The Decision Support System Applied in Agile Supply Chain

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ABSTRACT

The Information Economics and its platform can input the vigor into manufacturing industry, i.e. garment industry, and help to increase its ability for good return, can promote the level of technology and management of Garments from a labor-intensive industry, and can move it toward the accurate management. The platform is designed as Comprehensive Information Platform by our research team. This paper is one of the series of papers about the design of Agile Infrastructure for Collaborative Manufacturing as well as Agile Supply Chain. This one lays emphasis upon the design of the decision support system for supply chain. We mainly concern and research into the design of decision support system for the production planning and interval inventory management. In production planning decision support, the author researches into the production planning model based on the multiple product requirements, promotes the algorithm about output risk decision of the Hopfield Neural Network based on the model of output risk decision and the Agent theory, and provides a new way of thinking to the solution of the algorithm about risk decision. The solving algorithm of Nash equilibrium point searching for the interval inventory management decision support is based on the Game Playing model of supply and requirement in the two-level Supply Chain as well as MAS theory. The paper tries to introduce the research of Agile Infrastructure and its key technologies, showing how well they work in some traditional manual industries.

Keywords: Agile Infrastructure, Manufacturing Industry, Supply Chain, CIP

I. INTRODUCTION

With the growing trend of economic and information-based globalization, manufacturing industry has to face the increasingly fierce competition as well as the frequent and unpredictable market fluctuations. An Agile theory thereupon emerges as the requirement of global market fluctuations. The life cycles of products are shortened and the pace of the product renewal is quickened, and the demands of customers are becoming more and more specific and diversified, thereupon, the producing and organizing models transfer from product-oriented to customer-oriented, requirement-oriented and service-oriented, and the aims of enterprises transfer from enterprise profit-driven to market and social profit-driven. The key for enterprise to gain its markets and customers is to improve some factors, such as time, quality, cost, service and environment. Agile Enterprise and Manufacturing Enterprise Alliance, as the running models of future enterprises, will fully make use of new technologies and coordinated operation which is more agile, compartmentalized, order-driven and dynamic to adapt to the markets.

The relationship among Agile Manufacturing Enterprise, Agile Supply Chain and Agile Infrastructure is like the relation between the sharpness of knife and the knife itself, which cannot be divided apart. Agile Infrastructure for Manufacturing System is the platform where the Agile Enterprise, Agile Supply Chain, Agile Manufacturer, Virtual Enterprise are put to good use. The essential condition of Agile Enterprise and Virtual Enterprise is the Agile Infrastructure which is reliable, cross-enterprise, cross-industry and trans-regional. The Agile Infrastructure is established to normalize the managerial practices of enterprise, such as production, sale, policy-making, financial affairs and personnel affairs. The member enterprises can be inserted flexibly, just like the circuit module with standard output and input jacks. In the Agile Infrastructure, member enterprises run business with common rules and establish dynamic Agile Enterprise Alliance, i.e. Virtual Enterprise. The members of Agile Enterprise Alliance negotiate abiding by common rules and accomplish the task of production and sale, which is a game of cooperation. According to the outside market environment and the group intention of inside members, the Virtual Enterprises make identical judgment and macrocosmic layout.

In this paper, the authors research into the construction of Agile Infrastructure for Collaborative Manufacturing and Agile Supply Chain and its key enabled technologies. It is supported by the achievements of some projects, such as the "Demonstration Projects of the Information-based Technology of Manufacturing Industry in Fujian" which is part of the major national supporting project of "the Eleventh Five-year Plan" (i.e. "Information-based Project in Manufacturing Industry"), the "Creative and Information-based Demonstration Platform of Modern Port with Large Logistics" (Project Number: RJZ20063500037) which is a major national project of software and integrated circuit, the "Research on Data Acquisition and Large Information Platform Construction of Distributed Information System" (JA06014) which is a project at provincial and ministerial level, the "Enterprise Informational Public Service Platform (EIPSP)" (2006H0106) which is a subject in textile and garment industry, "Research on the City Distributional System of GIS Platform" (2005J056).

