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# Development of Decision Support System for Solving the Machine Selection Problem in an Intermittent Manufacturing System Design

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**Abstract.** Capacity planning, which is integral to resource selection and allocation, is an important task in manufacturing system design. As budget is limited, investment in resources must be done carefully and appropriately in order to achieve desired capacity and system efficiency. One of the most expensive and valuable resources in the manufacturing system is machinery. Therefore, selecting an appropriate machine is of high significance. Among many types of manufacturing systems, intermittent manufacturing system is complex, yet flexible. The intermittent manufacturing system enables manufacturers to produce multiple products using multiple processes and multiple machines. The system comprises a network of multiple types of multi-process machines. A machine selection problem in the context of the intermittent manufacturing system is a delicate process, as it must correspond appropriately with production complexities. To alleviate this problem, we develop a decision support system for solving the machine selection problem in an intermittent manufacturing system design. We study several manufacturing systems producing multiple types of products with various multi-process machines to lay out the framework. This decision support system consists of four main parts, namely; data entry, data conversion, optimization model and report. To solve the machine selection problem, an optimization technique is used to identify the optimal number of machines and the allocation of production process of each machine. The objective of this optimization problem is to minimize total production costs (machine cost and operating cost) while maintaining production capacity and other production constraints. The decision support system is developed for and validated with the manufacturing company.

## 1. Introduction

The intermittent manufacturing system allows companies to make various types of product, process and order quantities. Machinery should be flexible enough to produce a wide variety of operations. Machinery and equipment are usually grouped as stated by function they perform. Moreover, the flow of production is varied and depend on product features. Then, the operation can be made more than one time for each workstation.

Due to the increasing of alternative machines in the market, it leads to the complexity of machine selection decision. Most of the time, selecting an appropriate machine is time consuming, costly and it also requires expert knowledge. Therefore, we develop the decision support system of machine selection for help non-specialist to determine appropriate machine to achieve both of product and process of capacity planning. Existing capacity in the manufacturing system effects overall production



performance such as capacity utilization, quality, on-time delivery, operating efficiency and production costs.

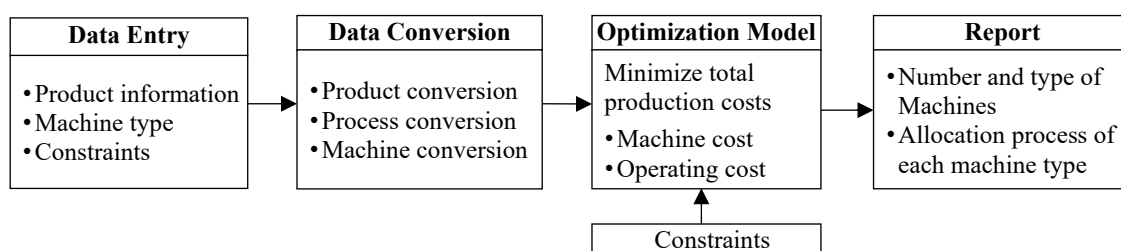
In this research, we propose the decision support system model that consists of four main parts because the machine selection process requires various data types and many steps. We need to clarify step-by-step processes that starts from data entry, data conversion, optimization model is used to determine both number and type of machines including the allocation of production process of each machine. The objective of optimization model aims to minimize total costs both machine cost and operating cost by consider the general manufacturing constraints of production time, number of machines and production constraints in order to satisfy customer's need. The final part is selected machine report.

## 2. Literature Review

Researches about machine selection process can be divided into two aspects, which are quality-based method and quantity-based method. The quality-based method is the selection method that uses quality data (criteria lists) to select the suitable alternative machine such as [1] provides the multi-criteria decision method and selects the highest score of machine lists. The quantity-based method is selection method that uses quantity data (capacity requirement, costs) such as [2] pays attention to the decision about product mix and capacity involve choosing between dedicated and multi-product facilities that concern both machine cost and operating cost. [3] proposes 0-1 linear programming and genetic algorithm by considering multi-objective to minimize various production costs; machine cost, material-handling cost, setup cost as well as maximize machine workload time. The model was developed to solve machine-tool selection and operation allocation problem. Moreover, [4] presents both a heuristic method named Five Simple Procedure (FSP) heuristic method and branch and bound method to assign operations to appropriate machine-tool combinations. The objective of model is to minimize some production costs. The results demonstrate that the FSP was efficiency to find good solutions and it helps a decision maker to select machine. [5] develop a decision support system for high speed milling machine tool selection. Since machine selection process is time-consuming and required advanced knowledge, [6] the decision support system is developed for the selection of machine tools. Multi-criteria weight average method by considering different criteria is used in process to rank the machine list.

