Research Article

Dynamic-Model Assembly Line Scheduling

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Abstract: The assembly line scheduling solution is restricted to two assembly lines that fulfill the requirement of small manufacturing industry by identifying the least cost path. Problem arises when large manufacturing industry comes under discussion where more than two assembly lines say three to fulfill the job, In this case two types of assembly line cost are involve: switching from one assembly line to another; switching from one station to the next. This study considers a solution for above mentioned scenario by least cost path identification, path cost calculation through back tracking, and a derived solution formula in order to reduce the computational complexity of scheduling at latter stages for n station. That provides the understanding for m number of assembly lines at the same time.

Keywords: Assembly line, configuration of assembly lines, dynamic programming, optimization based scheduling, scheduling algorithm

INTRODUCTION

Assembly line scheduling is manufacturing problem that provides a fastest way through a factory (Hui, 2005). There are two assembly lines and each with n stations; jth station on line i is known as Sij and the assembly time at that station is aij. An automobile chassis enters the factory and goes onto line i where i = 1 or 2, taking ej time. After reaching the jth station on a line, the chassis goes onto the (j+1)st station on either line (Shin and Zheng, 1991; Zhang et al., 1997). There is no transfer cost if it stay at the same line, but its takes time tij to transfer to the other line after station Sij. After exiting nth station on a line, it takes xj time for the completed auto to exit the factory (Altuger and Chassapis, 2010). The problem is to determine which station to choose from line 1 and which to choose from line 2 in order to minimize the total time through the factory for one auto (Cormen, 2001).

This study addresses one step ahead problem which arises when there is more than two assembly lines say three and there is another transfer cost Tij from one station to the next while product is on the same assembly line.

To determine which station to choose from line 1, which station to choose from line 2 (Minghai and Huanmin, 2010) and which station to choose from line 3 in order to minimize the total time through the factory for an automobile?

SCENARIO

Characterization of structure:

For line 1:
- Either the chassis arrive from S1j-1 to go through the station S1j
- Or the chassis arrive from S2j-1 to go through the station S1j

For line 2:
- Either the chassis arrive from S2j-1 to go through the station S2j
- Or the chassis arrive from S1j-1 to go through the station S2j

For line 3:
- Either the chassis arrive from S3j-1 to go through the station S3j
- Or the chassis arrive from S2j-1 to go through the station S3j

If j = 3, 4....n then
For line 1:
- Either the chassis arrive from \( S_{1,j} \) to go through the station \( S_{1,j} \)
- Or the chassis arrive from \( S_{2,j} \) to go through the station \( S_{1,j} \)
- Or the chassis arrive from \( S_{3,j} \) to go through the station \( S_{1,j} \)

For line 2:
- Either the chassis arrive from \( S_{2,j} \) to go through the station \( S_{2,j} \)
- Or the chassis arrive from \( S_{1,j} \) to go through the station \( S_{2,j} \)
- Or the chassis arrive from \( S_{3,j} \) to go through the station \( S_{2,j} \)

For line 3:
- Either the chassis arrive from \( S_{3,j} \) to go through the station \( S_{3,j} \)
- Or the chassis arrive from \( S_{2,j} \) to go through the station \( S_{3,j} \)
- Or the chassis arrive from \( S_{1,j} \) to go through the station \( S_{3,j} \)

Recursive definition of values: Let \( f_{i,j} \) be the fastest possible time to get a chassis from the starting point through station \( S_{i,j} \).

Let \( f^* \) be the fastest time to get the chassis all on line 1 or line 2 or line 3 then to the factory exit:
\[
f^* = \min (f_{1,i} + x_i, f_{2,i} + x_2, f_{3,i} + x_3)
\]
From starting,

For \( j = 1 \):
\[
\begin{align*}
&f_{1,1} = e_1 + a_{11} \\
&f_{2,1} = e_2 + a_{21} \\
&f_{3,1} = e_3 + a_{31}
\end{align*}
\]

Now for \( j = 2 \):
\[
\begin{align*}
f_{1,j} &= f_{j-1} + T_{j-1,i} + a_{1,j} \\
f_{2,j} &= f_{j-1} + T_{j-1,i} + a_{2,j} \\
f_{3,j} &= f_{j-1} + T_{j-1,i} + a_{3,j}
\end{align*}
\]

\[
\begin{align*}
f_{1,j} &= \min(f_{j-1} + T_{j-1,i} + a_{1,j}, f_{j-1} + T_{j-1,i} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j}) \\
f_{2,j} &= \min(f_{j-1} + T_{j-1,i} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j}) \\
f_{3,j} &= \min(f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j})
\end{align*}
\]

Now for \( j = 3, 4, \ldots \):
\[
\begin{align*}
f_{1,j} &= f_{j-1} + T_{j-1,i} + a_{1,j} \\
f_{2,j} &= f_{j-1} + T_{j-1,i} + a_{2,j} \\
f_{3,j} &= f_{j-1} + T_{j-1,i} + a_{3,j}
\end{align*}
\]

\[
\begin{align*}
f_{1,j} &= \min(f_{j-1} + T_{j-1,i} + a_{1,j}, f_{j-1} + T_{j-1,i} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j}) \\
f_{2,j} &= \min(f_{j-1} + T_{j-1,i} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j}) \\
f_{3,j} &= \min(f_{j-1} + T_{j-1,i} + a_{3,j}, f_{j-1} + T_{j-1,i} + a_{3,j})
\end{align*}
\]

Derived function:
\[
\begin{align*}
f_{1,j} &= \{ e_1 + a_{11} \} \quad \text{for } j = 1 \\
&= \min(f_{j-1} + T_{j-1,i} + a_{1,j}, f_{j-1} + T_{j-1,i} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j}) \quad \text{for } j = 2 \\
&= \min(f_{j-1} + T_{j-1,i} + a_{3,j} + a_{2,j}, f_{j-1} + T_{j-1,i} + a_{3,j} + a_{2,j} + a_{3,j} + a_{3,j}) \quad \text{for } j = 3
\end{align*}
\]

Define \( l_{i,j} \) to be line no either 1 or 2 or 3 whose station \( j = 1 \) is used in the fastest way through station \( S_{i,j} \) (Table 1, 2).

