Integrating Markdown Policy in Aggregate Production Planning Environment by Developing an APP-MP Model

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Abstract. The high competition in the market of short lifecycle products forces the retailer to use markdown pricing strategy for maximizing the revenue and the manufacturer to develop more appropriate aggregate plan for minimizing the cost. Hence, it is believed that the information sharing and cooperation between them become important now for improving their performance. This paper is to study the significance of the cooperation between the markdown policy and the aggregate planning so as to simulate the cooperation between retailers and manufacturers by a new model, Aggregate Production Planning-Markdown Pricing Model (APP-MP) which is established by integrating the markdown model into Aggregate Production Planning model. The APP-MP is a nonlinear integer programming model which is able to help the retailer and the manufacturer simultaneously make the pricing decisions, including the magnitude and time of markdown, and operational decisions e.g. inventory, outsource etc. so that greater profits could be obtained. The example solution shows that the cooperation definitely increases the profits. Besides, this paper’s result also implies that, instead of holding the belief “selling more and earning more”, the retailer should cooperate with manufacturer to plan the production by providing demand information to reduce the demand variation. Other insights for markdown pricing strategies are concluded in this study as well. In: Shebani K (ed). Proceedings of the 1st International Conference on Applied Operational Research – ICAOR (2008), pp 100–119. Lecture Notes in Management Science Vol. 1. ISSN 2008-0050.

Keywords: Markdown policy, aggregate production planning, cooperation, short lifecycle product.

1 Introduction

In recent years, the fierce competition and rapid technological progress lead to the reduction of products’ lifecycle, e.g. mobile phone and computers. The demand of this kind of products is highly uncertain and its value decrease sharply in a short period (low salvage value). For this particular kind of products, the dynamic pricing strategy, such as markdown pricing strategies, are commonly employed by retailers
for a significant impact on the total profits. The markdown pricing is a set of policies that the retailer gradually reduces the price of a certain product to spur the demand in the end of the product’s lifecycle or the time of promoting new products. Nevertheless, most of retailers make such a decision about price by themselves and ignore the manufacturer who fabricates those short lifecycle products.

On the other hand, the adoption of pricing and revenue management among the manufacturer is still limited. The manufacturer may also neglect the marketing information and pricing strategies used by the retailer and they just arrange the production plan based on the order pattern from the retailer.

The manufacturer normally develops or adopts different planning to allocate their capacity. For instance, the Aggregate production planning (APP) is a medium term capacity planning process to satisfy the predicted demand in a way that minimizes the expected costs for the manufacturer.

In mainland China and other developing countries, we observed that the current traditional business mode (or practice), that is, the retailer and the manufacturer do their business individually without any information sharing and cooperation, is still used for the short lifecycle products.

Hence, this article is to study how significant it will be for the manufacturer and the retailer if they consider markdown pricing and aggregate production planning in a collaborative way. We believe that there is a potential opportunity for improving the performance of the whole system (i.e. the manufacturer and the retailer) by linking pricing information with planning activities in the manufacturing side, allowing them to refine pricing, capacity, production and inventory decisions.

Fleischmann, Hall and Pyke (2005) mentioned that “Such coordination could give marketing managers visibility to true costs and responsiveness as they make pricing and promotion decisions, and it could provide supply chain managers with a better understanding of pricing structures as they make capacity and inventory decisions. The result would be total profit optimization rather than myopic optimization of revenues or costs.”

In this paper, an Aggregate Production Planning – Markdown Pricing model (APP-MP) is developed first in which the typical APP model integrates with one-off markdown pricing strategy which denotes that only one markdown pricing activity is allowed during the lifecycle of the product. Then the APP-MP model is used to find the optimal pricing and production decisions for those short lifecycle products to maximize the profits.

Figure 1.1 below represents the traditional transaction mode between the retailer and the manufacturer while Figure 1.2 illustrates the cooperative business mode provided in this paper.

