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OPTIMIZING KANBAN CONFIGURATION IN HIGH MIX, LOW VOLUME ENVIRONTMENTS BY APPLYING MULTI OBJECTIVE GENETIC ALGORITHM

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ABSTRACT

Kanban system is a part of the Lean Manufacturing method which aims to reduce internal logistic effort by setting materials in supermarket or inventory at the point of use in production assembly lines. Kanban is selectively chosen with relatively high runner and stable demand raw or semi-finished good materials. A High Mix, Low Volume sensor manufacturing company located in Bintan Indonesia which produces both a high variance of product portfolios and customer demand fluctuation having problems in implementing Kanban. Fluctuations in customer demands and product mix in a relatively short period of time require dynamic Kanban configuration to adapt such situations. Dynamic Kanban configuration needs to be considered to maintain the minimum cost of total Kanban inventory but yet obtain maximum total savings from the material picking process. The Optimum Kanban configuration is proposed by applying a Multi-Objective Genetic Algorithm programmed using VBA (Visual Basic Application) and run in Microsoft Excel focusing on selecting groups of materials according to total minimum Kanban inventory cost as the first objective and total maximum saving in the internal logistic effort as the second objective. The proposed model has been validated by testing using company-sourced data. The result has been compared to the minimum global optimum from data, obtaining 89% for the first objective and 93% for the second objective.

Keywords: *Kanban Configuration, Multi-Objective Genetic Algorithm, High Mix, Low Volume, Lean Manufacturing*

1. INTRODUCTION

Pull system is a technique of Lean manufacturing concept to reduce waste in the internal logistic process. Implementing a pull system starts from only carrying out the production process when there is a request signal from the customer to minimize the inventory level, transportation of raw materials and other wastes. Part of pull system, there is Kanban system that regulates the flow of material from the Source (source) to the Sink (user) by using a signal in the form of a physical or electronic card [1]. Kanban comes from the word "View card" is a scheduling system in Lean Manufacturing and JIT (Just in Time). In a high mix, low volume environment where manufacturers produce high variants of products with relatively small quantities per variant coupled with the high volatility demand from customers, the implementation of Kanban must go through careful consideration and study [2]. With such as situation, Kanban configuration must be done dynamically, since many items that were originally high runners, but in relatively short time they are low runner. A multinational company which focuses on sensor manufacturing for industrial automation purposes located in Bintan Indonesia is the subject of this case study. The company itself characterized as a high mix, low volume environment, which globally has more than 35,000 product portfolios, while within Bintan subsidiary has more than 2000 active products which using around 5000 part number of materials. Current Kanban material selection process is requiring several steps including:

1. The process selection of material items will be set as Kanban. Historical data of material consumption is analyzed to select suitable material with relatively high runner represented by “ABC” class category

which contribute of 80%, 15% and 5% of highest demand respectively and stable amount of demand in units represented by “XYZ” class category having standard deviation of less than 0,35, within 0,35 to 0,7 and more than 0,7 respectively that generating final category which category “AX” is the most suitable for Kanban and the rest is less suitable or even not suitable for Kanban, this stage is important to make sure Kanban material stock has good turn over in production area.

2. Calculation of the number of Kanban bins and lot size. The calculation of the quantity of the maximum allowable stock of Kanban items is adjusted to the level of consumption or demand for the Kanban Items within a certain period of time and the length of replenishment which means the production process and or delivery from “Source” to “Sink”. In our case the system use maximum weekly consumption level as maximum lot size.

3. Physical storage & system settings. After the first 2 stages above are completed, it can be continued with physical storage & system settings where Kanban Item will be determined by the type of packaging based on the dimension and order system electronically or using the card.

The Kanban material selection process carried out here or in point 1 above is carried out periodically and the current process only selects materials to be applied as Kanban based on the frequency or frequency of materials taken from the warehouse to be brought to the production area (picking) in accordance with the amount requested by the production area is based on past historical data without regard to the value of the material, which means that materials that are selected as Kanban materials can have a high value or value so that they will contribute to the high value of stock or Cost of Inventory, plus the stages above must be carried out regularly and quite a lot of effort and require a long process to carry it out.

Optimum dynamic Kanban configuration proposed by implementing Artificial Intelligence using a Multi-Objective Genetic Algorithm for this subsidiary, in this case, to determine the best combination of Kanban material with considering evaluation parameters such as minimum total inventory of Kanban material and maximum total saving from internal logistic efforts.

