, and a column for the smoothing factor of exponential smoothing, which considered as a production sector strategy. In the strategic map, each cell, which indicates the crossing point of a row and a column, shows the objectives indices in economics including expected net return (*EN*), expected return (*ER*), expected cost (*EC*), expected lead time at *N* inventory level (ET(N*)).

The maximum *ER* at each strategy combination is also calculated based on the demand and the price at the demand. The mathematical model to calculate *ER* is shown in section 4.1. Steps to make the strategic map are explained in section 4.2 in detail.

3.3 Aggregate Planning

The aggregate planning calculates production quantities in every month which minimize *EC* including production cost and inventory cost, back order penalty cost, and cost of idle resource, using liner programming. The monthly production quantity is provided by the demand forecasting. The numerical formula to obtain an aggregate plan is shown in section 4.

3.4 Selection of a Demand-to-Supply Plan

The strategic map visualizes the value of objective functions as a matrix in order to find the optimum combination of sales strategies and production strategies as shown in figure 5. The strategic map is completed using the results from the aggregate planning. The detailed steps to make a map are shown in section 4. The plan, where *EN* takes maximum value, is recognized as the optimum strategy consisting of a sales strategy and a production strategy.

In the steps to find optimum strategy and its aggregate plan, the role of the strategic map is to find the possible combination of strategies by both sectors and also examine the expected performance of the selected aggregate plan in a comprehensive way. Because the value of parameters doesn't always be precise to make a strategic map, more detailed performance is examined in the next scheduling step using more precise data and detailed conditions.

3.5 Scheduling

The scheduling step simulates the aggregate plan, selected from the strategic map, with detailed production conditions including production sequence, machine speed, production lot size, number of products and production volume of each product, setup time, overtime work, and so on. Based on the results of scheduling, the planner rebuilds the strategic map if the expected production capacity is different form the aggregate planning condition significantly.

The result of scheduling is assumed to show the actual production capacity under the current production conditions. Therefore the planner replaces capacity parameters of the aggregate planning, and makes more accurate strategic map (Wang 2007).

Scheduling enables us to examine the aggregate plan selected from a strategic map under detailed production conditions, and to make more accurate plan with comparing the results of scheduling and the aggregate plan.

3.6 Progressive Analysis

Progressive analysis, which is an application of progressive-curve-based control (Usuki *et al*. 2001), depicts the cumulative figures of input to and output from production system graphically. Using the figure, we can analyze the work in process, order fulfillment time, and their fluctuations.

In the planner, the progressive analysis is used to compare the plans from a strategic map and form scheduling. Based on the results of comparison, the progressive analysis supports to evaluate these plans and to find the points for improving the accuracy of the strategic map.

4. MODEL OF THE PLANNER

4.1 Mathematical Model

At sales sector and production sector, the objective function of each sector, i.e. - expected return (*ER*) and Expected cost (*EC*), respectively, is optimized mathematically by giving strategic parameters. Combination of a sales strategy and a production strategy lead an expected net return (*EN*). The relationship of objective function and strategic parameters is given as (1). In this equation, *N, d,* and α, respectively, stand for the standard inventory level, the expected demand quantity, and the smoothing factor at demand forecasting.

$$EN(N,d,\alpha) = ER(d,\alpha) - EC(N,d,\alpha) \rightarrow \max \quad (1)$$

ER is given as (2). *T* stands for the term of planning.

$$ER = \sum_{t=1}^{T} P_t D_t / T \rightarrow \max \quad (2)$$

D_t stands for the forecasted demand at the *t-th* term, obtained from historical demand data d_t by equation (3).

$$D_t = \alpha d_t + (1-\alpha) D_{t-1} \quad (0 \le \alpha \le 1) \quad (3)$$

P_t stands for the price at the *t-th* term. It is given as (4).

$$P_t = P_0 + \frac{P_0 |d_0 - d|}{b \rho d_0} \quad (4)$$

P_0, d_0, *ρ, b,* stands for, respectively, standard price, standard demand quantity, rate of utilization, and price elasticity which means sensitivity of demand when the price changes.

