Modeling and Optimization of Generic Pull Supply Chain

M. Aminnayeri, Sa.Shokuhyar, Si.Shokuhyar

***Abstract*— Nowadays pull system is widely used in many industries. In the recent decade, many researchers adopt pull system to supply chain and present preference of this system. In this paper, a general Pull system for a stochastic supply chain process will be adapted along with optimizing a Pull Stochastic Supply chain. This Supply Chain, SC, is used with combining CONWIP and KANBAN, the two famous pull systems, for controlling the SC. Under assumptions of stochastic demand rate, stochastic production and transportation times, and stochastic distributions for backlog cost, a simulation modeling is used. In optimization process, concerning supply chain complexity, a simulation optimization procedure is applied along with a combination of simulation software package and methahuristic algorithms such as, genetic and Guided Local Search, GLS, algorithms, which are more flexible to solve the problem. Finally, the superiority of this design is observed.**

***Index Terms*— Supply chain, stochastic process, genetic algorithm, Guided Local Search.**

I. Literature Review

The KANBAN technique is an approach to just in time (JIT) systems. The goal in this technique is to reduce lead times and work-in-process levels. The first one who proposed the KANBAN technique, was Monden [1].Many researchers attracted to the method since then. Originally, Monden summarized the Toyota approach for determining the appropriate number of KANBANs at a workstation [2].

KANBAN is applied recently in supply chain systems in order to manage the flow of materials, efficiently. Numerous models have been developed to describe supply chain systems; most studies published did not consider many essential characteristics of manufacturing systems, such as the supply-retailers relationship, number of KANBAN, and KANBAN operations [2].

Karmarkar and Kekre[3], Wang and Wang [4], Deleersnyder et al. [5], Askin et al. [6], Co and Sharafali[7], and Nori and Sarkar [8] considered the KANBAN operations between two adjacent stages only, and they did not link the raw material stage and finished good stage together[2].

M. Aminnayeri, Assistant Professor of Industrial Engineering, Amirkabir university of Technology, Tehran, Iran, (phone: +98-021-64542769; fax: +98-02166413025; e-mail: mjnayeri@aut.ac.ir).
Sajjad Shokuhyar, PHD student, Department of Industrial Engineering, Amirkabir university of Technology; (email: Shokuhyar@yahoo.com)
Sina Shokuhyar, BSC student, Department of Industrial Engineering, sharif university of Technology; (email: Sina_Shokoohyar@yahoo.com)

However, the limited applicability of KANBAN has motivated researchers to find another alternative for control strategy. One of these strategies is Constant Work In Process, CONWIP, that illustrated many desirable characteristics for application of this strategy in production line [9].

Sperman and Woodruff present CONWIP as a new control procedure [10]. They used this strategy in serial production line and compare advantages of this with KANBAN policy.

Herer and Masin developed mathematical model for setting optimized sequence of jobs in multi-product serial production line [11]. Wang and Sarker developed KANBAN control policy in assembly supply chain. For solving this model they modeled mixed integer linear programming and optimized this model with objective of total production, set up, transportation, and holding costs. The back log cost was no considered in the model [12].They developed a heuristic procedure to speed solving the problem [2].

Recently, some new pull strategies have been developed such as, The CONWIP and a KANBAN /CONWIP hybrid. Managers, now, are asking which of pull control strategies has to be chosen for a given manufacturing system [13]

A disadvantage of CONWIP is that inventory levels inside the system are not controlled individually. For instance, high inventories can appear in front of slow machines. Similarly, inventories can reach high levels when a machine breakdown occurs. CONWIP does guarantee an upper bound for the overall WIP, which remains constant over the time. Bonvik et al have proposed, recently, a new control strategy [14]. The idea is to combine the advantages of CONWIP (a high throughput with a low overall WIP level) with KANBAN system to control the inventory levels at each stage. Gaury et al. applied an evolutionary algorithm for optimizing hybrid CONWIP/ KANBAN system. The objective function of their model is WIP level. In this model the number of the CONWIP/ KANBAN card is changed and the lot size is constant [9].

