# The Dynamic characteristics and Stability Research of VMI-APVIOBPCS in Apparel Industry Based on Complex system Theory

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*Abstract:* In this paper, we mainly investigate the dynamic performance of VMI-APVIOBPCS in apparel industry. With the increasing important integration of supply chain system, VMI-APVIOBPCS can integrate various kinds of elements in the operation, which is proved to be very effective in solving complex problems. Apparel industry supply chain has relatively more complicated dynamic behaviors because of the volatile demand, the strong seasonality of sales, the wide number of items with short life cycle or the lack of historical data. In order to clear these behaviors and come up with new ideas to solve existing difficulties, we apply classic control theory to build up the model of VMI-APVIOBPCS in apparel supply chain. Then we analyze the dynamic performance of apparel industry supply chain and use Routh-Hurwitz Stability Criterion to analyze the stability on the expectation that the outcomes of our research can be useful in the practical occasions.

*Key–Words:* VMI-APIOBPCS, apparel industry, control theory, dynamic performance, Stability analysis,

## 1 Introduction

Supply chain, which generally includes supplier, manufacturer, distributor and retailer, has been proved to be able to solve various problems in management and operation, including reducing high cost, promotion of efficiency and so on[1]. The related parameters and factors in supply chain are displayed in figure1. According to figure1, we can refer that the supply chain system is very complicated. Besides, this model is widely used in different industries and its model, at the same time, was improved into a so-called supply chain family, mainly including OBPCS, VIBPCS, IOBPCS, APIOBPCS, APVIOBPCS (Automatic Pipeline, Variable Inventory and Order Based Production Control System) and so on.

As for APVIOBPCS model, the problems of inventory and production have posed lots of significant problems in the history of manufactured goods. A lot of different analytical techniques and operational research methods, have been used with no one technique being wholly adequate in providing all the necessary solutions to planning and optimisation. However the consideration of the information flows, the effects of batch sizes and scheduling has now reached a position where the economic penalties of excess stock and the western poor practices are thrown into sharp relief by lean production regimes, such as that practiced by Toyota in the global market place. Furthermore, as the requirement for integration of information and resources in the whole supply chain, VMI-APVIOBPCS, (vendor managed inventory combined with APVIOBPCS) was developed. VMI, a scenario where vendor totally coordinates the inventory in supply chain, enables the operators to coordinate the overall finished goods inventory of the whole supply chain[1].

In recent years, this high-efficient model has been applied in apparel industry management [2]. CHIU.SHUI, a famous Chinese apparel brand, targeting at city female customers, has achieved excellent operation performance by adopting VMI policy.

However, we all know that it is an unprecedented challenge to manage such a complex system. On one hand, the management of supply chain is involved with so many factors that it is tough for managers to obtain good performance. Therefore, some problems, such as bullwhip effect, inventory backlog, are inevitably [3].

Disney and Towill [19] at Cardiff University, White and Censlive [20] and others have analysed Supply Chains with Automatic Pipeline, Inventory and Order Based Production Control Systems (API-

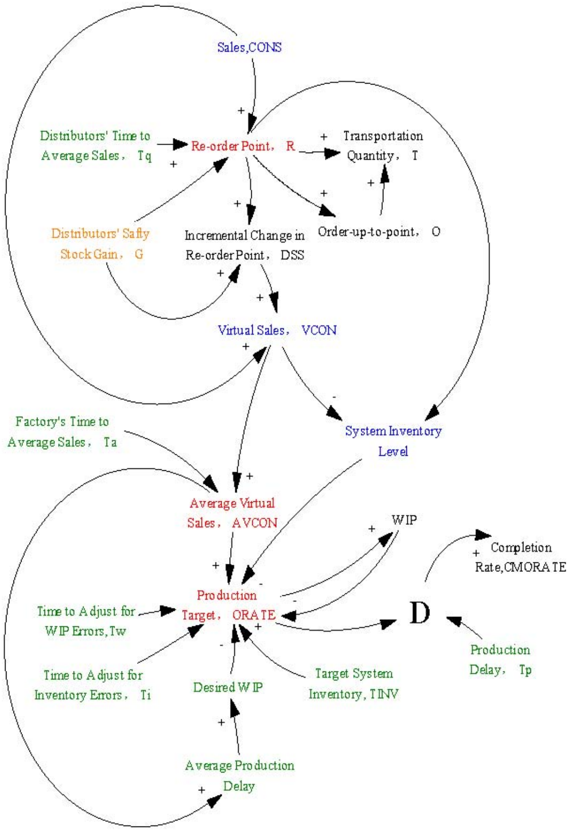


Figure 1: Causal loop diagram of VMI supply chain

OBPCS) and more latterly APVIOBPCS, extensively, to determine system stability and optimisation [21].

