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4

# Model Sequencing and Worker Transfer System for Mixed Model Team Oriented Assembly Lines

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## 1. Introduction

Assembly lines are the most commonly used method for a mass production environment. Their main purpose is to increase efficiency by maximizing the ratio between throughput and required costs. However, in the last few decades, market demands have changed enormously. The emphasis is now on shorter lead times, larger product variety, higher quality and more customized options. At the same time, socioeconomic conditions have improved and workers have a greater interest in work satisfaction. Increasing the importance of quality and flexibility of the assembly system, while providing a satisfying work environment, these changes lead to the utilization of teamwork for assembly line design. Unlike conventional assembly lines, team-oriented assembly lines consist of multimanned workstations, where workers' groups simultaneously perform different assembly works on the same product and workstation. In addition, it is also different from installing parallel (multiple) stations, where individual products are distributed among several workers who perform the same tasks but on different products (Dimitriadis, 2006). Team-oriented assembly systems in which workers are organized in groups outperform traditional assembly systems in terms of cost, lead time, flexibility, quality, and worker satisfaction. However, in such lines, performance is affected in a negative way on the condition that high level of variability among station times result in utility and idle times.
Some research in the literature states the convenience of team oriented assembly systems for current market needs when compared to conventional assembly lines the stations of which consists of one worker. For instance, Wild, R. (1975) examined the types, basic design considerations and benefits of teamwork. The author stated that implementing teamwork yields good results in quality development and workers may benefit via increased confidence through the development of social skills in a teamwork environment. Groover, M. P. (2001) maintained that compared with workers on a conventional line, the members of an assembly team achieved a greater level of personal satisfaction at having accomplished a major portion of product. Bukchin, J. et al. (1997) provided a straightforward study applying teamwork approach to assembly line design. According to the authors, team-oriented assembly system approach should be used to overcome the disadvantages of classical assembly design: low quality, poor working environment, long flow time and high costs of material handling. In spite of the fact that teamwork approach is applied in assembly lines frequently, very few reported studies have utilized. Johnson, R. V. (1991) discussed the fact that labor cost increases with both the number of the teams and the percentage of tasks that

can be allocated to one team only when using disconnected teams for balancing. Bukchin J. and Masin M. (2004) presented a multi objective design of team oriented assembly system requiring bill of materials of the product. They proposed both the optimal solution procedure based on a backtracking branch and bound algorithm and a heuristic algorithm based on the optimal algorithm for large-scale problems. More recently, in Dimitriadis (2006), a two-level heuristic for single model team-oriented ALBP has been proposed. However, this heuristic attempts to solve balancing problem for only single model assembly line.

What is more, the capability of synchronous assembly of products an important matter when considering current market needs. However, in mixed model assembly lines (MMAL), complication exists as result of congestion and starvation caused by the arrival of different models to the line, having different assembly time requirements at each station. In this context, an effective model sequencing for mixed model assembly line (i.e. determining the order in which products have to be introduced into the assembly line) increases the performance of such a line.

Sequencing is usually carried out with the two primary goals such as levelling the workload (total operation time) at each workstation on the assembly line to reduce line inefficiencies such as idleness, utility work, work deficiency and work congestion (Thomopoulos, 1967; Macaskill, 1973, Bolat and Yano, 1992; Xiaobo and Ohno, 1997; Hyun et al., 1998; Sarker and Pan, 2001; Erel et. al., 2007), keeping a uniform parts usage (Xiaobo, et al., 1999; Tamura, et al., 1999; Jin and Wu, 2002; Kurashige, et al., 2002; Ventura and Radhakrishnan, 2002). What is more, some attempts have been made to solve multi-objective MMAL sequencing problem via heuristics (Kotani et al., 2004; Aigbedo and Monden, 1997; Korkmazel and Meral, 2001), metaheristics (Tavakkoli-Moghaddam and Rahimi-Vahed, 2006; Akgunduz and Tunali, 2010) and mixed integer linear programming models (Giard and Jeunet, 2010).

When considering the large body of literature, it is revealed that there has not been any published study addressing both worker transfer and sequencing in MMALs. That being the case, in this chapter, a model sequencing and worker transfer systematic for team oriented assembly lines is developed. Utility time is considered in the determination of bottleneck station(s) via simulation. Then, model sequencing with four method alternatives and worker transfers between sequential stations are utilized as the two techniques to reduce utility time. Last but not least, the proposed systematic has the potential of being applied to real-life industrial sized MMALs. In this context, a real life mixed model tractor assembly system is presented to demonstrate the application of the proposed system.

The remaining sections of the chapter are organized as follows. In Section 2, the description of the problem is presented. In Section 3, proposed model sequencing and worker transfer systematic given.. Section 4 contains industrial application of the proposed methods to a real life assembly system and finally in Section 5, conclusions are provided.

## 2. Description of the problem

The following are the characteristics of the mixed model assembly line in which the problem arises and problem assumptions:

- The assembly of the products is performed when they are moving on the conveyor system with a constant speed through the assembly line which consists of $K$ work stations.
- An assembly team work in each station. The members of a team simultaneously perform different assembly works on the same product and workstation.

- Consecutive products are launched on the line from the first station at a constant time interval.
- The products enter each work station in the same sequence.
- There is no buffer between work stations.
- Each product model may have different assembly times which are assumed to be deterministic.
- The product moves on a conveyor which has a constant speed.
- Each work station has upstream and downstream boundaries.
- The operator returns to the upstream boundary of the station or to the next product, whatever is reached first, in zero time after finishing the work load on the current product due to the fact that the speed of conveyor is much slower than the walking speed of the workers.
- When utility work occurs (i.e. the operator can not complete the assembly tasks of a product within his/her allowable work zone), utility workers are utilized. Whenever the operator finds that he/she might fail to complete the operation within his/her work zone, he/she calls the utility worker who additionally assists such that the work can be completed on time.
- Each utility work can be performed on time (i.e. a constraint in terms of utility worker does not exist.)

