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Study the Impact of Fatigue and Optimizing Productivity of an Assembly Line of Garment Industry

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Abstract—Improving productivity is one of the main concerns of apparel industries. This paper provides the idea how productivity levels changes at different time during normal working hours in apparel industries. A noble approach is also proposed to optimize the productivity level. There are many factors which act as obstacles to higher productivity. Unskilled workers, physical fatigue from extended working hour without rest, misplacement of worker at workstation, lack of training, lack of knowledge, awareness are few factors related to worker which directly affect the productivity. Fatigue lowers average productivity, measured as output per worker hour, for almost all of the apparel industries. As the overall daily performance of each worker is not same and the change in their performance defer from one worker to another worker bottleneck creates in the assembly line. During the investigation attention is concentrated on how physical fatigue of workers influences the daily production rate and how to optimize the productivity. If physical fatigue exists, loss due to fatigue can be reduced to a remarkable label. Here, a study has been carried out to find out the effect of fatigue on productivity and to form a framework to improve the productivity based on the overall performance of workers by reducing fatigue.

Index Terms— Productivity, Apparel industries, Fatigue, Optimization, Efficiency, Bottleneck, Utilization

1 Introduction

THE apparel manufacturing industries are now shifting focus from low cost items to high quality and high value products. In addition to customer driven demands, companies are more concerned for good working conditions on the floor due to government regulations and tight labor markets. Now garment manufacturers must explore different ways to meet quality standards while reducing costs through improving productivity, efficiency and safety work. Fatigue has severe affect on productivity and profitability. Fatigue can result mental mistakes, work inefficiently or work beyond their physical capabilities to the point of injury. Fatigue reduces work performance mainly by increasing the time needed to accomplish tasks. Reducing fatigue results concentrating and decreasing operation time means higher productivity. Apparel industries play an important role to the economy of developing countries like Bangladesh, Sri Lanka, Vietnam etc. and it deteriorates with low labor productivity, low efficiency of the workers, fatigue of the workers, lack of efficient infrastructure, low level of investment, lack of opportunities on the job training, lack of knowledge and awareness of the tools for productivity improvement. So it is necessary for apparel industries to develop a framework for some functions of productivity to maintain international level of standards to meet the changing needs of all the customers. Optimization of the assembly line is needed to improve productivity. In this paper the framework is limited only on fatigue and optimization of a garment assembly line.

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2 Literature Review

Many works have done on the effect of fatigue on productivity in the overtime hours. However no works is done on productivity change due to fatigue in the normal working hours.

Savage and Pipkins (2006) worked to find the effect of rest period on hand fatigue and productivity. According to there study the experimental task consisted of collecting hand strength measurements and recording the number of drilled screws. Sixteen study volunteers were randomly assigned and divided into two groups. Half of participants are control group and another half are experimental group. Recovery time was used as the main treatment effect under the experimental condition. The control group worked without having recovery time versus the experimental group receiving recovery time. In 20 minutes the mean number of screws of control group is 157.5 and experimental group is 162.5. The mean hand strength of control group is 83.4 pounds and experimental is 89.4 pounds. Collected data shows a very significant impact of intermittent rest period on recovery.

Hanna, Chang, Sullivan and Lackney (2008) worked on the qualitative part details why and how shift work affects labor productivity, and then addresses the appropriate use of shift work considering labor fatigue. The quantitative component determines the relationship between the length of shift work and labor efficiency. The results of the research show that shift work has the potential to be both beneficial and detrimental to the productivity of manufacturing labor. Small amounts of well-organized shift work can reduce fatigue and a very effec-

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tive response to schedule compression and productivity. The productivity loss, obtained from the quantification model developed through this study, ranges from −11 to 17% depending on the amount of shift work used and fatigue of the labor.

Allen, Slavin and Bunn (2007) worked on secondary analyses of a longitudinal employee panel. Average hours worked during spring 2001 were assessed relative to health, safety, and productivity outcomes. Those working 60+ hours were more likely to report new injuries and diagnoses, but these effects greatly negative affect on labor productivity. More than 60+ hours in a week, the significant impact of fatigue is clearly visible and results less injury with better performance.

