AN INTEGRATED FRAMEWORK OF APPLYING LINE BALANCING IN APPAREL MANUFACTURING ORGANIZATION: A CASE STUDY

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Abstract: *For every manufacturing organization, price of the product primarily comprises of manufacturing cost and desired profit. If a company wishes to increase its profit, one way is to reduce the manufacturing cost with maintaining the quality of the product. Waste reduction, especially the (wait) time waste, is an important factor to shrink the manufacturing cost. The purpose of this paper is to identify and address the way to reduce idle time in the apparel manufacturing organization using various line balancing technique to improve productivity and efficiency in domestic context. Line balancing job has been done through the 'Largest Candidate Rule' and 'Ranked Positional Weight Technique'. Using these techniques, a software has been developed to arrange the elemental tasks in the workstation, and to show the balancing efficiencies of each method and other important information. The overall job may be very helpful in some decision making process of the organization. At last an efficient and balanced line has been proposed through the study.*

Keywords: *Line balancing, Elemental time, Service time, Largest Candidate rule (LCR), RPE Methods, Balancing efficient*

INTRODUCTION

Quality product and to be capable to cope with customers' demands are important aspects that should be taken into account especially for small and medium industry. Management & technical committee of an organization usually take part into planning, controlling and measuring parameters related to the performance of the sectors. Companies generally appraise the performance how well the production line performs in term of output. Line balancing is a tool that can be used to optimize the workstation or assembly line throughput. This tool will assist in cutback the production time and maximizing the output or minimizing the cost. Line balancing is also exploit to reduce waiting time as well as the waste.

LITERATURE REVIEW

Line Balancing is fundamentally related to the waste reduction. It lessens time waste by idle time reduction. Decrease in the service time causes also reduces overtime cost. Therefore, a balance production line certainly minimizes the production line resources e.g. reduction in workstation numbers.

The Apparel Waste Categories

Waste is anything that adds cost to the product without adding value[1]. Waste generates the problems within the system (at both process & value stream levels)[2]. Generally it's a symptom rather than a root cause of problem. In spite of its classification all of the categories are interrelated. A single change in one category can affect others or the entire system[3].

Over Production It refers to the waste that we usually never think this as a waste at all. This means producing something before of its actual requirement. This process can be applied in to the bigger picture or in the more localized sense. In the smaller view, the word over production denotes producing a part of a product before it is required by the assembly line or the process after that. The extra amount will be a loss[4].

Waiting In conventional batch processing, some studies show that, goods are waiting to be processed around 90% of the total time. This is higher as 99%[5].

Work In Progress or Excess Inventory Work in progress or WIP is a direct result of over production and waiting[6]. Every imperfection in the system will trigger WIP. Therefore, WIP also known as the mirror of the wastes that system has. But WIP itself becomes a waste due to many consequences. It blocks money in the form of non finished products. It hides quality damages, and will only be revealed when a considerable damage is done. Therefore, a perfect operation should proceed with the target for a system where there is no requirement for WIP[26].

Excess Transportation No matter how well an organization does transporting but it does not add value to the end product. Therefore, simply, transportation is one of the wastes that has to be eliminated or reduced as much as possible from the production system. This accounts for the quality defects, maintenance of a higher WIP, and additional cost of transporting the goods as well.

Transportation often caused by poor or less developed work place of the organization. Inflexibility of the layout plays a big role here. This can be avoided by careful redesigning of the layout of the organization[6].

Inappropriate Processing/over processing This happens due to using of incorrect tools for the job. This does not mean to use complicated or expensive tools to do the job. It is about using the correct tool for the correct job. People naturally think that best equipment for the job would be expensive and complex. If the industry can overcome this problem that will not only save money for the organization but also motivate people immensely. Changing the mindset of the people by education and training can give a good result in this regard. Also creating a culture of continuous improvement will be tremendously helpful. In that case, people will always look for the better ways of doing things, which creates opportunity for new kinds of innovations [23].

Excess Motions / Ergonomic Problems This waste is often overlooked. When performing a certain task people have to repeat their motions again and again. Although we do not realize, in many places people have to move, bend or reach to collect some part or to reach the machine. It causes waste of large amounts of time. Workplaces become untidy & filthy. Workers get tired easily. To prevail over this problem, a detailed study has to be carried out regarding working conditions. Then they have to be rearranged accordingly to eradicate these problems. Even changing of simple equipments like from normal chairs to revolving or adjustable chairs can be conducive to reduce this problem. In addition, introduction of modern workplace engineering can also be helpful to surmount over these problems[23].