Define \( l^* \) to the line whose station \( n \) is used in a fastest way through the entire factory.
\[
l^* = 3 \quad l^*_{3,6} = 2, \quad l^*_{2,5} = 2, \quad l^*_{1,4} = 1, \quad l^*_{1,3} = 1, \quad l^*_{1,2} = 1
\]

RESULTS

From Table 1 we have derived Table 3 in it we mention that line 3 is efficient and fast which we will get to know from \( f^* \) which came from adding \( x_j \) in \( f_{1,j} \) where \( j = 6 \). Table 3 shows the result of scenario discussed in Fig. 1.

\[
f^* = 23 + 2 = 25 \quad \text{so line 3 is more efficient and fast}
\]

| Table 1: Computation of values in bottom up way |
|-----------------|---|---|---|---|---|---|
| \( f_{ij} \) | 1 | 2 | 3 | 4 | 5 | 6 |
| \( f_{11} \) | 3 | 7 | 12 | 18 | 21 | 24 |
| \( f_{21} \) | 7 | 14 | 14 | 17 | 27 |
| \( f_{31} \) | 8 | 11 | 17 | 22 | 23 |

| Table 2: Construction of optimal solution |
|-----------------|---|---|---|---|---|---|
| \( l_{ij} \) | 1 | 2 | 3 | 4 | 5 | 6 |
| \( l_{11} \) | 1 | 1 | 1 | 2 | 2 |
| \( l_{21} \) | 1 | 1 | 2 | 2 | 2 |
| \( l_{31} \) | 2 | 3 | 3 | 2 | 2 |

| Table 3: Results with optimal path |
|-----------------|---|---|---|---|---|---|
| \( f_{ij} \) | 1 | 2 | 3 | 4 | 5 | 6 |
| \( f_{11} \) | 3 | 7 | 12 | 18 | 21 | 24 |
| \( f_{21} \) | 7 | 14 | 14 | 17 | 27 |
| \( f_{31} \) | 8 | 11 | 17 | 22 | 23 |
**Algorithm:** (Kaufman, 1974; Hsu, 1984) Fastest-way

\((a, t, e, x, n, T)\)

- \(f_{[j]} \leftarrow e_t + a_{1,1}\)
- \(f_{[2]} \leftarrow e_t + a_{2,1}\)
- \(f_{[3]} \leftarrow e_t + a_{3,1}\)
- if \(f_{1,j} + T_{1,1} \leq a_{1,1}\) then \(l_{[2]} \leftarrow 1\)
- else \(f_{[2]} \leftarrow f_{1,j} + T_{1,1} + a_{1,2}\)
- \(l_{[2]} \leftarrow 2\)
- if \((f_{1,j} + T_{1,1} + a_{1,2}) \leq f_{2,j} + T_{2,1} + a_{2,2}\) and \((f_{2,j} + T_{2,1} + a_{2,2}) \leq f_{3,j} + T_{3,1} + a_{3,2}\) then \(l_{[2]} \leftarrow 1\)
- else \(f_{[2]} \leftarrow f_{1,j} + T_{1,1} + a_{1,2}\)
- \(l_{[2]} \leftarrow 3\)
- if \(f_{3,j} + T_{3,1} + a_{3,2} \leq f_{2,j} + T_{2,1} + a_{2,2}\) then \(l_{[2]} \leftarrow 1\)
- else \(f_{[2]} \leftarrow f_{1,j} + T_{1,1} + a_{1,2}\)
- \(l_{[2]} \leftarrow 2\)
- for \(j \rightarrow 3\) to \(n\)
- if \((f_{j,j} + T_{j,1} + a_{j,1} \leq f_{j-1,j} + T_{j-1,1} + a_{j-1,1})\) and \((f_{j,j} + T_{j,1} + a_{j,1} \leq f_{j,1} + T_{j,1} + a_{j,1})\) then \(l_{[j]} \leftarrow 1\)
- else if \((f_{j,j} + T_{j,1} + a_{j,1} < f_{j-1,j} + T_{j-1,1} + a_{j-1,1})\) and \((f_{j,j} + T_{j,1} + a_{j,1} < f_{j,1} + T_{j,1} + a_{j,1})\) then \(l_{[j]} \leftarrow 2\)
- else \(l_{[j]} \leftarrow 3\)

**PREVIOUS WORK**

In previous work, the assembly line scheduling solution is defined that is restricted to two assembly lines that fulfill the requirement of small manufacturing industry by identifying the least cost path. Problem arises when large manufacturing industry comes under discussion where more than two assembly lines say three to fulfill the job. So our work fulfills that requirement.
CONCLUSION

To fulfill the need of customer nowadays is a huge challenge for the manufacturer. This paper provides the dynamic solution for the fastest way through the entire factory assembly line overloading problem which deals with more assembly lines and station-to-station transfer cost that will make work flow more efficient and fluent.

FUTURE WORK

This research study is initial step to enhance the capabilities of assembly line scheduling by proposing an idea to upgrading this scheduling algorithm for three assembly lines which faces the same complexity issues as any number of assembly lines (more than three) will face. This idea could be upgrade for unlimited number of assembly lines to deal with the dynamic need of manufacturing industry as discussed above by designing a more dynamic solution.

REFERENCES