On the other hand, the apparel industry is more complicated in nature, which is showed in figure 2. The production of garments includes some procedures such as weaving and dying that are correlated and are supposed to share information in all aspects in order to offer qualified products to their clients. Besides, as is shown in the figure3, the garments always have varied categories with different sizes, colors and departments for the sake of excellent consumer service level. Therefore, the integration of materials requires comprehensive coordination of all the related supply chain units.

Whats more, these problems appear to be much tougher when the demand is not practically predictable [4]. In the apparel supply chain, factors liking the volatile demand, the strong seasonality of sales, the wide number of items with short life cycle or the lack of historical data malfunction the traditional forecasting techniques. In addition, the development of electrical commerce greatly changes the running surroundings of the fashionable apparel industries. Consumers are more sensitive to the information of fashionable trend and prices of different brands. The great pressures from both inside and outside really challenge the apparel industry supply chain.

In conclusion, the unnecessary waste of material due to the incapability of integration and the backlogged inventory that incurs inventory holding cost and reduction of expected profit burden the supply chain operation. The decrease of profit is definite because the price discount that try to attract the customers who are already ignorant of out-dated fashion styles [5,6].

The complexity of the supply chain itself and the special features of apparel industry supply chain pose obstacles to manage successfully supply chain.

Thus, with the existences of those practical drawbacks and obstacles, how to management the apparel well enough? How to identify the impact of changing related parameters on the whole supply chain? Is the VMI-APVIOBPCS model so perfect that this existing performance cannot be improved further? How to achieve new breakthrough in the present model?

Finally, this paper, in order to optimize the operation of apparel industry, applies the classic control theory which makes an overall coordination possible in the already-proved excellent model—-VMI-APVIOBPCS.

The following part of this paper mainly focuses on the general introduction of VMI-APVIOBPCS model, the simulation of the model under different parameters changes and the analysis of the results of simulation. Besides, we come up with a simple but effective method to analyze the stability of the system. At last, we come up with the management insight which aims to help the managers and operators in the workshop to do the correct decision-making.

# 2 VMI-APIOBPCS Model

General speaking, supply chain is consisted of retailer, distributor, manufacturer, supplier. However, the apparel industry supply chain is different. To be specific, the apparel industry supply chain is usually consisted of retailer, distributor, core business (brand owner), manufacturer, supplier [7]. In this supply chain, the brand owner is the dominant character, unlike in the other supply chains, the manufacturer is dominant. The brand owner always outsources their manufacturing to the third part. In this case, the integration of the whole supply chain tends to be destroyed because the brand owner cannot completely control the manufacturer. But, in this paper, we assume that the brand owner and the manufacturer are the same as the one unit such as the brand owner can totally control the manufacturing part.

$$\begin{aligned}&VCON_t = CONS_t + VCON_{t-1} - VCON_{t-1}\\&+\frac{1}{1+T_q/\Delta t}\left(G\cdot CONS_t - VCON_{t-1}\right)\\&-\frac{1}{1+T_q/\Delta t}\left(G\cdot CONS_{t-1} - VCON_{t-2}\right)\end{aligned} \tag{1}$$

## 2.1 Demand Policy

In this paper, we use simple exponential smoothing prediction that is widely used in literatures [1][8-9]. Differently, in this model, it is used in several periods. At first, retailer and vendor have to reach an agreement on the re-order point that enables managers to guarantee adequate availability and avoid excessive stocks. The retailer will make decision about a replenishment order if the actual inventory is below the re-order point every planning period. Therefore, both of them also need to agree with the order-up-to point, O [8]. (All the marks used in this paper are explained in Table1.) And its mathematical model is (1). Then the whole system prediction formula is (2).

$$\begin{aligned}&AVCON_t = AVCON_{t-1}\\&+\frac{1}{1+T_a/\Delta t}\left(VCON_t - AVCON_{t-1}\right)\end{aligned} \tag{2}$$

As to the relationship between smoothing constants $\alpha_a$, $\alpha_q$, $T_a$ and $T_q$, it is shown in (3) and (4)

$$T_a = \frac{1-\alpha_a}{\alpha_a} \tag{3}$$

$$T_q = \frac{1-\alpha_q}{\alpha_q} \tag{4}$$

Generally, the values of $T_a$ and $T_q$ are always set to be equal so as to make the system more simple and easier to be understood. And in this paper, we also consider that $T_a$ equals to $T_q$.

## 2.2 Production Delay

In apparel industry, the production delay or production lead time is extremely important. Fashion tendency is hypersensitive to particular time period. The tedious production delay can lead to the decrease of sales [6].

In this paper, $T_p$ means the time of production delay. Its transform function is (5).

$$G\left(s\right) = \frac{1}{T_p\cdot s+1} \tag{5}$$

Here we assume that the production capacity is infinite. Actually, it is very reasonable in the real world. Especially, the development of e-commerce changed the customers purchasing habit from limited time to broader time period [10]. In other word, people not only buy summer clothes in summer but also very likely in winter. Therefore, in order to keep the precious customers loyalty, the brand owners are supposed to preserve some stock even it can bring extra inventory holding cost to preserve good relationship quality between brand and consumer. After all, the production capacity is always bigger than the demand.