An example of operators' movements in their work stations is shown in Figure 1. The lines with arrowheads represent assembly times and dotted lines represent the movement of the operators. The conveyor moves from the left to the right. Physical length of workstation "$k$" is denoted by $PL_k$. The line consists of four work stations the boundaries of which are represented by vertical lines. Tem sizes of stations are two, one, three and two, respectively. Two utility workers exist to assist operators in the work stations when they fail to complete their work in their work zone. The first utility worker is responsible for performing utility work occurred in work stations 1 and 2 (i.e. Line Segment 1). Similarly, the second utility worker performs utility work occurred in work stations 3 and 4 (i.e. Line Segment 2). To reach the product in position 7 in work station 1, the operator can not go beyond the upstream station boundary and he/she has to wait $ot_1$ time units. In work station 2, the operator can not complete the jobs on products in the positions of 3 and 7 until downstream boundary. Therefore, a work overload of $ut_1$ time units are performed on product 3, and $ut_4$ time units on product 7 is performed by utility worker 1. Similarly, in work station 3, a work overload of $ut_2$ time units are performed on product 4 is performed by utility worker 2.

## 3. Proposed methodology

Proposed methodology consists of five steps as shown in Figure 2. Each of these steps will be explained in this section. As mentioned above, the chapter focuses on model sequencing and worker transfer. These two concepts are the last two stages of a five-stage methodology developed by Cevikcan et al. (2009) that can be seen for a detailed discussion of the first three stages. Due to the fact that this chapter focuses on model sequencing and worker transfer system, first three steps of the methodology have not been explained in detail so as not to expand the study in scope.

The following notation is used within this chapter:

$UT_t$= total utility time for team combination "$t$"

$C_m$ = cycle time for model "$m$"

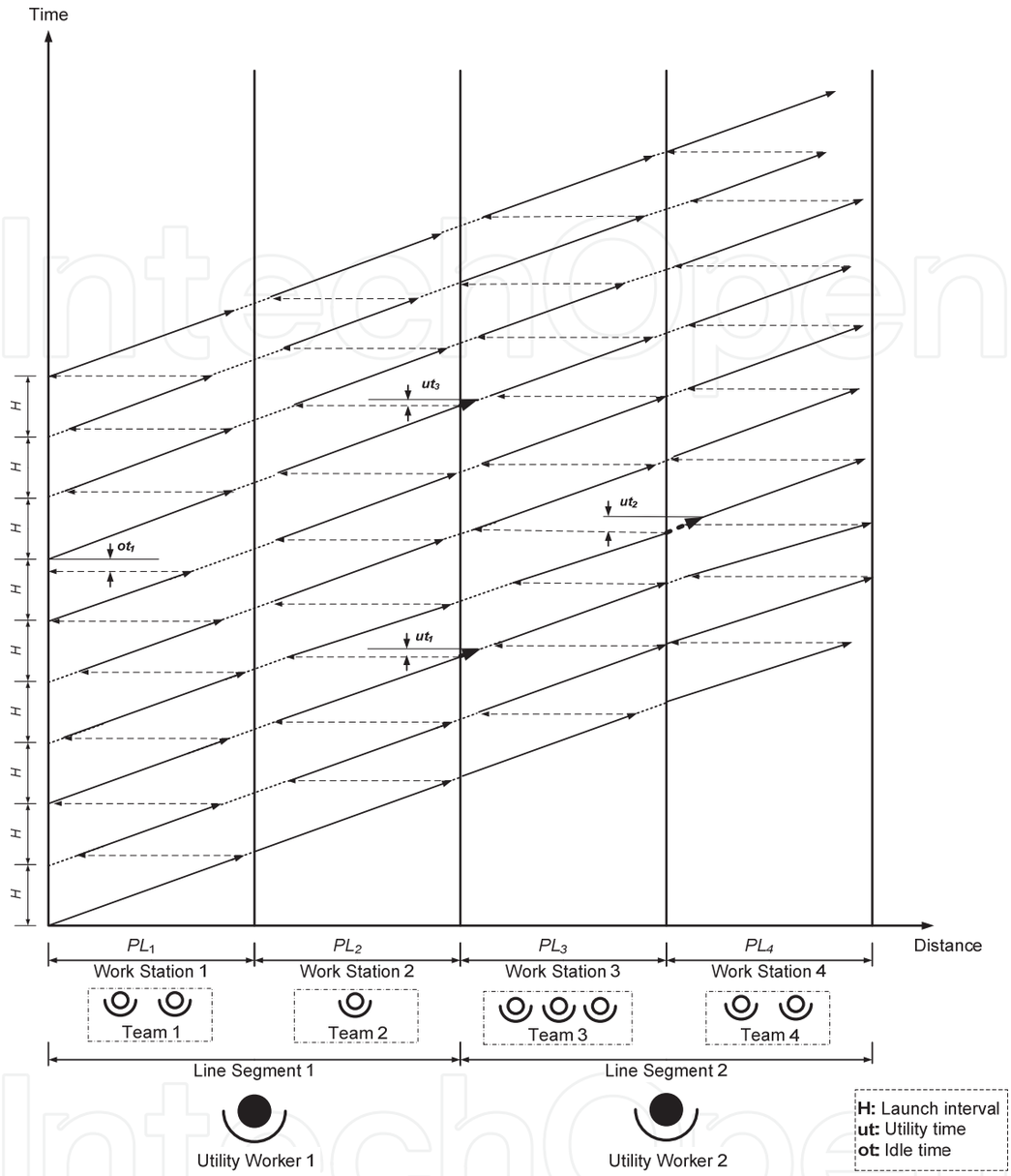



Fig. 1. Operator movement diagram

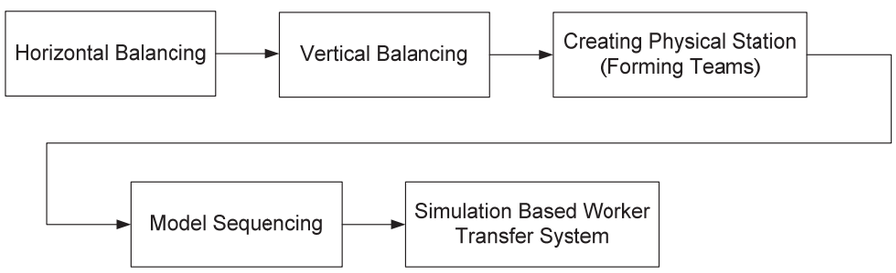



Fig. 2. Proposed methodology

$CW$ = weighted average cycle time
$d_m$ = demand for model "$m$"
$D$= total demand
$DD(m,p)$ =Priority value of $p_{th}$ product of model "$m$"
$M$ = the number of models
$m(j)$ = the model in the $j_{th}$ sequence
$m$ = index for model
$m_k$ = the size of $k_{th}$ team before worker transfer
$m'_k$ =the size of $k_{th}$ team after worker transfer
$p_m$ = $p_{th}$ product of model "m"
$sr$ = parameter value of search range
$t$ = index for team combination