EC is expressed as (5), and is obtained using linear programming. Constraints are given as (6) and (7). Table 1 describes the nomenclature of each equation.

$$EC = \sum_{t=1}^{T} \{c_1 X_t + c_2 Y_t + c_3 Z_t + c_4 I_t + c_5 B_t + c_6 (X_{\max} - X_t)\} / T \rightarrow \min \quad (5)$$

$$I_t - B_t = I_{t-1} - B_{t-1} + X_t + Y_t + Z_t - D_t \quad (6)$$

$$X_t \le X_{\max}, \quad Y_t \le Y_{\max}, \quad Z_t \le Z_{\max} \quad (7)$$

Table 1. Explanation of variables and constants

	Variables
X_t	Regular production quantity
Y_t	Overtime work production quantity
Z_t	Outsourcing production quantity
I_t	Inventory at the end of the *t-th* term
B_t	Back order quantity
	Constants
c_1	Cost of regular production
c_2	Cost of overtime work production
c_3	Cost of outsourcing production
c_4	Inventory keeping cost
c_5	Back order cost (penalty)
c_6	Cost of idle resource
I_0	Inventory at the beginning of the planning
$X_{\max}$	Capacity of regular production
$Y_{\max}$	Capacity of overtime work production
$Z_{\max}$	Capacity of outsourcing production

The objective function (5) can be modified as (8) to add the condition on the standard inventory level (*N*). Namely, in the objective function (8), penalty costs are defined on the gap between I_t and *N.*

$$EC = \sum_{t=1}^{T} \{c_1 X_t + c_2 Y_t + c_3 Z_t + c_4 N + c_7 (L_t - N)^+ + c_8 (N - L_t)^+\} / T \rightarrow \min \quad (8)$$

s.t. ($L_t = I_t - B_t$ $\quad (a)^+ = \max(0,a)$, c_7 means penalty cost when L_t is larger than *N*, and c_8 means penalty cost when L_t is smaller than *N.*)

Lead time (*LT*) in a year is set as (9).

$$LT = \{\sum_{t=1}^{12} (I_t - B_t) / D_t\} / T \quad (9)$$

4.2 Steps for Making Strategic MAP

The strategic map is a matrix consisting of smoothing factor of the exponential smoothing and the expected demand.

The simplified steps for making the map are shown in figure 4. In addition, an example of map is shown in figure 5.

At the first step, the demand data as well as the minimum and maximum values of α, *d*, and *N* are defined. Then the intermediate values between minimum value and maximum value of α, *d*, and *N* are initiated, respectively. The strategic map represents objective functions, i.e. - *EN*, *ER*, and *EC*, of all the combination of α, *d*, and *N*. The number of intermediate values defines the degree of detail of the strategic map.

The values of α and *d* are set as each minimum value at the beginning, and are increased at each iteration of the steps in figure 4. The *EN*, *ER*, and *EC* of each combination of α, and *d* are calculated based on the demand forecasting and the aggregate planning. The strategic map, therefore, is made as step-by-step fashion by changing the combination of α, and *d*. In the same combination of α and *d*, the strategic map shows the *EN*, *ER*, and *EC* which make the *EN* maximum regarding *N*.

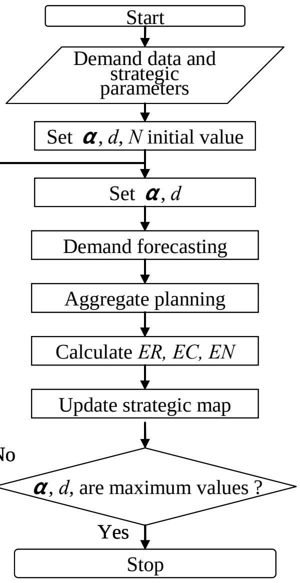

Figure 4: Steps for making strategic map

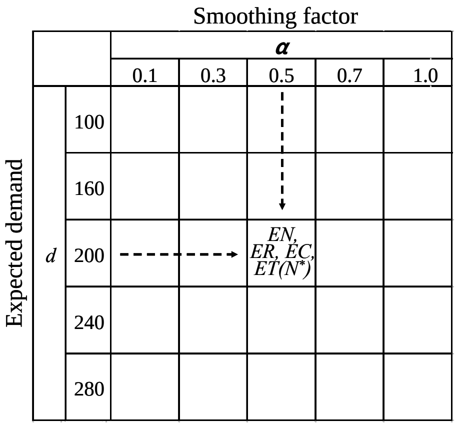

Figure 5: Example of strategic map

5. A NUMERICAL EXAMPLE OF THE PLANNER

In this section, we demonstrate a numerical example of the planner.