As to $Tpbar$, estimate of the production leadtime, it is used to decide desired work in progress $(DWIP)$, such that

$$DWIP_t = AVCON_t\cdot Tpbar \tag{6}$$

Usually, $Tpbar$ is considered to be equal with $T_q$ in simulations[1][8]. However, in [11], the inequality between the real transportation delay (the transportation delay is equal to production delay in the paper) and perceived transportation delay acts as an important unstable factor that can lead to chaos in the supply chain. Here we remodel this unstable factor using classic control theory and observe its impact on stable system in time domain, which can allow us to be informed of the real tendencies of related variables vividly.

## 2.3 Work-in-progress Feedback

Actually, in the real business world, most of apparel brand owners outsource the manufacturing part to the third part for the sake of reducing manufacturing cost. Under this condition, the brand owners can avoid the management of raw material stock cost, supplier relationship management that is energy consuming for requiring evaluating the trust, reputation and so on[12]. However, it is not approved in this modern economic world because today we positively call on integration of the use of resources in order to save as much precious resources as we can[16].

Besides, the requirement to the materials that are used to be made of clothes is complex and change all the time. Unlike the work-in-progress management of automobile manufacturers, the materials needed to be dyed in various colors even in only one shape.

Therefore, it is necessary for us to set the work-in-progress feedback in the control process, which can enable the managers make more accurate decisions [19]. The calculation of the is in (6).

$$WIP_t = WIP_{t-1} + (ORATE_t - COMRATE_t)*\Delta t \tag{7}$$

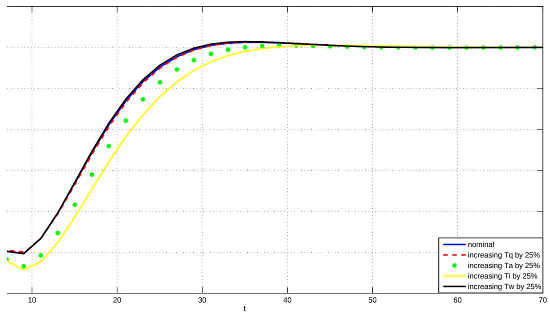


Figure 2: Effects of $T_q$, $T_a$, $T_i$, $T_w$ on inventory recovery following a step input

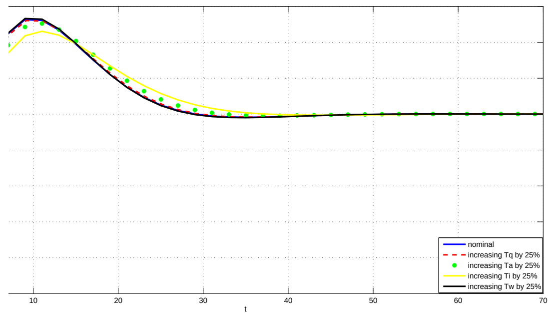


Figure 3: Effects of $T_q$, $T_a$, $T_i$, $T_w$ on order rate regulation following a step input

## 2.4 TINV and ORATE

The ideal $TINV$ condition is 0, which means there is no inventory holding cost. Here is a shortage of this model. In real condition we need to take the customer service level into consideration such that $TINV$ should be changed according to the demand. In this paper, in order to make this model more practical and reliable to the real world conditions, we just set $TINV$ changes with the assumed consumption. Therefore, in figure1, we use $TINV = xAVCON$ to define the level of $TINV$. But in order to simplify the model when investigate the other performances of the system, we set $TINV = 0$[1][1].

$$\begin{aligned} &AINV_t = AINV_{t-1} \\ &+ (COMRATE_t - VCON_t) * \Delta t \end{aligned} \quad l \tag{8}$$

$$\begin{aligned} &ORATE_t = AVCON_{t-1} \\ &+ \frac{TINV_{t-1} - AINV_{t-1}}{Ti} + \frac{DWIP_{t-1} - WIP_{t-1}}{Tw} \end{aligned} \quad l \tag{9}$$

# 3 Simulation

The simulation is conducted in the simulink, Matlab2011a.

## 3.1 Dynamic Performance

In the figure5, we can clearly know the dynamic performances in time domain of $ORATE$, $TINV$, $WIP$ which are three most important state parameters we always assess.

Figure6, figure7 and figure8 show us the changes of $ORATE$, $TINV$, $WIP$ stimulated by the changes of $T_q$, $T_a$, $T_i$, $T_w$. In the simulation, we make the four important parameters increase by 25% respectively.

