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BUSINESS PROCESS BASED SIMULATION: A POWERFUL TOOL FOR DEMAND ANALYSIS OF BUSINESS PROCESS REENGINEERING AND INFORMATION SYSTEM IMPLEMENTATION

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ABSTRACT

Demand analysis is of fundamentally importance in the implementation of information system. Business process reengineering (BPR) often gets involved in the process of demand analysis and play a crucial role in the achievement of project objectives. Business process based simulation (BPS) provides a precise and visual method to analyze and compare the concerned performances before and after BPR. The paper presents an industrial experience in using the BPS tool to demonstrate the effects of BPR on restraining stocking-up and overdue payments in the distribution management of a supply chain. Before significant investment involved, the related design result of BPR is validated both by the analytical method and simulation experiments. Based on the mutual supportive results, the BPS method approves its correctness and show its nicety, flexibility and the capacity of visualization.

1 INTRODUCTION

Standard implementation process of management information system (MIS) includes three main stages which are demand analysis, system analysis and design, and system implementation (Chai Yueting and Liu Yi 2000). Among them, the step of demand analysis is fundamentally important because it is supposed to discover and analyze managerial problems in current business functions and define core objectives of the coming system. During the process of demand analysis, investigation and analysis on the business processes are usually involved. Traditionally, the MIS has been used for supporting the existing business functions (such as increasing organizational efficiency), while it now plays a role as enabler of new organizational forms and patterns of collaboration within and between organizations. Consequently, new business process will be proposed to achieve specific managerial purposes during the step of demand analysis. The term of business process reengineering (BPR) usually refers to this kind of process, which is defined as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical measures of performance(Hammer and Michael 1990).

Business process based simulation (BPS) (Aguilar etc. 1999) has been viewed as an efficient approach to analyze and evaluate the newly designed business process ahead of remarkable financial investment involved. Relatively to traditional analytical method, three prominent specialties of the BPS method enable the quality improvement and risk control of MIS projects. Firstly, precise modeling capability enhances the analysis and contrast of business scenarios in detail. The specific business functions can be modeled and numerically tested by BPS to ensure its efficiency on solving the managerial problems. While traditional analytical method is more suitable to derive general conclusions and appears kind of rough and rigid when discussing real industry case. Secondly, visualized numerical outputs of BPS are much easier for industrial people to understand and thus may be more persuasive than mathematical analysis. The industrial people is more used to thinking based on data and curves in daily business analysis while traditional analytical method always involves many formal languages including symbols, terms, and equations which need much more patience to be comprehended. Thirdly, modeling flexibility of BPS is another advantage in analysis on BPR. Business scenarios can be frequently switched and tested due to different design schemes of business process. So the optimal scenario to solve the managerial problem can be picked up, which will be an important guideline in the subsequent process of the MIS project.

This paper portrays a comprehensive picture on the implementation process of a MIS project in textile industry of China and shows how the BPS method is used during the analysis of BPR. Both analytical method and simulation tests are applied to the real industry case,

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demonstrating whether the newly designed business structure can improve the performance of the supply chain.

Following parts are organized as this: in chapter 2, case background and problem statements are presented. Related literatures on the managerial problem of distribution management are briefly reviewed. After describing the content of the BPR in detail, theoretical analysis and simulation tests are brought out in chapter 4 and 5 respectively. Finally, the architecture of the MIS in introduced based on the re-designed business process. Conclusions are summarized in chapter 7.

2 DEMAND ANALYSIS

2.1 Case Background and Problem Statements

China has been playing an increasingly important role in the global economy (Xiaodi Zhang and Jingwei Sun 2007). Merchandises labeled as "made in China" spreads all over the world. But against the world-wide background of the buyers' market (Hinojosa etc. 2008), Chinese manufacturers are in a disadvantaged position compared to distributors and are facing fierce competition at all time. To preserve the market share and maintain a steady long-term partnership with the downstream distributors, manufacturers usually offer some preferential services to share risk and interest in the supply chain. In the Chinese textile industry, the manufacturer, which in our case is a state-owned clothing group, usually adopts two kinds of favorable policies to cooperate with their distributors (LIU Yi and LIU Zhi 2006), which named as periodical balancing and full buy-back.