In this paper we propose and develop a hybrid KANBAN /CONWIP strategy in serial supply chain. In order to model the problem we applied hybrid simulation and heuristic procedure for optimizing model. By this technique, we can add any assumption to the model which will make our proposed model be different from other previous models.

In the next section the proposed problem will be described. In section three an optimization procedure is designed. Section four is devoted to simulation software which is used in this paper. In section five applications of genetic and GLS algorithms are described. In section six, stopping rule for optimization model is defined. In section seven results is shown And finally, section eight concludes the paper along with some suggestions for further work.

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II. THE DESCRIPTION OF THE PROBLEM

A supply chain is usually composed of a series of organizations and/or independent companies. A supply chain is a set of procedures that, in an efficient way, integrate suppliers, manufacturers, warehouses, distribution centers, retailers, and ultimately the customers. so that, the merchandise is produced and distributed at the right quantities to the right locations and at right times, in order to minimize the total cost of the system, while satisfying the service level requirements [3].

According to this, the model will be constructed under the following assumptions:

- The type of products that are needed, demand rate and the lot size are probabilistic. This assumption makes the distinction between this research and other previous ones.
- The lot size is variable for any type of products and is optimized. Furthermore, the number of KANBAN /CONWIP cards is also optimized.
- The production time can be random variable with a distribution.
- The transportation cost is applied in the model and the time of transportation could be random with a distribution.

With the above assumptions, the simulation optimization technique is utilized to minimize the cost. This technique is applied due to its capability for solving stochastic models. In order to rich to a near optimal solution, genetic and GLS algorithms are used, which will be described in the next section.

The hybrid KANBAN /CONWIP control strategy is implemented by adding KANBAN card to CONWIP system. As shown in Figure 1, The last stage in production system does not need a KANBAN control card, because any final product that has sent to customer, one CONWIP card will be sent to plant 1 [13].

In this strategy, the input of the system is controlled by CONWIP and KANBAN cards and the objective function is minimization of WIP subject to the constraints of the model.

As described in this system with product of any lot, one production CONWIP and KANBAN card is sent to beginning of the line and the production of new parts is begun. Also KANBAN card in the final stage is sent to the previous stage.

III. DESIGN OPTIMIZATION PROCEDURE

Nowadays, many optimization soft wares have been developed with the capability of solving problems in the right time with thousands of variables. But in most cases, due to complexities in manufacturing, converting a real problem to a linear or a non linear programming model is almost impossible. These techniques need some simplifying assumptions to model a real world problem. These constraints force a modeler to use other techniques so that be able to model assumptions and prepare an appropriate, not always an optimum, results. This technique called simulation optimization. [15]

The merging of optimization and simulation technologies has encountered a rapid growth in recent years. A Google search on “Simulation Optimization” returns more than six thousand pages with the exact phrase. The content of these pages ranges from articles, conference presentations and books to software, sponsored works and consultancies. This is an area that has sparked as much interest in the academic world as in practical settings [16]. In this approach, the metaheuristic optimizer chooses a set of values for the input parameters, i.e., factors or decision variables, and uses the responses generated by the simulation model to make decisions regarding the selection of the next trial solution [16].

After each run of the model and examining the answer in the objective function, variables or the structure of the model can be changed. This procedure is shown in Figure 2.As shown in Figure 2, the simulation optimization method is applied in this paper. Each part is modeled separately, in order to apply this technique. For clarifying the simulation optimization method, main parts of the technique will be explained in this paper.

IV. SIMULATION SOFTWARE

The simulation allows you to dynamically analyze the behavior of the system modeled, to test management criteria, to assess situations as particularly critical, to validate design choices and finally to compare results.

Arena is an integrated graphical simulation environment that contains all the resources for the modeling, design, representation of processes, statistical analysis and analysis of results.