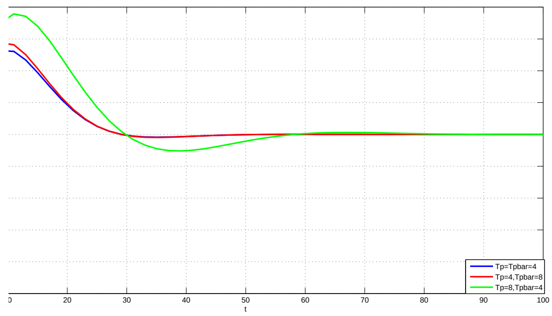


Figure 4: Effects of $T_q$, $T_a$, $T_i$, $T_w$ on $WIP$ following a step input

Generally, $Tp$ and $Tpbar$ are regarded as the same in simulation. Actually, in the real world, random factors always make it impossible. For example, in the apparel manufacturing workshop, equipments collapse or nature disasters can inevitably change the $Tp$ [11]. When $Tp$ is equal to $Tpbar$, the dynamic performance can be the best. In order to specifically identify the difference when $Tp$ is not equal to $Tpbar$, we set a big difference in the simulation. And finally, we can receive the result that the differences change the dynamic very dramatically. It is easy for to find the reasonable explanation in the real world. When make prediction based on an evaluation that actually doesnt happen, the dynamic performance will suffer from severely deviation away from the expectation. From Figure9 we can know that the difference leads to the actual inventory deviates the target inventory which directly raises the inventory holding cost.

In Figure8, we can figure out that the effect of the changes of $T_q$, $T_a$, $T_i$, $T_w$ on $WIP$ is relatively small. It means that in the practical world, the factors related with the decision-making parameters have moderate

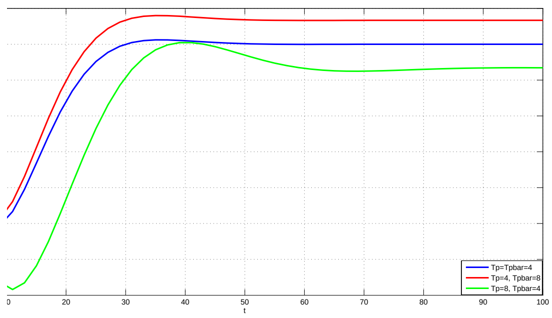


Figure 5: Effects of different actual and perceived production lead times on the $AINV$ dynamic response

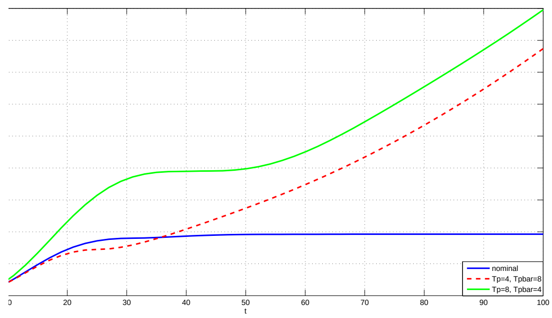


Figure 7: Effects of the different actual and perceived production lead times on the $WIP$ dynamic response

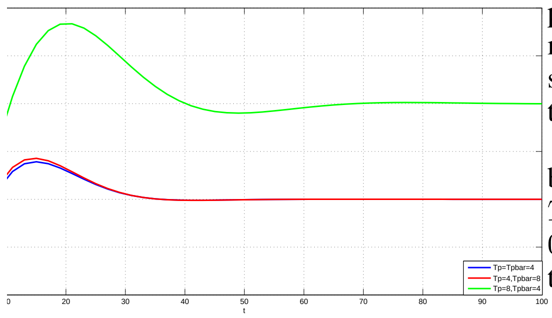


Figure 6: Effects of the different actual and perceived production lead times on the $ORATE$ dynamic response

impact on the inventory of work-in-progress.

In this paper, we apply a measure of $ITAE$ to indentify the dynamic inventory performance changes when $Tp$ is not equal to $Tpbar$. The advantage of using $ITAE$ is that persistent error after long time is to be penalized by the time weighting. The system that is regulated by reaching the minimized $ITAE$ objective can have good dynamic performance finally [8].

From figure 10 and figure 11, we can conclude that the difference generated between $Tp$ and $Tpbar$ can greatly influence the dynamic behaviours of $AINV$, $ORATE$ and $WIP$, which makes the management difficult to control. In figure12, the sharply changes of $ITAE$ produced when there is difference generated between $Tp$ and $Tpbar$, indicating the vital importance to make perceived production lead time more approximate the real production delay.

Generally, the target of inventory is considered to be zero for the minimum inventory holding cost. However, the holding cost is not equal to the total cost in supply chain. At present, different partners in supply chains tend to seek the win-win state that is the maximized total benefit. Taking this issue into consideration, we investigate the influences of different targets of inventory level on the dynamic behaviours.