![fig1.1](image.png)

**Fig. 1.1. Traditional Business Mode**
Fig. 1.2. Cooperative Business Mode.

The APP-MP model is a Nonlinear Integer Programming (NIP) model by which the optimal solution for both markdown pricing and the production planning decisions in the APP-MP model can be obtained. The objective function relates to the total profits which equals to the revenue from the retailer minus the cost from the manufacturer. Then, the constraints include all the constraints of the classical APP model and some other related to the pricing and demand. The following problems will be addressed for the system by means of the APP-MP model:

1) Determining the operational decisions like the inventory level, the production level, the subcontracting level, etc.
2) Determining the time and magnitude of markdown pricing in the whole period

The rest of the paper is organized as follow: Section 2 is a literature review. In section 3, a typical APP model and the Markdown Pricing (MP) model will be introduced and the APP-MP model will be proposed. Section 4 includes applications of those models in a numerical example in order to examine the performance of the cooperative business mode. We focus on the result analysis including the comparison between cooperative and traditional business mode. Final section is about the conclusion and the future research.

2 Literature Review

In this part, we review the development of APP models and the dynamic pricing articles. Aggregate production planning (APP) has attracted considerable attention from both practitioners and academia. Saad (1982) categorized all traditional models of APP problems to six ones—(1) linear programming (LP), (2) linear decision rule (LDR), (3) transportation method, (4) management coefficient approach, (5) search decision rule, and (6) simulation. In 1978, Zimmermann (1978) first extended his FLP approach to a conventional multi-objective linear programming (MOLP) problem. Recently, Wang and Fang (2001) then developed a fuzzy multi-objective linear programming (FMOLP) model for solving the multi-product APP decision problem in a fuzzy environment.

On the other hand, the markdown pricing research is developing fast now. Lazear (1986) started to study the pricing of a single good when all buyers have the same reservation price drawn from a known distribution function. Pashigian
(1988) further investigated the markdown pricing model in Lazear (1986) empirically. Various models and empirical studies about dynamic pricing have been proposed since then. Later, Smith and Achabal (1998) developed optimal clearance prices and inventory management policies that the impact of reduced assortment and seasonal changes on sales rate took into account. A decision-support system that helped retailers decide order quantities and markdowns for fashion goods is proposed by Rao and Mantrala (2001) based on MARK, a stochastic dynamic-programming model. Heching, Gallego and Van Ryzin (2002) studied an empirical analysis of markdown policies at an apparel company whose results indicated that markdown policies could potentially increase revenue significantly.

More recently, the markdown analysis has been extended to supply chain and operation management fields reported in a small amount of papers. Nair and Closs (2006) proposed an examination of impact coordinating supply chain policies and markdown policy by means of Monte-Carlo Simulation, whose results suggested that the high variation demand good was more suitable for adopting such a combination. Another one is a researchers’ Ph.D thesis, Swan (2001), in which the supply chain planning models integrated the dynamic pricing policies. The results show that the dynamic pricing will improve the performance of supply chain planning.

In light of above recent works, a conclusion can be drawn that the pricing policy and the APP were generally studied individually. In order to study the combination of the integration of pricing policy and the APP model, this article will adopt the deterministic APP model and the above-mentioned pricing models to develop the APP-MP model. Thereby, it is nature to establish the specific mathematical programming models in the next section.

3 MP, APP and APP-MP Models

As mentioned before, Markdown Pricing (MP) model and aggregate planning (APP) model are used by the retailer and the manufacturer respectively (old business mode) so that MP and APP models are considered to be the reference for the APP-MP model. The APP-MP is build for the system (cooperative mode). All of them will be presented in this section.

3.1 Model Assumptions And Variables

Some basic assumptions are necessary for our model building:

1) We focus only on the short lifecycle products which have a quite small salvage value by the end of their lifecycle. Moreover, we only consider single product in the model.

2) The whole planning time horizon is considered as almost the whole lifecycle of this product and is set to be T months. Normally the planning time horizon equal to six to twelve months.

3) The capacity of production considered here is only the workforce size without concerning any machinery.
4) The capacity is a bit fixed because we cannot hire or fire workers freely according to the labor law. However, we assume that the workforce size can be changed by means of temporary workers.