Periodical balancing refers to the manufacturer delivering their goods before receiving the corresponding payments and then periodically balancing the bills with the buyers. So the distributors can possess the products before paying for them and thus obtain the hidden profit from the spread between the current value and future value of cash flow.

Full buy-back refers to the distributors probably returning the unsold merchandise after the selling season with the original purchase price. This policy passes on the distributors' risk to the manufacturer, especially in the textile industry with its distinct seasonal nature.

Such kinds of "most-favored" treatments make sense to maintain the stable partnership between the upstream (manufacturer) and downstream (distributors), but at the same time, some managerial difficulties inevitably arise from the manufacturer's goal and cause negative effects.

Firstly, periodical balancing cannot guarantee on time payment and may cause overdue payment, which increases the manufacturer's risk in balancing the financial flow. Secondly, full buy-back exempts the distributors from undertaking inventory risk, which makes them highly inclined to stock up. Rationally, before every selling season the distributors place their orders with exaggerated demands. After the season begins, they sell the merchandise without finishing the corresponding payments (due to the periodical balancing), and then return the unsold merchandise to the manufacturer when the selling season ends. What's more, the performance of the salesmen (employees of the manufacturer) is usually evaluated by their sales amount, and thus the salesmen, the same as the distributors, prefer to exaggerate order quantities. Consequently, the salesmen act in collusion with the distributors, which not only encourages the formation of the current trading contract but also intensifies its negative effects.

The preferential policies place the manufacturer between the hammer and anvil. Moreover, the whole distribution channel is inefficiency due to the rational behaviors of the distributors, such as retaining payables, stocking up, and returning purchases. Significant resource waste occurs in the supply chain. Facing these problems in distribution management, the core managerial objectives of the MIS project is to dispel the distributors' intention of stocking up and encourage on-time payments by means of BPR.

2.2 Related Literature

Distribution management is a frequently discussed topic in the field of management science. The buy-back contract, because of its positive effects on the distribution channel, such as risk share and sales encouragement, receives much attention in both academics and industries. For instance, Pasternack (1985) analyzed the buy-back contract based on the Newsboy Model and reached a generalized conclusion that the supply chain can be coordinated when its global profit can be formalized as the linear combination of the supplier's profit and the retailer's profit. In fact, this general conclusion has been proved in previous work (Jeuland A and S Shugan 1983); however, no concrete contracts have been brought out to validate the theoretical result.

Many literatures focus on the analysis based on more complicated models. Anupindi R and Y. Bassok (1999) discusses the effect of buy-back contract with the scenario of two retailers and finds the conditions to coordinate the supply chain. The model in the (Wu D. J. etc. 2002) is based on the capital-intensive supply chain and is very similar to the buy-back model. Padmanabhan (1995) is also a very important literature on this topic, which lists many negative effects of the buy-back contract and suggests some typical scenarios suitable to use this kind of management method, for example, in the attire supply chain the manufacturer usually adopts the buy-back contract to prevent the distributors selling the goods with discounted prices so as to protect the reputation of its brand.

Although buy-back contracts are frequently used in practice, the discussions on this topic, especially its positive effects, are much more sufficient from the theoretical view. But in our real industrial case, various negative effects are disclosed and adjustments of the traditional buy-back process is necessary.

3 BUSINESS PROCESS REENGINEERING (BPR)

3.1 Proposed Solution

To solve this problem, we proposed a Credit Service System (CSS) which we implemented in our case. The CSS is integrated as a part of the management information system of the clothing group (manufacturer of the supply chain) to improve the distribution management of the supply chain. By means of evaluating the salesmen's and distributors' credit-line based on their behaviors (such as purchase return and overdue payment), the manufacturer can decide the delivery amount to each distributor in every selling season. Methods of managing credit-lines are carefully designed to eliminate stocking up and encourage on-time payment. As a result, the supply chain works more efficiently than before.