## 3. Methodology

Due to the complexity of machine selection problems in the context, we develop the decision support system for supporting machine selection process. The machine selection process requires various data types involved in the production system and many steps to solve the problem. To simplify the complexity of decision process, we propose the methodology in four main parts Figure 1 that starting from import data process to acquire the solution. First part is about the collected data in three types of data. Second part is about data conversion that the collected data from previous part will be converted into the specific model template. The converted data is used to find the optimal solution in third part. Then, the report shows the optimum number and type of machine including allocation of production process of each machine type in fourth part.



**Figure 1.** Flow process of the decision support system.

### 3.1. Data Entry

The machine selection process requires various types of data that can be collect from the person who involved in the manufacturing system design. The data entry is first part of the decision support system that consists of two data types namely; main data, which are basic product information, machine type, and constraints of the production system shows in Table 1 and additional data, which are changeover time and operating cost that was made machine selection model more realistic.

**Table 1.** Input data

| Type of data        | Components  |
|---------------------|---|
| Product information | Product type, Production process, Ratio and type of input and output part   |
| Machine type        | Machine type (Machine, Tool, Labor), Machine capability, Machine cost, Setting time   |
| Constraints         | Capacity requirement (Each product type), Production time (Working time per day), Number of machines (Maximum or minimum machine in system), Maximum budget |

### 3.2. Data Conversion

The collected data are converted into the specific model template before inputting into the optimization model. The procedure of data conversion consists of three steps. First step, the product information and machine type are converted into specific abbreviation which the raw material of product type X is RMX, the process number Y is PY, the finished goods X is FGX and the machine type Z is MCZ. Second step, the converted data both product information and machine type are linked to define the capability of each machine type such as machine type Z can produce process Y of product X. Third step, the from-to table is generating for input changeover time by using both product and process capability of each machine.

### 3.3. Optimization Model

The converted data is used in the optimization model. We propose a mixed-integer linear programming (MILP) for solving machine selection problems. Both Visual Basic for Applications (VBA) and OpenSolver are develop for generating and solving the optimization model. We generate small problems to verify the proposed model could provide the correct solution.

**3.3.1. Problem description.** The optimization method is used to find the appropriate machine both number and type of machine and allocate the process to each machine. The objective of optimization model is to minimize total production costs both machine cost and operating cost. We also consider limitation of each manufacturing system such as production time, number of machine and production constraints. The assumptions of optimization model that the machine lifetime is five years.

### 3.3.2. Notations

#### Indexes

|   |  |
|---|--|
| P | Process type index, $P = 1, 2, \dots, p$ |
| I | Part type index, $I = 1, 2, \dots, i$    |
| M | Machine type index, $M = 1, 2, \dots, m$ |

#### Parameters

|                |   |
|----------------|---|
| $Input_{pim}$  | Number of input part type $i$ of process type $p$ at machine type $m$           |
| $Output_{pim}$ | Number of output part type $i$ of process type $p$ at machine type $m$          |
| $Capreq_i$     | Capacity requirement of part type $i$   |
| $Ratio_{pi}$   | Ratio of process $p$ of part type $i$   |
| $MCost_m$      | Machine cost of machine type $m$  |
| $OCost_{pim}$  | Operation cost of process type $p$ of product $i$ part type at machine type $m$ |
| $TIME$         | Production time per period  |
| $U_m$          | Percent allowance of capacity at machine type $m$                               |
| $T_{pim}$      | Operating time of process type $p$ of part type $i$ produce at machine type $m$ |
| $Budget$       | Maximum budget  |
| $MaxNum_m$     | Maximum number of machine type $m$  |

### Decision Variables

$Num_m$  Number of machine type  $m$

$NumProcess_{pim}$  Number of cycles of process type  $p$  of part type  $i$  produce at machine type  $m$

### 3.3.3. Model

#### Objective function

$$\text{Minimize } Z = \sum_{m \in M} (MCost_m) Num_m + \sum_{p \in P, i \in I, m \in M} (OCost_{pim}) NumProcess_{pim} \quad (1)$$

