Line Balancing, Pareto Analysis and Industry 4.0 in an Indian footwear industry

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Abstract- *Line Balancing algorithm like Kilbridge and Wester Method is discussed in detail and noted that it can implemented in footwear industry too. An example of Pareto Analysis in Indian footwear industry is also discussed. Industry 4.0 concept is discussed.*

Keywords- Line Balancing, Pareto Analysis, Indian footwear industry

I. EXAMPLE PROBLEM FOR LINE BALANCING

A small electrical appliance is to be produced on a single-model assembly line. The work content of assembling the product has been reduced to the work elements listed in Table 1.1. The table also lists the times for each element and the precedence order in which they must be performed. The line is to be balanced for an annual demand of 100,000 units/yr. The line will operate 50 wk/yr, 5 shifts/wk, and 7.5 hr/shift. There will be one worker per station. Previous experience suggests that the uptime efficiency for the line will be 96%, and repositioning time lost per cycle will be 0.08 min. Determine (a) total work content time Twc, (b) required hourly production rate Rp to achieve the annual demand, (c) cycle time Tc, (d) theoretical minimum number of workers required on the line, and (e) service time Ts to which the line must be balanced.

Table 1.1. Work Elements for Example

No.	Work Element Description	T_{ek}	Must be preceded by
1	Place frame in work holder and clamp	0.2	-
2	Assemble plug, grommet to power cord	0.4	-
3	Assemble brackets to frame	0.7	1
4	Wire power cord to motor	0.1	1,2
5	Wire power cord to switch	0.3	2
6	Assemble mechanism plate to bracket	0.11	3
7	Assemble blade to bracket	0.32	3
8	Assemble motor to brackets	0.6	3,4
9	Align blade and attach to motor	0.27	6,7,8
10	Assemble switch to motor bracket	0.38	5,8
11	Attach cover, inspect, and test	0.5	9,10
12	Place in tote pan for packing	0.12	11

Solution:

(a) The total work content time is the sum of the work element times in Table 1.1.

Twc = 4.0 min

(b) Given the annual demand, the hourly production rate is

Rp = 100,000 / 50 (5)(7.5) = 53.33 units/hr

(c) The corresponding cycle time Tc with an uptime efficiency of 96% is

Tc = 60(0.96) / 53.33 = 1.08 min

(d) The theoretical minimum number of workers is given by

w* = Min Int ≥ 4.0 / 1.08 = 3.7 rounded up to 4 workers

(e) The available service time against which the line must be balanced is

Ts = 1.08 - 0.08 = 1.00 min

1.1 Kilbridge and Wester Method

This method has received considerable attention since its introduction in 1961 and has been applied with apparent success to several large line balancing problems in industry. It is a heuristic procedure that selects work elements for assignment to stations according to their position in the precedence diagram. This overcomes one of the difficulties with the largest candidate rule in which an element may be selected because of a high T_e value but irrespective of its position in the precedence diagram. In general, the Kilbridge and Wester method provides a superior line balance solution to that provided by the largest candidate rule.

In the Kilbridge and Wester method, work elements in the precedence diagram are arranged into columns, as shown in Figure 1.1.1. The elements can then be organized into a list according to their columns, with the elements in the first column listed first. Such a list of elements has been developed for the example problem in Table.1.1.

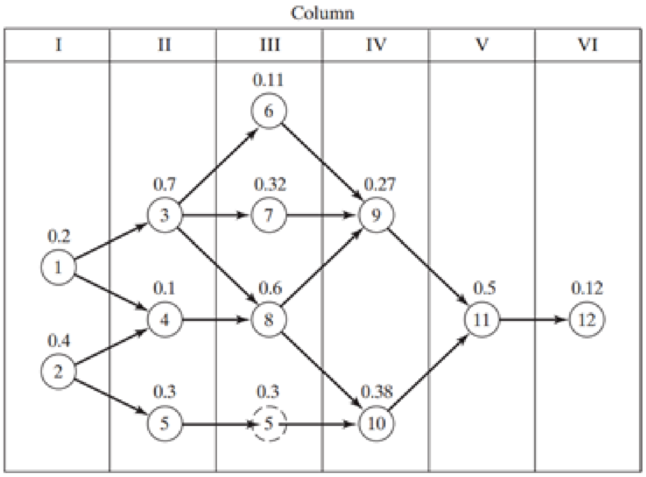


Figure 1.1.1. Work elements in example problem arranged into columns for the Kilbridge and Wester method.