5) Initially, the price of the product is set at the average level in the market. The manufacturer can reduce the price one or two times during the whole planning time horizon.

6) The markdown policy only allows the price reduction and no increase later.

7) The manufacturer are responsible for the inventory including paying for restore the inventory and getting back the salvage value of the inventory by the end of products’ lifecycle.

8) The retailer is assumed to implement the markdown policy only once over the whole lifecycle of the product.

9) All ordered products by the retailer are to sold out during the planning period.

This paper introduces the following decision variables and parameters for the APP model and MP model.

- \( W_t \): The workforce size for month \( t \)
- \( H_t \): The number of employees hired in month \( t \)
- \( L_t \): The number of employees being laid off in month \( t \)
- \( P_t \): The quantity of units produced in month \( t \)
- \( I_t \): The quantity of inventory at the end of month \( t \)
- \( B_t \): The quantity of units stocked out/backlogged at the end of month \( t \)
- \( S_t \): The quantity of units subcontracted for month \( t \)
- \( O_t \): The number of overtime hours worked in month \( t \)
- \( D_t \): Demand forecast for month \( t \)
- \( v_t \): The price of the product in month \( t \)
- \( c_{rl} \): Labor cost in regular time ($/unit)
- \( c_{ro} \): Labor cost in overtime ($/unit)
- \( c_{h} \): Hiring and training cost ($/worker)
- \( c_{l} \): Layoff cost ($/worker)
- \( c_{i} \): Unit inventory holding cost ($/unit/month)
- \( c_{m} \): Unit marginal cost of stockout/ backlog ($/unit/month)
- \( c_{m} \): Unit material cost ($/unit)
- \( c_{s} \): Unit subcontracting cost ($/unit)
- \( \sigma \): Required labor hours for unit product (hours/unit)
- \( \theta \): The proportion of maximum capacity that can obtain from outsourcing
- \( N_{d} \): The number of working days in each month for one worker (days/month)
- \( N_{h} \): The number of working hours at regular time everyday for one worker (hours/day)
- \( I_{0} \): The initial inventory level at the start of planning horizon
- \( W_{0} \): The fixed number of workers who have long-term contracts from the manufacturer
- \( W_{max} \): The maximum workforce size level in each month
- \( \gamma \): The ratio of salvage value to the price
- \( \lambda \): Unit of overtime hour for each worker
3.2 Demand Model

3.2.1 Demand Function
Various formulations of demand function related to price have been proposed to forecast the future demand. This paper focuses on such a kind of demand model that can reflect the demand feature of short lifecycle products: high variation and sharp reduction at the anaphase of the lifecycle. Accordingly, we found that the demand model in Heching, Gallego and Ryzin (2002) described in the above feature demand without considering the timing and effect of markdown price. Hence, we enhance their model as follows:

\[ D_t = f(\alpha_t, v_t, \beta, t) \]

\[ = \alpha_t(a + bv_t)e^{-\beta|t-t_{peak}|} \]  

(1)

In that model, the formulation \(a+bv_t\) is the deseasonalised demand of month \(t\), where \(a\) and \(b\) are constant. Additionally, this model also considers two factors.

A calendar factor, \(\alpha_t\), which captures monthly variations in store traffic which can be attributed, for example, to holiday or traditional shopping seasons;

\[ e^{-\beta|t-t_{peak}|} \]

is an exponentially decaying age factor, which captures the expected increase in demand before the peak-demand month \(t_{peak}\) and decline in demand after \(t_{peak}\). It is a function of time what \(\beta\) manipulates the degree of variation. The estimation of all the parameters in this paper refers to Heching, Gallego and Ryzin (2002).

