Production Adjusting Method based on Predicted Distribution of Production and Inventory using Dynamic Bayesian Network

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Abstract: In general, the production quantities and the delivered goods are changed randomly, and then the total stock is also changed randomly. This paper deals with the production and inventory control of an automobile production part line using the Dynamic Bayesian Network. Bayesian Network indicates the quantitative relations between the individual variables by the conditional probability. The probabilistic distribution of the total stock is calculated through the propagation of the probability on the network. Moreover, an adjusting rule of the production quantities to maintain the probability of the lower bound value and the upper bound value of the total stock to certain values is shown.

Keywords: Dynamic Bayesian Network, Production Adjusting Method, Predicted Distribution, Delivery data

I. INTRODUCTION

In the manufacturing business, the delivery guarantee of quantities is a prerequisite for improving the credit of corporation and securing profit. However, the delivery quantity, the production quantity, and the inventory is changed according to various unexpected reasons. Then the prediction of production inventory which can cope with such irregular fluctuations is required. This paper deals with an adjusting production method using the Dynamic Bayesian Network (DBN) for all factors which influence the production quantity, the delivery quantity, and the inventory quantity for an automobile part production process. This study also provides an adjusting production schedule algorithm that adjusts sequentially the production schedule for appropriate guarantee of the deadline. Furthermore, an adjusting rule of the production quantities to maintain the delivery guarantee is provided.

II. CONSTRUCTION OF DBN MODEL FOR PRODUCTION AND INVENTORY CONTROL IN AN AUTOMOBILE PARTS PRODUCTION PROCESS

The production quantities and the delivered goods are changed randomly in real problem, and then the total stock is also changed irregularly under these conditions.

Dynamic Bayesian Network is applied to the production and inventory control of the automobile part that calculate the probabilistic distribution of the total stock through the propagation of the probability on the network. The target production system is as that:

· Item of the production: :
Automobile engine valve lifter
· Max of production quantity: 1,000,000ea/month
· Actual data period: JAN.2003 ~ DEC.2005

Production quantity for each month is decided by the inventory of previous month and the delivery quantity of the month. However, the production quantity must take into consideration the conditions at the production site. The reason is that the production quantity can be changed according to the trouble of equipments and the outbreak cancels, etc. And, the delivered goods is also assumed that it can be changed randomly according to the order-change, the control of inventory quantities, and the manufacturing trouble, etc. The production process is as follows.

· Production quantities : A_t
· Delivery quantities : D_t
· Total stock : S_t
· Its forecast and an adjustment period of the production schedule hold between m months
($t=1,2,...,l$ l : forecast adjustment months).
· Factors for the production quantities
$RA\alpha_t$: ($\alpha=A,B,\ldots,Z$ α: factors)
$RA\alpha\beta_t$: ($\beta=A,B,\ldots,Z$ β: factors)
$RA\alpha\beta\gamma_t$: ($\gamma=A,B,\ldots,Z$ γ: factors)
$RA\alpha\beta\gamma\zeta_t$: ($\zeta=A,B,\ldots,Z$ ζ: factors)
$RA\alpha\beta\gamma\zeta^i_t$: (i=1,2,...,m m:The number of factors)
· Probabilistic change factor of the delivery quantities
$RD\kappa_t$: ($\kappa=A,B,\ldots,Z$ κ: factors)
$RD\kappa\lambda_t$: ($\lambda=A,B,\ldots,Z$ λ: factors)
$RD\kappa\lambda\mu_t$: ($\mu=A,B,\ldots,Z$ μ: factors)
$RD\kappa\lambda\mu\nu_t$: ($\nu=A,B,\ldots,Z$ ν: Factors)

$RD\kappa\lambda\mu\nu^j_t$: (j=1,2,...,n n:The number of factors)

· Production quantity of every month : $A_t \leq A_{max}$

Thus, the total stock of the product S_t of tth month can be expressed as eq. (1)

$$S_t = S_{t-1} + A_t - D_t \tag{1}$$

The stochastic model of the production and the inventory control considering the practical dependence of the productions, deliveries, and inventories changed randomly is illustrated in Fig.1. In addition, each factor which corresponds to each node is shown in Table 1.