Processes of the credit service can be modeled in detail as follow. Firstly, control variables are defined to restrain the salesman's behaviors, including:

(1) $w_i^{(k)}$, the estimated payables for distributor i in period k, represents the amount the distributor should pay to the manufacturer after it receives the purchased products in period k. i.e. $w_i^{(k)} = a_i^{(k-1)} + s_i^{(k)} \cdot c$

(2) $W_i^{(k)}$, the upper limit of estimated payables, named as credit line for distributor i in period k, represents the maximum of allowed estimated payables. i.e. $w_i^{(k)} \le W_i^{(k)}$

(3) $w_b^{(k)}$, the estimated receivables for the salesman, is the sum of all his distributors' estimated payables. i.e. $w_b^{(k)} = \sum_{i=1}^{n} w_i^{(k)}$

(4) $W_b^{(k)}$, the upper limit of estimated receivables, named as credit line for the salesman, is the maximum of the allowed sales on credit. i.e. $w_b^{(k)} \le W_b^{(k)}$. And usually we have $W_b^{(k)} < \sum_{i=1}^{n} W_i^{(k)}$

The new business process can be described as Figure 1: at each end of the selling season, the distributors make his decision on the repayment and goods return. Then the credit service sector will adjust their credit lines based on the remaining payables and the returned quantities. Then accordingly the credit line for the salesman is updated. New credit lines $W_b^{(k+1)}, W_i^{(k+1)}, \forall i = 1, 2, \cdots, n$ will affect the delivery quantities in the next selling season.

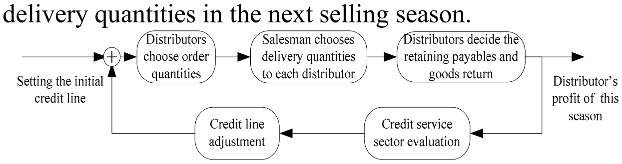

Figure 1: Distribution process with credit service

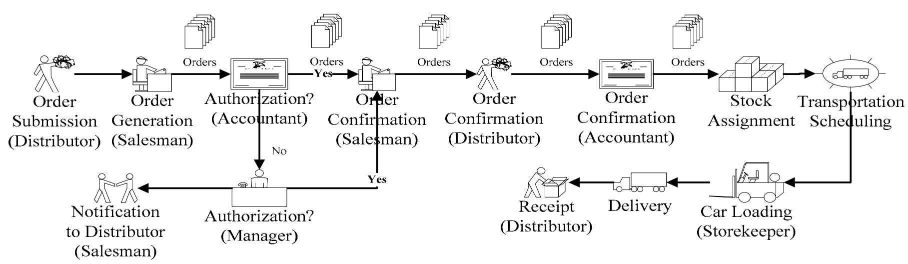

Figure 2: The Original Distribution Process

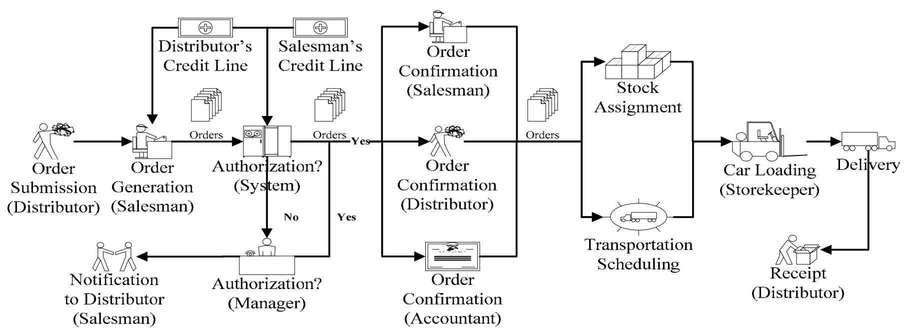

Figure 3: The Improved Distribution Process

3.2 Process Re-design

Standard implementation process of the management information system includes three steps which are demand analysis, system analysis and design, and system implementation (Chai Yueting and Liu Yi 2000).

Among them, the step of demand analysis is of most importance, which is related to the approaches of business process investigation, managerial problem discovery, and the business process reengineering.