Shepard and Clifton (2000) provides statistical evidence of the effects of overtime hours on worker productivity using aggregate panel data for 18 manufacturing industries within the US economy. He suggest that use of overtime hours lowers average productivity, measured as output per worker hour, for almost all of the industries included in the sample. Working long times results fatigue that affect badly on productivity.

Thomas and Raynar (1997) studied on 121 weeks of labor productivity data from four industrial projects. The objective is to quantify the effects of scheduled overtime. The results show losses of efficiency of 10-15% for 50-h and 60-h work weeks. Losses of efficiency are caused by the inability to provide materials, tools, equipment, information and labor fatigue at an accelerated rate.

In this work it is shown that productivity varies time to time in the normal working hours. And optimization of an assembly line, results efficiency increasing from 88.8% to 92.7%.

3 Work Fatigue And Productivity

3.1 Work Fatigue

Fatigue is a physical or mental state caused by over exertion. It reduces a person's capabilities to an extent that may impair their strength, speed, reaction time, coordination, decision making, or balance. Normally, good quality sleep reverses the imbalance, allowing the body and the brain to recover. However, working long hours, working with intense mental or physical effort, or working during some or all of the natural time for sleep can all cause excessive fatigue. Fatigue can also have longer-term effects on health. Fatigue is defined as a state of being tired. The signs, symptoms and affect fatigue has on workers varies from one person to the next, however fatigue may affect the individual worker's ability to perform. Most frequent possible Indicators of Workplace Fatigue are feeling drowsy or relaxed, feeling tired or sleepy or not feeling refreshed after sleep, blurred vision, increased irritability, finding it difficult to keep eyes open, taking more frequent naps during leisure hours or falling asleep at work, finding it hard to concentrate or making more mistakes than usual, excessive head nodding or yawning, increased absenteeism, repeatedly moving off track while driving vehicles and plant, near misses etc. In this study, loss due to fatigue has been calculated based on loss at the bottleneck point. Assume P_a is the units of work actually produced by worker; P_m is the units of works which could be produced at standard performance, P_M is the maximum production capacity considering no fatigue of worker at bottleneck point.

Number of unit loss $= P_M - Pa$ …..……….………..……….. (3.1)

Loss due to fatigue

$$= \frac{P_M - P_a}{P_M} \times 100\% \quad \text{(3.2)}$$

3.2 Productivity

Productivity may be defined as the ratio between output and input. Output means the amount produces or the number of items produced and inputs are the various resources employed. There are many factors affecting productivity of assembly line such as product and system design, machine and equipments, skills and effectiveness of the workers, production volume. In true sense, the productivity can be said as increased if more products can be obtained from the same amount of resources. Indoor environmental quality may affect physiological and psychological processes that, in turn, may affect performance of tasks that may interact with other factors to affect overall productivity. To improve productivity, most efficient workers should be placed at the bottleneck points. It is necessary to improve the existing production capacity of assembly lines through proper optimization technique. Some applications can not be applied. Though the decision variable performance is known and the efficiency of the workers is distinctive i.e. there is no way to use a portion of the efficiency of worker, linear programming optimization technique is not applicable. In network optimization model, there are many paths to follow and sometimes there has a provision to skip any path. But in the apparel assembly line there is no way to skip any operation as well as path, it is also not applicable. Transportation model is not applicable because in assembly line production system there is a distinctive path to follow and there is no provision of skipping any operation for the shack of completing a finish product and sequence of operations must have to be maintained. Assignment model is not suitable because production capacity of assembly line does not depend on several points but depends on the bottleneck points. Genetic algorithm is not applicable because in an assembly line there is no impact of one worker to other.