### 3.1 Horizontal balancing

Horizontal balancing is an efficiency improvement process that groups the tasks into families such that of each task family takes the time as close as the required cycle time (or takt time) of each model or model family without exceeding this cycle time and violating the precedence relation between tasks. When the five steps of the methodology are considered, the horizontal balancing will have a marginal effect on the whole system performance. Therefore, the algorithms which seek the optimal solutions, were not comprehensively analyzed in the literature, a practical and fast algorithm was decided to be chosen for industrial cases. The chosen algorithm is "regional approach" heuristic which is suggested by Bedworth and Bailey (1987).

### 3.2 Vertical balancing

Although the result of the horizontal balancing satisfies the cycle time constraints, it could be unfair task assignments between workers. Therefore a vertical balancing procedure is performed (Merengo et al., 1999). This procedure tries to reassign some of the tasks of the workers who have more workload than the average, to the workers who have less, under the constraints of precedence relations and cycle time.

### 3.3 Creating physical station

In traditional assembly lines, only one worker per station is assumed, however this is not the actual situation on the shop floor in today's assembly systems. Different number of workers works together as a team in one place/station. Figure 3 shows the algorithm developed for forming teams.Team formation approach in this chapter, is based on the heuristic algorithm which is developed for project scheduling under limited resources (Elsayed and Boucher, 1985). Here, a modified version of this algorithm is used for a different field. Re-allocating tasks to workers (resources) under assembly time (ASTIM) criterion are performed using this algorithm.
The maximum allowable number of workers for a physical station, i.e. the maximum size for teams is an important external constraint for the methodology. The team has to be large enough in order to enable team dynamics and allow a variety of ideas and skills, yet small enough to enable cohesiveness of the team members.
Human interactions are added to the algorithm, considering the different design parameters of a real life assembly system. The user compares physical station assembly time with model

cycle times for each team size and eliminates each the team size alternative even if its physical station assembly time exceeds the pre-determined tolerance of cycle time for a single model. The different design parameters of a real life assembly system is considered during this stage. The determination of the team size in the considered station could depend on the location of the station and the location depends on the task sets being assigned to the teams until the considered station. In a team oriented assembly line, some work elements assigned to a worker of a specific workstation can be delayed by the work elements assigned to some other worker of the same workstation, hence physical station assembly times are allowed to exceed model cycle times within a tolerance (0-20%).
The step of creating the physical station begins with the first worker, and proceeds consecutively with respect to the sequence of workers. For instance, if he/she chooses three as the size of the first team, the algorithm starts to schedule team size alternatives such that the first worker of the second team is worker 4. The algorithm stops creating the physical station process when the last worker is assigned to the last team. The following section describes the scheduling of assembly tasks for a team of workers.

### 3.4 Model sequencing

At this step, the sequence with which the models of the product will enter the assembly line will be determined. Figure 4 shows the model sequencing flow diagram of the methodology. While evaluating each sequencing algorithm, total utility time is regarded as the performance measure. The sequencing algorithm with the lowest utility time is preferred among alternative methods for the current scheduling period.
According to Figure 4, on the condition that a mixed model sequence is developed instead of batch sequence, the utilization of cycle time as a parameter is concerned. When cycle time of each model is used for model sequencing, cycle time based sequencing algorithm is applied. If demand values of models are considered as a sequencing parameter, demand value based sequencing algorithm is focused. What is more, an algorithm is included to the systematic so as to improve the performance of demand value based sequencing algorithm in terms of utility time.

#### 3.4.1 Cycle time based sequencing algorithm (CTBSA)

That models with longer station times should not enter the line consequently is considered in model sequencing because of the fact that in the sequence, consecutive positions of models with long assembly times trigger utility time. On the other hand, the assembly times are proportional to cycle time due to cycle time constraint in assembly line balancing problem. Therefore, regarding cycle time as an indicator of a work content for a product model, CTBSA utilizes the cycle time with the aim of workload levelling among stations. CTBSA attempts to position models with longer cycle time and models with shorter cycle time consecutively with the aim of decreasing utility time. The steps of the cycle time based sequencing algorithm are as follows:

1. Calculate the weighted average cycle time (*CW*).

$$CW = \sum_{m=1}^{M} C_m * d_m \tag{1}$$

2. Assign the value of 1 to *j* (sequence index).

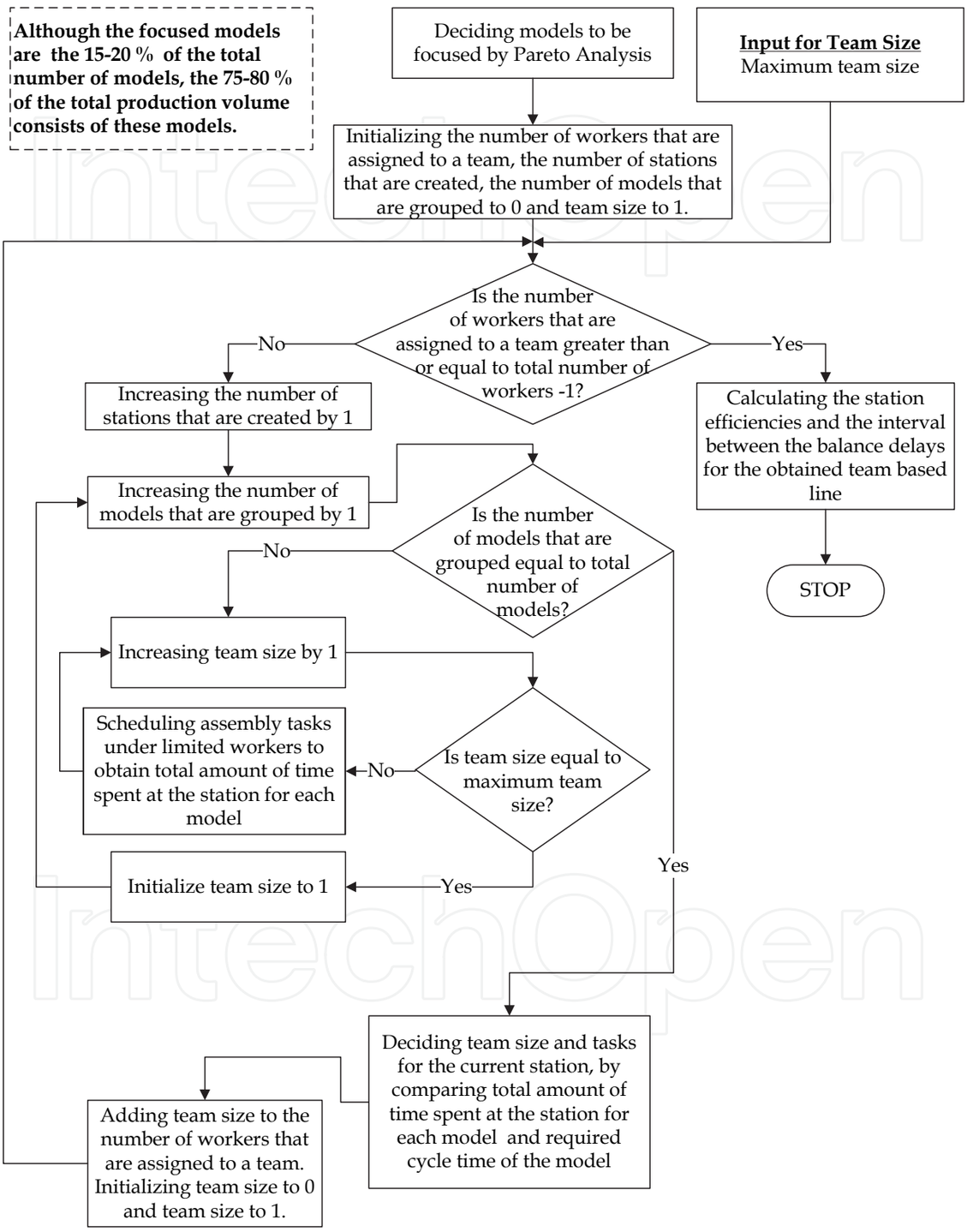



Fig. 3. Algorithm for team forming

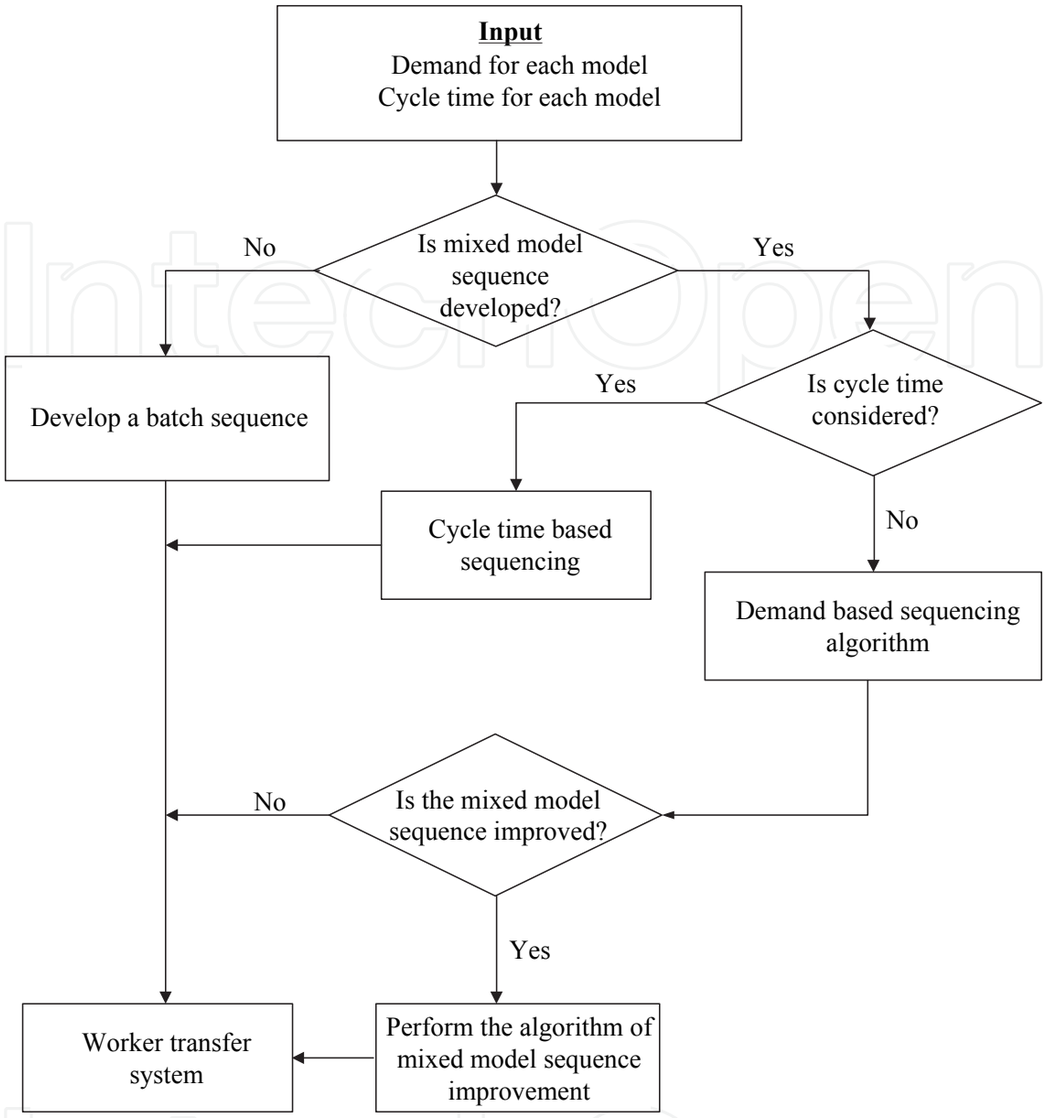



Fig. 4. The model sequencing flow diagram

3. Calculate binary average cycle time of $j_{\text{th}}$ model and each of the following models in the sequence.
4. Calculate the absolute value of the difference between the weighted average cycle time and each binary average cycle time.
5. Find the following model with the lowest absolute value other than itself.
6. Assign the value of "$j$+1" to the sequence number of this model.
7. Increase "$j$" by one.
8. Go to step 9 if $j$=$D$-1, otherwise go to step 3.