Re-design of the business process in usually a direct method to achieve managerial purposes. In the implementation of the credit service system, the related business process of distribution and return are modified, as shown in Figure 2-5. As we can see, the BPR improves the workflow mainly from the following three aspects:

(1) Parallelization, which strengthens the concurrency of the business activities based on the easier information dissemination, such as the order confirmation in Figure 2 and 3

(2) Automation, which uses the computer to substitute for the hand-made operations and thus reduces errors and speeds up the workflow.

(3) Knowledge accumulation, which emphasizes on recording richer and more orderly datum for decision assistance, such as the credit line update in Figure 4 and 5.

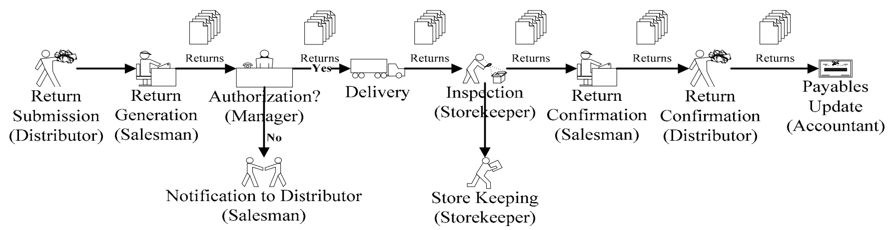

Figure 4: The Original Return Process

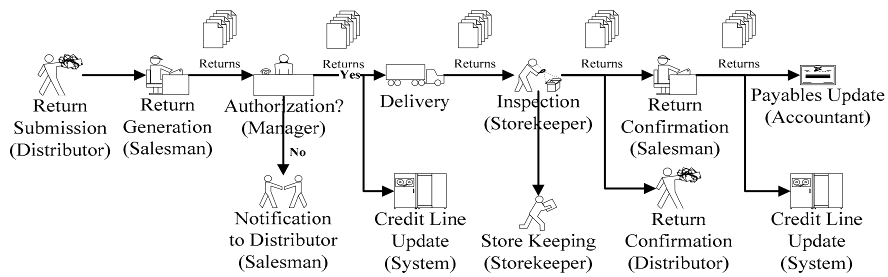

Figure 5: The Improved Return Process

4 THEORETICAL ANALYSIS

4.1 Analytically Modeling Before BPR

Suppose the product demand of distributor i is $D_i(\omega)\ (\forall i = 1, 2, \cdots, n)$, which are independent random variables with normal distribution $N(E(D_i), \sigma_i^2)$. Let its probability density function be $f_{D_i}(x)$. Then the expected income $P_i^{(k)}$ of distributor i is calculated as (1).

$$P_i^{(k)}(s_i^{(k)}) = \int_0^{s_i^{(k)}} f_{D_i}(x) \cdot x \cdot (p-c)dx + \int_{s_i^{(k)}}^{+\infty} f_{D_i}(x) \cdot s_i^{(k)} \cdot (p-c)dx \quad (1)$$

where $s_i^{(k)}$ is the delivered quantity to the distributor i in period k, p is the retail price and c is the unit cost for the distributor to purchase.

Analyzing the expected incomes of distributor i in period k, the derivative of the equation (1) is

$$\frac{dP_i^{(k)}}{ds_i^{(k)}} = (p-c)\frac{d[E(s_i^{(k)} - k_i^{(k)})]}{ds_i^{(k)}} = (p-c)\int_{s_i^{(k)}}^{+\infty} f_{D_i}(x)dx > 0 \quad (2)$$

where $P_i^{(k)}(s_i^{(k)})$ is the monotonously increasing function of $s_i^{(k)}$. the payoff function of the salesman is as (3):

$$U_b = \sum_{k=1}^{\infty} \lambda^k \cdot U_b^{(k)} = \sum_{k=1}^{\infty} \lambda^k \cdot U_b(s_1^{(k)} - k_1^{(k)}, s_2^{(k)} - k_2^{(k)}, \cdots, s_n^{(k)} - k\, 3)$$

and $U_b^{(k)}$ is a monotonously increasing function of $s_i^{(k)} - k_i^{(k)}$ $(\forall i = 1, 2, \cdots, n)$. Moreover,

