Mathematical Approach to Solve Multi-Model Assembly Line Balancing Problem

Fatin Fuad

Production Engineering and Metallurgy Department, University of Technology, Baghdad

Abstract: ***The problem of the multi-model line balancing is considered as a complex problem in balancing and more complicated than the single-model problem because the setup times have variety and relatively high, in addition to numerousness and variety of the products. The studies related to this subject is few, therefore, in this research detailed study is made on the multi-model line balancing problem and focusing on describing its characteristic and formulate the mathematical presentation and steps are suggested to solve the problem by using heuristic methods.***

Keywords: multi – model, line balancing, single model problem, heuristic methods

1. Introduction

Balancing of production line means, the arrangement of production line in the form and style in which easily flow occurs and systematic production processes move from one workstation to the next, so there is no delay or breakdown in any workstation, which would cause a stop in the next work, in the case of any breakdown, pending the arrival of the materials or parts to complete the manufacturing operations for them.

Assembly line is considered as a production type, which consists of a number of workstations arranged along an automated material handling system such as a conveyor belt. Work pieces are moved along the line from station to station, while each station performs a number of repeated operations necessary to manufacture a desired final product [1].

2. Literature Review

Liu et al (2005) [2]: propose a heuristic algorithm to solve the single-model assembly line balancing. For a given number of workstations, the proposed algorithm tries to obtain a solution with the smallest cycle time

Eryuruk et al. (2008) [3]: use two heuristics assembly line balancing techniques known as the "ranked positional weight" and "probabilistic line balancing". They applied to solve the problem of multi models assembly line balancing in a clothing company for two models. The aim of their study is the comparison of the efficiencies of two different procedures applied for the first time to solve line balancing in a clothing company.

There are three types of assembly line balancing problem, we clarified below:

1. Single-Model Assembly Line Balancing Problem: A single-model line produces only one product in large quantities. Every work unit is identical, so the task performed at each station is the same for all products. This line type is intended for products with high demand. The product flow in single model is presented in Figure (1) [4, 5, 6, 7].

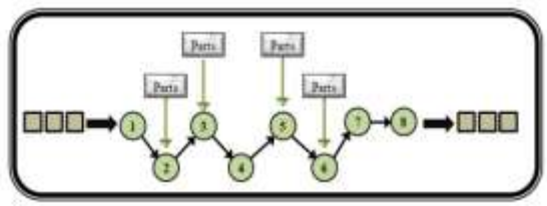

Figure 1: Product Flow in Single-Model Assembly Line

The single-model line problem is generated because of varying times of tasks. The goal of solution is trying to get to balanced times of workstations to reach the highest possible efficiency of the line. Single-model can be presented by a matrix which has one dimension (1*n)

Table 1: 1D Matrix of Single-Model

J	1	2	3	4	....	n
1	t_1	t_2	t_3	t_4	....	t_n

Where: t_J = (time of task J)
J = 1, 2, 3,…….., n
n = number of tasks

2. Multi-Model Assembly Line Balancing Problem: Multi-model line is designed to produce two or more products or different models of the same product. A multi-model line produces each model in batches. Workstations are set up to produce the required quantity of the first product, and then the stations are reconfigured to produce the next product, and so on. It is generally more economical to use one assembly line to produce several products in batches than to build a separate line for each different model.

When it is stated that the workstations are set up, we refer to the assignment of tasks to each station on the line, including the special tools needed to perform the tasks, and the physical layout of the station. In multi-model line there is a certain degree of similarity in production processes. However, differences exist among models so that a different sequence of tasks is usually required, and the tools used at a given workstation for the last model might not be the same as those required for the next model. Worker retaining or new equipment may be needed to produce each new model. For these kinds of reasons, changes in the station setup must be made before production of the next model can begin. These changeovers result in lost production time on a multi-model line. The products flow in multi-model line is presented by Figure (2) [4, 5, 8] .