$$D = \sum_{m=1}^{M} d_m \tag{2}$$

9. Stop.

### 3.4.2 Demand based sequencing algorithm (DBSA)

The data requirement is a critical issue for the methods for production systems. Therefore, data requirement affects the adoption of the method in real life production systems. For instance, when BOM (Bill of Materials) data for assembly is required for a MMAL sequencing method, the potential of applying sequencing method reduces because of the fact that it is very difficult to update BOMs in real life assembly systems. That being the case, for real life assembly systems, the sequencing methods with simple data requirement is preferred and developed within this chapter. As an indicator of this issue, demand based sequencing algorithm, the parameter of which is only demand value of each model, is included to the study. The following simple formula is suggested for DBSA (Merengo et al., 1999):

$$DD(m,p) = \left( p - \frac{1}{2} \right) \frac{D}{d_m} \tag{3}$$

This value is calculated for each model type and $p$, and then the sequence is generated by sorting these values in ascending order. Since DBSA does not include time-based parameters, it can be enhanced in terms of workload leveling via the algorithm the steps of which are given below:

1. Calculate the weighted average cycle time.
2. Assign the value of 1 to $j$ (sequence index).
3. Determine "$pc$" value (the number of pair-wise comparisons).

$$pc = \left( \frac{D}{d_{m(j)}} \right)^{+} + sr \tag{4}$$

4. Calculate binary average cycle time of $j$th model and each of the following "$pc$" models in the sequence seperately.
5. Calculate the absolute value of the difference between the weighted average cycle time and each binary average cycle time.
6. Find the following model with the lowest absolute value other than itself.
7. Assign the value of "$j$+1" to the sequence number of this model.
8. Increase "$j$" by one.
9. Go to step 10 if $j$=$D$-1, otherwise go to step 3.
10. Stop.

### 3.5 Simulation based worker transfer system

In order to eliminate the problems arising from the system unexpected events such as noise factors, the worker transfer (WT) system is built between neighbor stations by the help of computer simulation after model sequencing. The bottleneck and idle stations are determined with respect to the status of the assembly system (i.e. changing the model sequence, the model demands etc.) before the day starts. The worker transfer strategy is established based on the output of the simulation. The proposed methodology is a dynamic design methodology. Horizontal/vertical balancing and creating physical station are performed at the time for only adding or extracting the models. The frequency of model sequencing and worker transfer system is once or more than once every day if necessary. Developed procedure to eliminate bottlenecks is as follows:

1. Determine current team combination as the result of the third step of the methodology.
2. Determine the bottleneck station "*R*" with the highest total utility time in current team combination via simulation.
3. Generate team combinations by decreasing the size of station "*R*" by one when increasing the size of an upstream station of station "*R*" by one.

$$m'_R = m_R - 1 \tag{5a}$$

$$m'_k = m_k + 1 \qquad k=R-1, R-2, \ldots, 1 \tag{5b}$$

4. Generate team combinations by increasing the size of station "*R*-1" by one when decreasing the size of an upstream station of "*R*-1" by one.

$$m'_{R-1} = m_{R-1} + 1 \tag{6a}$$

$$m'_k = m_k - 1 \qquad \forall k : m_k \neq 1 \wedge k < R-1 \tag{6b}$$

5. Determine assembly time of stations of each generated team combination.
6. If there exists one or more team combination satisfying cycle time constraint with respect to assembly times for each model, go to step 7; otherwise go to step 11.
7. Calculate total utility time for each feasible (satisfying cycle time constraint) generated team combination.
8. If there exists one or more team combination(s) which has/have lower utility time than current team combination, go to step 9; otherwise go to step 11.
9. Determine the team combination with the best performance by regarding total utility time.
10. Make the team combination which is determined in step 9 be the current team combination and go to step 2.
11. Make the current team combination be the final team combination and stop.

## 4. Industrial application

The proposed methodology is applied to a chosen segment of a tractor assembly system. The tractor assembly system consists of ten segments and each segment includes many interrelated tasks (Figure 5). Among these segments, the fourth segment of the main line is chosen for the analysis of the proposed methodology. Brake pedal, motor, bumper support assembly is performed in this segment. Table 1 shows the cycle time of each model.

| Model | Code | Cycle time (seconds) |
|---|---|---|
| T240 | 1 | 355 |
| T266 | 2 | 576 |
| T3075 | 3 | 576 |
| T3085 | 4 | 672 |
| T431 | 5 | 456 |
| T461 | 6 | 486 |