TABLE 1.1.1. Work Elements Listed According to Columns from Figure 1.1.1 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

If a given element can be located in more than one column, then all of the columns for that element should be listed, as in the case of element 5. An additional feature of the list is that elements in a given column are presented in the order of their Tek value; that is, the largest candidate rule has been applied in each column. This is helpful when assigning elements to stations, because it ensures that the larger elements are selected first, thus increasing the chances of making the sum of Tek in each station closer to the allowable Ts limit. Once the list is established, the same three-step procedure is used as before.

Example 1.1.1. Kilbridge and Wester method

Apply the Kilbridge and Wester method to Example 1.1.

Solution: Work elements are arranged in order of columns in Table 1.1.1. The Kilbridge and Wester solution is presented in Table 1.1.2. Five workers are required and the balance efficiency is Eb = 0.80. Note that although the balance efficiency is the same as in the largest candidate rule, the allocation of work elements to stations is different.

TABLE 1.1.2. Work Elements Assigned to Stations According to the Kilbridge and Wester Method

Station	Work Element	Colum n	Tek (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

Similarly, one can go for

- Largest Candidate Rule
- Ranked Positional Weights Method1

The above concept can be used in Line Balancing in shoe manufacturing industry by listing the precedence relationship.

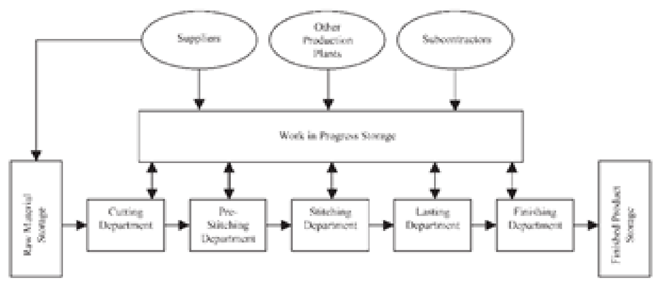


Figure 1.2. Shoe Manufacturing Company2

II. PARETO ANALYSIS

a. What Is Pareto Analysis?

Pareto analysis is a technique used for business decision-making, but which also has applications in several different fields from welfare economics to quality control. It is based largely on the "80-20 rule." As a decision-making technique, Pareto analysis statistically separates a limited number of input factors—either desirable or undesirable—which have the greatest impact on an outcome.

Pareto analysis is premised on the idea that 80% of a project's benefit can be achieved by doing 20% of the work—or, conversely, 80% of problems can be traced to 20% of the causes. Pareto analysis is a powerful quality and decision-making tool. In the most general sense, it is a technique for getting the necessary facts needed for setting priorities.

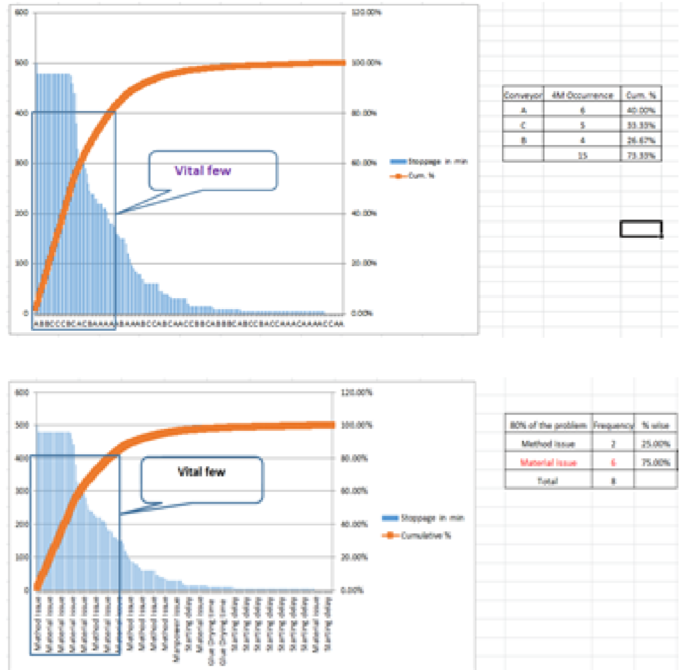
b. How to Create a Pareto Chart

A common part of Pareto analysis is to graphically depict the occurrence of each variable being tracked. This depiction is called a Pareto chart, and it organizes and displays information to show the relative importance of various problems or causes of problems. It is similar to a vertical bar graph in that it puts items in order (from the highest to the lowest) relative to some measurable effect of interest: frequency, cost, or time. Here is the process of making a Pareto chart.

