

## Integrating Assembly Planning and Line Balancing Using Precedence Diagram

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### Abstract

Traditionally, assembly planning and assembly line balancing are considered as two independent tasks. Assembly planning represents a fundamental step in the operation of a manufacturing system that involves product assembly while line balancing represents one of the biggest technical problems in designing and operating a manual assembly line. Although there have been several reported researches on assembly planning for mechanical products, there is no available research on integration of assembly planning and assembly line balancing.

In this paper, a methodology called COMSOAL-PLB (Computer Method of Sequencing Operations for Assembly Lines of Assembly Planning and Line Balancing) was developed to incorporate making decisions on process planning and production planning for assembly product. Using ASIA-PLB, a planner or manufacturing engineer can determine optimum or near optimum assembly sequence(s), optimum allocation the task sets that will maximize the efficiency. The system has been tested on product(x) in Seven Nissan Company. It resulted in reduction of idle time about 32%.

**Keywords:** Line Balancing, Assembly Planning.

### تكامُل التخطيط للتجميع وموازنة الخطوط باستخدام مخطط الاسبقية

#### الخلاصة

يعد التخطيط للتجميع وموازنة الخطوط مهمتين منفصلتين حيث يمثل التخطيط للتجميع خطوة رئيسية في أنظمة التصنيع والتي تتضمن تجميع المنتج بينما تمثل موازنة الخطوط من أعظم المشاكل التقنية في تصميم وتشغيل خطوط التجميع. ليس هناك بحث متوفر على التكامل لتخطيط التجميع وموازنة خطوط التجميع.

في هذا البحث المنهجية تدعى (COMSOAL-PLB) (نظام مؤتمت لتخطيط التجميع وموازنة الخطوط). يستخدم هذا النظام من قبل مهندس التخطيط او التصنيع يمكنه من تحديد افضل تتابع لتجميع المنتج, ويحدد تخصيص مهام التجميع الذي يعطي اعلى كفاءة. تم اختبار النظام على احد المنتجات الميكانيكية في شركة 7 نيسان حيث أدى الى تقليل الوقت الضائع بنسبة 32%.

### 1- Introduction

Assembly involves the integration of components and parts to create a product or system. Assembly planning is a crucial design step for generating a feasible assembly

sequence. Traditional assembly planning is manual and based on the experience and knowledge of industrial engineers. However, manual analysis does not allow the feasibility of assembly sequences to be easily

verified. Good assembly sequence planning has been recognized as a practical way to reduce operation difficulty, the number of tools and working time [1].

Assembly lines are a traditional widely used type of production systems for mass and large-scale production. They consist 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. Each sub-product unit remains at each station for a fixed work rate called the cycle time of the line [2]. The assembly line balancing problem (ALB) is a decision problem arising when an assembly line has to be configured or redesigned. The problem consists of determining the optimal partitioning (balancing) of the assembly work among the workstations while optimizing one or more objectives without violating the restrictions imposed on the line [3].

COMSOAL (Computer Method of Sequencing Operations for assembly Lines) is a computer heuristic originally being a solution approach for the ALB problem. It can be used to generate a feasible solution to resource allocation problems for each iteration. After repeatedly running COMSOAL, it results in many feasible solutions which the best is chosen. Many researchers indicate that COMSOAL is a viable method to solve resource allocation problems when compared to the results from several well-known

resource allocation algorithms. In some cases, optimal solutions can also be found [4,5].

## 2- Basic Problem of ALB

An assembly line consists of (work) stations  $k = 1, \dots, m$  usually arranged along a conveyor belt or a similar mechanical material handling equipment. The workpieces (jobs) are consecutively launched down the line and are moved from station to station. At each station, certain operations are repeatedly performed regarding the cycle time (maximum or average time available for each work cycle).

Manufacturing a product on an assembly line requires partitioning the total amount of task into a set  $V = 1, \dots, n$  of elementary operations named tasks. Performing a task  $j$  takes task time  $t_j$  and requires certain equipment of machines and/or skills of workers. The total workload necessary for assembling a workpiece is measured by the sum of task times. Due to technological and organizational conditions precedence constraints between the tasks have to be observed. These elements can be summarized and visualized by a precedence graph. It contains a node for each task, node weights for the task times, arcs for the direct and paths for the indirect precedence constraints. Fig.1 shows a precedence graph with  $n = 9$  tasks having task times between 2 and 9 (time units). Any type of assembly line balancing problem (ALBP) consists in finding a feasible line balance, i.e., an assignment of each task to a station such that the precedence constraints (Fig. 1) and further restrictions are fulfilled [5,6].