$$E(s_i^{(k)} - k_i^{(k)}) = \int_0^{s_i^{(k)}} f_{D_i}(x) \cdot x dx + \int_{s_i^{(k)}}^{+\infty} f_{D_i}(x) \cdot s_i^{(k)} dx \quad (4)$$

$$\begin{aligned} &\frac{d[E(s_i^{(k)} - k_i^{(k)})]}{ds_i^{(k)}} \\ &= f_{D_i}(x) \cdot s_i^{(k)} dx - f_{D_i}(x) \cdot s_i^{(k)} dx + \int_{s_i^{(k)}}^{+\infty} f_{D_i}(x) dx \\ &= \int_{s_i^{(k)}}^{+\infty} f_{D_i}(x) dx > 0 \end{aligned} \quad (5)$$

So the expected sales of distributor i in period k ($s_i^{(k)} - k_i^{(k)}$) is the monotonously increasing function of $s_i^{(k)}$, which means the expectation payoff to the salesman is also monotonously increasing function of $s_i^{(k)}$. So the salesman will choose the maximal delivery quantity, i.e. $s_i^{(k)} = Q_i^{(k)}$, which is the reason why the salesmen act in collusion with the distributors.

To maximize $P_i^{(k)}$, the distributor will maximize $Q_i^{(k)}$ as long as the manufacturer can tolerate. Consequently, the equilibrium is achieved in this game when the order quantities are exaggerated, the receivables are in arrears, and the collusion between the salesman and the distributors ($s_i^{(k)} = Q_i^{(k)}$) is reached.

4.2 Analytically Modeling After BPR

Considering the payoff function (3) of the salesmen, in each selling period, the salesmen make a decision about the delivery quantity with the dual constraints of their own credit lines $W_b^{(k)}$ and the corresponding distributor's credit line $W_i^{(k)}$. As mentioned before $W_b^{(k)} < \sum_{i=1}^{n} W_i^{(k)}$, there is a kind of situation that the demand from the distributors can not be met completely, so the salesmen will assign the products based on the credit records of the distributors.

Supposing in some period, the salesman does not take the distributor's credit performance into accounts, to maximize his current sales, he will choose the delivery quantity to satisfy all the order quantities from the distributor, i.e. $s_i^{(k)} = Q_j^{(k)}$, which increases the expected return quantity $E(k_j^{(k)})$ in the end of the selling period and therefore has a negative effect on the distributor's credit records. Consequently, the credit line of the distributors and the salesmen in $k+1$ period will be brought down and the maximal delivery quantity of the salesman will also be reduced in the following seasons. And the final result is that, taking the long-term earnings into accounts, the total expected payoff of the salesman U_b becomes lower. Now we can see, under the schema with the credit service, there is no good for the salesman to meet the distributor's demand unconditionally even though from his own interest exclusively. Thus the salesman is incentive to efficiently allocate the finite resources, which is aligned with the manufacturer's objective.

Investigating the distributor's behaviors based on the payoff function (1), if the distributor does not care about the influence of the credit service and still adopts the upper limit, instead of the capacity of the real market, as his order quantity, the situation will evolve like this: the short-term expectation $E(k_j^{(k)})$ will increase but the possibility of playing down his credit line is also increased. When taking a long-term thinking, the total expected payoff of the subsequent periods may probably reduce. So the distributor's inclination of exaggerating the demands is under control. What's more, the distributors know that the salesman decides the delivery quantities based on their credit records, so the distributors would like to maintain or improve their credit line via reducing the payables and proposing appropriate order quantities, which is also aligned with the manufacturer's objective.

Based on the above analysis, the distribution mechanism with the credit service is incentive-compatible. With the objective of maximizing the expected payoff, the salesman takes the responsibility of the returned products via allocating the limited products based on the distributors' credit records. On the other hand, the distributor, also with the objective of maximizing his own expected payoff, has the intention to choose appropriate order quantities and reduce his returns, which is in favor of his credit records. Consequently, after repeated gaming, the final equilibrium satisfies the manufacturer and the objectives of BPR is reached.