Research contribution from this paper is conducting feasibility on implementing the concept of Multi-Objectives Genetic Algorithm (MOGA) using parameter of frequency & value of the inventory as Kanban parameters by using the Microsoft Open Database Connectivity (ODBC) data sourced from the company database which is pulled using a designed MS Access Query. The Query function creates links and sorting as well as mathematical operations on data tables. The query will collect the dataset needed to be analyzed in the developed programming using Visual Basic Application (VBA) languange run using built in macro in MS Excel platform which is relatively well know by the users.

2. LITERATURE REVIEW

2.1 Genetic Algorithm

Genetic Algorithm (GA) is one of the first population-based stochastic algorithms proposed in the history. Similar to other evolutionary algorithm, the main operators of genetic algorithm are selection, crossover, and mutation. Steps that carried out in GA are first Chromosome Selection techniques such as Roulette wheel selection, Tournament selection, Rank Selection, Steady State Selection. Second, Selected Chromosome will be regenerated using cross over or recombination by using techniques such as one-point, two-point or uniform which resulting in the birth of 2 chromosome. Third, mutation by altering one or more gene values in the chromosome. Fourth, the fitness of these chromosome is determined using fitness function, the best fit is chosen as the solution [3].

2.2 Related Works

In this paper, a literature review needs to be done also. [4] presents study was developed with the purpose of recommending an alternative to sizing of Kanban supermarkets based on robust optimization and analyzed the application of the method in the context of a literature case with simulated experiments. [5] develops an integrated multiple-objective genetic algorithm (MOGA) based system to determine the Pareto-optimal Kanban number and size, and is applied in a JIT-oriented manufacturing company to demonstrate its feasibility. In the integrated system, a simulation model is built to simulate the multi-stage JIT production system of the company. Then an experimental design of different Kanban numbers and sizes for different production stages is applied to test the production performances. Based on the simulation results, regression models are built to represent the relationships between the Kanban numbers of different production stages and the production performance. These regression models are then used in genetic algorithms to generate the performance for chromosomes. Finally, the proposed Multi-

Objective Genetic Algorithm (MOGA) based system uses the generalized Pareto-based scale independent fitness function (GPS OFF) as the fitness function to evaluate the multiple objectives for chromosomes and used to find the Pareto-optimal Kanban number and size for multiple objectives such as maximizing mean throughput rate and minimizing mean total WIP inventory. A comparison in the performance of the proposed system with that of the current Kanban number is conducted to demonstrate the feasibility of the proposed system. [6] create a simulation model to address the selection of two important parameters, which are the number of Kanbans and the lot size. A gradient-based heuristic is applied to a genetic algorithm for the design of a multi- product Kanban system and adapted to new crossover and mutation methods. Several case studies in different sizes have been tried out and solutions from the modified genetic algorithm were compared to those from the classical genetic algorithm. The results show that the proposed GA needs less computational efforts and its computing time is obviously shorter than the classical GA. For its high efficiency, the proposed GA can find better solutions in the other large-scale cases under the same limit of the generation times. These experiments show that the gradient-based heuristic plays an important role in improving the speed and quality of the design of Multiproduct Kanban systems. [7] Hybrid method of fuzzy simulation and GA demonstrate models solve problems of Multi- periodic inventory control problems. A hybrid method of fuzzy simulation (FS) and genetic algorithm (GA) is proposed. The performance of the proposed method is then compared with the performance of an existing hybrid FS and simulated annealing (SA) algorithm through three numerical examples containing different numbers of products The comparison results show that, at least for the numerical examples under consideration, the hybrid method of FS and GA shows better performance than the hybrid method of FS and SA. [8] propose a mixed-integer nonlinear programming (MINLP) model in order to minimize total cost to determine number of Kanban, batch size, and number of batches. To avoid the large computational time in optimal solution, a particle swarm optimization (PSO) and simulated annealing (SA) algorithms as metaheuristic methods are used for solving a large MINLP. Some problems are solved by PSO and SA and performance of the PSO and the SA is evaluated by comparing their results with the optimal solution. It is shown that both PSO and SA result in a near optimal solution but the PSO algorithm gives a better performance than the SA method. [9] propose integer programming model and real genetic algorithm (RGA) in which custom chromosomes representation, two custom mating and two custom mutation operators to investigate the location problem of supermarkets, feeding by material the mixed model assembly lines using tow trains. It determines the number and the locations of these supermarkets to minimize transportation and inventory fixed costs of the system. The performance of RGA is very good since it gives results that are very close or identical to the optimal ones in reasonable CPU time. [10] establishes a mathematical model constructed for multi-objective storage location allocation optimization. The multi-population genetic algorithm is proposed to solve the mathematical model of storage location allocation optimization. Combining with the experiment data of toy car assembly and automated warehouse, the results of the automated warehouse storage location allocation are obtained.