Table 2 shows sample demand data for 12 planning terms. In the demand forecasting, the historical data is adjusted by the equation (3), and the average demand is set as expected demand (*d*). In this example, we calculate exponential smoothing on the α from 0.1 to 1.0 with increments 0.1. *d* is defined from 100 to 280 with increments 20, and *N* is defined from 40 to 200 with increments 20. Therefore there are 900 strategies, consist of the combination of α, *d*, *N*, in this example.

Table 2: Demand data

t	d_t	t	d_t
1	284	7	314
2	268	8	253
3	253	9	275
4	252	10	264
5	271	11	238
6	325	12	292

Table 3 shows the constants of linear programming. The linear programming described in section 4.1 is used to obtain the optimum aggregate plan under the constraints, *N*, and the forecasted demand of each strategy.

Table 4 shows the aggregate plan selected using linear programming. The plan which can attain maximum *EN* among the combinations of α, *d*, *N* is selected. The conditions of the selected plan are as follows;

Smoothing factor (α) : 0.6,
Expected demand (*d*) : 200,
Normal inventory quantity (*N*) : 40.

The forecasted demand (D_t) is less than the data shown in table 2 because the demand data is adjusted with *d* so as to maximize *EN*.

Figure 6 shows a part of the strategic map obtained. As shown in figure 6, the maximum *EN* is located between the minimum *EC* and the maximum *ER*. This phenomenon is called the ellipse-cross theory (Matsui, *et al.*, 2006), which usually appears in the strategic map. This theory is useful to identify the direction how to improve the demand-to-supply management strategy.

After an aggregate plan is selected, the scheduling step examines the plan under detailed production conditions. The planner modifies the plan based on the results of scheduling, if necessary, to improve accuracy of the plan. Figure 7 shows the scheduling model in this example. We assume that a job shop lot production system is employed. In the model, the production system makes two kinds of products. Setup time is required at any production process to change a kind of product. In this example, we set the lot size as 5 units per lot, and setup time as 120 minutes at every production process.

In the current version of the planner, we use ASPROVA (http://www.asprova.jp/) as a production scheduler. ASPROVA is a commercial based scheduler employed in the world-wide. It can build scheduling model based on practical conditions as well as provides scheduling algorithms to solve complex scheduling problems. Therefore the planner can apply to complex production systems in practical problems.

The differences between the scheduling and the aggregate plan are visualized by progressive curves as shown in figure 8. In the figure, the result of scheduling indicates that the aggregate plan, in fact, has production capacity not enough to supply products. The scheduling step evaluates several scenarios to increase production capacity. For example, figure 9 shows the inventory as results of the scheduling step. In this case, the production system at the 1st scheduling has capacity not enough to satisfy the demand, therefore it cannot keep the standard inventory level. In this situation, the overtime work capacity is expanded to provide the supply capacity enough to satisfy the demand. The result of the scheduling after changing the capacity is shown as 2nd scheduling in figure 9.

The evaluation of the plans obtained from the strategic map and from the scheduling is different because the assumed production conditions in the scheduling are more detailed than the plan in strategic map. For example, production lot size, variety of product, and setup time are not considered in the plans of the strategic map.

Therefore we need to return the more accurate information to the aggregate plan, so as to rebuild the strategic map, if necessary. The points to be feedback are production capacity, lot sizing, the frequency of setup, and so on (Hayashi 2007).