Defected Products Above mentioned criteria are wastes themselves. But they lead to another waste which is extremely costly. It is termed as "defected product". Defects call for higher inspection and related costs. If a defect is found, it has to be removed. The raw materials, time, efforts and the money spent into this product are evaluated as a waste then. Even worst, if this defected product goes to the customer’s hand company losses the respective image, also there is a risk of claims. Substandard raw material, mistakes from the workers, problems in the system, machinery related problems all are liable for this issue.

Under Utilization of Human Resource Under utilization of workforce which is generally known as "disconnectivity" is another vital waste. But most people do not think it as a waste. Japanese is a nation who are not blessed with huge natural resources as other countries. But they are in the leading position in case of manufacturing & production today. They do this by using their human resources with its full potential. Every worker, even the people do the most routine job in the organization possess something to contribute to the organization than their muscle power. For an example, a floor cleaner, if he is asked how to clean the floor much faster, it is sure that he will come up with some fantastic ideas. So there is no other way without extracting ideas from all level of the people in the organization and to use them for the betterment of the organization.

LINE BALANCING

Line Balancing is a process generally originated from lean manufacturing. As Lean manufacturing is a performance-based process used in manufacturing organizations to increase competitive advantage, line balancing works as an aid of some important waste for increasing efficiency. These wastes are over production, waiting, WIP inventory, excess transportation and excess motion etc[27].

OBJECTIVES OF THE PAPER

The objectives of this paper are:

- ❖ Identifying & reducing apparel manufacturing organization’s time waste with Line Balancing.
- ❖ Study the current task assignment to different stations.
- ❖ Assign task to stations by Ranked Positional Weights Methods and New Model (Developed by authors)
- ❖ Developing software for using in the purpose of line balancing of that product line when orders of various quantities with different lead times arrive.

OPERATION PRINCIPLES

Ranked Positional Weights Method (RPW)

This method was introduced by Helgeson and Birnie in 1961. The RPW takes account of both the "elementary task time (T_e)" value of the element and its position in the precedence diagram. Then, the elements are assigned to workstations in the general order of their RPW values.

Procedure

Step1. Calculate the RPW for each element by summing up the elements task time (T_e) together with the T_e values for all the elements according to the precedence diagram.

Step2. List the elements according to their RPW, by setting largest RPW at the top of the list. For convenience, include the T_e value and immediate predecessors for each element.

Step3. Assign elements to stations according to RPW, without avoiding precedence constraint and time cycle violations.

A NEW MODEL

The detail algorithm is shown in figure. If a station time remain below the 95%* of the service time, then the next job will be split into two portions i,e one portions of the job is done in current station and later portion moves to the next station. This splitting of job requires more time than a normal job. So, the sum of the job's time becomes higher. For example job no. 21 has been split in station 2 & station 3. and Station 1 has been used more than 95% of its service time. So the next job No. 15 is not split.

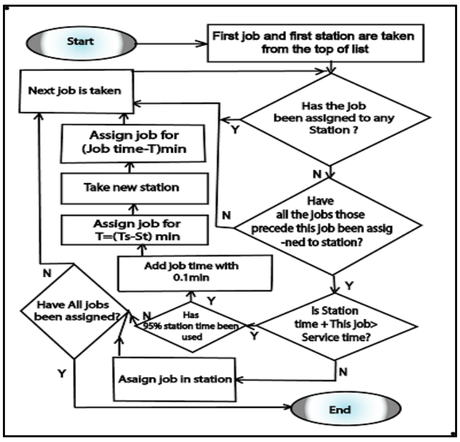

Figure 1. Algorithm for software development

Here, a apparel manufacturing company's certain operation is considered in this purpose. Four pocket command pant is the studying product. All computation has been done for an order of 10000 pieces and the lead time is 7 weeks.

SERVICE TIME CALCULATION

Sample calculation for,

Annual Production, p= 10,000 piece,*

Available Weeks, w= 7,*

Reposition Time, T_r = 0.08 min,*

Worker Efficiency, E=0.96,*

Shift per week, s=6,*

Hours per Shift, h=8,*

Then, Production rate, P_r= p/(w*s*h)