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Observed time is the time, receiving work from previous workstation to the delivery the work to the next workstation is the observed time for an operation. It defers from one operation to another operation. A bottleneck is defined as any resource whose capacity is less than the demand placed upon it. It is a constraint within the system that limits the throughput. In other word the point in the manufacturing process where the flow thins to a narrow stream. Production Capacity is the ratio of available time to cycle time. Available time means the time of the shift.

Maximum daily actual output-

$$P = \frac{T}{C} \quad \text{(3.3)}$$

Where, *T*= Available time, second; *C*= Cycle time (second/unit)

Performance Rating or Efficiency is the ratio of units of work actually produced by worker and units of work which could be produced at standard performance.

Performance rating or efficiency-

$$\eta_K = \frac{P_a}{P_m} \times 100\% \quad \text{(3.4)}$$

$\eta_k =$ Performance rating or efficiency of worker; K=A, B, C……………L

Where A, B, C…L are the respective workers.

Utilization means the productive time on the available time of a cycle. At the non bottleneck point, the productive time is less than the cycle time and some portion of the cycle time is not used. Assuming number of workstation in the assembly line is n, C is the cycle time (sec) and the productive time is T_j (sec), where j=1, 2, 3……………n

The relationship between productive time T_j and cycle time C is given as follows $T_j \leq C$

Utilization-

$$\mu = \frac{\sum_{j=1}^{n} T_j}{nC} \times 100\% \quad \text{(3.5)}$$

nC = Total line capacity, second, n = Total number of workstation.

Line Efficiency is how effectively the line is used in term of line capacity. In other words it is the ration of produce time to spend time. Line efficiency is expressed through the following equation:

Line efficiency-

$$\eta_K = \frac{\frac{\sum_{j=1}^{n} T_j}{n}}{C} \times 100\% \quad \text{(3.6)}$$

Line and work cell balancing is an effective tool to improve the throughput of assembly line and work cells while reducing manpower requirements and costs. Assembly Line Balancing, or simply Line Balancing (LB), is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense. LB has been an optimization problem of significant industrial importance.

4 Proposed Optimization Model

It is developed based on the overall daily performance of each worker. Due to the physical fatigue of worker, performance of worker changes with time and the label of performance of each worker do not remain same. Assumptions are continuous flow of material through the assembly lines, efficient workers are placed at bottleneck points where bottleneck point's workers are placed at less processing time taken operation's and can do that operation at its own efficiency, replaced bottleneck point workers have the capability of reaching the line target at 100% efficiency or more, one workstation can be half, one or a group, there is no effect on performance due to change in weather, variation in working environment, no effect of fatigue of data collector in collecting whole day data.

At first by using stop watch, the observed processing time and average processing of each operation has been obtained. Standard processing time of each operation is considered as factory standard. Then using average processing time of each operation of each time segment, the performance of individual worker has been found. Standard processing time of each operation is different. Then workers are assigned randomly at different workstations without considering their level of performances. Number of workers at each workstation depends on standard time of the corresponding operations. Then identify bottleneck points based on more processing time taken operations. The efficient workers are placed at bottleneck point where less efficient worker occupied by less processing time took operation. Then again the new bottleneck points are identified and the process is repeated until decreases the assembly line efficiency as well as increase the processing time at bottleneck points. The production capacity of each workstation of each time segment has been calculated based on processing time of bottleneck points. Then excess capacity has to remove by releasing inefficient worker or increasing capacity or distribute works as well as balancing assembly line. Unnecessary workers increase the production cost and the workers have no contributions in improving production capacity. Finally the optimum production capacity, loss due to fatigue, line utilization and line efficiencies are calculated. In the following figure 1, shows the steps necessary for optimizing productivity.