#### Subject to constraints

$$\sum_{m \in M} Output_{pim} NumProcess_{pim} \geq Ratio_{pi} Capreq_i \quad ; \forall p \in P, \forall i \in I \quad (2)$$

$$\sum_{m \in M} Output_{pim} NumProcess_{pim} \geq \sum_{m \in M} Input_{p+1,i,m} NumProcess_{p+1,i,m} \quad ; \forall i \in I, \forall p \in P \quad (3)$$

$$Num_m U_m TIME \geq \sum_{p \in P, i \in I} T_{pim} NumProcess_{pim} \quad ; \forall m \in M \quad (4)$$

$$Num_m \leq MaxNum_m \quad ; \forall m \in M \quad (5)$$

$$\sum_{m \in M} MCost_m Num_m \leq Budget \quad ; \forall m \in M \quad (6)$$

$$Num_m, NumProcess_{pim} \geq 0, \text{integer} \quad ; \forall i \in I, \forall p \in P, \forall m \in M \quad (7)$$

The objective (1) is to minimize total costs consists of machine cost and operating cost. Constraint (2) is the capacity requirement each process of product. Constraint (3) is balancing constraint to be built finished goods. Constraint (4) is the available time of machine. Constraint (5) is the maximum number of each machine type. Constraint (6) limits the investment budget for the machine selection. Finally, decision variables are imposed to be positive integer in constraint (7).

**3.3.4. Report.** The output from the optimization model provides the optimal number and type of machine and process allocation to each machine type at the minimum total production costs. The selected machine is able to produce multiple products and multiple processes. One process can be produced by multi-machine types by considering constraints. Table 2 shows the selected machine solution that three MC1 machines allocate to produce process P1 of product A and P1, P2, P3 of product B.

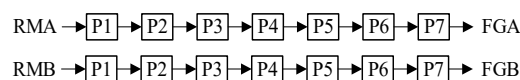
**Table 2.** Selected machine report

| Selected machine report |                    |              |              |
|-------------------------|--------------------|--------------|--------------|
| Machine type            | Number of machines | Product type | Process type |
| MC1                     | 3                  | A            | P1           |
|                         |                    | B            | P1, P2, P3   |

## 4. Numerical Example

The decision support system is validated with various types of the manufacturing system that have difference characteristic such as mouse key manufacturing has to produce and assembly process with one product and fruit and vegetable processing manufacturing is multiple products using multiple processes. Therefore, we present one example is clamps manufacturing.

A decision maker has to prepare capacity for clamps manufacturing system. The production system consists of two product types that is characterized by size such as Large(A) and Small(B) clamps. Both of two product has seven steps. The processes have difference input and output part ratio and five difference types of machines. They operate eight hours per day and five days a week to produce clamps 100,000 units per month with a ratio 1:1. The report of example is shown in Table 3.



**Figure 2.** Clamps production process.

Figure 2 shows the clamps production process. To achieve finished goods A (FGA), the raw material of product A have to produce in seven steps (P1, P2, P3, P4, P5, P6, P7). The product B also have the production process as product A

**Table 3.** Report of example

| Selected machine report |                    |              |                    |
|-------------------------|--------------------|--------------|--------------------|
| Machine type            | Number of machines | Product type | Process type       |
| MC1                     | 7                  | A, B         | P1, P2, P3, P4, P5 |
| MC3                     | 1                  | A, B         | P4, P6             |
| MC4                     | 2                  | A, B         | P6, P7             |

Table 3 shows the optimal solutions of the clamps manufacturing system. The number of selected machine types MC1, MC3, and MC4 are seven, one and two respectively. Each process can be produced by multi-machine types such as machine MC3 and MC4 allocate to produce process P6 of product A and B. Moreover, only one machine type is able to produce multiple products and multiple processes such as machine MC1 is allocated to produce process P1, P2, P3, P4 and P5.

## 5. Results and Discussion

The results of the model evaluation indicate the ability of the decision support system that can be applied in various types of the intermittent manufacturing system. Then, the decision support system evaluated by users (engineers) who working with the manufacturing system design such as clamps manufacturing, fruit and vegetable processing manufacturing and car seat manufacturing.

Their responses show the program capabilities that user-friendly design, quick and easy way to identify a solution, able to handle complex and unexpected machine selection problems and selecting an appropriate machine at minimum costs. However, a user has to understand the machine selection process which the data affects the solution of selected machine and import data requirements correctly.

## 6. Conclusion

This research, we develop the decision support system that intends to help decision makers to select an appropriate machine in order to achieve desired capacity and system capability. The model attempts to minimize total production costs by considering constraints. The proposed model can be applied in other intermittent manufacturing systems that contains multiple products using multiple processes including multi-machine types. In this research, the numerical example used to validate the model.

The result shows that the features of model are easy to import data and get the report. Moreover, the model focuses on simplify both complexity and uncertainty of machine selection problem to help decision makers (engineers, managers and owners) to reduce time and resources in the decision-making process.

## Acknowledgement

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