=29.76 piece per hour

Table 1. Operations for four Pocket Command Pants

Element No.	Operations' names	Operations' Time, min
1	Top stitch	0.48
2	Front stitch	0.29
3	Front part seam	0.19
4	fly piping (right)	0.13
5	fly piping (left)	0.2
6	front pocket facing sewing	0.31
7	front pocket fabric sewing	0.44
8	Pocket covering	0.59
9	pocket reversing (flap)	0.64
10	Pocket flap seam (twin needle)	0.56
11	Shade marker remove	0.54
12	Knee pocket edge stitch & preparing	0.96
13	Over lock Welt	0.11
14	Welting	0.47
15	Opening Welt	0.4
16	Welt top topstitching	0.78
17	Welt bottom topstitching	0.98
18	Back pocket bagging and fancy seam	1.01
19	Bar tacking at back pocket	0.19
20	Assembling piece above back pocket	0.72
21	Assembling and top stitch	0.4
22	Drawing seam line (front pocket)	0.11
23	edge double stitch (front pocket)	0.23
24	Top stitch (front pocket)	0.28
25	Bagging (front pocket)	0.37
26	Bag top stitch (front pocket)	0.31
27	Assembling (front pocket)	0.36
28	Over lock and front pocket lining	0.27
29	Top stitching and left fly assembly	0.57
30	Side stitching	0.39
31	Side chain stitching	0.54
32	Piece assembling above knee pocket	0.96
33	Knee pocket assembling	0.77
34	Flap assembling and signing	1.06
35	Flap double stitch	0.69
36	Assembling zipper	0.64
37	Fly top stitch	0.41
38	Close fly assembling	0.28
39	Back centre stitch & Inside leg	0.61
40	Back center double stitch	0.2
41	Belt loop assembling	0.33
42	Washing instruction assembling	0.32
43	Waistband attaching	0.63
44	Waistband end making	0.3
45	Waistband label assembling	0.47
46	Cutting and reversing waistband end	0.38
47	Waistband closing	0.87
48	Label assembling above the belt loop	0.68
49	Assembling belt loop	0.9
50	Leg hemstitch	0.59
51	Bar tacking (1)	0.82
52	Bar tacking (2)	0.36

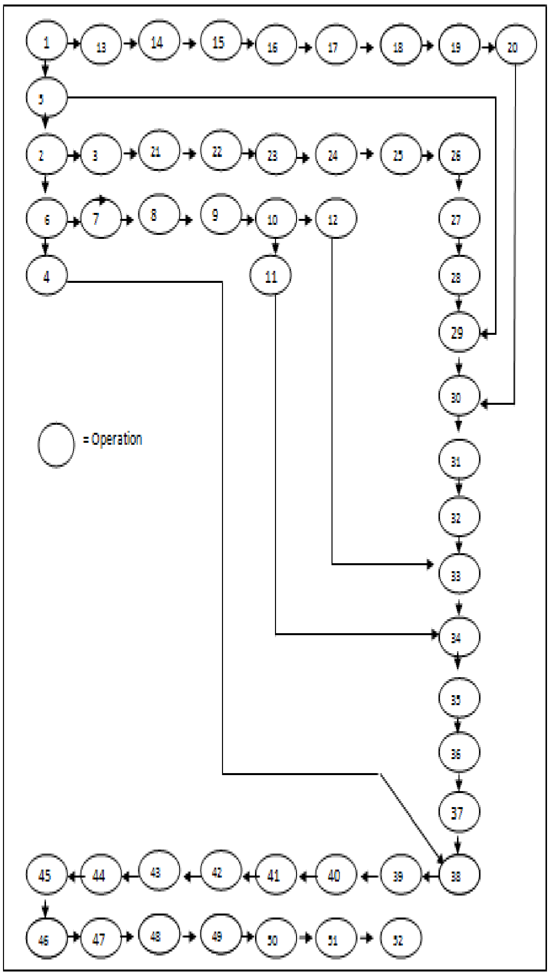

Figure 2. Precedence Relationship of operations.

Station No	Operation No	Stations' Time (Minute)
1	1,13,14,15	.48+.17+.47+.40=1.52''
2	16,17	.78+.98=1.76
3	18	1.01=1.01
4	19	1.19=1.19
5	20,5,2,3,4,6	.72+.20+.29+.19+.13+.31=1.84
6	7,21,22,23,24,25	.44+.40+.11+.23+.28+.37=1.83
7	26,27,28,28,29	.31+.36+.27+.57=1.51
8	30,31	.39+.54=.93
9	32,33	.96+.77=1.73
10	8,9,10	.59+.64+.56=1.79
11	11,12	.54+.96=1.50
12	34,35	1.06+.69=1.75
13	36,37,38	.64+.41=1.33
14	39,40,41,42	.28+.61+.20+.33+.32=1.46
15	43,44,45,46	.63+.30+.48+.38=1.79
16	47,48	.87+.68=1.55
17	49,50	.64+.59=1.23
18	51,52	.82+.36=1.18

Figure 3. Existing job assignment to workstations.