2.3 Research Objective

This case study has purposes to:

1. Designing model, framework, and analysis for optimization Kanban configuration problem.
2. Evaluating effectiveness of the proposed model with comparison of existing Kanban system.

3. METHODOLOGY

3.1 Framework

To work with the problem, the author establishes structured framework of genetic algorithm method starting from the data pull design process from the company database continued with constraint analysis and algorithm development. Genetic algorithm operator's concept development along with programming carried out afterwards and finally conducting evaluation for the method effectiveness as explained in figure 1.

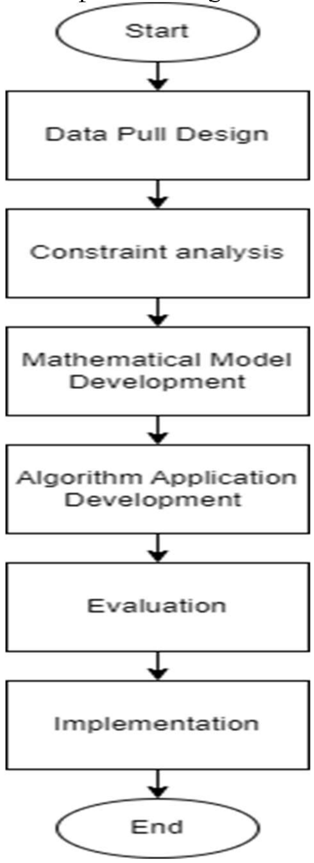

Figure 1: Study Case Steps

3.2 Data Structure

The data need to be retrieved such as picking frequency and quantity from warehouse to production, work center of material consumer, dimension for each material and other supporting data for Factory Automation (FA) products taken from the live ERP system used at the company. In order to retrieve the data Microsoft Access Query tool is used. The data are obtained from the last 12 months. The following Table 1 explains the data retrieved from the system.

3.3 Chromosome Representation

We begin by defining a particular limit to the number of part number in the Chromosome, say 20. These 20 part number related to index number of material list collected from database using Query that have been selected only which having positive saving from internal logistic effort comparing between normal material picking and Kanban replenishment method. The genes as shown in figure 2 inside chromosome is representing the sequence number from list of material data generated from previous steps.

Table 1: Table of Data Structure.

No	Name	Explanation
1	Material List Number	Sequence number of material in data list.
2	Material Part Number	6 digits unique number of raw or semi-finished good material.
3	Material Description	Raw or semi-finished good material name decsription.
4	Consumer Work Center	4 digits number for material consumer assembly line code.
5	Weekly Material Consumption	Average of material consumption level by each consumer assembly line in units.
6	Material value	Price of the material per unit in Euro.

1	4	21	34	44	..n

Figure 2: Chromosome Structure

3.4 Initiate First Population and Evaluation

First population is generated by randomly select unique integer number within maximum and minimum integer value say 250 and 1, using Object property in VBA program for 100 Chromosomes within one population. Chromosomes generated from this step then evaluated by its objectives (Z1 and Z2). Objectives evaluation is performed by using equations 1 and 2 as below :

$$Z1 = \sum_{i=1}^{20} P * WS \qquad (1)$$

$$Z2 = \sum_{i=1}^{20} (FPN - FPK) * CP \qquad (2)$$

Where :

Z1= Objective 1 Function (Total inventory from Kanban material stock).

Z2 = Objective 2 Function (Total saving value from material picking process).

CP = *Cost of material picking* (Cost for internal logistic operator to pick material) in Euro.

FPN = Frequency of normal picking (if the material not set as Kanban) by weekly basis in times per week.

FPK = Frequency of Kanban picking (if the material we set as Kanban) by weekly basis in times per week.

P = *Cost of value or price per one unit material* in Euro.

3.5 Fitness Evaluation

The next step in this algorithm is to carry out the Fitness Evaluation stage where this function is responsible for calculating the fitness value of each chromosome in the current population. The first step in this step is to determine the values of both the minimum and maximum objective for all chromosomes in the current population. In this case, starting from Z1 and Z2 of the first chromosome, it will be used as the default for the minimum and maximum values of Z1 and Z2, then the Z1 and Z2 values of the second chromosome, and so on until it reaches the population size, will be compared with the default maximum and minimum values of Z1 and Z2. , if the values of Z1 and Z2 are smaller or greater than the maximum and minimum default values of Z1 and Z2, then the maximum and minimum values of Z1 and Z2 will be updated, as stated in the logic flow below:

EvaluateZ1 and EvaluateZ2
$\boldsymbol{MinZ1 = Z1, MaxZ1 = Z1}$
$\boldsymbol{MinZ2 = Z2, MaxZ2 = Z2}$
For each Chromosome ($\boldsymbol{i}$ = 2 to Size of Population) do
EvaluateZ1 and EvaluateZ2
If Z1 > MaxZ1 and Z2 > MaxZ2 then
MaxZ1 = Z1 and MaxZ2 = Z2
End if
If Z1 < MinZ1 and Z2 < MinZ2 then
MinZ1 = Z1 and MinZ2 = Z2
End if
Next

After getting the maximum and minimum values of Z1 and Z2, each chromosome will calculate its fitness value using the following formula :

$$score = 1 - \frac{Z - Zmin}{Zmax - Zmin} \quad (3)$$

Formula 3 gives the chromosome with the highest fitness value of 1 and the chromosome with the lowest fitness value of 0, while the other chromosomes will have a fitness value between 1 and 0 and the greater the fitness value of a chromosome, the greater the chance to survive in the next stage.

3.6 Select Chromosome

The next stage is the Select Chromosome. In this function, this stage has a goal in the form of a chromosome selection process or a solution, where promising chromosomes will be selected to produce the next generation. In this process, we use the Selection Operator, the purpose of this operator is to identify a chromosome or a solution that is good above the average of the chromosomes or other solutions. In this case study, we have 2 objectives Z1 and Z2, in this selection process the standard Roulette Wheel Tournament method is used, where 2 chromosomes will be selected with a probability of being selected that is proportional to the fitness value or in another sense a chromosome with a high fitness value has a high probability of being selected, whereas for chromosomes with a low fitness value will also have a low probability of being selected.
In VBA programming for this process, the SelectChromosome property will be used to select candidates from the current generation where the probability of selecting each individual chromosome is proportional to the fitness score or the fitness function of the chromosome. where the ranking of the chromosomes will follow the fitness function and will select the best chromosomes for the next operation process, namely Mating or crossing and Mutating or mutation.

3.7 Mating

The next stage in this algorithm is the Mating operator which is responsible for creating new chromosomes or solutions, which in this case aims to explore in the search space. In the previous stage, where the Roulette Wheel Tournament occurs, the chromosomes or solutions selected from the tournament are 2 times the population and are pinned as the father's and mother's chromosomes to be crossed. In VBA programming for this process, the Mate property is used to generate offspring chromosomes. As the name implies, this method takes two chromosomes and combines them into one in such a way as to produce offspring chromosomes consisting of several combinations of the parents' genes. In this method, Property Mate will combine these solutions to obtain offspring chromosomes that consist of several combinations of the parent chromosome genes. The approach taken is to calculate the average of each gene from the parent chromosomes.

3.8 Mutation

After the Mating operation, it will be continued with the Mutation operator. Mutation Operation will be closely related to Mutation Rate. The Mutation Rate will specify the chance or probability of the chromosome to mutate. The Mutation Rate number value should be adjustable to obtain acceptable results. If the Mutation Rate is too low, then new genetic material will be generated in a very slow process which means it will take a long time for a population to converge to an optimal solution. On the other hand, if we set the Mutation Rate value too high, it may never reach convergence at all, because

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even though a fit chromosome will mutate, it will likely destroy its superior fitness.
The property used in VBA programming is the Mutation Rate which is useful for specifying the probability of chromosomal mutations. The value of the Mutation Rate should be adjustable to achieve acceptable results. Many researchers use the number 0.01, so in this case study we will use the value 0.01 as the Mutation Rate. If the value of the Mutation Rate is too low, then new genetic material will be generated at a very slow rate, this means that it will take a long time for the population to converge towards the optimal solution. Conversely, if the Mutation Rate is too high, it will never converge at all because even good chromosomes will mutate, so it is possible to destroy its superior fitness. The chromosomal method for mutating its genes is using the Mutate property. The first step in this Mutate property is to generate a random value between 0 and 1 using the Random function and will store the value in a local variable, then proceed with comparing the random value with the value of the Mutation Rate. If the random value is less than the Mutation Rate, then the chromosome will undergo mutation, otherwise nothing will happen.

3.9 New Generation

After all stages in the Genetic Algorithm method are executed, the best results are obtained that have fulfilled all existing constraints and meet the optimal criteria, then the individual is declared the optimal solution of the configuration. In each resulting configuration it will refer to the best fitness value which will be passed on to become a new generation. In this process there is a Survivor or Elimination stage in which the best chromosomes or solutions will be selected for the next generation.

The property used in VBA programming is Copy. This function serves to store and replace the chromosomes in the current population with new generation chromosomes resulting from selection, crossing and mutation.