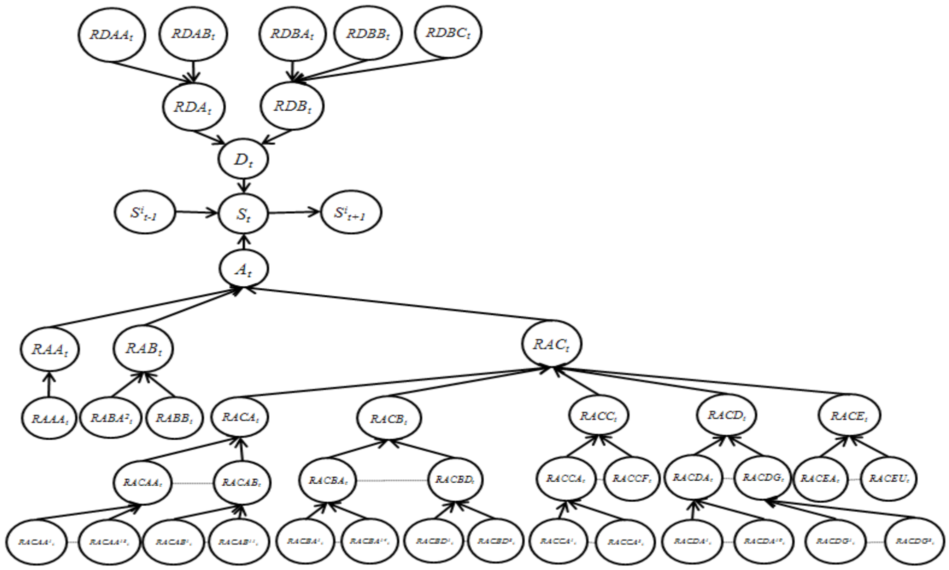

Fig. 1. Stochastic model of production and inventory by Dynamic Bayesian Network

Table1. The stochastic variable of delivered goods and production

S_t	**Inventory quantities**	$RACAF_t$	An external diameter processing
D_t	**Delivered goods**	***$RACB_t$***	Inferior of B2
RDA_t	The cause of external	$RACBA_t$	Lathe processing
$RDAA_t$	A poor outbreak process	$RACBB_t$	Dimensional check
$RDAB_t$	A poor delivery inspection	$RACBC_t$	An external diameter processing
RDB_t	The cause of in-company	$RACBD_t$	The inside diameter processing
$RDBA_t$	Strike of customer	***$RACC_t$***	Inferior of DPL
$RDBB_t$	Order-change of A/S products	$RACCA_t$	DPL-lathe processing
$RDBC_t$	Change of production schedule	$RACCB^t$	Crowning
A_t	**production quantities**	$RACCC_t$	Hole-processing
RAA_t	The cause of external	$RACCD_t$	An external diameter processing
$RAAA_t$	Order-change	$RACCE_t$	Hole polishing
RAB_t	The cause of in-company	$RACCF_t$	An external diameter processing
$RABA_t$	Control of Inventory quantity (+)	***$RACD_t$***	Inferior of assembling
$RABB_t$	Control of Inventory quantity (-)	$RACDA_t$	HOLE -CHECK
RAC_t	Inferior a manufacturing process	$RACDB_t$	CLIP Insertion
$RACA_t$	Inferior of B1	$RACDC^t$	DPL-assembling
$RACAA_t$	Body-lathe processing	$RACDD_t$	Stratification
$RACAB_t$	Hole-processing	$RACDE_t$	Stratification
$RACAC_t$	An external diameter processing	$RACDF_t$	Assembling
$RACAD_t$	Crowning	$RACDG_t$	OIL-pouring
$RACAE_t$	Swaging	***$RACE_t$***	Product inspection

III. MAINTENANCE OF APPROPRIATE INVENTORY THROUGH PRODUCTION ADJUSTING ALGORITHM

1. Prior Probabilistic Distribution

Actual data on the production and delivery for 36 months are shown in Fig.2. Also, Fig.3 represents all factors related to the production and delivery.