### 3- The Most Methods of Line Balancing.

They are heuristic approaches - based on logic and common sense rather than on mathematical proof. They do not guarantee an optimal solution, but result in good solutions which approach the true optimum.

1. Largest-candidate rule:
2. Kilbridge and Wester's method:
3. Ranked positional weights

method:

### 4- Methodology

An assembly line is a sequence of workstations connected together by a material handling system. It is used to assemble components into a final product. The assembly process consists of a sequence of tasks or work elements. A task consists of some elemental operations which are tied together because of the use of a common tool or fixture. Accordingly, tasks cannot be sub-divided and must be completed at their assigned workstations. The tasks in an assembly process typically must be ordered and have priority requirements to be enforced. The assembly line balancing problem is the issue of assigning tasks to work stations. Because tasks may require widely different times, the assignment of task times to work stations are rarely equal. This leads to idle time at workstations.

#### 4-1 Procedure for Line Balancing

**Step 1:** Draw a precedence diagram to show the tasks' sequential relationships on cycle times.

**Step 2:** Compute the cycle time, which is the length of time between two successive units to be completed.

$C = \text{Production time per day} / \text{Throughput per day}$

**Step 3:** Compute the theoretical minimum number of work stations.

$N_t \geq \text{Total task time} / C \dots [2,4]$

**Where  $N_t$ :** theoretical workstation

**Step 4:** Determine the actual number of work stations used,  $N_a$ .

**Step 5:** Compute the efficiency of the line.

$\text{Efficiency} = \text{Total task time} / (N_a * C)$   
... [2,4]

$\text{Balance Delay} = 1 - \text{Efficiency}$

#### 4-2 System Development

The general algorithm for the construction of assembly sequences is the following as shown in figure (2):-

**Step 1** The starting point are the lists of part names, ordered in accordance with the spread graphs. Assume for the analysis a list which has not been considered yet. Go to **Step 2**.

**Step 2** Check the possibility of creating a sequence based on single parts, starting from the top, and sequences starting from the bottom. When such sequences exist, go to **Step 1**. Otherwise go to **Step 3**.

**Step 3** In **Step 2** one has come across a part which cannot be assembled individually, e.g., it is not suitable for a base component, it does not have a frontal contact with the parts which have been mounted, etc. Now, try to construct a subassembly including this part and fulfilling such constraints. If this is successful, describe the subunit in the assembly sequence, i. e replace single parts from the spread list with a subunit structure. Repeat this procedure until the assembly sequence is complete. Go to **Step 4**.

**Step 4** For all the subunits: repeat the procedure **Step 2**, **Step 3** until you obtain a sequence composed of single parts. Go to **Step 5**.

**Step 5** Check if there are still any unconsidered lists. If so, go to **Step 1**. Otherwise, terminate.

#### **5- Analysis of Assembly Object and Process for the Product (x)**

The product (x) is one of the most important products produced in Seventh-Nissan Company as illustrated in figure (3). An assembly chart for the product (x) is prepared from the assembly drawing. Through this chart main assembly and sub-assemblies can be determined. Also this chart shows each step in the assembly process and the parts which go into final product, as illustrated in figure (4).

Depending on assembly of the drawing for Product (x), we can see the product is composed of two sub-assemblies: the striker sub-assembly and the safety sub-assembly as well as some parts such as pin, cone, standard balls, body, large, washer and booster. The final assembly needs 19 process of assembly tasks, as shown in table (1) while figure (11) shows the precedence diagram for main assembly.

#### **6- The COMSOAL-PLB Testing:**

COMSOAL-PLB is a new and versatile approach to solution of a classic volume manufacturing problem. It is intended for use by Industrial and Manufacturing Engineers or production supervisors, managers, or planners to allocate labor to progressive assembly lines to achieve the most productive output. This unique program finds the absolute

optimum solution for balancing work tasks on any progressive assembly line, providing a solution in both text and graphic formats. In COMSOAL-PLB, you can save entire process descriptions and summary graphs as well as individual work elements. You can build a "library" of work elements and insert or append new elements or groups into your assembly line process at any time.

