Kilbridge and Webster's Method

- **Rather complicated line balancing**

It is a heuristic procedure which selects work elements for assignment to stations according to their position in the precedence diagram.

The elements at the front of the diagram are selected first for entry into the solution. This overcomes one of the difficulties with the largest candidate rule, with which elements at the end of the precedence diagram might be the first candidates to be considered, simply because their T_e values are large.

Balancing Procedure

Step 1. Construct the precedence diagram so that nodes representing work elements of identical precedence are arranged vertically in columns. This is illustrated in Figure 6.5. Elements 1 and 2 appear in column I, elements 3, 4, and 5 are in column II, and so on. Note that element 5 could be located in either column II or III without disrupting precedence constraints.

Step 2. List the elements in order of their columns, column I at the top of the list. If an element can be located in more than one column, list all the columns by the element to show the transferability of the element. This step is presented for the problem in Table 6.4. The table also shows the T_e value for each element and the sum of the T_e values for each column.

Step 3. To assign elements to workstations, start with the column I elements. Continue the assignment procedure in order of column number until the cycle time is reached. T_c in our sample problem is 1.0 min.

Work Elements Listed According To K-W Method

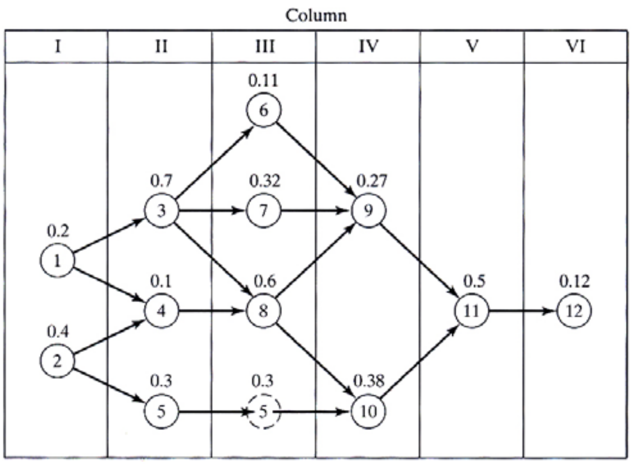

Figure 17.7 Work elements in example problem arranged into columns for the Kilbridge and Wester method.

TABLE 17.7 Work Elements Listed According to Columns from Figure 17.7 for the Kilbridge and Wester Method

Work Element	*Column*	*T_{ek} (min)*	*Preceded By*
2	I	0.4	–
1	I	0.2	–
3	II	0.7	1
5	II, III	0.3	2
4	II	0.1	1,2
8	III	0.6	3,4
7	III	0.32	3
6	III	0.11	3
10	IV	0.38	5,8
9	IV	0.27	6,7,8
11	V	0.5	9,10
12	VI	0.12	11

Work Elements Assigned to Stations According to K-W Method.

TABLE 17.8 Work Elements Assigned to Stations According to the Kilbridge and Wester Method

Station	*Work Element*	*Column*	T_{ek} *(min)*	*Station Time (min)*
1	2	I	0.4	
	1	I	0.2	
	5	II	0.3	
	4	II	0.1	1.0
2	3	II	0.7	
	6	III	0.11	0.81
3	8	III	0.6	
	7	III	0.32	0.92
4	10	IV	0.38	
	9	IV	0.27	0.65
5	11	V	0.5	
	12	VI	0.12	0.62

Balance delay = $\dfrac{5(1.0) - 4.0}{5(1.0)} = 0.2 = 20\%$

Ranked Positional Weight Methods

In a sense, it combines the strategies of the largest-candidate rule and Kilbridge and Wester's method. A ranked positional weight value (call it the RPW for short) is computed for each element. The RPW takes account of both the T_e value of the element and its position in the precedence diagram. Then, the elements are assigned to work stations in the general order of their RPW values.

Balancing Procedure

Step 1. Calculate the RPW for each element by summing the element's T_e together with the T_e values for all the elements that follow it in the arrow chain of the precedence diagram.

Step 2. List the elements in the order of their RPW, largest RPW at the top of the list. For convenience, include the T_e value and immediate predecessors for each element.

Step 3. Assign elements to stations according to RPW, avoiding precedence constraint and time-cycle violations.