Table 1. Cycle time of each model

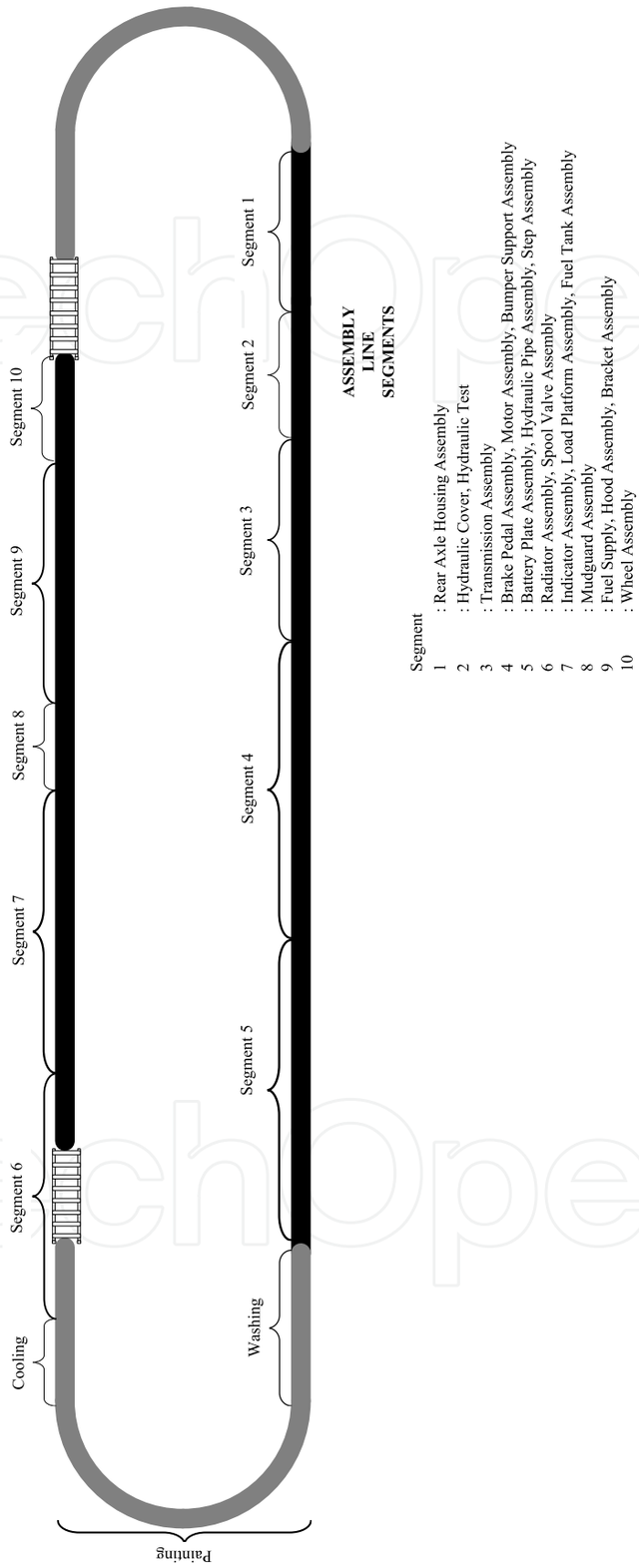



Fig. 5. The Segments of Tractor Assembly Line

In the step of physical station creating, 7 is regarded as the maximum allowable number of workers for a physical station. In this step, the computer program gives user team size alternatives, their assembly time and % deviations of physical station assembly time from cycle time for each model. In this context, the user decides a team size for each physical station. In this application, the user eliminates each the team size alternative when its physical station assembly time exceeds % 15 of cycle time for a model. Fourteen workers are grouped in seven assembly teams as the output of this step. The sizes and assembly times of teams are given in Table 6.

| | **Station Number** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **Team Size** | **3** | **1** | **2** | **3** | **2** | **2** | **1** |
| **Models** | **Assembly Time (seconds)** | | | | | | |
| **1** | 355 | 301 | 265 | 286 | 246 | 321 | 285 |
| **2** | 400 | 398 | 393 | 556 | 483 | 234 | 285 |
| **3** | 335 | 330 | 393 | 402 | 448 | 341 | 285 |
| **4** | 335 | 228 | 393 | 414 | 395 | 363 | 285 |
| **5** | 342 | 264 | 265 | 285 | 293 | 345 | 285 |
| **6** | 342 | 345 | 265 | 317 | 339 | 345 | 285 |

Table 6. The sizes and assembly times of assembly teams

When determining the most appropriate model sequence, four different alternatives are considered which are listed below. Furthermore, the relevant data about sequencing methods are given in Table 7.

| **Model** | **Code** | **Demand Weight** | **Daily Demand** | **Number of pairwise comparisons** |
|---|---|---|---|---|
| T240 | 1 | 0.492 | 39 | 3 |
| T266 | 2 | 0.255 | 21 | 5 |
| T3075 | 3 | 0.042 | 3 | 25 |
| T3085 | 4 | 0.061 | 5 | 17 |
| T431 | 5 | 0.114 | 9 | 10 |
| T461 | 6 | 0.038 | 3 | 27 |
| *sr*=1 | | | | |
| *D*=80 | | | | |
| *CW*=456 | | | | |

Table 7. Relevant data for model sequencing

- Batch sequence (model batch with the lowest average assembly time first)-BS
- Cycle time based model sequence-CTBSA
- Demand based model sequence-DBSA
- Improved demand based model sequence-IDBSA

Assembly line is simulated under each model sequence via MS Excel. Total utility time, is considered with the aim of evaluating the performance of model sequences. Table 8 shows

the performance of model sequences. As can be seen in Table 8, improved demand based model sequence yields best results in terms of total utility time.

| Sequence | Total Utility Time (minutes) |
|---|---|
| BS | 322 |
| CTBSA | 183 |
| DBSA | 215 |
| IDBSA | 162 |