3.2.2 Impact Of Markdown
It is noted that the promotion or markdown will influence the price sensitivity of consumers, especially for the fashionable goods or short lifecycle products. Hence the price sensitivity is adopted. Obviously, higher price sensitivity indicates that little amount of markdown magnitude would bring more demand. To reflect this impact on the demand model, the coefficient \(\alpha_t\) is required to change once one-off markdown happens so that the stimulation of each time markdown is quantified. We define

\[ \Delta = \frac{v_0 - v_{in}}{v_0} \]  

(2)

\[ \alpha_{in}' = \alpha_{in} + \Delta \]  

(3)

to represent the impact of markdown on the demand model when the markdown strategy is implemented in the \(m^{th}\) month. It is actually a percentage of
changed magnitude to initial price. So, after the markdown time, the demand model will be revised to:

$$D'_t = \alpha' \left( a + b v_t \right) e^{-\beta \left| t - t_{\text{end}} \right|}$$  \hspace{1cm} (4)

3.3 Markdown Pricing Model [MP]

The retailer employs markdown itself and ignores the production cost from the manufacturer-side which allows them to pursue the maximum revenue by making the optimal markdown pricing decisions during the short lifecycle. The price parameters $v^* = (v_1, v_2, ..., v_T)$ are considered as decision variables in the MP model. Particularly the price-demand function is introduced to the MP model and add some constraints to assure the price is reduced gradually (markdown). The markdown model for retailers is presented as follow:

Objective function: The objective of the retailer is to maximize the revenue:

$$\sum_{t=1}^{T} v_t D_t$$  \hspace{1cm} (5)

Constraints:

Markdown constraints: The price must be reduced and never rises again provided that these reductions occur, which is given by:

$$v_t \leq v_{t-1}, \hspace{0.5cm} t = 2, ..., T$$  \hspace{1cm} (6)

where the initial price $v_0$ is known in advance and we set $v_1 = v_0$

Demand constraints: Demand function is set as the constraints of demand which reflect the deterministic relationship among time, price and demand:

$$D_t = \alpha_t \left( a + b v_t \right) e^{-\beta \left| t - t_{\text{end}} \right|}$$  \hspace{1cm} (7)

$$\alpha_{t+1} = \alpha_{t+2} = ... = \alpha_t \hspace{0.5cm} t = 1, ..., t_{\text{end}}$$

Since, according to the assumption (8), only one-off markdown is considered in this paper. The impact on the demand pattern will follow the equation (2) and (3) when the one-off markdown occurs.

From that month, Demand will follow such a new pattern in (4)

$$D_t = \alpha'_t \left( a + b v_t \right) e^{-\beta \left| t - t_{\text{end}} \right|}$$  \hspace{1cm} (8)

$$\alpha'_t = \alpha'_{t+1} = ... = \alpha'_T$$

Capacity constraints: the retailer orders products from the manufacturer. Thus, the total order amount should not exceed the maximum capacity of the manufac-
The maximum capacity consists of the regular time work and the overtime work of the maximum workers and the subcontracting amount over the planning horizon.

\[
\sum_{i=1}^{T} D_i \leq \text{capacity}_{\max} = T \left( \frac{N_d N_h W_{\max}}{\pi} + \frac{AW_{\max}}{\pi} \right) (1 + \theta) \tag{9}
\]

Consequently, this markdown model is formed as follow:

\[
\text{Max } (5)
\]

\[
s.t. \ (2); \ (3); \ (6) \sim (9); \ V_i > 0
\]

From this nonlinear programming model, the optimal pricing and the markdown magnitude can be discovered and, furthermore, the corresponding adjusted demand for each month.

The retailer traditionally delivers such a plan of demand (or order) to the manufacturer who then makes the aggregate plan for the production based on this demand (or order) pattern. Hence, this article provides the normal APP model as follows.

### 3.4 Aggregate Production Planning Model [APP]

Objective function: Receiving the order from retailers, the objective of the manufacturer is to minimize the total cost. The function consists of several cost components: Regular-time labor cost and overtime labor cost; cost of hiring and layoffs of temporary workers; cost of holding inventory; cost of stocking out; cost of subcontracting; material cost. Overall the objective function is the sum of all the costs shown in (17).

Constraints:

Workforce size, hiring and layoff constraints:

\[
W_t = W_{t+1} + H_t - L_t \quad t = 1, 2, ..., T \tag{10}
\]

Based on the assumption, the firm provides the long-term contract to workers \(W_0\) so that we cannot fire or hire them freely. So the workforce size is at least \(W_0\):

\[
W_t \geq W_0 \quad t = 1, 2, ..., T \tag{11}
\]

Further the maximum size of worker cannot exceed a certain level due to the labor law:

\[
W_t \leq W_{\max} = W_0 \left( 1 + \omega \right) \quad t = 1, 2, ..., T \tag{12}
\]

where \(\omega\) is the ratio of exceeding part.