This paper，which lays emphasis upon the design of the decision support system for supply chain. The overall organization of the paper is as follows. After the introduction, in Section II we present an example of Agile Infrastructure in application, the garment information platform, which is a practical platform for garment collaborative manufacturing. The relationships of the main GIP functions and the structure of GIP are also clarified in this section. In section III, we summarize of the design of decision support system for supply chain. Then, the analysis of optimal strategy for production planning is presented in Section IV. In Section V, the authors elaborate the problem's solution and algorithm design in optimal strategy for production. After that, three examples are analyzed in the following sections: the isometric increase example is introduced in Section VI; algorithm design of cooperative games for interval inventory decision support in supply chain is introduced in Section VII. Finally, Section VIII concludes the paper.

II. AGILE INFRASTRUCTURE AND IT'S APPLICATION[1]

Agile Infrastructure for Collaborative Manufacturing and Agile Supply Chain can standardize the output and input information of its member enterprises. As can be seen from Figure1, Our team had done a lot on Agile Infrastructure research, and named it as CIP (Comprehensive Information Platform). CIP stores the manufacturing and supply chain and human resource information in CIP's database and helps the enterprises to run their business in an Agile way designed by CIP, i.e. Agile Collaborative Manufacturing Execution Systems (ACMES), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM), Product Data Management (PDM), Supply Chain Management (SCM).

The Comprehensive Information Platform tries to affect every aspect of its members in their running mechanisms, and each registered enterprise becomes a standardized module of the Agile Infrastructure. All its members can build up Agile Manufacturing Enterprise, or construct Agile Supply Chain temporarily or permanently. Thus the Enterprises can concentrate on their core competences and they are able to recombine rapidly their interior and exterior capabilities and resources, thereby to respond rapidly to the market opportunity.

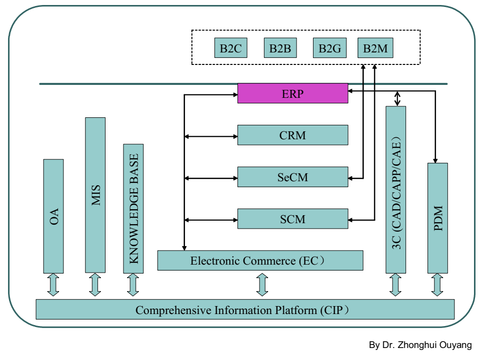

Figure 1. General Architecture of CIP

CIP theory has multiplications; one of them is GIP (Garments Information Platform) which is designed for CM (Collaborative Manufacturing) in garment industry in China. The garment industry was considered as the labor-intensive industry during the past several decades in China. The rough developing type was considered as its basic developing path. The expansion of information economics in garment industry changes these traditional views.

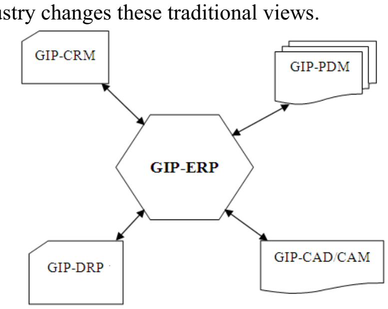

Figure 2. Relationship of the Main GIP Functions

In China, there are thousands of small garment factories which work for the same order form and cooperate to produce a same kind of overcoats or football shoes. Each one of them only manufactures very small part of finished production or small number of them. Those factories may not belong to the same company and most of them possibly are located in different places, thus, the information sharing becomes one of the bottle-neck of the garment industry. The information which needs to be communicated includes material management, cost control, manpower arrangement, quality control and manufacture technology sharing. All of them are becoming crucial in the chain of garment industry.

The garment industry can optimize the garments management by utilizing Garments Information

Platform Enterprise Resource Planning (GIP-ERP), can provide the advantages of manufacturing management by integrating GIP-ERP and GIP-PDM (Product Data Management), can combine the garments' Computer Aided Design/Manage (GIP-CAD/CAM) with the integrated GIP Distribution Resource Planning (GIP-DRP), can change the traditional sales channel's process, the garments Customer Relationship Management (GIP-CRM), can satisfy the relationship between company and customers, which can be seen in Figure 2 .