Firgure13, 14 and 15 show us the dynamic behaviours of $AINV$, $WIP$ and $ORATE$ when $TINV = 0$, $TINV = 0.2AVCON$, $TINV = 0.2AVCON$ and $TINV = 0.5AVCON$. However, the influences are not obvious. Figure 16 shows the $ITAEs$ in different $TINV$ levels. Apparently, the $ITAE$ decreases when the target of inventory level increases. In real world, we can coordinate the inventory system based on this conclusion. To be concrete, we can keep proper level inventory to raise the total benefit in the supply chain.

Figure17 displays the dynamic changes when $G$ changes. Obviously, it is much easier to predict linear effect on the system dynamic performance. Besides, we can know that the higher $G$ can lead to higher stock level fluctuation. Therefore, the managers need to find a balance between remaining a proper $G$ which can keep consumer loyalty and reducing inventory holding cost.

### 3.2 Deviation Analysis

It is inevitably to generate some deviation in the process of controlling. The actual inventory level cannot reach the targeted inventory level immediately, creating some deviations that lead to excess stock or insufficient stock which further break the consumer loyalty. According to the figure19, we can clearly observe the error changes in the time domain, which, at the same time, provides us another way to improve system dynamic performance in VMI-APIOBPCS such that minimizing ITAE by changing the decision-making variables.

As to bullwhip effect [6], it refers to the phenomenon that the orders to the supplier tend to have

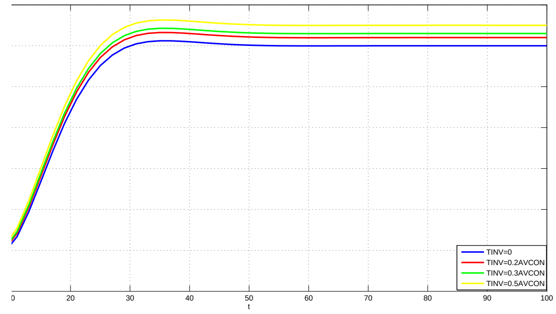


Figure 8: $ITAEs$ under the conditions of different actual and perceived production lead times