Cycle Time, $T_c = (60*E)/Pr$
$= (60*0.96)/29.76$
$= 1.94$ minutes

Service Time, $T_s = T_c - T_r$
$= 1.94 - 0.08$
$= 1.86$ minutes

Balance Efficiency Calculation:

Total Number of workstation= 18

Balance Efficiency, $E_b = T_{wc}/(W*T_s)$
$= (26.09) / (18*1.86)$
$= 0.78$

Here,
T_{wc}= Work content
W= No. of workstation
T_s=Service time

APPLYING THE LINE BALANCING TOOLS

Line balancing job has done through the Ranked Positional Weight technique and new developed model. The results are depicted in Figs. 4 and 5.

COST ESTIMATION

Cost of each station per month = $109
Existing line stations' cost per month =$(109*18) = $1962
RPW Method's line stations' cost per month = $109*16 = $1744
Proposed line stations' cost per month = $109*15= $1635
Cost saved per month =$ (1962-1635) =$327

SOFTWARE DEVELOPMENT

Production rate and available time often vary with time. So it has been persuaded to develop a system which can response to variable time and production rate. With the help of c++ language a software has been developed. It instigates both "Largest Candidate Rule" and "Ranked Positional Weights" Method. When the software runs, it prompts for production rate and available time. And internally the software has all other information inherently. In developing this software the following assumptions has been considered

a) Workstation Layout is fixed
b) Assignment of jobs to stations would not permit the precedence relationship

c) A station Cycle time can't be greater than service time

Station No	Operation No	Stations' Time
1	6,7,1,13,14	.31+.44+.48+.11+.47=1.81"
2	15,16,2,3	.4+.78+.29+.19=1.66
3	21,17,22,23	.40+.98+.29+.19=1.66
4	18,24,25	1.01+.28+.37=1.66
5	26,27,8	.31+.36+.59=1.26
6	9,19,20,28	.64+.19+.72+.27=.82
7	5,29,10,30	.20+.57+.56+.39=1.72
8	31,32	.54+.96=1.50
9	12,33	.966+.77=1.73
10	11,34	.54+1.06=1.60
11	35,36,37	.69+.64+.41=1.74
12	4,38,29,40,41	.13+.28+.61+.20+.33=1.55
13	42,43,44,45	.32+.63+.30+.47=1.72
14	46,47	.38+.87=1.25
15	48,49	.68+.64=1.32
16	50,51,52	.59+.82+.36=1.77
17		
18		

Figure 4. Job assignment to workstations by RPW method.

Station No	Operation No	Stations' Time
1	6,7,1,13,14	.40+.17+.47+.40=1.81
2	15,16,2,3,21(a)	.40+.78+.29+.19+.20=1.86
3	21(b),17,22,23,18(a)	.30+.98+.11+.23+.23=1.86
4	18(b),24,25,26	.88+.28+.37+.31=1.84
5	27,8,9,19	.36+.59+.64+.19=1.78
6	20,28,5,29,10(a)	.72+.27+.20+.57.10=1.86
7	10(b),30,31,32(a)	.56+.39+.54+.36=1.86
8	32(b)12,33(a)	.70+.96+.20=1.86
9	33(b),11,34(a)	.67+.54+.64=1.86
10	34(b),35,36	.52+.69+.64=1.86
11	37,4,38,39,40	.41+.13+.28+.61+.20+=1.86
12	41,42,43,44,45(a)	.20+.32+.63+.30+.40=1.86
13	45(b)46,47,48(a)	.17+.38+.87+.44=1.86
14	48(b),49,50	.34+.64+.59=1.86
15	51,52	0.82+.36=1.18

Figure 5. Job assignment to Workstations by New Method.

Table 2 Comparisons among the tools

Item name	Existing Line	Line Balanced by	New Model
Work Station No.	18	16	15
Balance Efficiency	0.78	0.88	0.93
Station facility cost Reduction	-	$218/month	$327