The system automatically draws assembly Precedence Diagrams which show relationships between and among all Standard Elemental Tasks. Tasks are color-coded, numbered, and tagged with standard time values. Diagrams of virtually any complexity are structured automatically as tasks are added to the program. The node (circle) for any element can be dragged and repositioned with a mouse as shown in figure (6).

you can select the criteria to solve any line balancing problem – use either cycle time or the number of workers desired on the line. Flexible line balancing will perform hundreds of computations to arrive at the optimum solution for the conditions you've provided. When done, the program will present a graphic analysis of the balancing solution. The graph below shows the cycle time, the longest station time and how elements are combined at each worker's station. Flexible Line Balancing also instantly computes Line Balancing Efficiency, which is measure of lost time due to imbalance in the process, as shown in figure (7).

## 7- Conclusions

Integration assembly planning and assembly line balancing (ASIA-PLB) system is being developed to help planner and manufacturing engineers to select optimum sequence for product. From the research work, the following conclusions can be drawn.

1. The choices of assembly sequence without the aid of computer is are very difficult for two reasons. First, the number of valid sequences can be large even at a small parts count and can rise with increasing part count, and second minor demand of product changes can modify the available choices of assembly sequences.
2. Usually the assembly sequence is considered at the final stages when the engineer tries to balance the assembly line.
3. The process is generally constrained by particular characteristics of the process itself, of the system and of component parts of the product.
4. The opportunity to group assembly operations at one workstation criteria is considered assembly tasks requiring the same facility so they must be grouped together. The objective of this criterion is to minimize the fixtures used and / or maximize tool sharing or them.

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Table (1) Assembly task for final product (x).

Process number.	Description of assembly process	Standard time (sec)
1	Assembly body with striker	13.18
2	Put paper washer	5.98
3	Inspection paper washer	7.59
4	Inspection primer	8.55
5	Assembly primer with body	10.46
6	Put paper washer	5.17
7	Inspection paper washer	1.00
8	Put the standard balls	3.71
9	Put the cone	8.76
10	Put pin inside body	5.69
11	Assembly pin with body	3.77
12	Fold the cone	4.00
13	Inspection	12.50
14	Put the safety inside body	1.72
15	Assembly safety-subassembly with body	13.87