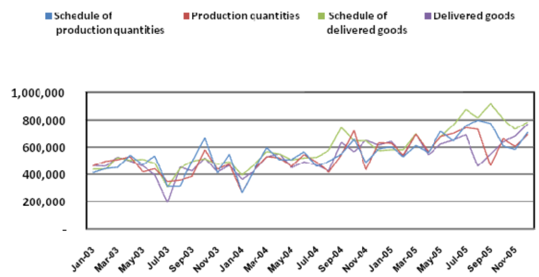

Fig.2. Schedule and actual data of production, delivered good and inventory quantities

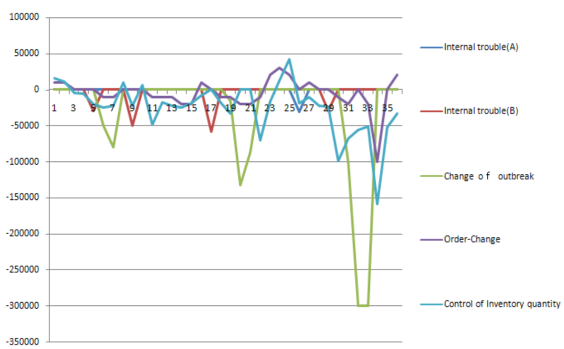

Fig. 3. Main cause of change

Delivery quantity is changed according to various factors such as the order-change and the manufacturing trouble postponement of delivery. Here, the prior probability on the change of delivery quantity is calculated based on the actual data from January 2003 to December 2005 (36 months). The prior probability is calculated using the quantity and frequency of each factor, and is set as shown in Fig4.

The prior probability of the internal trouble is shown in Fig.7, and the prior probability of the order change can be founded shown in Fig.8. In addition, the actual production quantity for each month has to take account of the change which results from various factors including the order change, the inventory control and the defect in the process. These prior probabilities are calculated based on the past data as shown in Fig.9, Fig.10, and Fig.11.

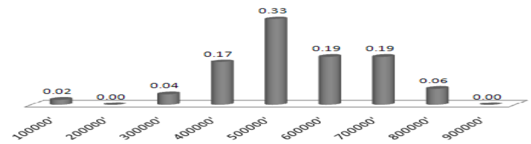

Fig.4. Prior probability of delivered goods

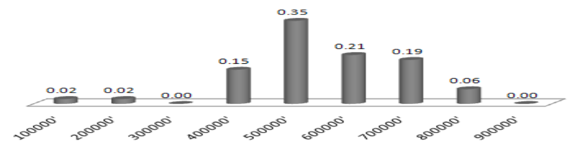

Fig.5. Prior probability of production quantities

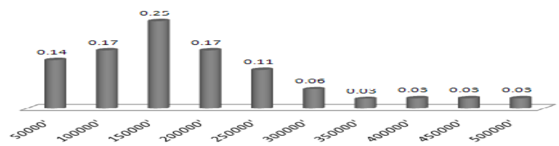

Fig.6. Prior probability of inventory quantities

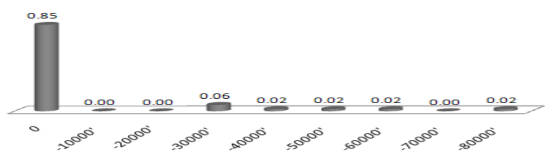

Fig.7. Prior probability of internal trouble

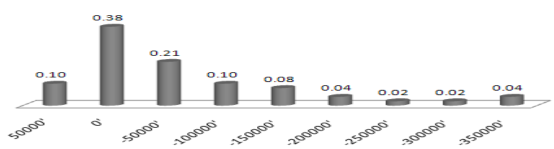

Fig.8. Prior probability of change of outbreak

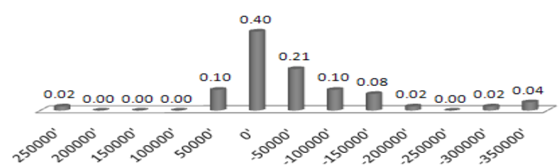

Fig.9. Prior probability of order change

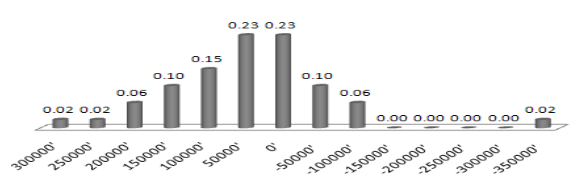

Fig.10. Prior probability of control inventory quantity

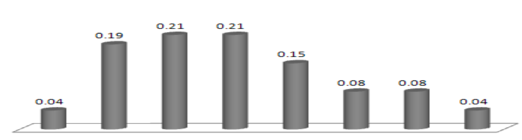

Fig.11. Prior probability of trouble-amount

Therefore, the probability distribution for the amount of the product A_i in stock of the ith month can be calculated as that:

$$P(S_t^i) = \sum_{S_{t-1}^i} \sum_{A_t^i} \sum_{D_t^i} \sum_{RA\alpha_t}^{C} \sum_{RD\kappa_t}^{B} \sum_{RA\alpha\beta}^{E} \sum_{RD\kappa\lambda_t}^{C} \sum_{RA\alpha\beta\gamma_t}^{U} \sum_{RA\alpha\beta\gamma\zeta_t}^{G} P(S_t^i, S_{t-1}^i, A_t^i, D_t^i, RA\alpha_t, RD\kappa_t, RA\alpha\beta_t, RD\kappa\lambda_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \quad (2)$$

$$\begin{aligned} & P(S_t^i, S_{t-1}^i, A_t^i, D_t^i, RA\alpha_t, RD\kappa_t, RA\alpha\beta_t, RD\kappa\lambda_t, RA\alpha\beta\gamma_t,, RA\alpha\beta\gamma\zeta_t) \\ &= P(S_t^i \mid S_{t-1}^i, A_t^i, D_t) P(S_{t-1}^i) P(A_t^i) P(D_t^i) \\ &\times P(A_t^i \mid RA\alpha_t, RA\alpha\beta_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &\times P(D_t^i \mid RD\kappa_t, RD\kappa\lambda_t) \\ &\times P(RA\alpha_t \mid RA\alpha\beta_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) P(RA\alpha_t) \\ &\times P(RD\kappa_t \mid RD\kappa\lambda_t) P(RD\kappa_t) \\ &\times P(RA\alpha\beta_t \mid RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &\times P(RA\alpha\beta_t) P(RD\kappa\lambda_t) \\ &\times P(RA\alpha\beta\gamma_t \mid RA\alpha\beta\gamma\zeta_t) P(RA\alpha\beta\gamma_t) P(RA\alpha\beta\gamma\zeta_t) \end{aligned} \quad (3)$$

$$\begin{aligned} P(S_t^i) &= \sum_{S_{t-1}^i} \sum_{A_t^i} \sum_{D_t^i} \sum_{RA\alpha_t}^{C} \sum_{RD\kappa_t}^{B} \sum_{RA\alpha\beta}^{E} \sum_{RD\kappa\lambda_t}^{C} \sum_{RA\alpha\beta\gamma_t}^{U} \sum_{RA\alpha\beta\gamma\zeta_t}^{G} P(S_t^i, S_{t-1}^i, A_t^i, D_t^i, RA\alpha_t, RD\kappa_t, RA\alpha\beta_t, RD\kappa\lambda_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &= \sum_{S_{t-1}^i} \sum_{A_t^i} \sum_{D_t^i} \sum_{RA\alpha_t}^{C} \sum_{RD\kappa_t}^{B} \sum_{RA\alpha\beta}^{E} \sum_{RD\kappa\lambda_t}^{C} \sum_{RA\alpha\beta\gamma_t}^{U} \sum_{RA\alpha\beta\gamma\zeta_t}^{G} P(S_t^i \mid S_{t-1}^i, A_t^i, D_t) \\ &\times P(A_t^i \mid RA\alpha_t, RA\alpha\beta_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &\times P(D_t^i \mid RD\kappa_t, RD\kappa\lambda_t) \\ &\times P(RA\alpha_t \mid RA\alpha\beta_t, RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &\times P(RA\alpha\beta_t \mid RA\alpha\beta\gamma_t, RA\alpha\beta\gamma\zeta_t) \\ &\times P(RA\alpha\beta\gamma_t \mid RA\alpha\beta\gamma\zeta_t) P(RD\kappa_t \mid RD\kappa\lambda_t) \\ &\times P(S_{t-1}^i) P(A_t^i) P(D_t^i) P(RA\alpha_t) P(RA\alpha\beta_t) \\ &\times P(RA\alpha\beta\gamma_t) P(RA\alpha\beta\gamma\zeta_t) P(RD\kappa_t) P(RD\kappa\lambda_t) \end{aligned} \quad (4)$$

Eq.(2) is simplified as eq.(3) by the D-separation which is the feature of Dynamic Bayesian Network. Therefore, the probability distributions of the inventory quantity are calculable from eq.(4).

2. Adjusting Algorithm of Production Schedule

The total stock is decided by an amount of stock of the previous month, delivered goods, and production quantities on the month. But, it is necessary to consider a large amount of the shipment after the month, and to keep more than a certain amount. Then, an adjusting rule of the production schedule to maintain the probability of the lower limit and upper limit value of the total stock to a certain value is necessary.