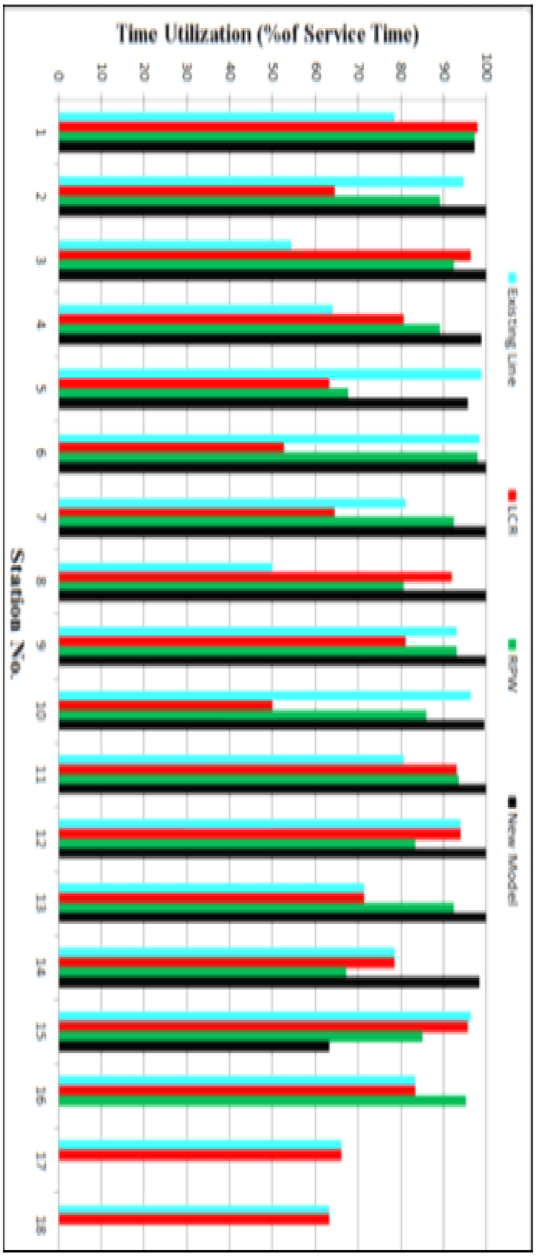

Figure 6. Time utilization obtained in different methods.

OPERATIONS PRINCIPLES

The detail algorithm is shown in Fig. 1. If a station time remain below the 95%* of the service time, then the next job will be split into two portions i,e one portions of the job is done in current station and later portion moves to the next station. This splitting of job requires more time than a normal job. So the sum of the job's time becomes higher. For example job no. 21 has been split in station 2 & station 3. and Station 1 has been used more than 95% of its service time. So the next job No. 15 is not split.

Input Required

Following inputs should be given to the software

a) Production Required:

It is the total no. of product in a accepted order

b) Available time:

It is the time in which the product is to deliver

Output Obtained

a) No of Workstation
b) Balance efficiency
c) Production rate
d) Service time
e) Station time
f) Task allocation to workstation

Results according to New Model:

Station no=1	Element No: 6.00	Tek=0.31	
Station no=1	Element No: 7.00	Tek=0.44	
Station no=1	Element No: 1.00	Tek=0.48	
Station no=1	Element No: 13.00	Tek=0.11	
Station no=1	Element No: 14.00	Tek=0.47	Station time: 1.81
Station no=2	Element No: 15.00	Tek=0.40	
Station no=2	Element No: 16.00	Tek=0.78	
Station no=2	Element No: 2.00	Tek=0.29	
Station no=2	Element No: 3.00	Tek=0.19	
Station no=2	Element No: 21.00	Tek=0.20	Station time: 1.86
Station no=3	Element No: 21.00	Tek=0.30	
Station no=3	Element No: 17.00	Tek=0.98	
Station no=3	Element No: 22.00	Tek=0.11	
Station no=3	Element No: 23.00	Tek=0.23	
Station no=3	Element No: 18.00	Tek=0.23	Station time: 1.86

Figure 7. Programming interface of assigning task to different workstation (software output).

RESULTS AND DISCUSSION

In this paper, an ordinary company's sewing floor product (four pocket command pant) was studied. This company is an organization who are bit of indifferent of using proper tools and techniques. They produce products without considering the standard minute value concept. They generally counts the time of each elemental tasks and adds a rough allowance to obtain the task time through which they determine their workstation requirements. The workstation requirements are found by moving along the processing sequence. So, a vital decision has to make whether the present procedure for task assignment to workstation should continue or proposed system should be superimposed. It needs to compare the methods in some dimensions. Time utilization, cost effectiveness, reduction in the numbers of workstation etc. are the measuring criteria for selection process.

Results based on New Model

Total No of Workstation	:	15
Balance Efficiency	:	0.93
Production Rate is	:	29.76
Service Time is	:	1.86

For details scroll up

Figure 8. Programming interface showing no. of workstation, balance efficiency (software output).

CONCLUSION

From the above study, it can be concluded that Line Balancing is an effective tool to suggest ways to reduce workstation number and increase the throughput of a manufacturing process. These balancing process is used here actually are of two types. These are "Ranked Positional Weight" method and a new model developed by authors.. The both methods are well-organized & competent but differ in efficiency in case of different sized orders. The method which yields the greater efficiency will be selected for determining workstation numbers.

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