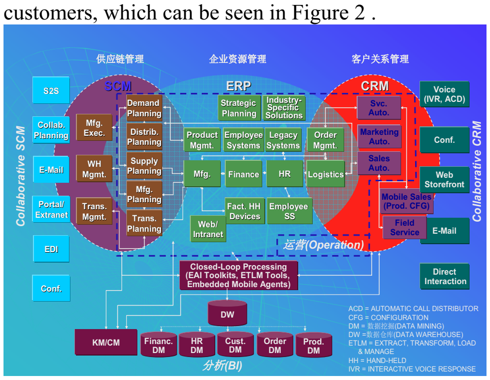

Figure 3. The Design of Agile Infrastructure for Garment Industry

The garments Enterprise Resource Planning (ERP) is the centre of GIP, where CRM, CAD/CAM, DRP, PDM system combined together, the useful information of enterprises is shared. GIP-ERP is a system which can efficiently process information and effectively communicate with other parts in the GIP system. Thus the enterprise resource can be well managed and adjusted, and the efficiency of production and management of enterprise can be much improved.

A structure map of GIP with more details is shown in Figure 3, where we can see the structure of GIP is complicated, including office automation system (OA), management information system (MIS), knowledge base, electronic commerce (EC), CAD/CAM/CAE (3C) and product data management (PDM).

III. THE DESIGN OF DECISION SUPPORT SYSTEM FOR SUPPLY CHAIN

In the area of the managing policy of Agile Supply Chain in Agile Infrastructure for Collaborative Manufacturing, we mainly concern with the decision support system design.

Concerning the production planning decision support, the author researches into the production planning model based on the multiple product requirements, promotes the algorithm about output risk decision of the Hopfield Neural Network based on the model of output risk decision and the Agent theory, and provides a new way of thinking to the solution of the algorithm about risk decision.

Concerning the interval inventory management decision support of Supply Chain, the team researches into the issue of Cooperative Games of the member enterprises in AIMS, elaborates the solving algorithm of Nash equilibrium point based on the Game Playing model of supply and requirement in the two-level Supply Chain and MAS theory. This algorithm treats the members of the Supply Chain as an Agent system which has independent decision-making ability and explores the maximized self-interest. It imitates the process of Cooperative Games and decision-making of every agency in the Supply Chain, seeks the Game Playing equilibrium point of the members' maximized profit in the Cooperative Game in Supply Chain, which achieves satisfactory results in practical applications while the optimized decision of Cooperative Games improves the stability of Agile Supply Chain. The research on some issues such as risk decision, arrangement of production, Game Playing equilibrium point, possesses favorable effect on increasing the efficiency of production and management of Agile Enterprises by a large amount.

IV. OPTIMAL STRATEGY FOR PRODUCTION PLANNING

Optimal strategy for production planning of upriver-product-line can be realized by an algorithm based on Hopfield neural network, and optimality criterion is formula 1. The module is based on the demands and output of two-level product line, i.e. upriver-product-line and downriver-product-line. The production planning module of upriver-product-line based on limited cost of input buffer of downriver-product-line can be described as Eq. (1). [2]

$$J = \min \left\{ \begin{array}{l} \sum_{i=1}^{M} \sum_{k=1}^{N} \left(\begin{array}{l} a_i^T x_i(k) \\ + b_i^T [T_i u_i(k) - \rho_i(k)]^+ \\ + \bar{b}_i^T [\rho_i(k) - T_i u_i(k)]^+ \\ + c_i^T [\tilde{y}_i(k) - \tilde{z}_i(k)]^+ \\ + \bar{c}_i^T [\tilde{z}_i(k) - \tilde{y}_i(k)]^+ \end{array} \right) \\ + \sum_{i=1}^{M} a_i^T x_i(N+1) \end{array} \right\} \qquad \textbf{Eq. (1)}$$