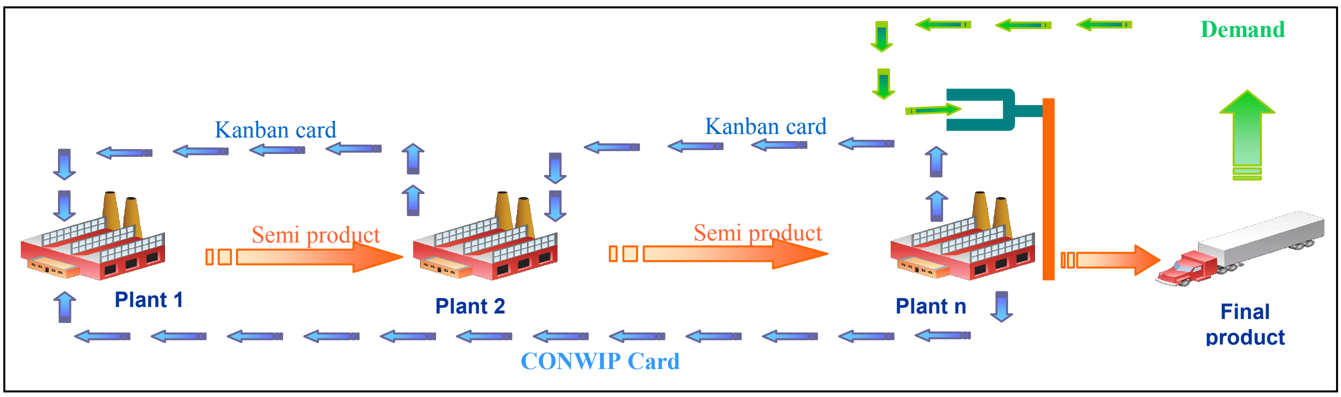

Fig 1- KANBAN /CONWIP hybrid Policy in supply chain

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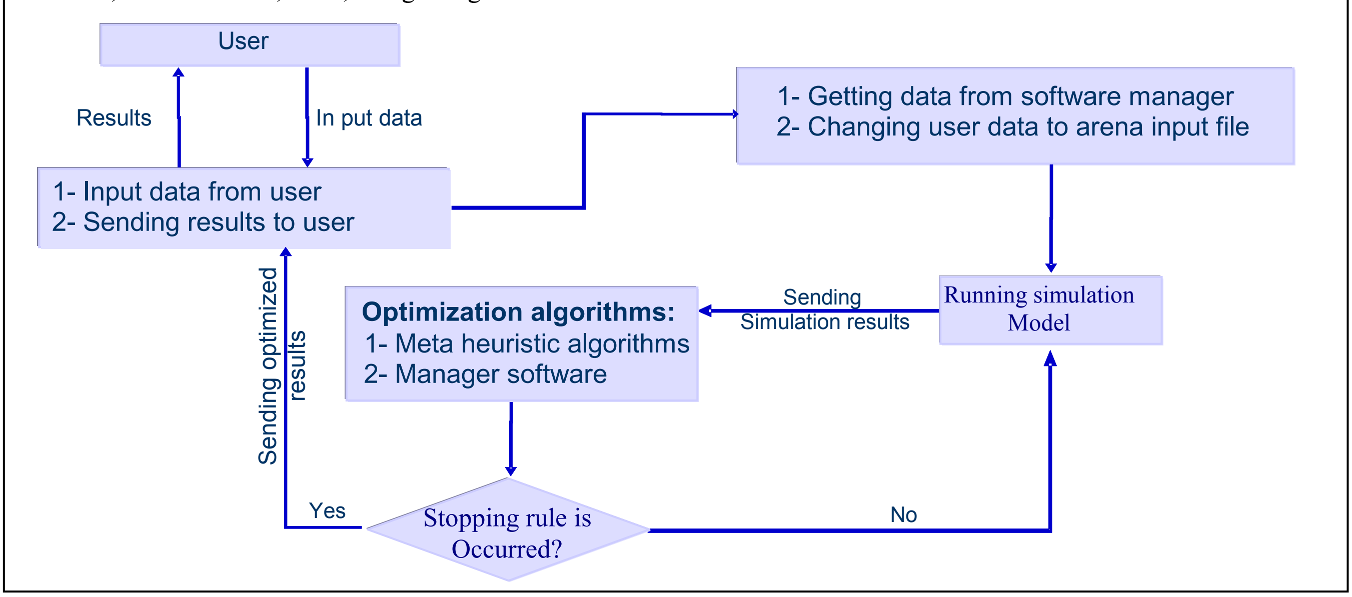

Fig 2 - Optimization procedure for optimizing problem

Arena is regarded by leading experts in the field as the most innovative simulation software that combines the resources of the simulation language to facilitate their use in an integrated graphical environment.