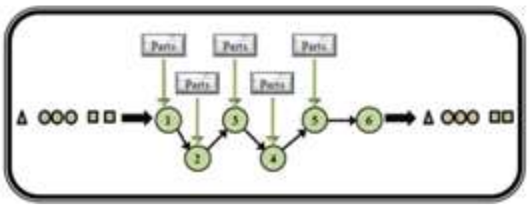

Figure 2: Products Flow in Multi-Model Assembly Line

Multi-model can be summarized by a matrix have two dimension (* J) as shown in Table (2).

Table 2: 2D Matrix of Multi-Model

I \ J	1	2	3	4	……..	n
1	x_{11}	x_{12}	x_{13}	x_{14}	……..	x_{1n}
2	x_{21}	x_{22}	x_{23}	x_{24}	……..	x_{2n}
3	x_{31}	x_{32}	x_{33}	x_{34}	……..	x_{3n}
⋮		⋮ ⋮	⋮	⋮	…..	⋮
K	x_{K1}	x_{K2}	x_{K3}	x_{K4}	……..	x_{Kn}

where: n = (the number of tasks)
J = 1, 2, 3, ……., *n* (task number)
K= (the number of products)
i = 1, 2, 3, ……, *K* (product number)

$$X_{iJ} = \left\{ \begin{matrix} 1 \text{ Product i is need task J} \\ 0 \quad \text{otherwise} \end{matrix} \right\}$$

3. Mixed-Model Assembly Line Balancing Problem: A mixed-model line also produces more than one product or model; they are made simultaneously on the same line. While one station is working on one model, the next station is processing a different model.

I \ J	1	2	3	4	……	n
1	t_{11}	t_{12}	t_{13}	t_{14}	…..	t_{1n}
2	t_{21}	t_{22}	t_{23}	t_{24}	….	t_{2n}
⋮	⋮	⋮	⋮	⋮	….	⋮
K ⋮	t_{K1} ⋮	t_{K2} ⋮	t_{K3} ⋮	t_{K4} ⋮	….	t_{Kn} ⋮

Each station is equipped to perform the variety of tasks needed to produce any model that moves through it. Many consumer products are assembled on mixed-model line and can be expressed in the same way as the expression of the multi-model assembly line. Products flow in mixed-model is presented in Figure (3) [9].

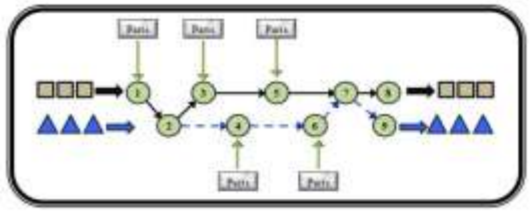

Figure 3: Products Flow in Mixed-Model Assembly Line

3. Experimental Procedure

In order to determine balancing formulation of the problem of multi-model, some of the important symbols and the basic formulation and features that affect the problem and how to resolve them are explained below:

1) Size of batches for each product

$$Z_i = \frac{Q_i}{B_i} \text{ …… …….. } (1)$$

Where:
$Z_i = Z_1, Z_2, \dots \dots Z_K$
$i = 1, 2, \dots \dots K$ (Number of products)
$Q_i = Q_1, Q_2, \dots \dots Q_K$ (Required quantity for each product)
$B_i = B_1, B_2, \dots \dots B_K$ (Number of batches for each product)

2) Time needed to complete a batch for each product

$$t_{B_i} = C_i * Z_i \text{ ………… } (2)$$

Where:
$t_{B_i} = t_{B_1}, t_{B_2}, \dots . t_{B_K}$
$C_i = C_1, C_2, \dots \dots C_K$ (Cycle time for each product)

3) The efficiency of the multi-model line

$$E_{multi} \% = \frac{\sum_{i=1}^{K} (E_i * t_{B_i})}{\sum_{i=1}^{K} t_{B_i}} * 100 \text{ ……(3)}$$

Where :
E_i : Efficiency of line for each product.

we can explain the most important determinants of the multi-model problem by process matrix (P. Matrix) and tasks times matrix (T.T. Matrix) as shown in Tables (3,4) respectively