Capacity constraints: The quantity produced in each month cannot be larger than the available capacity within the industry. The capacity within the plant is represented by: the regular-time and the overtime production. For the regular-time
capacity, the maximum amount of units produced in one month is \( N_d N_h \pi \) where \( \pi \) is also thought as the productivity and constant in the model. Similarly, the maximum amount in the overtime of each month is \( O_t \pi \). Therefore, this constraint is given by:

\[
P_t \leq \frac{N_d N_h}{\pi} W_t + \frac{O_t}{\pi} \quad t = 1, 2, ..., T
\]

(13)

Inventory balance constraints: This constraint balances inventory at the end of each month. The inventory by the end of last month \( I_{t-1} \), the current production quantity \( P_t \), and the subcontracting quantity equal to the sum of the real demand this month and \( I_t \), subtracting the backlog amount this month \( B_t \):

\[
I_{t-1} + P_t + S_t = D_t + B_{t-1} + I_t - B_t \quad t = 1, 2, ..., T
\]

(14)

Additionally, the initial inventory \( I_0 \) must be zero in the model: \( I_0 = 0 \). We also assume that there must be no any backlog at the end of the planning horizon:

\( B_T = 0 \) and initially: \( B_0 = 0 \).

Overtime constraints: No employee is allowed to work more than \( 2 \) hours of overtime each month:

\[
O_t \leq 2 W_t \quad t = 1, 2, ..., T
\]

(15)

Subcontracting constraints: We assume that the outsourcing amount is a fraction of the maximum capacity within the plant which consists of regular-time capacity and maximum overtime capacity:

\[
S_t \leq \theta \left( \frac{N_d N_h}{\pi} W_{max} + \frac{2 W_{max}}{\pi} \right) \quad t = 1, 2, ..., T
\]

(16)

In addition, all the variables are nonnegative here. Thereby, the complete APP model is built as follow:

**Model 3.2 [APP]**

\[
\begin{align*}
M_t \sum_{i=1}^{T} & N_i N_h W_t \sum_{i=1}^{T} c_i Q_t + \sum_{i=1}^{T} c_i H_t (15) + \sum_{i=1}^{T} c_i L_t + \sum_{i=1}^{T} c_i B_t + \sum_{i=1}^{T} c_i P_t + \sum_{i=1}^{T} c_i S_t - I_t y_t \\
\end{align*}
\]

(17)

s.t. (10)–(16); \( W_t, H_t, L_t \) are positive integers; \( P_t, I_t, B_t, S_t, O_t \geq 0 \). \( I_0 = 0 \); \( B_T = 0 \); \( B_0 = 0 \).

Note that \( I_T y_t \) is the salvage value income of the final inventory by the end of the planning horizon. This mixed-integer linear programming provides the optimal solution related to operation decisions such as inventory, workforce size and outsource.

These two models [MP] and [APP] represent the conventional mode without any information sharing except the retailer’s order pattern. Therefore, proposing a
new model by adding some information sharing (the markdown pricing strategy) to the model may bring a significant improvement to total profits of the system.

### 3.5 Aggregate Production Planning-Markdown Pricing Model [APP-MP]

The new mechanism presented in Section 1 displays a new relationship between the retailer and the manufacturer which needs to be modeled by different perspective from the conventional business mode.

The APP-MP model is an integration of APP and MP models and is an integer nonlinear integer programming model which shares some properties with APP or MP model. However, the price becomes a decision variable and therefore the optimal solution will give the optimal markdown price in each month accompanying with other variables’ optimal decisions.