For implementing the designed model, we use Arena software with concerning the ability for controlling of the model and using Visual Basic Language for coding user defined module[17].

V. Applied Genetic and GLS Algorithms

One of the most important parts of simulation optimization problem is setting of optimization algorithm. For doing this in most cases Meta heuristic algorithm is used. Nowadays many types of these algorithms have developed that can generate near optimal solutions. In optimization parts we applied metaheuristic algorithms which are used as an efficient optimization tool in recent decade.

Any optimization problem has an objective function that defines the objective of the model with respect to variables in the model which may be a minimization and/or a maximization problem. In cases that parameters are probabilistic, the objective function is probabilistic, too.

One of the most useful and applicable met heuristic algorithm is genetic [18].In genetic algorithm, a set of feasible results is used as population of genes. At first, the algorithm selects some genes form the population, with the best solution. Then, by making the crossover and, sometimes the mutation, new genes are created. This procedure is continued until the best result is achieved.

To obtain a better result in optimizing procedure, we use another Meta heuristic algorithm that is a powerful tool to avoid a local optimum. This algorithm, namely, a guided local search, GLS, is introduced by Voudouris. [19]

GLS is an intelligent search scheme for combinatorial optimization problems. A main feature of this approach is the iterative use of local search. The information is gathered from various sources and exploited to guide local search in promising parts of the search feasible solution space. Two of the applications of GLS could be solving the Traveling Salesman and the Quadratic Assignment Problems.

Results reported show that GLS out performs simulated annealing and Tabu search, the two well known and well established optimization techniques. Given the novelty of the approach and the very encouraging results, the method could have an important contribution to the development of intelligent search techniques for combinatorial optimization [19].

To apply the algorithm, we need tuning and setting up parameters of genetic and GLS algorithms.

The main objective of applying KANBAN/ CONWIP strategy, in supply chain, is using the benefit of reduction WIP. To achieve this objective, we optimize the lot size and the number of CONWIP and KANBAN cards for all types of products.

As an example, we model a serial supply chain with 4 products and 4 stages. Figure 3 shows a chromosome for this system. The gene is the lot size and card for CONWIP and KANBAN.

Product 1	Product 2	Product 3	Product 4	Stage 1	Stage 2	Stage 3	Stage 4
CC_1	CC_2	CC_3	CC_4	KC_{1k}	KC_{2k}	KC_{3k}	KC_{4k}
CQ_1	CQ_2	CQ_3	CQ_4	KQ_{1k}	KQ_{2k}	KQ_{3k}	KQ_{4k}
CONWIP				Kanban			

Fig 3 - Structure of result in any replication of algorithm

In genetic algorithm, a set of results is used as the population. For our problem, after test run we defined the population with 200 members.

The steps of using GLS are running the simulation optimization problem with Genetic algorithm, getting the solution, and to set this result, as a penalty in objective function and run problem again. To avoid a local optimum,

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the algorithm uses this penalty and goes out from the local optimum. The function of this algorithm is as follows:

$$h(s) = g(s) + \lambda \cdot \sum_{i=1}^{M} P_i \cdot I_i(s)$$

Where, M is the number of features defined over solutions, P_i is the penalty parameter corresponding to the feature I_i and the index i, is the regularization parameter. The penalty parameter P_i is the degree of getting out the local optimum. The regularization parameter, i, represent the relative importance of penalties with respect to the solution cost and has a great significance. Since, it provides a tool to control the influence of the information on the search process [19].

