A Preliminary Design of CSS Production-Distribution Board-Type Simulation Game

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ABSTRACT

The coordination in industrial systems should be one of the major challenges for future competitive advantages. The issues of industrial system's coordination have been studied in system dynamics at the very beginning of the field. However, system dynamists had not put enough efforts to study the industrial "systems". This paper attempts to use system dynamics approach to study the "dynamic complexity" issues in industrial systems. The Center-Satellite System simulation game (CSS game), which based on Taiwan's center-satellite industrial system (a huge industrial system with over 120 Center-factories, each with up to 400 networked Satellite-factories) was developed. Future research directions are discussed.

INTRODUCTION

Since the success of Japanese management style and the wild spread of Deming's management philosophy, the coordination in industrial systems is one of the major challenges for future competitive advantages. The issues of industrial system's coordination have been studied in system dynamics since the very beginning of the field. The first book of system dynamics, that is "Industrial Dynamics" (Forrester, 1961), had shown how the structure of the multi-stage production-distribution systems tends to amplify disturbances that occur at the previous stage. George Stalk and Thomas M. Hout (1990), the authors of "*Competing Against Time: How Time-based Competition Is Reshaping Global Markets*", had reviewed the work of Forrester (1958) to explain time's impact on the corporate's performance. One central concept of "Time-based Competition" or "Just in time" is the same as Forrester's model, that is, to reduce delay time to get smooth and stable flows (order flow and material flow). However, "Time-based Competition" and "Just in time" are much more famous and operational than "Industrial Dynamics". In our opinion, although there were some system dynamics researches concerning industrial systems (e.g., Aloso and Frasier, 1991; Fey, 1962; Kim, 1990; Lyneis, 1980; Sterman, 1984), system dynamists had not put enough efforts to study the potential of system dynamics in the industrial systems.

This paper attempts to use the System Dynamics approach to study the "dynamic complexity" issues in industrial systems. The paper was a preliminary report of the project sponsored by Taiwan's "CSD" (Center-Satellite Factory System Development) Industrial Coordination Center. The objectives of CSD were to help the coordination of Taiwan's Center-Satellite industrial system, and to help those corporates to solve systemic problems between center-factories and satellite-factories. After some contacts between CSD and us, the first project was to develop a Center-Satellite System simulation game (CSS game). The CSS game is designed (1) to improve managers' shared mental model in the "dynamic complexity" feature of the center-satellite system, and (2) to develop manager's systems thinking abilities to discover more coordination opportunities in their own center-satellite systems.

THE CSS GAME

Problem setting

Through the help of CSD, the problem selected in the CSS game was the issue about JIT. One of the general difficulties of implementing JIT in Taiwan was the ill-fitness of satellite-factories. When JIT technic was implemented in the center-factory, the satellite-factories were asked to provide their products in "just in time" rate. In order to provide products "just in time", strategies usually used by the satellite-factories were either reduce the quality standard or increase the inventory level. The first strategy (reduce quality) would interrupt the process in the center-factory; the quality control expenditure and the probability of parts shortage would increase, and the quality of final products would decrease. The second strategy (increase inventory) would increase the satellite-factory's inventory costs, which might come from the reduction of other resources (e.g., R&D budget).

The fundamental solution of this problem should be to implement JIT technic at the satellite-factories at the same time. However, due to the deeply imbeded "corporate boundary" in the manager's mental model, the center-factories either unaware of this need, or unwilling to help the satellite-factories.

The CSS game is designed to simulate some dysfunctional consequences if the JIT technic is implemented in the center-factory only. There are three center-factories in the CSS game. One center-factory has the opportunity to shorten the delay time (that is, implementing JIT), while the others remain the same. The conditions of the satellite-factories are all the same. Their capacities are all constrained. The constrained capacities represent the lack of fundamental solution (i.e., the satellite factories implement JIT at the same time).

Task description

As shown in Figure 1, there are three center-factories, three satellite-factories, one consumer sector, and one consumer agency in this game. The consumer sector is represented by paper cards with fixed consumer orders, which are received by the consumer agency. The consumer agency distributes consumer orders to the center-factories (depends on the center-factories' delivery delay and it's product's quality, which are the determinants of his performance). The center-factories order key parts from their own satellite-factories, and manufacture final products for their customers. The final products are shipped to consumers through the consumer agency, as shown in the shadowed area of the "consumer's use period" in Figure 2. Those ill-quality final products will be "out of work" after the consumer's use period, and then are shipped to the center-factories for repairing.