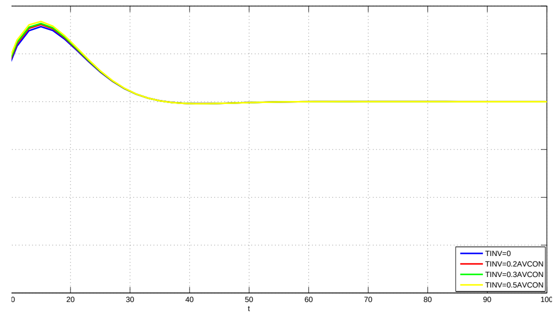


Figure 9: Response of $AINV$s under the conditions of different $ITAEs$

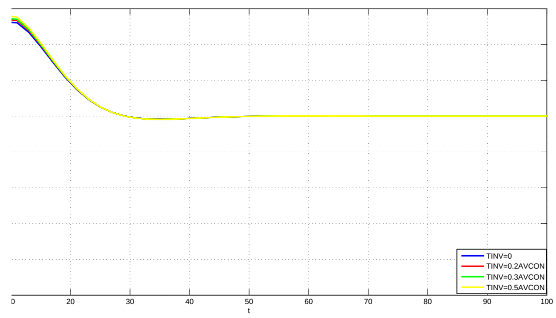


Figure 10: Response of $WIPs$ under the conditions of different $TINVs$

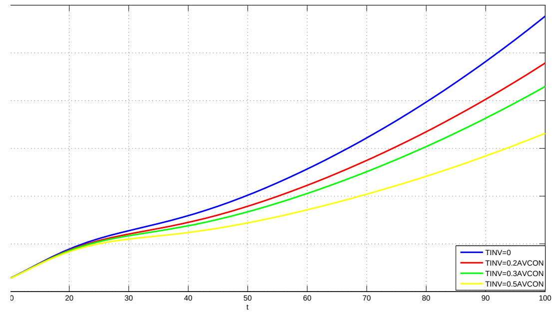


Figure 11: the response of $ORATEs$ under the conditions of different $TINV$

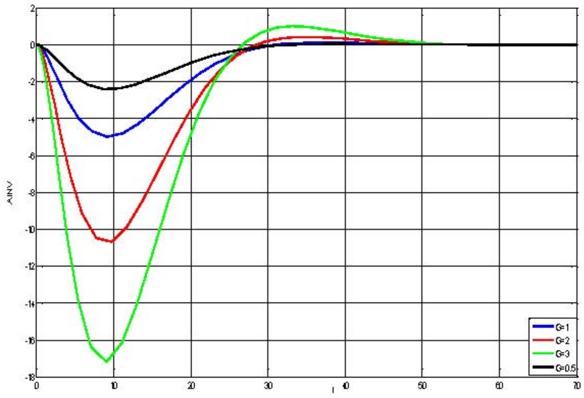


Figure 12: Effects of changes of $G$ on the $AINV$ response to a step unit input

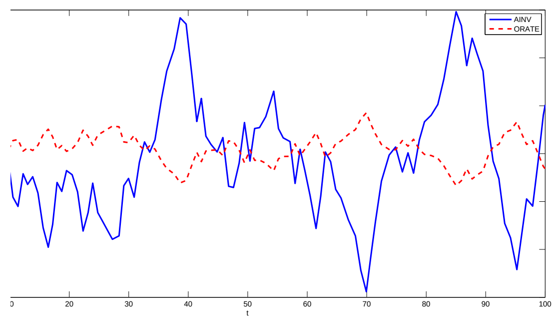


Figure 13: Dynamic responses of $ORATE$ and $AINV$ to random input

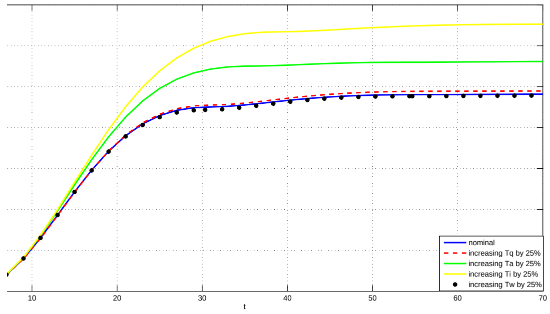


Figure 14: Effects of $T_q$, $T_a$, $T_i$, $T_w$ on regulation following a step input

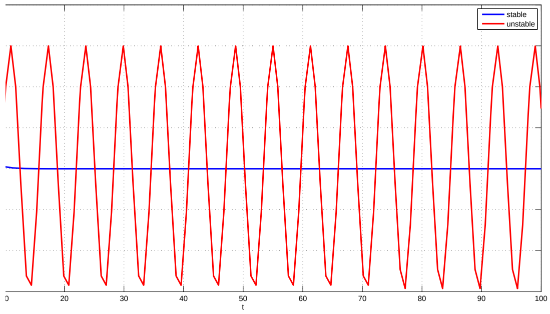


Figure 16: The changes of bullwhip effect under the changes of $T_a$, $T_i$, $T_w$

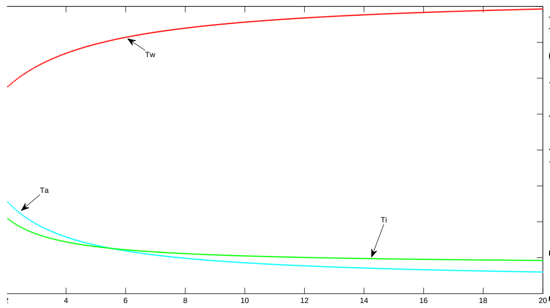


Figure 15: Bullwhip effect

larger fluctuations than sales to the buyer and the distortion propagates upstream in an amplified form.

In control theory background, we always use noise bandwidth to quantify and measure bullwhip effect [13].

$$W_N = \int_0^{\pi} \left| F\left(e^{i\omega}\right) \right|^2 d\omega \tag{10}$$

The transformation of the $\frac{ORATE(s)}{CONS(s)}$ is

$$\frac{ORATE(s)}{CONS(s)} = \frac{2G\left(Tp \cdot Ta + Ti \cdot Tp + Tp \cdot T\bar{p} \cdot Ti/Tw\right)s^3 + \left[\begin{array}{c} 2G\left(Ta + Ti + Tp + T\bar{p} \cdot Ti/Tw\right) + \\ \left(Tp \cdot Ta + Ti \cdot Tp + Tp \cdot T\bar{p} \cdot Ti/Tw\right) \end{array}\right] s^2 + \left[\left(Ta + Ti + Tp + T\bar{p} \cdot Ti/Tw\right) + 2G\right]s + G}{(1+Ta \cdot s)\left[1+(Ti+Tp \cdot Ti/Tw)s+Tp \cdot Ti \cdot s^2\right](Tq \cdot s+1)(s+1)} \quad l \tag{11}$$

Both the $ITAE$ and bullwhip effect can be called the deviation in the $VMI - APVIOBPCS$ control, which always generates unnecessary operation cost. In figure 19 and 20, we know the tendencies of $ITAE$ and bullwhip under different decision parameter configurations, and thus we can successfully control the supply chain in practice. From Figure21, we can clearly refer that the increase of and leads to the reduction of bullwhip effect, which is a meaningful conclusion in the practical world.

# 4 Deviation Analysis

The decision parameters are influenced by many random factors, such as weather changes, transportation condition and so on. In order to reduce the unnecessary cost, we need to use some simple methods to judge the stability analysis when some of the parameters are changed unpredicted. In this paper, we introduced a kind of simple and understandable methodłł Routh-Hurwitz Stability Criterion to evaluate the stability of system.