Table 8. Performance of model sequences

Procedure for eliminating the relevant bottleneck is performed as below.
**Step 1 of the procedure:** Current team combination=3-1-2-3-2-2-1
**Step 2 of the procedure:** Station 4 is determined as bottleneck station due to the fact that it has the highest total utility time (8.4 minutes) with respect to IDBSA.
**Step 3 of the procedure:** The following team combinations are generated by decreasing the size of station 4 by one when increasing the size of an upstream station of station 4. Note that team sizes written in bold are changed.
3-1-**3**-**2**-2-2-1
3-**2**-2-**2**-2-2-1
**4**-1-2-**2**-2-2-1
**Step 4 of the procedure:** The following team combinations are generated by increasing the size of station 3 by one when decreasing the size of an upstream station of 3 by one.
**2**-1-**3**-3-2-2-1
**Steps 5&6&7 of the procedure:** Assembly time of stations of each generated team combination is determined. The performance of feasible team combinations are obtained and listed in Table 9.
**Step 8 of the procedure:** Team combinations of **(**3-1-3-2-2-2-1) and (2-1-3-3-2-2-1) have lower utility time than current team combination has (24.6 minutes).
**Step 9 of the procedure:** Between **(**3-1-3-2-2-2-1) and (2-1-3-3-2-2-1), (3-1-3-2-2-2-1) has the lowest total utility time (19.4 minutes).
**Step 10 of the procedure:** (3-1-3-2-2-2-1) is assigned as the current team combination and step 2 is directed.
**Step 2 of the procedure:** Station 3 is determined as bottleneck station due to the fact that it has the highest total utility time (6.8 minutes) with respect to IDBSA.
**Step 3 of the procedure:** The following team combinations are generated by decreasing the size of station 3 by one when increasing the size of an upstream station of station 3.
**3**-2-**2**-2-2-2-1
**4**-1-**2**-2-2-2-1
**Step 4 of the procedure:** The following team combinations are generated by increasing the size of station 2 by one when decreasing the size of an upstream station of 2 by one.
**2-2**-3-2-2-2-1
**Steps 5&6&7 of the procedure:** Assembly time of stations of each generated team combination is determined. Table 10 gives the feasibility and performance of feasible team combinations.
**Step 8 of the procedure:** The only feasible generated team combination **(**2-2-3-2-2-2-1) have higher total utility time (29.3 minutes) than current team combination has (19.4 minutes).
**Step 11 of the procedure:** (3-1-3-2-2-2-1) is determined as the final team combination.

| | Team Combination | Cycle Time Constraint Feasibility | Total Utility Time (minutes) |
|---|---|---|---|
| | 3-1-2-3-2-2-1 **(*)** | | 24.6 |
| | 3-1-3-2-2-2-1 | Feasible | 19.4 |
| Step 3 | 3-2-2-2-2-2-1 | Infeasible | - |
| | 4-1-2-2-2-2-1 | Infeasible | - |
| Step 4 | 2-1-3-3-2-2-1 | Feasible | 22.7 |

**(*)** Current team combination

Table 9. Feasibility and performance of generated team combinations

| | Team Combination | Cycle Time Constraint Feasibility | Total Utility Time (minutes) |
|---|---|---|---|
| | 3-1-3-2-2-2-1 (*) | | 19.4 |
| Step 3 | 3-2-2-2-2-2-1 | Infeasible | 19.4 |
| | 4-1-2-2-2-2-1 | Infeasible | - |
| Step 4 | 2-2-3-2-2-2-1 | Feasible | 29.3 |

(*) Current team combination

Table 10. Feasibility and performance of generated team combinations

## 5. Conclusions

Teamwork is a flexible, quick response production system consisting of self organised, self motivated, multi-skilled operators who work collectively in stable teams, making joint decisions and sharing responsibility for the team's output in terms of both quality and quantity. Teamwork, however, adds another dimension, moving the emphasis away from just a production method towards a change in the philosophy and culture of a company. In parallel, the emphasis begins to focus on 'reducing non value added activities' ; that is, the cost and time associated with factors that add nothing to the value of the product.

Reflecting the advantages of teamwork to assembly lines, team-oriented assembly systems provides higher level of effectiveness in terms of cost, lead time, flexibility and worker satisfaction when compared to traditional assembly systems. However, in team-oriented assembly systems, output from an assembly line may be severely restricted if high level of variability among station times lead to bottleneck and idle stations. Team-oriented assembly systems are in accordance with the objectives of modern assembly systems such as system flexibility and product quality while creating a more satisfactory working environment. In this context, determining the most effective assembly team combination is a critical success factor of team oriented assembly system design.

Simulation based worker transfer system for team oriented mixed model assembly lines is introduced in this chapter. Meanwhile, the suitability of model sequencing and worker transfer systematic for industrial sized problems is demonstrated by the application in a real life mixed model assembly line. Fourteen operators are grouped into seven assembly teams in order to provide synchronized implementation of parallel assembly tasks for shorter lead times in a chosen segment of the assembly line. Then demand oriented model sequence is decided as the most appropriate model sequence among four model sequences via

simulation. After bottleneck station is determined, worker transfer procedure to eliminate bottleneck is performed. Total utility time is decreased by 21.1% via worker transfer system according to the team combination obtained as the result of the step of team forming for the chosen segment. Thus, this systematic is suggested for decreasing non-value added times in assembly lines.

Future work is focused on worker transfer between different assembly line segments. The proposed systematic can be improved for unsteady demand structure. Furthermore, uniform parts usage may be included as a performance measure for determining the most appropriate model sequence.

## 6. References


Aigbedo, H. & Monden, Y. (1997). A Parametric procedure for multicriterion sequence scheduling for just- in-time mixed-model assembly lines, International Journal of Production Research, Vol.35, No.9, (December 1996), pp. 2543-2564, ISSN 0020-7543

Akgunduz, O., S. & Tunali, S. (2010). An adaptive genetic algorithm approach for the mixed-model assembly line sequencing problem, *International Journal of Production Research*, Vol.48, No.17, (November 2009), pp. 5157-5179, ISSN 0020-7543

Bedworth, D.D. & Bailey, J. (1987). Integrated Production Control Systems, Analysis, Design, *John Wiley & Sons*, ISBN 0471062235, New York, USA.

Bolat, A. & Yano, C.A. (1992). Scheduling algorithms to minimize utility work at a single station on paced assembly line, *Production Planning and Control*, Vol.3, No.7, (April 1991), pp. 393–405, ISSN 1381-1231.

Bukchin J., Darel, M. & Rubinovitz, J. (1997). Team-oriented assembly system design: a new approach, *International Journal of Production Economics*, Vol.51, No.2, (May 1996), pp. 47-57, ISSN 0360-8352

Bukchin, J. & Masin, M. (2004). Multi-objective design of team-oriented assembly systems, *European Journal of Operational Research*, Vol.156, No.7, (August 2003), pp. 326-352, ISSN 1094-6136.

Cevikcan, E., Durmusoglu, M. B. & Unal, M. E. (2009). A team-oriented design methodology for mixed model assembly systems, *Computers & Industrial Engineering*, Vol.56, No.5, (February 2008), pp. 576-599, ISSN 0360-8352.