1. Develop a list of problems to be compared.
2. Develop a standard measure for comparing the items. For example, how often it occurs: frequency (e.g., utilization, complications, errors); how long it takes (time); how many resources it uses (cost).
3. Choose a timeframe for collecting the data.
4. For each item, tally how often it occurred (or cost or total time). Then, add these amounts to determine the grand total for all items.
5. Find the percent of each item in the grand total by taking the sum of the item, dividing it by the grand total, and multiplying by 100.
6. List the items being compared in decreasing order of the measure of comparison: e.g., the most frequent to the least frequent. The cumulative percent for an item is the sum of that item's percent of the total and that of all the other items that come before it in the ordering by rank.
7. List the items on the horizontal axis of a graph from highest to lowest. Label the left vertical axis with the numbers (frequency, time, or cost).
8. Label the right vertical axis with the cumulative percentages (the cumulative total should equal 100%).
9. Draw in the bars for each item.
10. Draw a line graph of the cumulative percentages. The first point on the line graph should line up with the top of the first bar.

The final step is analysis. You can now analyze a Pareto chart by identifying those items that appear to account for most of the difficulty.

Figure 2.1. Some examples of Pareto Analysis in footwear industry



III. INDUSTRY 4.0

The scientific term ―Industry 4.0‖ was first introduces in Germany in 2011 at the Hanover fair, where it was used for denoting the transformation process in the global chains of value creation. In the report ―The Fourth Industrial Revolution‖, presented by K. Schwab at the World Economic Forum, it is stated that Industry 4.0 includes business processes in industry that envisage organization of global production networks on the basis of new information and communication technologies and Internet technologies, with the help of which interaction of the production objects is conducted.

The Basic Characteristics of Industry 4.0 are

- transition from manual labor to robotics, which ensures automation of all production processes
- modernization of transport and logistical systems, caused by mass distribution of unmanned vehicles
- increase of complexity and precision of manufactured technical products, manufacture of new construction materials due to improvement of production technologies
- development of inter-machine communications and self-management of physical systems, conducted with the help of "Internet of things"
- application of self-teaching programs for provision of constant development of production systems
- Technologies usually mentioned in Industry 4.0 frameworks:
- Big data/advanced analytics — The industrial world is filled with mountains of unanalyzed products and process

data. Analyzing it and turning it into actionable information can optimize production quality, improve services, and enable faster and more accurate decision making

- Advanced robotics — As robots become more flexible, cooperative, and autonomous, they will interact with one another, work safely with humans, and eventually learn from humans, too. Industry 4.0 provides a manufacturing context for these opportunities
- Advanced simulations — In Industry 4.0 environments, 3D simulation of product development, material development, and production processes will enable operators to test and optimize processes for products before production starts
- AI/cognitive computing — Cognitive manufacturing uses the assets and capabilities of the IoT, advanced data analytics, and cognitive technologies such as AI and machine learning. When used together these technologies will drive improvements in the quality, efficiency, and reliability of manufacturing processes
- Industrial Internet of Things — In the IIoT, an ever-greater number of products will incorporate internet-connected devices, which link with each other with standard protocols. This approach to manufacturing will decentralize analytics and decision making and enable real-time responses
- Cybersecurity — Industry 4.0 environments include connectivity and communications protocols as well as sophisticated identity and access management systems. These technologies enable manufacturers to provide secure, reliable communications and data flow throughout Industry 4.0 systems
- Additive Manufacturing — In Industry 4.0 manufacturing environments, these technologies are the best choice for producing small-batch, customized, and high-performance products
- Cloud-based service-enabling technologies — Industry 4.0 manufacturing operations require more data sharing across sites and companies than earlier processes do. Shifting data storage and management to the cloud will drive the development of more manufacturing execution systems (MESs) that use cloud-based machine data
- Augmented reality — AR provides an effective way to represent production processes by overlaying real-world views of production with virtual information. In ASEAN countries, the most likely role of AR lies in training future workers and technicians how production systems behave in real-time

Figure 3.1. Industry 4.0

IV. CONCLUSION

Line balancing algorithm that can be used in Indian footwear industry is discussed Kilbridge and Wester Method is discussed in detail. The most sought tool in management, Pareto analysis is implemented in a Indian footwear industry for productivity improvement. Industry 4.0 concept is touched upon.

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