To evaluating results of the simulation, we use the fitness function. The fitness function, here, is shown in the bellow:

$$Min\ Z = \underbrace{\sum_{i=1}^{n}\sum_{j=1}^{m}(Q_{ij} * C_{ij})}_{\text{Production cost}} + \underbrace{\sum_{i=1}^{n}\sum_{j=1}^{m-1}(QT_{ij} * CT_{ij})}_{\text{Transportation cost}} + \underbrace{\sum_{i=1}^{n}\sum_{j=1}^{m}(HQ_{ij} * H_{ij} * T)}_{\text{Holding cost}} +$$

$$\underbrace{\sum_{i=1}^{n}(FT_i * FQ_i)}_{\text{Final transportation cost}} + + \underbrace{\sum_{i=1}^{n}(FQ_i * FC_i)}_{\text{Final product cost}} + \underbrace{\sum_{i=1}^{n}(FHQ_i * FH_i * T)}_{\text{Final Holding cost}}$$

Where, parameters are:

C_{ij}: production cost for product type i in plant j
CT_{ij}: transportation cost for product type i from plant j to plant $j+1$
H_{ij}: average of holding cost for product type i in plant j
T: time of model replication

And variables are:

CC_{ik}: CONWIP card for product type i in replication k
CK_{ik}: KANBAN card for product type i in replication k
Q_{ij}: number of product type i in plant j
QT_{ij}: number of transported product type i from plant j to plant $j+1$
HQ_{ij}: average number of held product type i in plant j at time unit
FT_i: transportation cost for each part of final product type i to customer
FQ_i: number of final product type i
FC_i: cost of production of final product type i
FHQ_i: average of held cost of final product type i
FH_i: average of holding cost for product type i

In our problem for generating the population, we use genetic operator as bellow.

For any KANBAN/CONWIP card we generate one random number between 0 and 1. If the random number is less than or equal to 0.5, KANBAN/CONWIP card decreases one unit and if it is greater than 0.5, KANBAN/CONWIP increases one unit. For the lot size, a random number between 0 and 1 is generated and it is used as the percentage of a reduction or increase. To increase or decrease the lot size we proceed as the above by random number generation

VI. Stopping Rule

The stopping rule, here, is the number of replications, though, it can be set any other way. These rules depend on the user and the real problem which is going to be modeled.

VII. Running Optimization Model

Figure 4 shows results of running simulation optimization model with 300 replications. As the number of iteration is increased, the deviation in the result decreases.

Applying the combination of genetic/ GLS algorithm, causes results to be more smooth and close to each other. Obviously, this is the natural outcome of using the penalty policy in GLS /Genetic algorithm. Figure 4 shows the comparison of the two methods, using previous results along with 1300 times more simulation runs.

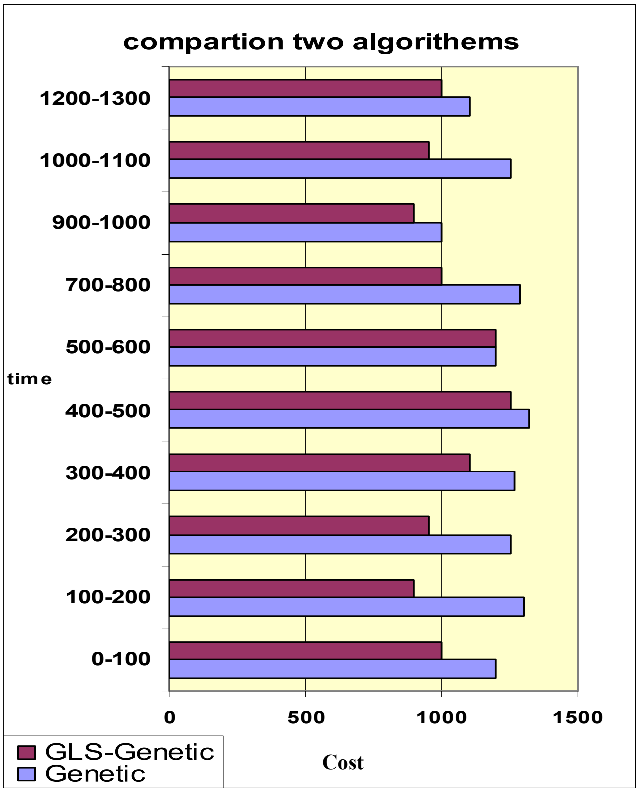

Fig 4 - comparison of the two methods

VIII. Conclusions and Recommendation for Future Work

In this paper we studied the hybrid KANBAN /CONWIP strategy and this system is modeled and optimized with simulation optimization technique that combines metaheuristic algorithm, Genetic and GLS, with simulation soft ware. For doing this we code algorithms in arena simulation package. We showed that this method is superior to genetic and also to GLS alone.