M represents the number of upriver-product-line, while N represents the number of the product-cycle of upriver-product-line in arranged. $u_i(k)$ represents the number of the workpiece output of upriver-product-line i in k product-cycle, which are $n_{gi} = n_i + m_i$ dimensional column vectors. n_i is the number of type of finished product of NO. i product-line in planning periods, while m_i is the number of type of subsidiaries of NO. i product-line in planning periods. $\tilde{y}_i(k)$ represents the total number of finished product of NO. i product-line from NO. i Periods to NO. k Periods, which are n_{gi} dimensional column vectors. $x_i(k)$ represents the original number of finished product of NO. i product-line before Periods k, which are n_{gi} dimensional column vectors. $\tilde{z}_i(k)$ represents total demands of upriver-product-line for finished product and subsidiaries of downriver-product-line NO. i from NO. i Periods to NO. k Periods. $\rho_i(k)$ represents machining time of working center of upriver-product-line NO. i during NO. k Periods, which are f_i dimensional column vectors. f_i represents the number of workers in NO. i product line. a_i represents the cost-coefficient related to finished product in NO. i product-line, which are n_{gi} dimensional column vectors. b_i represents cost-coefficient related to call-back pay in upriver-product-line NO. i, which are f_i dimensional column vectors. $\bar{b}_i$ represents cost-coefficient related to leave unused equipments in upriver-product-line NO. i, which are f_i dimensional column vectors. c_i represents cost-coefficient related to storage cost due to over demands of finished product and subsidiaries output in upriver-product-line NO. i, which are $n_i + m_i$ dimensional column vectors. $\bar{c}_i$ represents cost-coefficient related to storage cost due to unmet demands of finished product and subsidiaries output in upriver-product-line NO. i, which are $n_i + m_i$ dimensional column vectors. T_i represents machining hours of operator by machining n_{gi} kind of workpiece during Period k in upriver-product-line NO. i, which is a $f_i \times n_{gi}$ dimensional matrix. The algorithm can be seeing in Algorithm 1.

Algorithm 1 Production Planning Based on MAS

Step1. let minCost=maxnumber;
parameter_number={};
Step2. for(int i=1;i<=M; i++){
For(int k=1;k<=N; k++){

$$Costpartone = a_i^T * x_i(k) + b_i^T * \max[T_i u_i(k) - \rho_i(k)] + \bar{b}_i^T * \max[\rho_i(k) - T_i u_i(k)] + c_i^T * \max[\tilde{y}_i(k) - \tilde{z}_i(k)] + \bar{c}_i^T * \max[\tilde{z}_i(k) - \tilde{y}_i(k)];$$

}}

Step3. for(int i=1; i<=M; i++){

$$Costparttwo = a_i^T * x_i * (N+1);$$ }

Costx=Costpartone+Costparttwo
Step4 Get new Costx by change the plan by Hopfield Neuron network, then go to Step1, until no new extreme value in five circles, and let R to be the number of Costx ;
Step5. for (int x=1; x<=R; x++){
if minCost >Costx{
parameter_number=x; minCost=costx;};
Step5. Output(minCost, correlation_parameter)

V. COOPERATIVE GAMES FOR INTERVAL INVENTORY DECISION SUPPORT IN SUPPLY CHAIN

We use to do research on the efficiency enhancement of the supply chain as a whole system, and want to find a set of optimal strategies for all the participants and calculate the sum of profit of participators. But we forget that the highest profit of the sum of all players is always costed by the lower profit of some members of supply chain. So, if one of participants finds out that he has to sacrifice his profit for the others, he may quit and join another supply chain to search an equitable business status.

To clarify this problem, we can see through an example of two-stage Supply Chain. In this cooperative game, each side may change its inventory decision without the permission of the opposite side. Then if there are any changes that will lead to more profits, the player will choose to change to satisfy their profit-push intention.