Table 3: Value of constants for linear programming

Constants	Value	Constants	Value
c_1	100	P_0	130
c_2	107	d_0	270
c_3	115	b	2
c_4	5	I_0	0
c_5	270	$X_{\max}$	200
c_6	80	$Y_{\max}$	20
c_7	200	$Z_{\max}$	30
c_8	300		

Table 4: The aggregate plan selected by the planner

t	D_t	X_t	Y_t	Z_t	I_t	B_t
1	194	200	34	0	40	0
2	195	195	0	0	40	0
3	189	189	0	0	40	0
4	186	186	0	0	40	0
5	193	193	0	0	40	0
6	219	200	19	0	40	0
7	225	200	25	0	40	0
8	201	200	1	0	40	0
9	201	200	1	0	40	0
10	196	196	0	0	40	0
11	183	183	0	0	40	0
12	201	200	1	0	40	0
sum	2382	2342	81	---	---	0

d	α	0.1	0.3	0.6	0.8	1
100	ER	23643.17	24828.5	25167.17	25336.5	25421.17
	EC	18128.33	18221.67	18248.33	18261.67	18268.33
	EN	5514.833	6606.833	6918.833	7074.833	7152.833
	ET	[illegible]	0.41	0.405199	0.403156	0.40295
	N^*	40	40	40	40	40
160	ER	26938.83	28281.25	28763.92	28854.42	28960
	EC	19243.33	19391.67	19445	19455	19510.17
	EN	7695.5	8889.583	9318.917	9399.417	9449.833
	ET	0.269012	0.2565	0.252597	0.252258	0.251962
	N^*	40	40	40	40	40
200	ER	29016	30459	[illegible]	31122	31226
	EC	20109.92	20497.92	[illegible]	21018.58	21195.42
	EN	8906.083	9961.083	10153.42	10103.42	10030.58
	ET	0.215266	0.205261	0.202114	0.201576	0.201379
	N^*	40	40	40	40	40
240	ER	31255	32795	33343.33	33471.67	33623.33
	EC	23052.42	24251.42	24699.83	24816.58	24951.83
	EN	8202.583	8543.583	8643.5	8655.083	8671.5
	ET	0.179353	0.171088	0.168535	0.168217	0.167874
	N^*	40	40	40	40	40
280	ER	33322.67	34986.67	35552	35722.67	35829.33
	EC	27201.67	28696.67	29196.67	29348.75	29432.92
	EN	6121	6290	6355.333	[illegible]	[illegible]
	ET	0.153802	0.146626	0.139326	0.138526	0.131074
	N^*	40	40	40	40	40