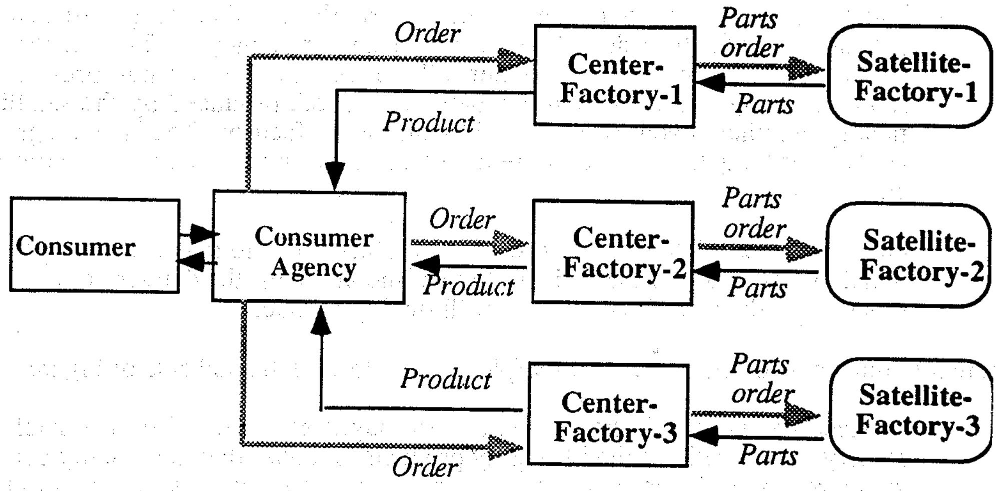

Figure 1: System Map

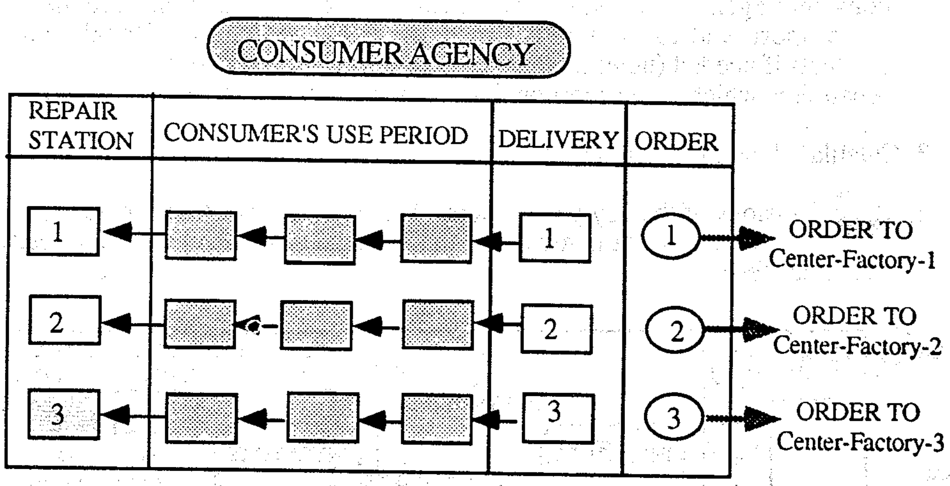

Figure 2: Consumer Agency Sector Board

When playing this game, there are four steps for the consumer agency (see Figure 2) :

1. (a) Send orders and the ill-quality products to the center-factories, then take back the satisfied orders (with it's products) and the repaired products, which were sent in the previous runs. (b) Calculate the delivery delay of the satisfied orders and the repairing time of the ill-quality products.

2. Ship products to the "consumer's use period" and move forward respectively all the "in-using" products. Examine those products that are currently at the repair stations.

3. Check those ill-quality products and record the number of the ill-quality products. (note: In order to avoid the consumer agency to find out the ill-products on "consumer's use period" in advance, the final product is represented by two combined magnets: one is red, produced by the satellite-factory; another is yellow, produced by the center factory. The "two magnets" are "closed" together until they are delivered to the "repair station" to be opened and checked.)

4. Make decisions of the product orders. The objective is to maximize the profits, which is a function of the delivery time of the products, the delivery time of the repaired products, and the number of ill-quality products.