Dimitriadis, S. G. (2006). Assembly line balancing and group working: A heuristic procedure for workers' groups operating on the same product and workstation, *Computers & Operations Research*, Vol.33, No.5, (January 2006), pp. 2757–2774, ISSN 0020-7543.

Elsayed, E.A. & Boucher, T.O. (1985). Analysis and Control of Production Systems, *Prentice Hall*, ISBN 0073377856, New Jersey, USA.

Erel., E., Gocgun, Y. & Sabuncuoğlu, İ. (2007). Mixed-model assembly line sequencing using beam search, *International Journal of Production Research*, Vol.45, No.22, (February 2006), pp. 5265-5284, ISSN 0020-7543.

Giard, V. & Jeunet, J. (2010). Optimal sequencing of mixed models with sequence-dependent setups and utility workers on an assembly line, *International Journal of Production Economics*, Vol.123, No.2, (March 2010), pp. 290-300, ISSN 0925-5273.

Groover, M. P. (2001). Automation, Production Systems, and Computer Integrated Manufacturing, 2e, P*rentice Hall*, ISBN 849385962, New Jersey, USA.

Hyun, C. J., Kim, Y. & Kim, Y. K. (1998). A genetic algorithm for multiple objective sequencing problems in mixed model assembly lines, *Computers & Operations Research*, Vol.25, No.7, (May 2007), pp. 675–690, ISSN 0305-0548.

Jin, M. & Wu, S. D. (2002). A new heuristic method for mixed model assembly line balancing problem, *Computers & Industrial Engineering*, Vol.44, No.5, (December 2001), pp. 159-169, ISSN 0360-8352.

Johnson, R. V.(1991). Balancing assembly lines for teams and work groups, *International Journal of Production Research*, Vol.29, No.6, (September 1990), pp. 1205-1214, ISSN 0020-7543.

Korkmazel, T. & Meral, S. (2001). Bicriteria sequencing for the mixed model assembly line in just-in-time production systems, *European Journal of Operational Research*, Vol.131, No.7, (June 2000), pp. 188-207, ISSN 0377-2217.

Kotani, S., Ito, T. & Ohno, K. (2004). Sequencing problem for a mixed-model assembly line in the toyota production system, *International Journal of Production Research*, Vol.42, No. 23, (March 2003), pp. 4955-4974, ISSN 0020-7543.

Kurashige, K., Yanagawa, Y., Miyazaki, S. & Kameyama, Y. (2002). Time-based goal chasing method for mixed-model assembly line problem with multiple work stations, *Production Planning & Control*, Vol.13, No.8, (November 2001), pp. 735-745, ISSN 1381-1231.

Macaskill, J. L. C. (1973) Computer simulation for mixed-model production lines, *Management Science*, Vol.20, No.2, (May 1972), pp. 341-348, ISSN 1526-5501.

Merengo, C., Nava, F. & Pozzetti, A. (1999). Balancing and sequencing manual mixed-model assembly lines, *International Journal of Production Research*, Vol.37, No.12, (September 1998), pp. 2835- 2860, ISSN 0020-7543.

Sarker, B. R. & Pan, H. (2001). Design configuration for a closed-station, mixed-model assembly line: a filling cabinet manufacturing system, *International Journal of Production Research*, Vol.39, No.5, (October 2000), pp. 2251-2270, ISSN 0020-7543..

Tamura, T., Long, H. & Ohno K. (1999). A sequencing problem to level part usage rates and workloads for a mixed-model assembly line with a bypass subline, *International Journal of Production Economics*, Vol 60, No.7, (March 1998), pp. 557-564, ISSN 0925-5273.

Tavakkoli-Moghaddam, R. & Rahimi-Vahed, A. R. (2006). Multi-criteria sequencing problem for a mixed-model assembly line in a JIT production system, *Applied Mathematics and Computation*, Vol.181, No.8, (April 2005), pp. 1471-1481, ISN 0096-3003.

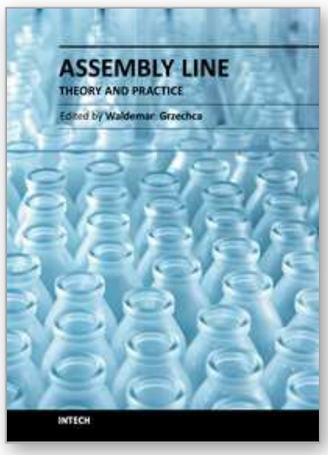
Thomopoulos, N. T. (1967). Line balancing-sequencing for mixed-model assembly, *Management Science*, Vol. 14, No.2, (December 1966), pp. 59-75, ISSN 1526-5501.

Ventura, J. A. & Radhakrishnan, S. (2002) Sequencing mixed model assembly lines for a just-in-time production system, *Production Planning & Control*, Vol.13, No.2, (May 2001), pp. 199-210, ISSN 1381-1231.

Wild, R. (1975). Work Organization: a Study of Manual Work and Mass Production, *John Wiley & Sons*, ISBN 0 471944068, New Jersey, USA.

Xiaobo, Z. & Ohno, K. (1997). Algorithms for sequencing mixed models on an assembly line in a JIT productıon system, *Computers &Industrial Engineering*, Vol.32, No.1, (November 1996), pp. 47-56, ISSN 0360-8352.

Xiaobo, Z., Zhou, Z. & Asres A. (1999). A note on Toyota's goal of sequencing mixed models on an assembly line, *Computers & Industrial Engineering*, Vol.36, No.10, (June 1998), pp.57-65, ISSN 0360-8352.

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An assembly line is a manufacturing process in which parts are added to a product in a sequential manner using optimally planned logistics to create a finished product in the fastest possible way. It is a flow-oriented production system where the productive units performing the operations, referred to as stations, are aligned in a serial manner. The present edited book is a collection of 12 chapters written by experts and well-known professionals of the field. The volume is organized in three parts according to the last research works in assembly line subject. The first part of the book is devoted to the assembly line balancing problem. It includes chapters dealing with different problems of ALBP. In the second part of the book some optimization problems in assembly line structure are considered. In many situations there are several contradictory goals that have to be satisfied simultaneously. The third part of the book deals with testing problems in assembly line. This section gives an overview on new trends, techniques and methodologies for testing the quality of a product at the end of the assembling line.



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