EC_{min}, EN_{max}, ER_{max}

Figure 6: A part of strategic map

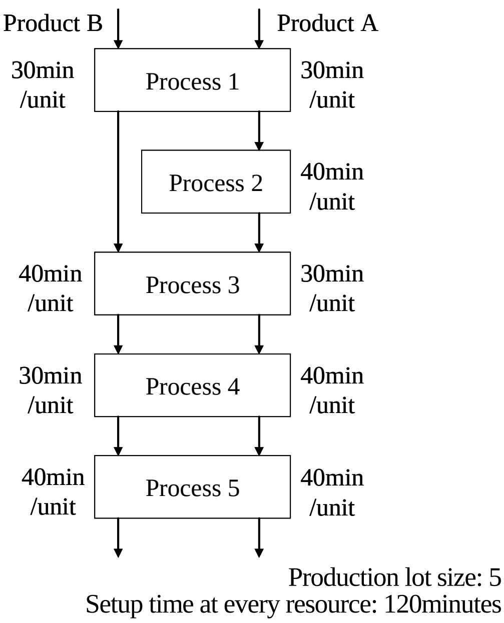

Figure 7: Model of scheduling

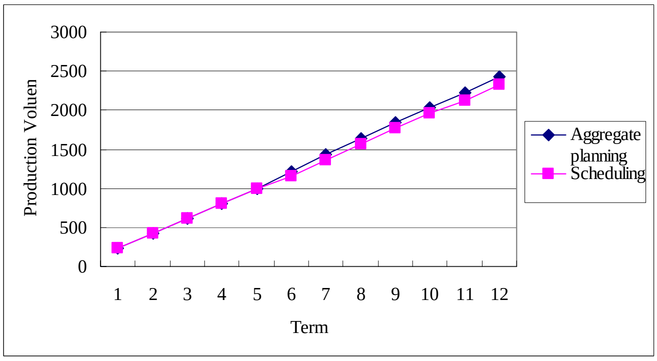

Figure 8: Progressive curve

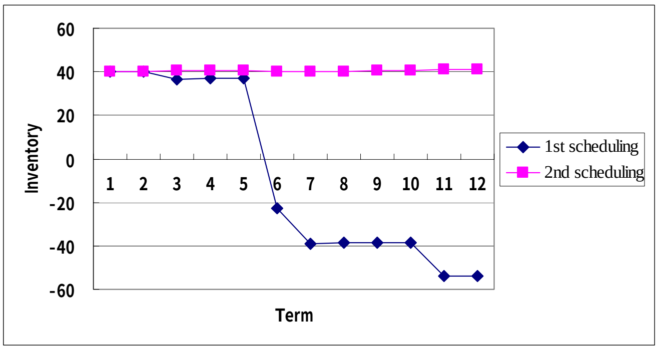

Figure 9: Change of inventory at scheduling step

6. AN EDUCATION SYSTEM OF DEMAND-TO-SUPPLY MANAGEMENT

In this section, we describe an education system on the demand-to-supply management as well as an application of the planner in the system. The planner is used as a learning tool to support exercises in the education system. As shown in section 6.3, the planner is a useful tool to understand the effectiveness of the demand-to-supply management.

6.1 Background

As stated in the above, the demand-to-supply management has an important role for establishing a sustainable company. In practice, however, it is the ordinary case that sales sector and production sector work individually for each sector's goal in spite of knowing importance of collaborative decision making, and therefore optimization of cooperate-wide profit and sustainability improvement of a company are not always attained. As Simon *et al.* (2006) stated, a market share-driven approach, which takes strategies for improved sales volume, revenue growth, and therefore increased market share, is still a good practice in most company, even in this SCM age.

In the circumstances, to improve cooperate-wide profit and sustainability, it is necessary to train skilled staffs who can establish the demand-to-supply management in the company successfully. For this reason, companies request the education system in consideration with the characteristics of the demand-to-supply management (Hayashi *et al.* 2008).

In addition, well established education systems, in general, are critical to improve sustainability in any company. For example, the balanced scorecard (Kaplan and Norton, 1992) forces on the learning and growth perspective as one of the four general perspectives as performance measures for corporate innovation.

Based on the above background, we have developed an education support system to learn the basis of the collaborative demand-to-supply management.

6.2 Overview of Education System

The education system described in this paper is designed for undergraduate students, graduate students, and corporate staffs who are in charge of the demand-to-supply management. In the education system, different goals are set based on the skill and knowledge of attendees as shown in table 5. The highest level of the goals is level 5.

Figure 10 shows a framework of this education system. As shown in the figure, this system consists of goal setting of education, study course consisting of a series of lecture, exercise, and measurement, as well as exercise support software, and evaluation of the effectiveness of education.

The evaluation examines the effectiveness of the education system based on the results of measurement though a series of lectures and exercises. The results of the evaluation are used to improve performance of the system.

Table 6 describes a course design in the system (Sakashita 2008). In the lectures, attendees study the essential concept and necessary knowledge of the demand-to-supply management, such as the demand-to-supply problem, demand forecasting, production planning, scheduling, inventory management, logistics, SCM, and examples in several industries.

Through the exercise after the lecture, attendees gain knowledge and comprehension of the demand-to-supply management. In the exercise, at first, attendees gain a skill for scheduling followed by group studies. Figure 11 shows steps of the group study. In the group study, demand groups and supply groups are formed. The number of groups depends on the size of attendees. Each attendance belongs to either group. In the exercise, conditions of the case study are provided. The case is selected depending on the knowledge and skill of attendees.

Each demand group makes a demand plan which maximizes sales, and each supply group makes a supply plan which minimizes production cost based on the conditions.

After the planning, a demand group and a supply group exchange their plans each other, and examine the difference of the plan. In addition, a demand group and a supply group work together to find an optimum plan which makes maximum profit. The planner is used as a software tool to make plans through exercises.

The series of exercises play a role of providing the experience of collaboration to attendees. It is expected that the exercises help attendees gain knowledge and skill of the demand-to-supply management.

In addition, the effectiveness of each course is measured through questionnaires, interviews to attendees, and so on. Attendees answer questioners before and after the course, therefore it is possible to compare the answers and evaluate the effectiveness of the course.