Hence the APP-MP model is defined as follow:

**Model 3.3 [APP-MP]**

Objective function: maximizing the total profits.

\[
\max \sum_{t=1}^{T} \left( \sum_{r=1}^{R} \left( \sum_{k=1}^{K} W_{kr} \right) + \sum_{t=1}^{T} \left( \sum_{r=1}^{R} c_{r} Q_{t} + \sum_{r=1}^{R} c_{r} H_{t} + \sum_{r=1}^{R} c_{r} L_{t} + \sum_{r=1}^{R} c_{r} B_{t} + \sum_{r=1}^{R} c_{r} S_{t} \right) \right)
\]

s.t. \quad (10)-(16) \quad t = 1, 2, ..., T.

\[
D_{t} = \alpha_{t} \left( a + b v_{t} \right) e^{-\beta_{t} |r_{mod}|} \quad ; \quad t = 1, ..., t_{m-1};
\]

\[
D_{t} = \left[ \alpha_{t} + \frac{v_{t} - v_{m}}{v_{0}} \right] \left( a + b v_{t} \right) e^{-\beta_{t} |r_{mod}|} \quad ; \quad t = t_{m}, ..., T;
\]

where **W**, **H**, **L** are positive integers; **P**, **I**, **B**, **S**, **O**, **v** > 0. **I_0** = 0; **B_0** = 0.

This integer nonlinear programming (NLP) model generates optimal solution for operation and pricing decisions with a clear plan to the whole system, e.g. markdown price, inventory level, overtime working arrangement etc. Because of sharing the cost information and the demand information with each other, both two parties will benefit from such a combination.

In the APP-MP model, the markdown times are to be set in advance. For instance, the 5th month could be considered as the markdown time. In order to find the optimal markdown time which is able to bring the maximized profits, a simple method is proposed to search the optimal markdown.

Profit denotes the profits from APP-MP model if the markdown time is the \( i \)th month. The method searches all the possible \( i \) and selects the optimal solution which can brings the maximum Profit. Since the number of periods is small, such traversal searching is not time-consumed.

Herewith, the optimal markdown time has been determined as well as the magnitude of each markdown in both one-off scenario. A numerical example is used to
illustrate the advantages of the proposed APP-MP models compared with the traditional business mode by individual MP model and APP model.

4 A Numerical Example

The feasibility of applying this proposed models is demonstrated by the following numerical example which is a hypothetical one-product and twelve-month problem \( T = 12 \). The product here is defined as the short lifecycle one. The coefficient within the model is presented in the tables Table 4.1- 4.3. Table 4.1 shows the parameters of the demand function without pricing consideration while Table 4.2 and 4.3 presents the parameters of the APP model. The baseline of the demand which does not include any markdown policy is shown in Figure 4.1.

The models, APP, MP, APP-MP, in this study are NP, LP and NIP respectively so that the LINGO 10.0 is capable of solving those models. Thereby details about the solution techniques will not be discussed here and only the result of each model representing different business mode will be presented below. The markdown time is assumed in the 5th month.

<table>
<thead>
<tr>
<th>Table 4.1. Parameters of demand function</th>
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<td>( v_0 )</td>
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<th>Table 4.3. Parameters of APP</th>
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<td>( \pi )</td>
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4.1 Reference Scenario [MP] and [APP]

In order to have a reference result, we obtain the results of the traditional business mode by using MP and APP individually shown in Table 4.4 to Table 4.6. Table 4.4 is the markdown policy made by the retailer based on MP only. Figure 4.2 describes the demand curve for Table 4.4 and the total demand is 7344 units. Figure 4.3 shows the magnitude of markdown in the 5th month from $60 to $43.41.
<table>
<thead>
<tr>
<th>$t$</th>
<th>$v_t$</th>
<th>$D_t$</th>
<th>( I_t )</th>
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**Table 4.5. Production Plan in reference model**

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Fig. 4.1. Demand Baseline

Fig. 4.2. Demand Curve of APP-MP model
4.2 One-off Markdown Scenario [MP-APP]

One-off APP-MP model’s optimal solution for this example is given in Table 4.6 and Table 4.8. The markdown magnitude is changed from $43.41 (reference in Table 4.4) to approximately $51 and the demand is quite different from table 4.4 due to the new markdown pricing strategy. The resulting demand and the markdown pattern are shown in Figure 4.4-4.5.
Fig. 4.4. Demand Curve of one-off APP-MP model

Fig. 4.5. Magnitude of one-off markdown in APP-MP model
Results ($D_i$ in Table 4.6) implies that the retailer no longer orders the largest amount of products which is the limitation of the manufactures’ capacity because the retailer adopts new markdown policy distinguished from the conventional mode so that the impact of markdown pricing on the demand pattern is “optimal” as well. The total quantity this retailer orders is 5781 that is rather lower than before.