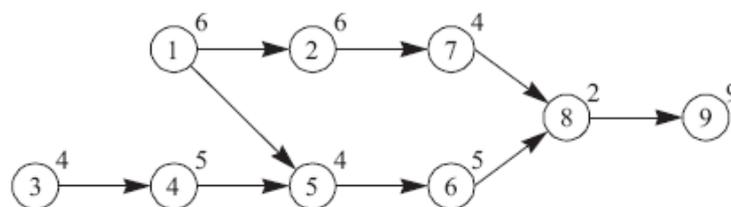


Figure (1) Precedence Graph

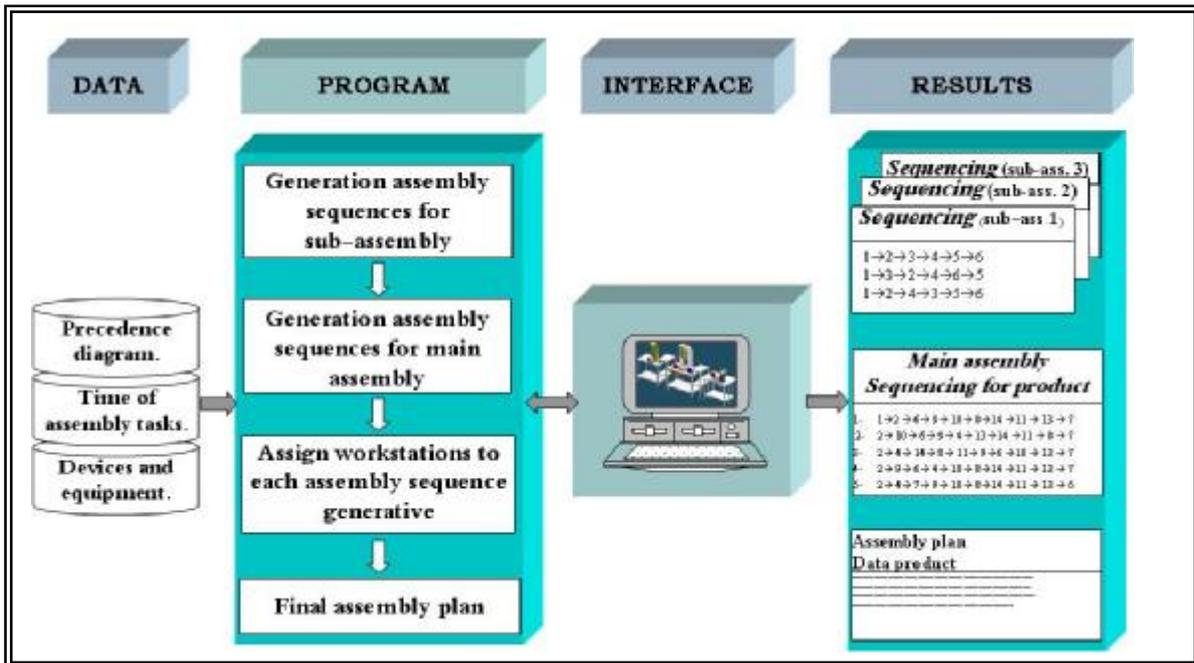


Figure (2) Depicted of The System Methodology

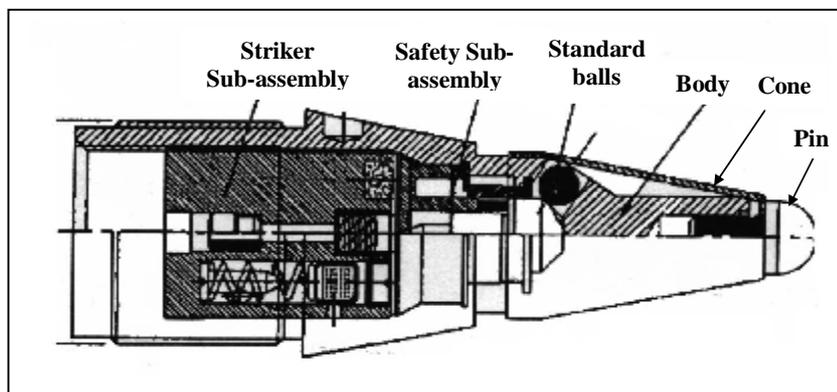


Figure (3) Assembly Drawing For Product (x)