Table 5: Goals of education for each attendee level
(U: Undergraduate student G: graduate student C: Corporate staff)

	Goal of education	Attendee		
		U	G	C
1	Understand the current business environment as well as necessity of the collaborative demand-to-supply management	Y	Y	Y
2	Understand technical terms on the demand-to-supply management	Y	Y	Y
3	Be able to explain the steps and mechanisms of profit maximization by the collaborative demand-to-supply management	Y	Y	Y
4	Be able to apply the collaborative demand-to-supply management to simple problems	-	Y	Y
5	Be able to apply the collaborative demand-to-supply management to practical problems	-	-	Y

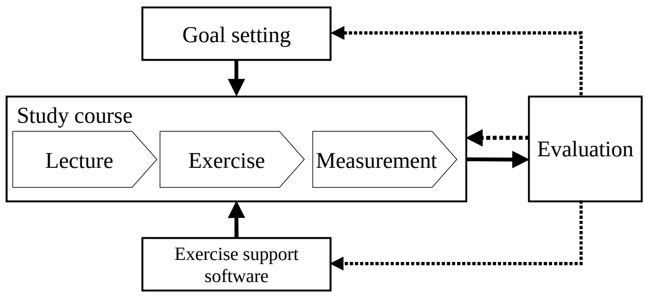

Figure 10: A framework of education system

Table 6: An example of course design

1	Lecture(1)	Introduction to the demand-to-supply management
2	Lecture(2)	Steps and mechanisms of the demand-to-supply management
3	Exercise	Learning fundamental operations of production scheduler
4	Group exercise(1)	Selection of a demand strategy and a supply strategy separately in each demand group and supply group using the planner
5	Group exercise(2)	Selection of a demand-to-supply strategy in collaboration with demand group and supply group