5 PROCESS BASED SIMULATION TESTS

Results of the theoretical analysis shows a bright future of the newly designed process to achieve the desired managerial objectives. But the problem is, as mentioned before, the symbols and functions may require academic background and sufficient patience to read and understand, which the industrial people may not get used to. In fact, ordinary persons in real industry handle data and curves in daily work and prefer to reading and discussing ideas based on visual materials.

What's more, probably more fatally, the analytical method either can not tell the exact amount the company will gain by adopting and investing the new design, or has difficulty in specifying parameter configurations of each individual scenario to optimize the outcomes. So to persuade the industrial people to invest, also to validate the new design in more detail, it is necessary to conduct simulation tests to quantitatively analyze the outcomes brought by BPR.

5.1 Simulation Modeling Before BPR

The original business process is modeled based on Figure 2 and Figure 4. Some activities, such as confirmation and inspection, are not taken into account and one salesman with one distributor is considered in our simulation model. All the parameters of the simulation model comes from the statistics of existed information system.

The salesman (representative of the manufacturer) meet all the demand proposed by the distributor and buy-back all the unsold purchase with the full wholesale price (set as 2.5 yuan/item) at the end of the selling season. The handling cost for each item of product is supposed to be 0.9 yuan.

The distributor uses exponential smoothing model to predict the end customers' demand quantity and propose orders at the beginning of each selling season. When the distributor adopts the strategy of stocking up, he will use 125% of the predict result as the order quantity. At each end of the selling season, the distributor is supposed to periodically balance their payables and the actual ratio of payments to payables obeys a uniform distribution on the interval of [0.75, 0.9]. After selling seasons end, the distributor return all the unsold purchase to his supplier and the handling cost of each item is supposed to be 0.1 yuan.

The end demand market is supposed to obey the normal distribution with mean value of 50 items and variance value of 5 items and the retail price is set as 4 yuan/item.

5.2 Simulation Modeling After BPR

The re-designed business process is modeled based on Figure 3 and Figure 5. We can management the credit of the salesman and distributor as following steps:

Every time the order is confirmed, the distribution agent will send the order quantity $Q_i^{(k)}$ and the actual delivery quantity $s_i^{(k)}$ to the centralized database. When the merchandise is received and confirmed by the customer, the corresponding payables $y_i^{(k)}$ and arrearages in current period $a_i^{(k)}$ are updated. These data will also be changed when return occurs and at the same time the return agent will also get the return quantity $k_i^{(k)}$ recorded.

The algorithm consists of two steps.

- Step 1: Credit Evaluation

Supposing the initial credit value $I_i^{(0)} = 100$, $(\forall i = 1, 2, \cdots, n)$, if the distributor's credit is evaluated mainly based on the percentage of the arrearages in the payables and the returns in the deliveries, the specific rules are as follow:

a) If $a_i^{(k)} / y_i^{(k)} > 10\%$, $\Delta I_i^{(k+1)} = -100(a_i^{(k)} / y_i^{(k)} - 10\%)$;

If $5\% \le a_i^{(k)} / y_i^{(k)} \le 10\%$, $\Delta I_i^{(k+1)} = 0$;

And if $a_i^{(k)} / y_i^{(k)} < 5\%$, $\Delta I_i^{(k+1)} = 100(5\% - a_i^{(k)} / y_i^{(k)})$;

b) If $k_i^{(k)} / s_i^{(k)} > 10\%$, $\Phi I_i^{(k+1)} = -100(k_i^{(k)} / s_i^{(k)} - 10\%)$;

If $5\% \le k_i^{(k)} / s_i^{(k)} \le 10\%$, $\Phi I_i^{(k+1)} = 0$

And if $k_i^{(k)} / s_i^{(k)} < 5\%$, $\Phi I_i^{(k+1)} = 100(5\% - k_i^{(k)} / s_i^{(k)})$.

c) Set $I_i^{(k+1)} = I_i^{(k)} + \Delta I_i^{(k+1)} + \Phi I_i^{(k+1)}$

If the market is violating, the evaluation algorithm will be supposed to consider the relative arrearages and returns according to the average level of all the distributors.