RPW Method : Example

Applying the RPW method to our example problem, we first compute a ranked positional weight value for each element. For element 1, the elements that follow it in the arrow chain (see Figure 6.3) are 3, 4, 6, 7, 8, 9, 10, 11, and 12. The RPW for element 1 would be the sum of the T_e's for all these elements, plus T_e for element 1. This RPW value is 3.30. The reader can see that the trend will be toward lower values of RPW as we get closer to the end of the precedence diagram.

TABLE 17.9 **List of Element Ranked According to Their Ranked Positional Weights (RPM)**

Work Element	*RPM*	*T_{ek} (min)*	*Station Time (min)*
1	3.30	0.2	–
3	3.00	0.7	1
2	2.67	0.4	–
4	1.97	0.1	1,2
8	1.87	0.6	3,4
5	1.30	0.3	2
7	1.21	0.32	3
6	1.00	0.11	3
10	1.00	0.38	5,8
9	0.89	0.27	6,7,8
11	0.62	0.5	9,10
12	0.12	0.12	11

EXAMPLE 17.4 Ranked Positional Weights Method

Apply the ranked positional weights method to Example Problem 17.1.

Solution: The RPW must be calculated for each element. To illustrate,

$$RPW_{11} = 0.5 + 0.12 = 0.62$$

$$RPW_8 = 0.6 + 0.27 + 0.38 + 0.5 + 0.12 = 1.87$$

Balancing Result by RPW Method

TABLE 17.10 **Work Elements Assigned to Stations According to the Ranked Positional Weights (RPM) Method**

Station	*Work Element*	*T_{ek} (min)*	*Station Time (min)*
1	1	0.2	
	3	0.7	0.90
2	2	0.4	
	4	0.1	
	5	0.3	
	6	0.11	0.91
3	8	0.6	
	7	0.32	0.92
4	10	0.38	
	9	0.27	0.65
5	11	0.5	
	12	0.12	0.62

$$E_b = \frac{4.0}{5(.92)} = 0.87$$

The cycle time is $T_c =$ max $\{T_{si}\} = 0.92 = 0.92$; therefore,

$$R_c = \frac{60}{0.92} = 60 \text{ cycles/hr}, \quad R_p = 60 \times 0.96 = 57.6 \text{ units/hr}$$

Line Balancing Results

TABLE 17.9 List of Elements Ranked According to Their Ranked Positional Weights (RPW)

Work Element	*RPW*	T_{ek} *(min)*	*Preceded By*
1	3.30	0.2	–
3	3.00	0.7	1
2	2.67	0.4	–
4	1.97	0.1	1,2
8	1.87	0.6	3,4
5	1.30	0.3	2
7	1.21	0.32	3
6	1.00	0.11	3
10	1.00	0.38	5,8
9	0.89	0.27	6,7,8
11	0.62	0.5	9,10
12	0.12	0.12	11

TABLE 17.10 Work Elements Assigned to Stations According to the Ranked Positional Weights (RPW) Method

Station	*Work Element*	T_{ek} *(min)*	*Station Time (min)*
1	1	0.2	
	3	0.7	0.90
2	2	0.4	
	4	0.1	
	5	0.3	
	6	0.11	0.91
3	8	0.6	
	7	0.32	0.92
4	10	0.38	
	9	0.27	0.65
5	11	0.5	
	12	0.12	0.62

Solution: The RPW must be calculated for each element. To illustrate,

$$\text{RPW}_{11} = 0.5 + 0.12 = 0.62$$

$$\text{RPW}_{8} = 0.6 + 0.27 + 0.38 + 0.5 + 0.12 = 1.87$$

Work elements are listed according to RPW value in Table 17.9. Assignment of elements to stations proceeds with the solution presented in Table 17.10. Note that the largest T_s value is 0.92 min. This can be exploited by operating the line at this faster rate, with the result that line balance efficiency is improved and production rate is increased.

$$E_b = \frac{4.0}{5(.92)} = 0.87$$

The cycle time is $T_c = T_s + T_r = 0.92 + 0.08 = 1.00$; therefore,

$R_c = \frac{60}{1.0} = 60$ cycles/hr, and from Eq. (17.6), $R_p = 60 \times 0.96 = 57.6$ units/hr

Balance delay : $d = \frac{5(0.92) - 4.0}{5(0.92)} = 0.13 = 13\%$