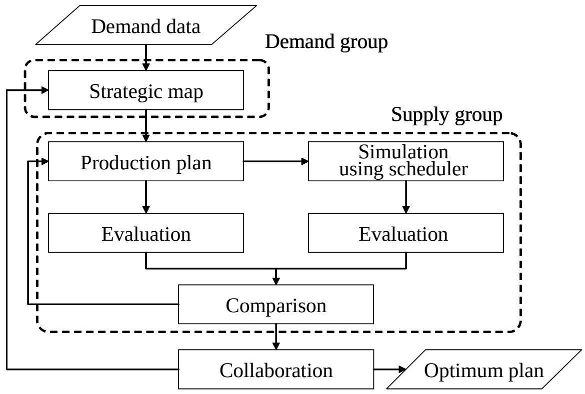

Figure 11: Steps of exercise

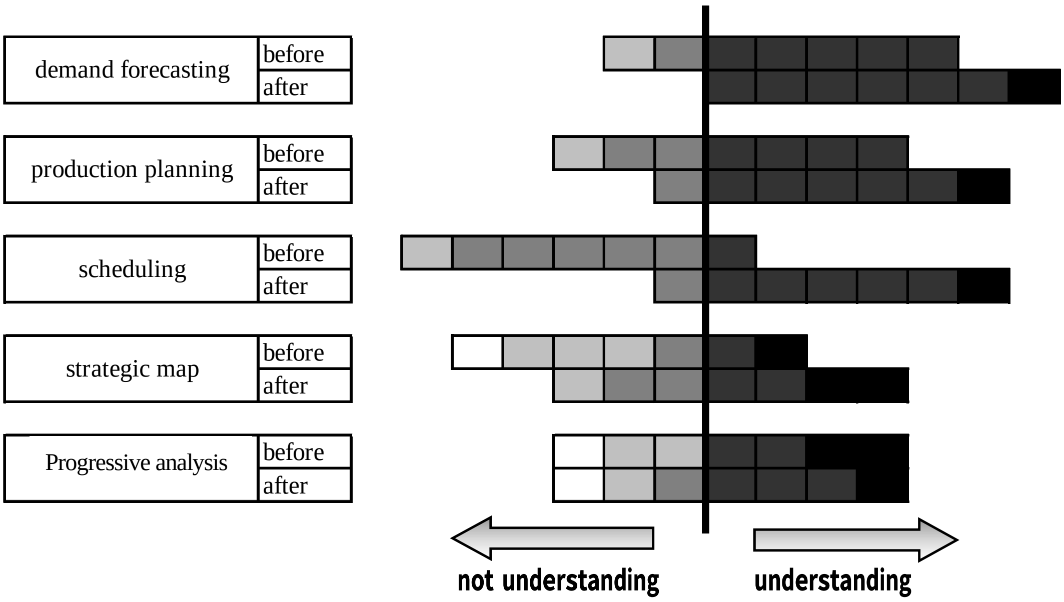

Figure 12: Evaluation of effectiveness of education system

6.3 Results of a Trial Class

We had a trial class to graduate students in order to evaluate the effectiveness of the proposed education system. Figure 12 compares the answers to questionnaires by the graduate students before and after taking the course at the trial class. The results of questionnaire are based on self evaluation regarding several categories learned through the course. In the figure 12, the upper rows of each category indicate the answers before taking the course. The lower rows, on the other hands, indicate the answers after taking the course. In addition, each row shows the degree of understanding on each category. The more right side bars indicate the higher understanding level. Therefore it is possible to recognize that the difference between the upper row and the lower row can show the effectiveness of the education system. In this case, we can say that the most attendees improved their understanding through the course. However, attendees' improvement of understanding cannot be observed in several categories, such as progressive analysis. We should reform lectures and exercises in the points to improve the effectiveness of the education system.

7. FUTURE DEVELOPMENT

One of the ultimate goals of the demand-to-supply management is to improve corporate sustainability under today's uncertain and unforeseeable market conditions. The overall framework of the demand-to-supply management can be depicted as shown in figure 13. The planner described in this paper covers a part of short term strategic perspective in the framework. The system for the medium-term strategic perspective makes a supply system plan including capacity expansion, outsourcing, and so on. It also makes a demand development plan including marketing strategy, pricing strategy, and so on, to improve corporate profit. In the long term strategic perspective, on the other hand, business life cycles based on core products should be considered. Any business has a life cycle. Any company must decide the right withdraw time from the market on matured products in any case. The system for the long-term strategic perspective supports decisions for products release and revision as well as the management for optimum products portfolio to improve corporate sustainability.

In the future development, the systems of long-term and medium-term strategic perspectives should be developed. In addition, the planner should be integrated with those systems in order to improve corporate sustainability.

Regarding the planner, flexibility should be increased to be applicable to diversified demand-to-supply problems in practice. For example, a generalized strategic map, which is applicable to many demand forecasting methods need to be developed. In addition, methodologies of the progressive analysis need to be improved. The progressive analysis evaluates the plan and indicates directions to improve the plan. Therefore methodologies used in the progressive analysis are critical to search the optimum plan in the planner.

Regarding the education system, more trial classes are required to evaluate the effectiveness of the system. Especially, it should be applied to corporate staffs to evaluate the system from several practitioners' points of view. In addition, more case studies should be prepared to increase variety of exercise.

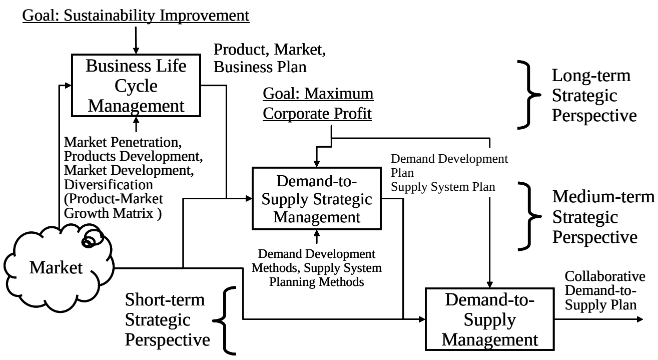

Figure 13: An overall framework for demand-to-supply management for sustainable company

8. CONCLUSIONS

In the SCM age, companies are exposed to severe competition than ever before. In this situation, the collaborative demand-to-supply management described in this paper is a critical issue to establish a sustainable company. However, sales sector and production sector have not always work together to make an optimum plan. In other words, the collaborative demand-to-supply management has not been well established in most companies.

In this paper, we described a framework of the demand-to-supply management and the planner used in the framework as a software tool for supporting the collaborative demand-to-supply management.

In addition, we propose an education system to gain skill and knowledge on the collaborative demand-to-supply management as an application of the planner. In this paper, we show the effectiveness of the system based on the results of a trial class.

We also describe the potential areas of future development on the demand-to-supply management and the planner.

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