- Step 2: Credit Line Update

Initially, the credit line will be set based on the capacity of the manufacturer, and then they are updated periodically based on

$$W_i^{(k+1)} = \frac{I_i^{(k+1)}}{I_i^{(k)}} W_i^{(k)} \quad \text{and} \quad W_b^{(k+1)} = \frac{\sum_i W_i^{(k+1)}}{\sum_i W_i^{(k)}} W_b^{(k)} \qquad (6)$$

If there are multiple times of ordering in one selling season or any other particular scenarios, additional control variables such as the times of order may be introduced to trim the algorithm.

5.3 Numerical Results

The simulation experiments are conducted on the supply chain simulation platform of Easy-SC (Juqi Liu, Wei Wang and Yueting Chai 2004; Linlin Cui, Jin Dong, and Yueting Chai 2006), which is also a business process based simulation tool. Selling seasons of 365 is simulated to observe a stable outcome against various scenarios.

The first experiment is designed to contrast the profits of a stocking-up distributor with a non-stocking-up distributor before BPR. Numerical results are shown in Figure 6 (a) and (b), in which the darker curves present the distributor's/manufacturer's profits if the order amount is more than the predictive demand, while the lighter curves is the outcome of a normal distributor who just order the same amount as it has been predicted.

From the result we can see, there is a kind of inconsistent between the manufacturer and the distributor before BPR: for rational distributors, they certainly prefer to exaggerating the demand amount to gain higher possibility of more payoff (the darker curves are above the lighter ones), which will do great harm to the manufacturer (the darker curves are below the lighter ones) as it has been observed in reality.

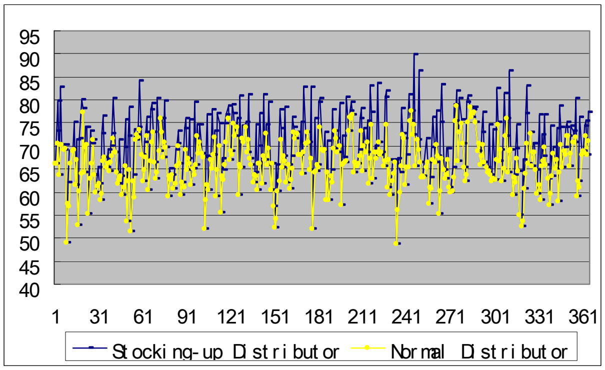

Figure 6(a): Distributor's Profit Before BPR.

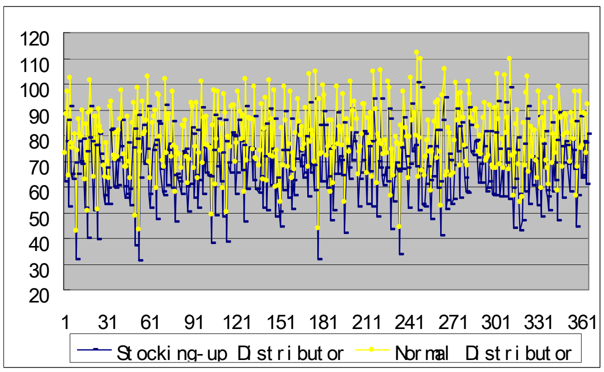

Figure 6(b): Manufacturer's Profit Before BPR.

Figure 7 shows the compared results after BPR. In this situation, both the distributor and the manufacturer gain more without demand exaggerations. That is to say, if the distributor adopts the strategy of stocking-up, not only his partner but also himself will be hurt. Thus, no conflict exists in this scenario (lighter curves are always above darker ones in both cases). The CSS introduces a kind of believable threaten to the stocking-up behavior and thus eliminates the inconsistence of the distributor and the manufacturer.