There are four steps for the center-factory (please refer to the left hand side of Figure 3):

1. (a) Receive and check the key parts (red magnets) produced by the satellite-factory. If the ratio of the ill-quality products is higher than the quality control standard, then all the products of this run could be rejected (also could be accepted, if needed). (b) Calculate the material costs which are proportional to the number of those accepted key parts.

2. (a) If one order is satisfied, then sent the satisfied order (and its products) to the consumer agency, else wait for the next run. (b) Calculate the revenues which are proportional to the number of delivered products. (c) Repair those ill-products if needed (note: it would consume its own key parts). (d) Calculate the repair fees which are proportional to the number of the repaired products.

3. Calculated the inventory costs.

4. Make decisions of the key parts orders. The objective is to maximize the profits, which is a function of the revenues, the material costs, the inventory costs, and the repair fees.

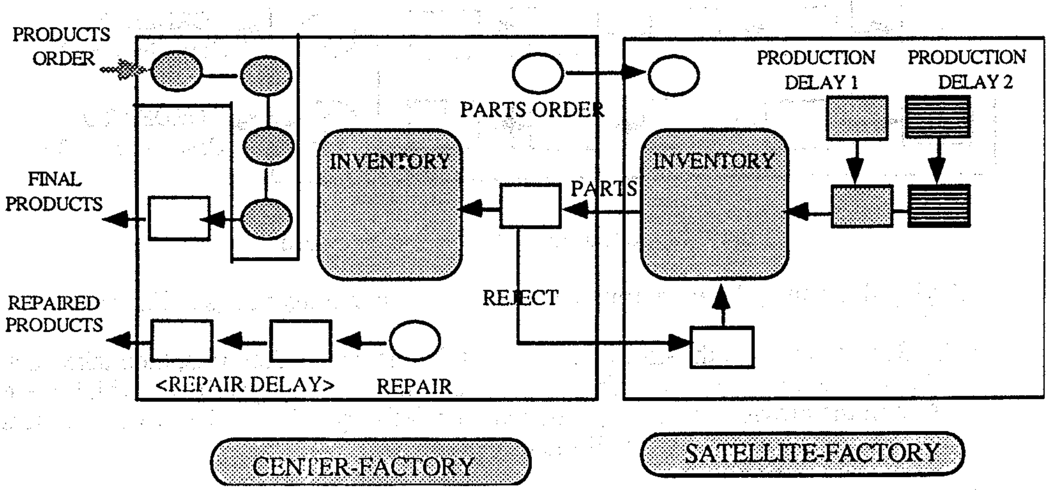

Figure 3: The Board of the Center-Factory Sector and the Satellite-Factory Sector

There are four steps for the satellite-factory (please refer to the right hand side of Figure 3) :

1. (a) Ship the key parts into inventory, and receive those key parts which are rejected by the center-factory. (b) Record the number of the rejected key parts.

2. Sent key parts to the center-factory.

3. Record the number of the inventories.

4. Make decisions of the key parts production. Since the production capacity is constrained, there existed trade-offs between the production number and the products' quality. The more the satellite-factory produced, the higher the probability of ill-quality products. The probability function is treated by dices in the CSS game. Finally, one of the objectives of the satellite-factory is to maximize his profit, which is a function of the delivered products, the inventories and the rejected products.

Behaviors of the CSS Game

The CSS Game have been tested by 87 college students and 30 managers. The typical behavior of the CSS game could be described by Figure 4 and Figure 5. As mentioned previously, one center-factory have the opportunity to shorten the delay time (that is, implementing JIT), while the others remain the same. As shown in Figure 4, since the delivery time is one determinant of the consumer agency's performance, the direct consequence of implementing the "JIT option" is to receive more orders from the consumer agency. In deed, almost all the subjects have perceived this direct consequence. They all want to have the this "JIT option".

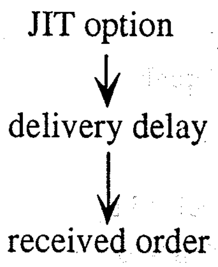

Figure 4: The Direct Consequence of the "JIT Option"

However, there were other indirect consequences compensated the effort of the "JIT option". As shown in Figure 5, since the center-factory received more orders, the center-factory will then order more key parts from the satellite factories. The increased orders could not be satisfied by the constrained capacity of the satellite-factories. The insufficient parts inventories of center-factory will then increase the delivery delay.