## 4.1 The Routh-Hurwitz Stability Criterion

Actually, in the real business world, most of apparel brand owners outsource the manufacturing part to the third part for the sake of reducing manufacturing cost[17-18]. Under this condition, the brand owners can avoid the management of raw material stock cost, supplier relationship management that is energy consuming for requiring evaluating the trust, reputation and so on[12]. However, it is not approved in this modern economic world because today we positively call on integration of the use of resources in order to save as much precious resources as we can.

We assume the characteristic equation of the closed-loop linear system can be expressed like the following equation[14]:

$a_0 s^n + a_1 s^{n-1} + \cdots a_{n-1} s + a_n = 0$

Then the prerequisite for the system stability can be explained liking the following: a. the coefficients of the characteristic equation $a_i\,(i = 0, \cdots, n-1)$

cannot be zero b. all the coefficients of the characteristic equation $a_i$ must be positive numbers or negative numbers at the same time

$$\begin{array}{lllll} s^n & a_0 & a_2 & a_4 & a_6 & \cdots \\ s^{n-1} & a_1 & a_3 & a_5 & a_7 & \cdots \\ s^{n-2} & b_1 & b_2 & b_3 & b_4 & \cdots \\ s^{n-3} & c_1 & c_2 & c_3 & \cdots & \\ \vdots & & & & & \\ s^2 & d_1 & d_2 & d_3 & & \\ s^1 & e_1 & e_2 & & & \\ s^0 & f_1 & & & & \end{array}$$

The first two rows of the Routh-matrix are consisted of the coefficients of the characteristic equation. The first row includes the first, third, fifth, coefficient.

The second row includes the second, fourth, sixth, coefficient.

In the Routh matrix

$$\begin{array}{l} b_1 = \frac{a_1 a_2 - a_0 a_3}{a_1}, \quad b_2 = \frac{a_1 a_4 - a_0 a_5}{a_1}, \quad b_3 = A, \quad \cdots \\ c_1 = \frac{b_1 a_3 - a_1 b_2}{b_1}, \quad c_2 = \frac{b_1 a_5 - a_1 b_3}{b_1}, \quad c_3 = B, \quad \cdots \\ \vdots \\ f_1 = \frac{e_1 d_2 - d_1 e_2}{e_1} \\ A = \frac{a_1 a_6 - a_0 a_7}{a_1}, B = \frac{b_1 a_7 - a_1 b_4}{b_1}. \end{array}$$

This process should be repeated until the nth row can be expresses out. All the coefficients together are showed in a shape of inverted triangle.

## 4.2 The Stability of the VMI-APIOBPCS Apparel Industry

Under this condition, the brand owners can avoid the management of raw material stock cost, supplier relationship management that is energy consuming for requiring evaluating the trust, reputation and so on[12]. However, it is not approved in this modern economic world because today we positively call on integration of the use of resources in order to save as much precious resources as we can.

The transform function of $\frac{AINV}{CONS}$ is (11).

$$\frac{AINV(s)}{CONS(s)} = \frac{Ti\{(Tp+Tw)-(1+Ta\cdot s)[Tp+Tw(1+Tp\cdot s)]\}G(2s+1)}{(1+Ta\cdot s)[Tw(1+Ti\cdot s)+Ti\cdot Tp\cdot s(1+Tw\cdot s)](Tq\cdot s+1)(s+1)} \quad l \tag{12}$$

Its characteristic equation is (12)

$$(1+Ta\cdot s)(A)(Tq\cdot s+1)(s+1)=0 \quad l \tag{13}$$

$$A=[Tw(1+Ti\cdot s)+Ti\cdot Tp\cdot s(1+Tw\cdot s)]$$

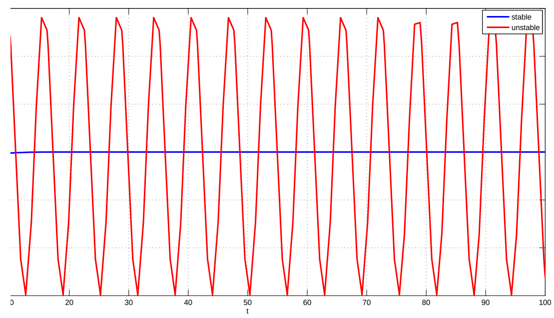


Figure 17: Responses of $WIP$ in stable and unstable states

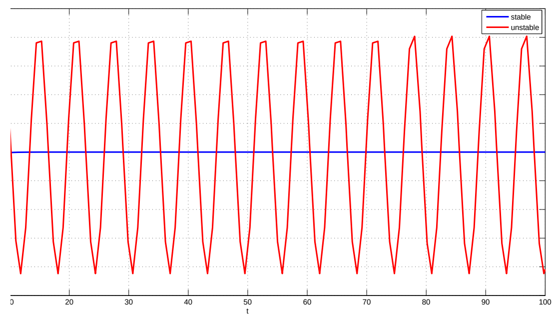


Figure 18: Responses of $ORATE$ in stable and unstable states

For example, $(Ta, Tw, Ti, Tp, Tq) = (1,1,1,1,1)$ its characteristic equation is $s^5+5s^4+10s^3+10s^2+5s+1=0$