As an example, the production schedule is improved as that the probabilities of more than the lower limit and upper bound of the total stock don't exceed 5%. Here the lower limit and the upper bound of the amount for the total stock A_t are 100,000 and 1,000,000, respectively.

The algorithm of the improvement rule is shown in Fig.12. The production schedule can be updated automatically by the algorithm.

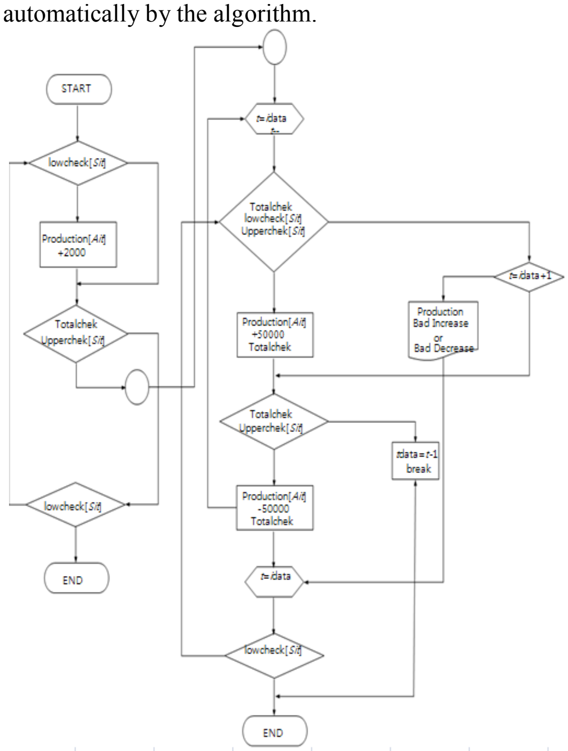

Fig.12. Adjusting rule of flow chart

3. Predictive Distribution of Inventory

The probability distribution of the total stock of one year(2006) based on the initial production schedule of Table 2 is shown in Fig.13.

Table 2. Schedule of production (2006year)

Month-Year	**Jan-06**	**Feb-06**	**Mar-06**	**Apr-06**
Schedule of Delivered goods	800,000	500,000	500,000	600,000
Schedule of Production	**550,000**	**500,000**	**500,000**	**500,000**
Month-Year	**May-06**	**Jun-06**	**Jul-06**	**Aug-06**
Schedule of Delivered goods	750,000	700,000	100,000	550,000
Schedule of Production	**450,000**	**500,000**	**300,000**	**450,000**
Month-Year	**Sep-06**	**Oct-06**	**Nov-06**	**Dec-06**
Schedule of Delivered goods	600,000	750,000	700,000	700,000
Schedule of Production	**750,000**	**700,000**	**400,000**	**450,000**

The production schedule updated by the adjusting algorithm based on the prior probabilities is shown in Fig.14. The new probabilistic distribution of the total stock by this corrected production schedule is as shown in Fig.15.