Table 3: Process Matrix (P. Matrix)

i \ J	1	2	3	4	… …	n
1	x_{11}	x_{12}	x_{13}	x_{14}	….	x_{1n}
2	x_{21}	x_{22}	x_{23}	x_{24}	…..	x_{2n}
⋮	⋮	⋮	⋮	⋮	…..	⋮
K ⋮	x_{K1} ⋮	x_{K2} ⋮	x_{K3} ⋮	x_{K4} ⋮	…..	x_{Kn} ⋮

where $x_{iJ} \left\{ \begin{matrix} 1 \text{ product i is needed task J} \\ 0 \text{ otherwise} \end{matrix} \right\}$

Table (4) Task Time Matrix (T.T. Matrix)

Where:
t_{iJ} (The time of task J for product i)

The Table (5) represents the information for each product (number and size of batches and the maximum tasks times for each product)

Table 5: The Demand of Products

i	Q_i	B_i	Z_i
1	Q_1	B_1	Z_1
2	Q_2	B_2	Z_2
⋮	⋮	⋮	⋮
K	Q_K	B_K	Z_K

4. The General Steps for Solving Multi-Model Assembly Line Balancing Problem

The multi-model line problem will be considered as a sub-single-model problem and the steps in balancing the assembly line are as following:

1) Formulate the (P. Matrix)
2) Formulate the (T.T. Matrix).
3) Determine the required quantity for each product (Q).
4) Specify the number of batches for each product (B_i).
5) Specify the batch sizes for each product (Z_i).
6) Specify the sequential relationships among tasks using a precedence diagram.
7) Determine the required cycle time (C_i) for each product which can be $\max t_J$.
8) Determine the number of workstations for each product required to satisfy the cycle time constraint.
9) Assign tasks, one at a time, according to heuristic rule (RPW) to the first workstation until no other tasks are feasible because of time or sequence restrictions. Repeat the process for workstation 2, workstation 3, and so on, until all tasks are assigned.
10) Evaluate the efficiency of the balance for each single line.
11) The required time to complete each batch.
12) Calculate the efficiency of the line.

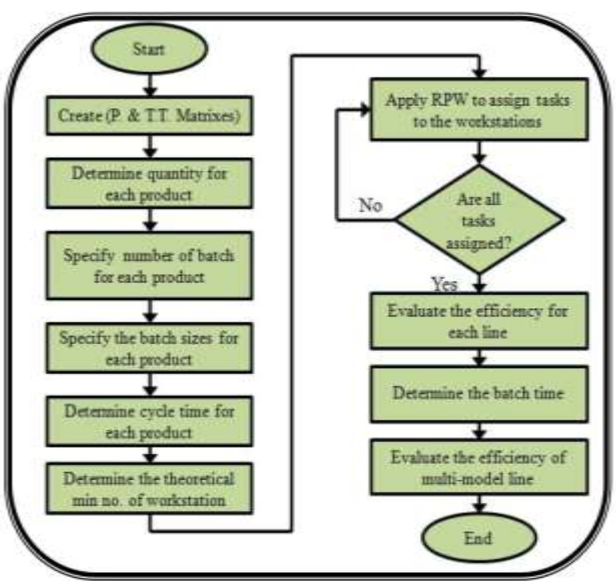

Figure 4: The details Steps for Solving the Problem

5. Conclusions

A detailed study of the concept of multi-model assembly line balancing problem where we reach the features of the multi-model line which include (the demand as batches, variation in technological route for products, the setup time is relatively high which are influence the total costs, variation in batch sizes, products are large and difficult to store in beginning or end or during the manufacturing process, the cycle time is different for each product, Restrictions and conditions of delivery of different batches, fulfill the batches without delay with the highest productivity and efficiency) The most important feature of these attributes is the amount of similarity in the technological route, which significantly affects the time and cost of the configuration of products, especially for large and heavy products, classified into the levels of adoption of the standard amount of similarity in route, symbolized by (S).

6. Future Scope

Further future work is needed as an extension to the work presented in this thesis, Extend the study to the mixed-model assembly line balancing problem, as well as apply simulation technology to simulate the problem.

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Author Profile

Ms. Fatin Fuad is a B.E. in Industrial engineering from university of technology/ baghdad and gets master degree of production planning, working at university of technology since 2012.