Its Routh-Matrix is

$$\begin{array}{llll} s^5 & 1 & 10 & 5 \\ s^4 & 5 & 10 & 1 \\ s^3 & 8 & 24/5 & \\ s^2 & 7 & 1 & \\ s^1 & 128/35 & & \\ s^0 & 1 & & \end{array}$$

To the same argument, when $(Ta, Tw, Ti, Tp, Tq) = (1,-1,1,1,1)$

the system is unstable. $Tw=-1$ means the influence of work-in progress on the order is negative in the decision-making. In the following, we compare the dynamic behaviours of the VMI-APVIOBPCS system in the following pictures.

From the Figure 22 to Figure 25, we can identify the differences between stable and unstable $VMI-APVIOBPCS$ systems. Obviously, the unstable behaviors change turbulent and pose many problems to

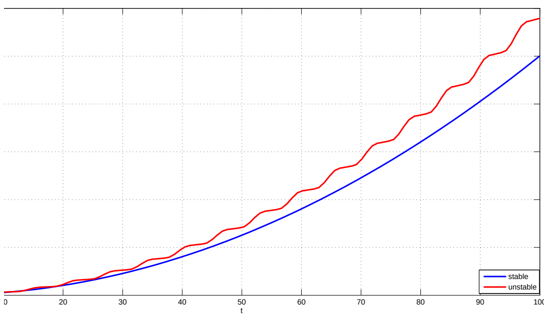


Figure 19: Responses of $ITAE$ in stable and unstable states

the management. In the contrary, the stable system is relatively predictable and easier to manage for the simple behaviors.

According to the prerequisites of The Routh-Hurwitz Stability Criterion, we can conclude that the system is stable.

Generally, the values of controlling parameters change in relatively small scale or predictive scale. In addition, the calculation of the Routh-Matrix can be realized by efficient computer programs. Thus using Routh-Hurwitz Stability Criterion is practical and useful. This method is familiar with the optimization method used in [15].

## 5 Summary

The turbulent fashion apparel industry market poses challenges to the frontline managers. In order to overcome this difficulty, we have to be clear about the influences of internal parameters on the dynamic performance which can be used to evaluate the operation cost in supply chain system.

When the dynamic performance is excellent with minimum deviation and fastest time to be stability, the supply chain can stay good operation condition, all the factors of which can be orderly organized. In the contrary, the supply chain system that suffers from poorly dynamic performance, like staying in periodic state or even in terrible chaotic state can always buy bills for some unnecessary cost.

In this paper we use the VMI-APVIOBPCS continues model for enjoy its accuracy to investigate the dynamic performance of fashion apparel industry. Furthermore, we use analyze the dynamic performance changes under the main parameters changes and obtain some useful conclusions
(1) Deviations cannot be avoided in any supply chain, but can be minimized according to particular objective function.
(2) As to the production delay Tp and the perceived value Tpbar, if the Tpbar can be precisely predicted or valued, the dynamic performance can be improved, vise verse.
(3) The Routh-Hurwitz Stability Criterion presents us a simple and effective way to identify the stability of the system.
(4) Enable the retailers to avoid the risk that the reduction of profit brought by demand fluctuation. The overall coordination help the manufacturers make the right decisions based on the sufficient information from both retailers and suppliers.

After all, the coordination of the whole VMI-APVIOBPC apparel industry is kind of micro system engineering. We can achieve good coordination performance when we fully regulate and organize all the related elements properly. This paper provides us with a foundation or reference to how to change the decision in order to minimize the cost and maximize the profit.

Since the issue of inventory and order-based control in the supply chain is so complicated that we are not capable to overcome it on one setting, we are supposed to insist this direction and go further.

To be specific, we can continuously research on how to improve the dynamic performance by changing the critical decision-making parameters.

## 6 Symbols

| | |
|---|---|
| AINV | Current Inventory level |
| AVCON | Average sales rate CONS |
| CONS | Sales consumption or market demand |
| COMRATE | Rate of production |
| CSL | Customer service levels |
| $C_LGW$ | estimated cost for lack of goodwill |
| EINV | Error in inventory level |
| EPOS | Electronic point of sale |
| EWIP | Error in WIP |
| DINV | Desired inventory |
| i | Interest rate |
| ORATE | Outstanding level of supplier orders |
| TINV | Target inventory |
| $T_i$ | Inventory order constant time |
| $T_w$ | WIP order constant time |
| $T_P$ | Production delay time |
| $T_Pbar$ | Multiplier from smoothed sales to WIP |
| $T_V$ | Constant multiplier to AVCON |
| $T_a$ | Smoothing time constant |

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