A module of Two-Echelon Supply Chain has been given based on the research of G. P. Cachon and P. H. Zipkin [3], where the relationship of Supplier and Demander can be described as a Cooperation Game. According to Nash's Equilibrium Discriminance theories, the Games must have an equilibrium point and the final choice of Supplier and Demander must constringe to the equilibrium point. Our research group design an algorithm based on a Two-Agent-Module.

We suppose participants of the negotiation have Perfect Information and Complete Information, that is, the participators have the correlative information clearly and correctly. The equilibrium searching process is a multi-agent Game playing process in the supply chain. By programming, we use agent to simulate the negotiation process in cooperative game. According to Nash Equilibrium Theory, there must be an equilibrium point in the negotiation process, and there will be no more profit got by any change of the player. Equilibrium point is the best result under the agreement of the each side of the participants. According to inventory module in a Two-Stage Supply Chain of G. P. Cachon and P. H. Zipkin, the interval inventory decision of the dealer is within the

$[s_r^S, s_r^L]$, and the interval of inventory decision of the supplier is within the $[0, S]$. Here, S represents a lager Constant, which is satisfied enough to the franchiser.

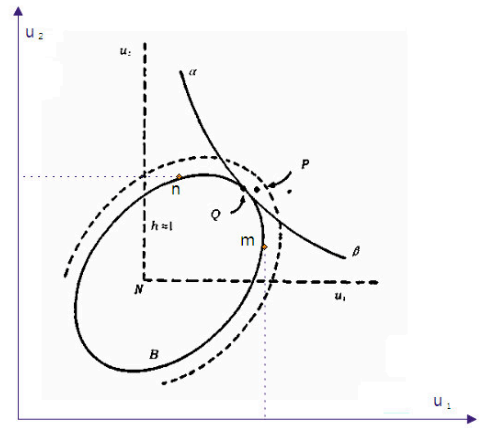

Figure 4. Negotiation Process of Cooperative Games[4]

The theorem about the Equilibrium point in the cooperative games had been proved by John F. Nash[4], that is, the reasonable outcomes of the two-person games $u = (u_1, u_2)$ should meet the requirement that $(u_1, u_2) \in B$, $u_1 \geq n_1, u_2 \geq n_2$, and let the product of $(u_1 - n_1)$ & $(u_2 - n_2)$ to be maximum.

As can be seen from figure 3, B is feasible solution set, N is the conflicting point, the X-axis represents the profit of enterprise II and the Y-axis represents the profit of enterprise I in the plane Cartesian coordinate system. m is the original decision of enterprise II, while n represents the original decision of enterprise I. Specifically, the region B means the feasible solution set where the cooperation game may strike a bargain in the negotiation procedure. During the negotiation procedure, the participants choose their decisions during the region B by mixed strategies in a strategic equivalence status; a new decision may suddenly cause the decision change of the other side.

Finally, the numerical results of the cooperative game constringe to the Nash's equilibrium point in through an argy-bargy procedure. Unless the plays reach the equilibrium point, the both sides will not satisfy with the result and will stop to change their inventory decision. A multi-Agent algorithm will be helpful to the both sides of the player in the cooperative game, because it will help the participants to reach the equilibrium point directly and quickly without wasting any time in the negotiation procedure. The numerical results of the MAS algorithm are on the assumption that all the participants have equality of bargaining skill and information. That is, the value of game of the algorithm is in compatibility with "reasonable outcomes".

Algorithm 2 Cooperative Games in Supply Chain

Step1. Let n=0; s_r int LAST= s_s LAST=maxnumber;

/* initialization*/

Step2. /* initializers*/

Let $s_s = s_s$ initia_number;

s_s temporal_number= s_s initia_number;

$s_r = s_r$ initia_number;

s_r temporal_number= s_r initia_number;

$$B_S(s_r, s_s) = B_s(s_r) F^{L_S}(s_s) + \int_{s_s}^{+\infty} B_s(s_r + s_s - x) f^{L_s}(x) dx$$