Consequently, the production plan given in Table 4.8 is also refined since the manufacturer considers the markdown pricing policy with the retailer. In a word, all the resources are reallocated, accompanying the cooperation with that retailer.

After all, despite the demand of this short lifecycle drop relatively compared with the reference result of the traditional business mode, the total profits of the system improve obviously than the previous one from $128443$ to $153366$. In detail, the revenue and cost are $310779$ and $157413$ respectively.
### Table 4.6. Pricing and Demand Pattern of APP-MP

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### Table 4.8. Production Plan in one-off APP-MP model

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### 4.3 The Optimal Markdown Time

The optimal time for markdown could be gained from the traversal search method presented before in Section 3.5. In Table 4.7, a comparison is made by laying out the one-off markdown in each month. It reveals that the 5th month is the optimal time of markdown if the peak demand month is set as the 3rd month.

Based on the result of selecting the markdown time, one observation is obtained: The performance of those potential markdown months, which locates around the peak demand month, is better than others. Afterwards, the later the first markdown starts, the lower the profits will be gained.

This numerical example suggests that the cooperation between the retailer and the manufacturer definitely enhances their performance. It can be concluded that, even under the assumption (9), the optimal choice of the retailer is sharing information with the manufacturer to seek a reasonable order quantity by the APP-MP model, instead of ordering the largest amount of products the manufacturer can supply.

According to Figure 4.6, the benefits of information sharing come from the reduction of the demand variation. The fact is, under the cooperative mode, although the revenue reduces because of decreasing demand, the cost of operations reduces more than the revenue so that more profits are earned than the traditional mode.
5 Conclusions

This paper emphasizes the importance of markdown pricing information sharing and cooperation between retailers and manufacturers. For short lifecycle products, the demand of each month fluctuates highly and the salvage value is relatively low than other durable goods. In order to exchange their individual information, the retailer and the manufacturer could have a meeting to simultaneously make the pricing plan included markdown policy and production plan. Sharing their information with each other will increase the total profits for the whole system.

According to this initial idea, this study developed an APP-MP model to link the markdown pricing strategy with the Aggregate Production Planning to achieve the goal of information sharing. The developed APP-MP model integrates the markdown model into the APP model. It is believed that the APP-MP model developed an approach to help the retailer and the manufacturer to have a cooperative planning. Furthermore, the proposed Nonlinear Integer Programming (NIP) model yields a positive solution to proof that linking the markdown pricing with the APP really improve the performance of the system.

The conventional concept of the retailer that “sell more products and gain more profits” seems to be suspicious based on the result of this paper. The retailer orders fewer goods in the proposed model from manufacturer than that in the traditional one but earns more money finally. The key factor for such a change is retailers realize the cost structure from manufacturers and share the demand information with them.

Moreover, the proposed model provides the markdown pricing in detail, including the optimal time and magnitude of the markdown policy. In general, the optimal solution markdown policy suggests one meaningful implication to guide the one-off markdown pricing: The markdown pricing needs to be used slightly later than the peak demand month or at least around it;

Increasing the frequency of markdown pricing over the horizon is one of the improvements for this paper, e.g. considering double markdown pricing. In that scenario, based on our preliminary observation related to double markdown, it would be quite positive and more useful implications related to markdown are obtained: If the system decides to use double markdown policy, the first markdown needs to be used slightly earlier before the peak demand month or at least around it; the interval between these two markdown months should be appropriate—neither too close nor too faraway. The proposed model has some potential extensions to develop. For instance, the fuzzy logic could be considered in our research (Zimmermann (1978)).

References