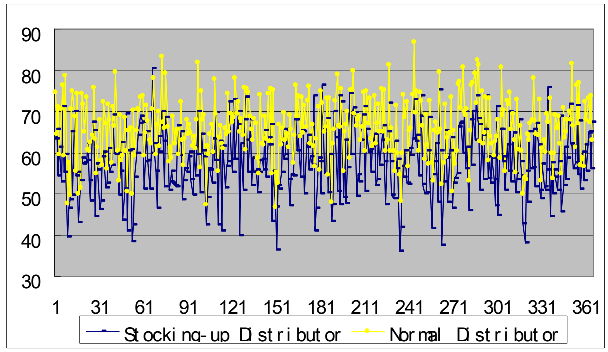

Figure 7(a): Distributor's Profit After BPR.

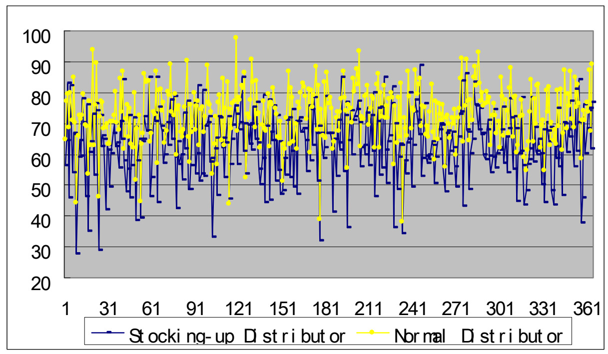

Figure 7(b): Manufacturer's Profit After BPR.

Further, the final experiment examines the robustness of the new business process when enhancing the coordination of the supply chain in different parameter configurations. The ESDI (Enterprises' Synergy Degree Index) (CUI Linlin, CHAI Yueting, and QIN Zhiyu 2007) is an index to quantitatively evaluate how the strategies of the enterprises in a supply chain are aligned, which basically reflects the utilization rate of the overall resources in a supply chain. Numerical results in Figure 8 show that with various wholesale prices (which implies different profit assignments among players in a supply chain), the resource utilization rates after BPR are all higher than the results before BPR.

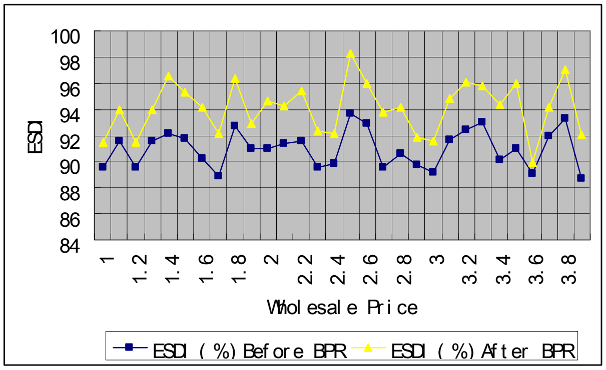

Figure 8: Robustness of BPR.

6 CONCLUSION

Demand analysis is of fundamentally importance in the implementation of information system. BPR often gets involved in the process of demand analysis and play a crucial role in the achievement of the project objectives. The design result of BPR not only influents how much it will be invested in the subsequent implementation process but also determines whether the existed managerial problems can be solved by means of information technology. Consequently, the validation and feasibility of the BPR should be investigated carefully.

Business process based simulation provides a precise and visual method to analyze and compare the concerned performances before and after BPR. Not only the modeling flexibility but also the visual outputs provided by BPS method make it free to quantitatively analyze various business scenarios and please the people without academic background. Considering the results in the form of data and curves are much easier for the industrial people to understand than formal symbols and functions do, BPS has been a powerful tool for the demand analysis during MIS projects. The paper presents a real industrial experience in using the BPS tool to demonstrate the effects of CSS on restraining stocking-up and overdue payments in distribution management. Before significant investment involved, the corresponding design result of BPR is validated both by the analytical method and simulation experiments. Based on the mutual supportive results, the BPS method approves its correctness and show its nicety, flexibility and the visual property.

Efficiency of the BPS method is mainly restricted by the description capability of the simulation model embedded in the simulation platform. To improve the modeling capability of the simulation tool, both the basic structure of the embedded simulation model and the richness of the model library deserve lucubrating. Carefully designed basic model structure may provides favorable extension capability by emphasis on the reusability. The rich model library is usually a gradual accumulation process as the simulation tool is more and more widely used. Both of the research topics should be further investigated in future discussions.

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