/* OOS(Out Of Stock) Cost Expectation of supply Agent */

$$\Pi_s(s_r, s_s) = h_s \int_0^{s_s} F^{L_s}(x) dx + B_S(s_r, s_s)$$

/*Cost Expectation of supply Agent*/

Step3. /*demand Agent*/

Let s_r new=0;

$\min \prod_s (s_r, s_s)$ = maxnumber;

$\prod_s (s_r, s_s) = 0$;

$s_s = s_s$ temporal_number;

$s_r = s_r$ temporal_number;

For (int $s_r = s_r^S$; $s_r \leq s_r^L$; s_r++){

$$C_r(y) = \alpha\beta(\mu^{L_r} - y) + (h_r + \alpha\beta) \int_0^y F^{L_r}(x) dx$$

$$\Pi_r(s_r, s_s) = C_r(s_r) F^{L_S}(s_s) + \int_{s_s}^{+\infty} C_r(s_r + s_s - x) f^{L_s}(x) dx$$

/*Cost Expectation of demand Agent*/

If $\min \prod_r (s_r, s_s) \geq \prod_r (s_r, s_s)$ {

$\max \prod_r (s_r, s_s) = \prod_r (s_r, s_s)$; s_r new = s_r;}}

s_r temporal_number= s_r new;

Step4. /*supply Agent*/

Let s_s new=0; $\min \prod_s (s_r, s_s)$ = maxnumber;

Let $\prod_s (s_r, s_s) = 0$; $s_s = s_s$ temporal_number;

$s_r = s_r$ temporal_number;

for (int $s_s = 1$; s_s <=S; s_s ++)

$$B_S(s_r,s_s)=B_s(s_r)F^{L_s}(s_s)$$

$$+\int_{s_s}^{+\infty}B_s(s_r+s_s-x)f^{L_s}(x)dx$$

/* OOS(Out Of Stock) Cost Expectation of supply Agent */

$$\Pi_s(s_r,s_s)=h_s\int_0^{s_s}F^{L_s}(x)dx+B_S(s_r,s_s)$$

/*Cost Expectation of supply Agent*/

If $\min\prod_s(s_r,s_s)\geq\prod_s(s_r,s_s)$ {

$\min\prod_s(s_r,s_s)=\prod_s(s_r,s_s)$; s_s new = s_s ;}}

s_s temporal_number= s_s new;

Step5. /*Nash's Equilibrium Discriminance Agent*/

if (s_s LAST== s_s temporal_number)

and(s_r LAST== s_r temporal_number)

{n++;}else n=0;

s_s LAST= s_s temporal_number;

s_r LAST= s_r temporal_number;

If(n<10){go to step3;}

Step6. Output(s_s NASH= s_s LAST, s_r NASH= s_r LAST)

The Module is composed of Supply Agent and Demand Agent, both of which have their own decisions based on the choice of the opposite side. The Algorithm constringes to the equilibrium point when any change of their decision will not bring them better profit respectively. The algorithm can be seen in Algorithm 2.

VI. CONCLUSION

In this paper, Comprehensive Information Platform designed for collaborative manufacturing was presented with an application case in garment industry. Specifically, the relation of GIP functions as well as the structure of CIP in the garment industry application was introduced. In addition, technical details about business resources planning model in manufacturing system, especially, the relation of subsystems are expressed clearly by figures, and then the design of the decision support system for supply chain is discussed in the following sections. We mainly concern and research into the design of decision support system for the production planning and interval inventory management. In production planning decision support, the author research into the production planning model based on the multiple product requirements, promote the algorithm about output risk decision of the Hopfield Neural Network based on the model of output risk decision and the Agent theory, and provide a new way of thinking to the solution of the algorithm about risk decision. The solving algorithm of Nash equilibrium point searching for the interval inventory management decision support is based on the Game Playing model of supply and requirement in the two-level Supply Chain as well as MAS theory. More elaborating performance report will come up after long period of observational and practical use. All technical details are touched upon run in application, and the main improvement in its performance can only come with application. Some parts of the Agile Infrastructure are almost completed, i.e. GIP, which seems to work well and more details can be seen on the internet on http://www.istqz.com.

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