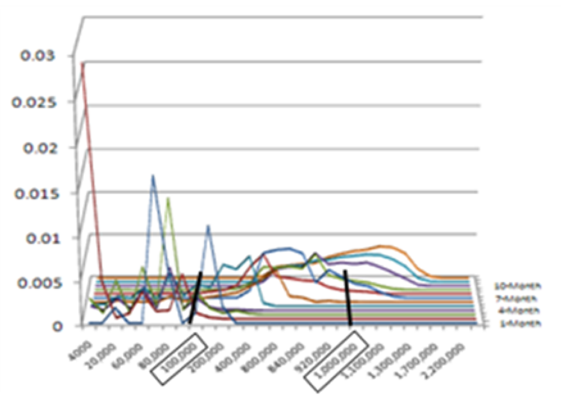

Fig.13. Probability distribution of production schedule

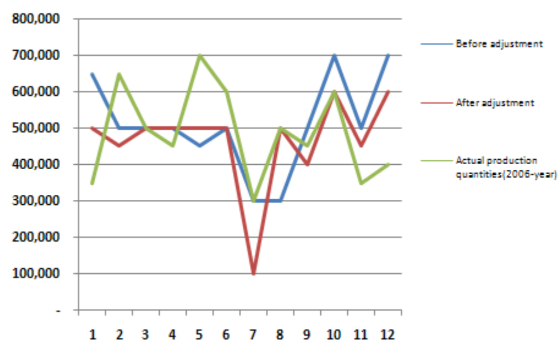

Fig.14. Adjustment of production schedule

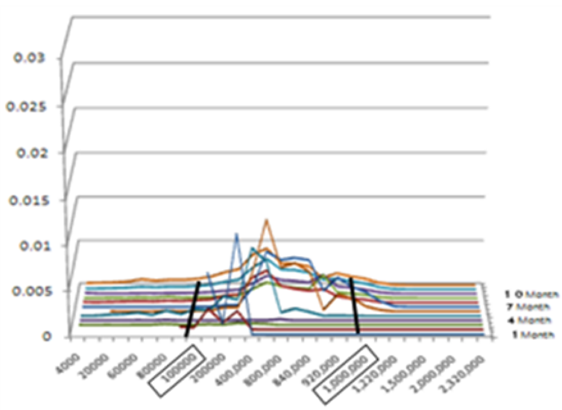

Fig.15. Adjustment of probability distribution of production schedule

As the results, it is understood that the probability for the stock to be 100,000 or less has become small more than 5% as shown in Fig.16. And also the probability for the stock to be 1,000,000 or more has become small more than 5% as shown in Fig.16.

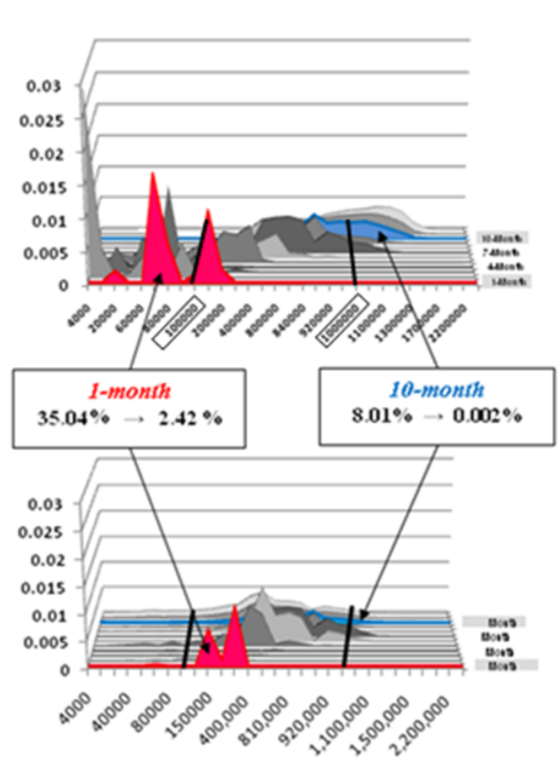

Fig.16. Adjustment of the lower limit

The inventory quantity before adjustment and after adjustment are compared with no adjustment as shown in Fig.17. As the results, the actual inventory dose not exceed target inventory (200,000 ~ 300,000 products). Therefore, the delivery guarantee goods and the maintenance of appropriate inventory can be achieved by considering the probabilistic changes in the delivery quantity and production quantity using the adjusting production algorithm.

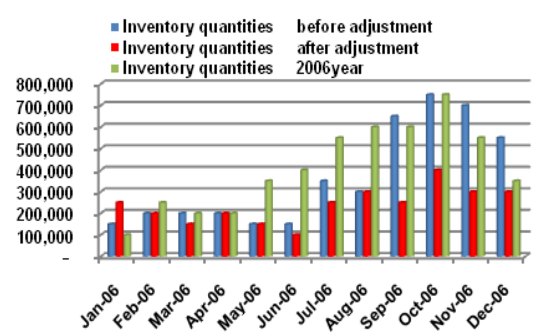

Fig.17 Inventory quantities of adjusted production and Actual production

VI. CONCLUSION

This paper dealt with the production and inventory control of the automobile part process using the Dynamic Bayesian Network. We consider the real situation in which the production quantities and delivered goods are changed randomly, then the total stock is also changed randomly.

Firstly, the probabilistic distribution of the total stock was calculated through the propagation of the probability on the network. Furthermore, the adjusting rule of the production quantities to maintain the probability of the lower limit and upper bound value of the total stock to a certain value was deduced.

As the result, the production schedule could be updated so as not to exceed the probability of the lower bound value and upper bound value of the amount of stock specified. By this method, the reduction in costs from the excessive production and the expense of the inventory management expense can be expected.

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