4. DISCUSSION

Figure 3 shows some result of this proposed algorithm, with a mutation rate set at 0,01 , maximal population at 100 and the number of generations ranging 500. The entire testing process uses a maximum limit of 500 iterations with 100 populations to get all solutions that are not dominated. Of the 100 population, there are 6 sets of non-dominated front solutions. From the 6 sets of non-dominated front solutions located in the Pareto front, an optimal solution was selected based on the Multi-Objective Genetic Algorithm method, namely solution or chromosome 99 which has 20 individuals in the form of index numbers from the material as shown in Figure 4. These chromosomes have an objective Z1 value of 1422.93 and a Z2 objective value of 368.83. From the data that was collected at the beginning, we tried to compare it with the global minimum of the two objectives based on the 20 part number materials that had the smallest total inventory value and the largest total saving value from the picking process. When compared to the optimal solution selected with the global minimum, the results of the algorithm converge 89% of the global minimum total inventory value, and 93% of the global minimum total value of savings from the picking process.

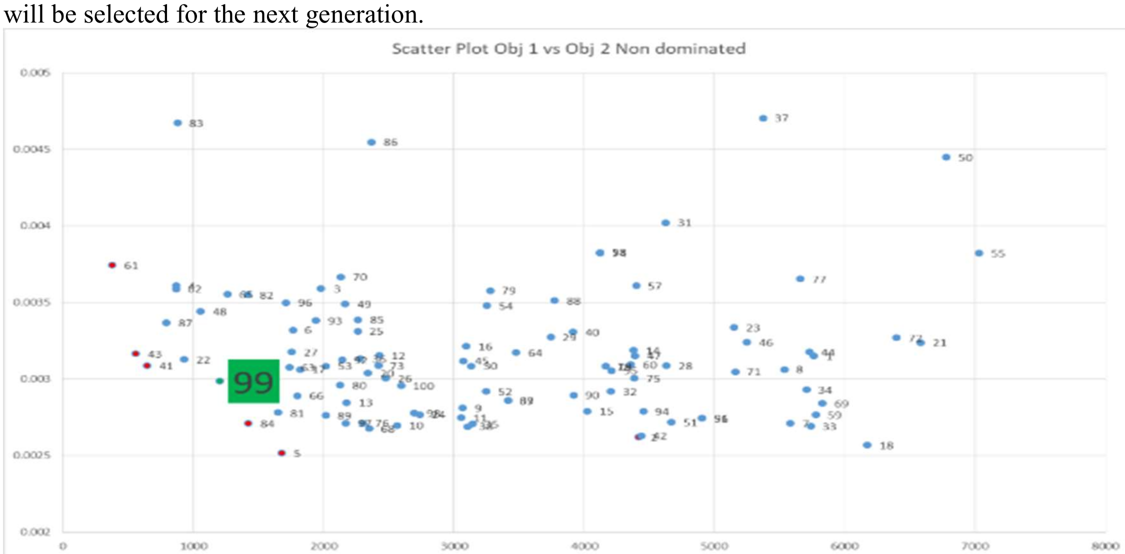

Figure 3 . Graph Of Number Total Population Along With Pareto Front Solution And Optimal Solution.

	Chromosomes																			
No	P/N 1	P/N 2	P/N 3	P/N 4	P/N 5	P/N 6	P/N 7	P/N 8	P/N 9	P/N 10	P/N 11	P/N 12	P/N 13	P/N 14	P/N 15	P/N 16	P/N 17	P/N 18	P/N 19	P/N 20
99	177	131	149	128	124	129	132	162	109	136	148	119	106	49	56	152	123	117	23	123

Figure 4 . Optimal Solution

This is the key benefit such as genetic algorithm where it converges towards the global optimum every time. On the other hand, genetic algorithms are robust and don't require gradient-based computation [15] while the algorithm are developed and run by Macro with the VBA (Visual Basic Application) platform embedded in Microsoft Excel 2013 with Microsoft Open Database Connectivity (ODBC) data sourced from the company database which is pulled using a designed MS Access Query. Compared with the current practic it can be concluded that the configuration of 20 part number material Kanban has a higher saving value from the picking process than the current Kanban system and has a lower total stock value than the current Kanban system.

5. CONCLUSIONS

In this paper, an effective multi-objective genetic algorithm is presented to find optimum Kanban configuration. In the presented approach, three constraints are set to limit the searching area. Mutation and crossover designed by comparing random number with probability defined by user. The result is obtained optimal solution of Kanban configuration with 89% from global minimum Z1 and 93% from global minimum . Nevertheless, from the experimental result, proposed technique is more effective to be implemented compared to current system prevailed in the company.

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