For future research we recommend the following objectives:

1- For studying and evaluating these algorithms one can uses other algorithms and tests in two aspects of the result quality and speed up the result generation.

2- In this paper we model simple hybrid KANBAN/CONWIP strategy. Other type of CONWIP or KANBAN Strategy can be modeled and optimized.

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3- We optimize Hybrid KANBAN/CONWIP Strategy with total cost objective function. One may test other objective functions such as the quality function.

REFERENCES

[1] Monden, Y., 1983. The Toyota Production System. Industrial Engineering and Management Press, Norcross, GA.

[2] Wang, S., Sarker, B.R., "Optimal models for a multi-stage supply chain system controlled by kanban under just-in-time philosophy", European Journal of Operational Research, Vol. 172, Issue 1, PP 179-200, 2006.

[3] Karmarkar, U.S., Kekre, S., 1989. Batching policy in kanban system. Journal of Manufacturing Systems 8 (4), 317–328.

[4] Wang, H., Wang, H.P., 1991. Optimum number of kanbans between two adjacent workstations in a JIT system. International Journal of Production Economics 22 (2), 179–188.

[5] Deleersnyder, J.L., Hodgson, T.J., King, R.E., Ogrady, P.J., Savva, A., 1992. Integrating kanban type pull systems and MRP type push systems—Insights from a Markovian model. IIE Transactions 24 (3), 43–56.

[6] Askin, R.G., Mitwasi, M.G., Goldberg, J.B., 1993. Determining the number of kanbans in multiitem just-in-time systems. IIE Transactions 25 (1), 89–98.

[7] Co, H.C., Sharafali, M., 1997. Overplanning factor in Toyota_s formula for computing the number of kanban. IIE Transactions 29 (5), 409–415.

[8] Nori, V.S., Sarkar, B.R., 1998. Optimum number of kanbans between two adjacent stations. Production Planning and Control 9 (1), 60–65.

[9] FRAMINAN, J.M., GONZALEZ, P.L., RUIZ-USANO, R., "The CONWIP production control system:review and Research issues", PRODUCTION PLANNING & CONTROL, vol. 14, no. 3, PP 255–265,2003.

[10]SPEARMAN, M.L., WOODRUFF, D.L., HOPP, W. J.,"CONWIP CONWIP, A Pull Alternative to Kanban" .INT.J.PROD.RES.,vol. 28, NO.5, PP 879-894,1990.

[11]Herer, Y.T., Masin, M., "Mathematical programming formulation of CONWIP based production lines; and relationships to MRP". International Journal of Production Research, Vol. 35, NO.4, PP 1067–1076, 1997.

[12]Wang, S., Sarker, B.R., "An assembly-type supply chain system controlled by kanbans under a just-in-time delivery policy", European Journal of Operational Research, vol. 162, Issue 1, PP 153-172, 2005.

[13]E . G . A . GAURY,H . PIERREVAL2 , J . P. C . KLEIJNEN,"An evolutionary approach to select a pull system among Kanban, CONWIP and Hybrid",2000, Journal of Intelligent Manufacturing,vol 11, 157-167.

[14]Bonvik, A. M., Couch, C. E. and Gershwin, S. B. (1997) A comparison of production-line control mechanisms, International Journal of Production Research, 35(3), 789-804.

[15]Carson, Y., Maria, A, "SIMULATION OPTIMIZATION: AND METHODS AND APPLICATIONS", Winter SimulationConference, PP 1693-1698, 1997.

[16]April, J., Glover, F., Kelly, J.P., Laguna, M., "PRACTICAL INTRODUCTION TO SIMULATION OPTIMIZATION", Winter Simulation Conference, 2003, PP 71-78.

[17] Rockwell Automation Technologies. www.arenasimulation.com

[18]L.Davis,1991, Handbook of Genetic Algorithms, Van Nostrand Reinhold, New York.

[19]Voudouris,Chris.PhDthesis.ftp://ftp.essex.ac.uk/pub/csp/Voudouris-PhD97-pdf.zip`