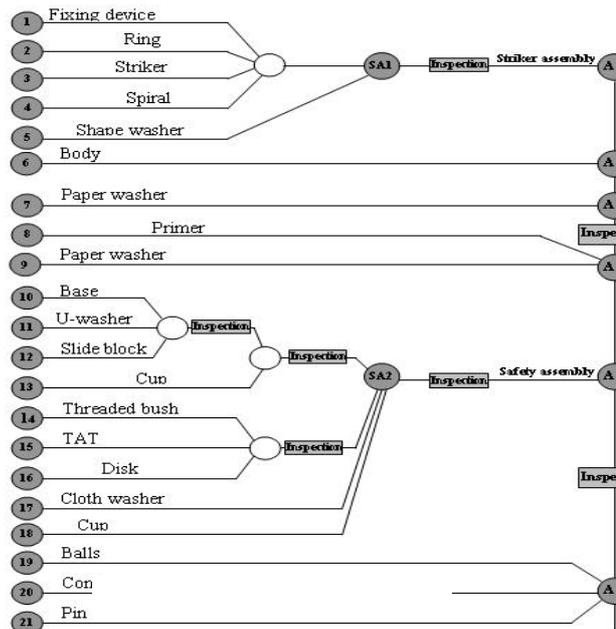


Figure (4) Assembly Chart For the

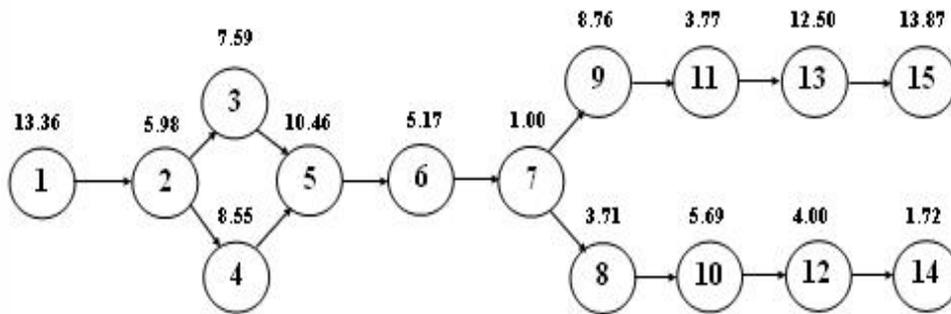


Figure (5) Precedence diagram for main assembly

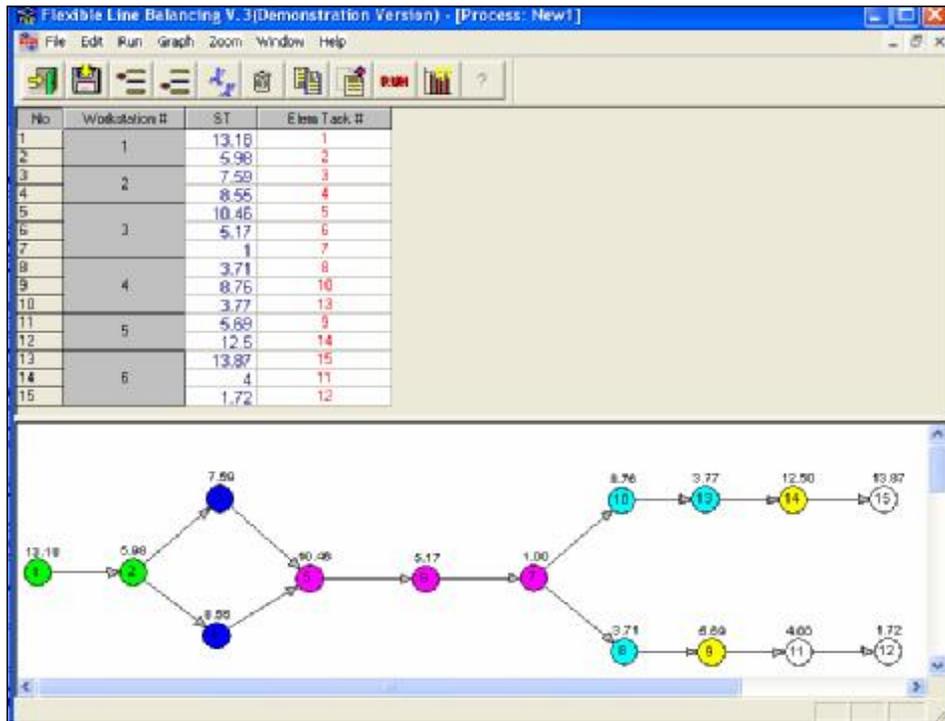


Figure (6) The Graphic Workplace Portion of the Screen.

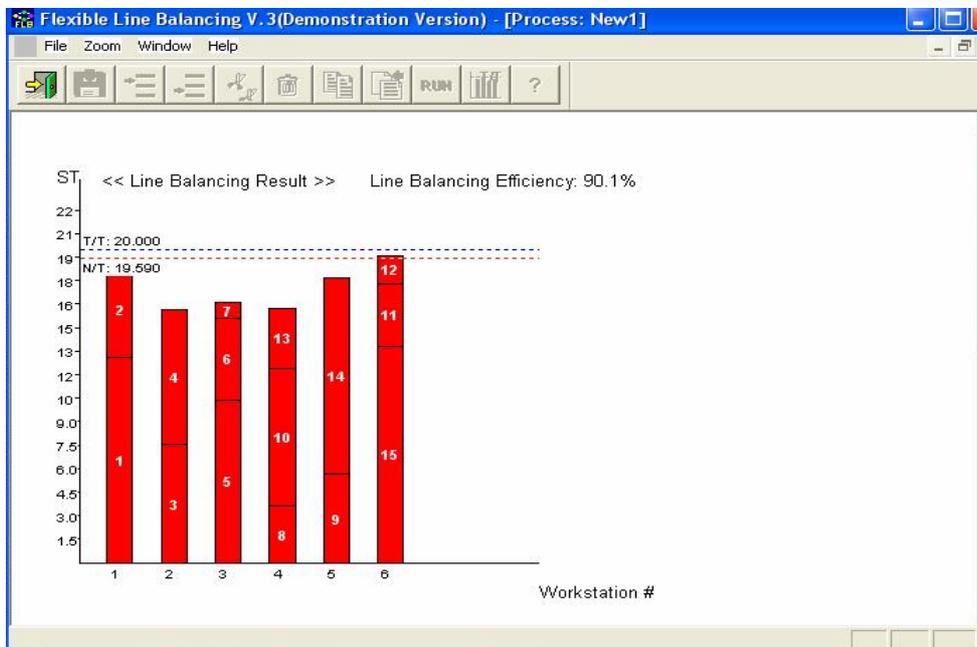


Figure (7) Line Balancing Result Screen