Moreover, due to the performance function of the satellite-factory and the constrained capacity, the satellite-factory tends to use "quality reducing" strategy to satisfy the

1. The CSS game's structure.

2. Application in JIT. As mentioned previously, the CSS game is designed to simulate some general dysfunctional consequences of implementing the JIT technic. The symptomatic solutions (reduce quality, increase inventory) and the fundamental solution (satellite factories implement JIT at the same time) are discussed.

3. The consequence thinking skills. Providing some skills, developed by the field of creative thinking, to help the managers to consider policy's unintended consequences.

4. System's boundary and coordination. In the CSS game, the boundary of the "JIT option" policy should include the satellite factory and the consumer agency. Based on these points, participants are asked to reflect the following questions: What is the "right" boundary while consider a particular policy? What kinds of policies should be communicated with your suppliers and your customers before implementing them?

5. Deming's management philosophy. Especially focused on two principles: (1) the product's prices which are not determined by its quality is meaningless. (2) focusing on the coordination rather than competition between businesses and suppliers (for a good introduction, see: Aguayo, 1990).

SUMMARY

The coordination in industrial systems should be one of the major challenges for future competitive advantages. However, in our opinion, system dynamists had not put enough efforts to study the industrial "systems". The CSS game introduced in the paper is just a preliminary attempt to use system dynamics approach to enhance the coordination of Taiwan's center-satellite industrial systems. Further experiments are needed to study the effectiveness of the CSS game. Field studies and case buildings should be important research directions. The organizational learning disciplines organized by Senge (Senge, 1990) will also be considered in our future efforts in this area.

REFERENCES

Aguayo, R. 1990. *Dr. Deming: The American Who Taught the Japanese About Quality.* Carol Publishing Group Press. : Chestnut Hill, Mass, U.S.A.

Aloso, R. L. and C. W. Frasier. 1991. "JIT Hits Home: A Case Study in Reducing Management Delays." *Sloan Management Review* (Summer 1991): 59-67.

Anderson, D. F., I. K. Chung, G. P. Richardson and T. R. Steward. 1990. "Issues in designing interactive games based on system dynamics models." *Proceedings of the 1990 International Conference of System Dynamics Society* :31-45.

Fey, W. R. 1962. "An Industrial Dynamics Case Study." *Sloan Management Review* 4(1): 79-99. also in E. B. Roberts ed. *Management Applications of System Dynamics*: 117-138, Mass: MIT Press, now published by Productivity Press, Cambridge, MA, U.S.A.

Forrester, J. W. 1958. "Industrial Dynamics: A major Breakthrough for Decision Makers," *Harvard Business Review* 36(4): 37-66, also in E. B. Roberts ed.

Management Applications of System Dynamics: 37-66, Mass: MIT Press, now published by Productivity Press, Cambridge, MA, U.S.A.

Forrester, J. W. 1961. *Industrial Dynamics*. Cambridge. Mass: MIT Press, now published by Productivity Press, Cambridge, MA, U.S.A.

Graham, A. K., J. D. W. Morecroft, P. M. Senge, and J. D. Sterman. 1992. "Model-Supported Case Studies for Management Education." *European Journal of Operational Research* 59(1): 151-166.

Kim, D. H. 1990. "Total Quality and System Dynamics: Complementary Approaches to Organizational Learning." *Proceedings of the 1990 International Conference of the System Dynamics Society:* 539-553.

Lyneis, J. M. 1980. *Corporate Planning and Policy Design: A System Dynamics Approach*. Cambridge. Mass: MIT Press, now published by Productivity Press, Cambridge, MA, U.S.A.

Meadows , D. L. 1989. Gaming to Implement System Dynamics Models , *Proceedings of the 1989 International System Dynamics Conference*, 635-640.

Senge, P. M. 1990. *The Fifth Discipline: The Art and Practice of The Learning Organization*, Doubleday, New York; U.S.A.

Stalk, G..& T. M. Hout. 1990. *Competing Against Time: How Time-based Competition Is Reshaping Global Markets*. The Free Press, New York; U.S.A.

Sterman, J. D. 1984. "Instructions for Running the Beer Distribution Game." Working paper D-3674, MIT System Dynamics Group, Cambridge, MA, U.S.A.