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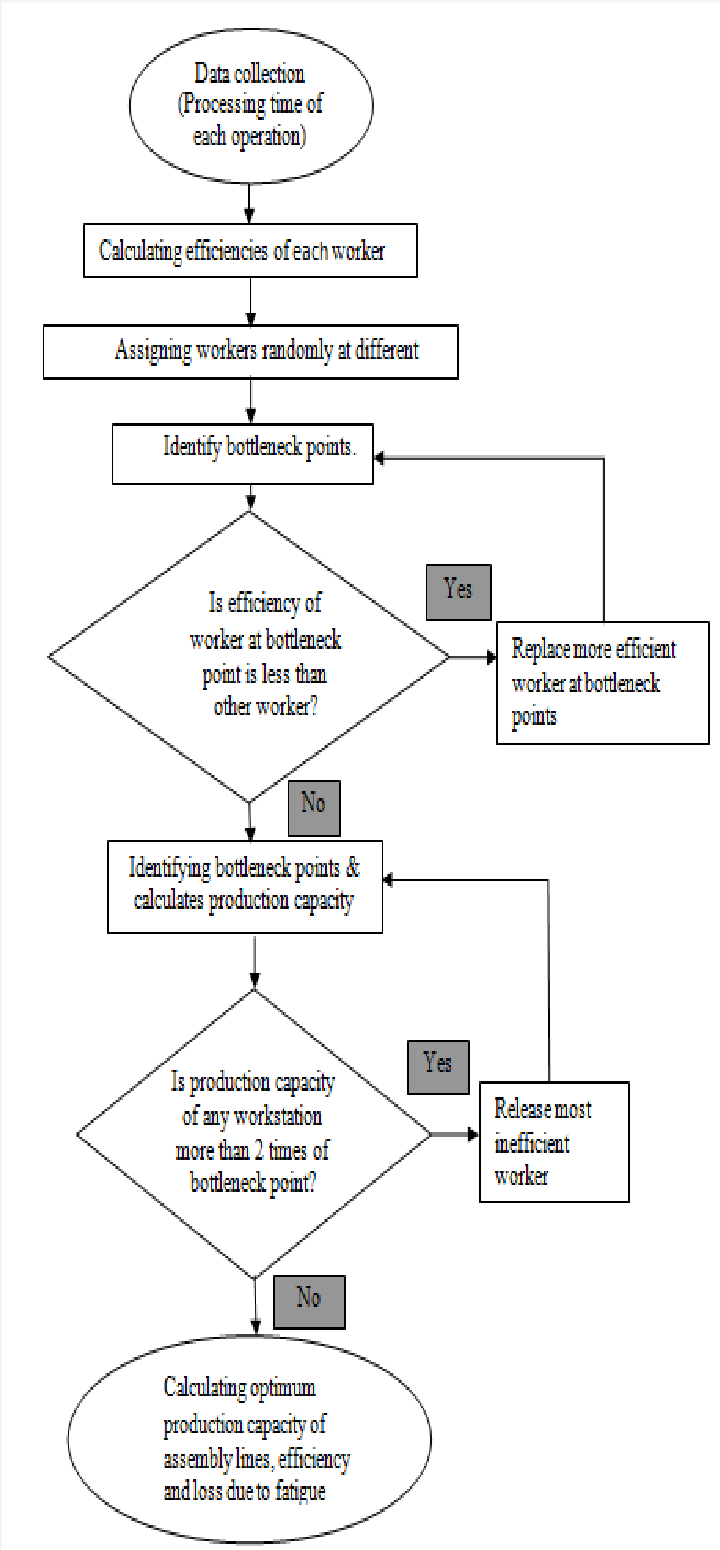

Figure 1: Steps for optimizing assembly line productivity.

5 Data Collection and Analysis

In this study a woven shirt manufacturing industry is selected to optimize the assembly line and observe the impact of fatigue on productivity. First operation bulletin of boy's short sleeve shirt is made. Sections, operations, machine, factory standard of each operation's cycle time and target based on it are exist. Line target at 100% efficiency and theoretical workstation exists. Operation bulletin is shown in table 1.

Table 1: Operation bulletin of boy's short sleeve shirt

Serial Number	Operation description	FS CT (sec)	Line CT (sec)	Efficiency (%)	Rank 1to5	W/S (FS)	W/S (Line CT)	Actual W/S
1	Front & pocket over o/l	24.12	26	92.8	1	1.87	1.83	2
2	Facing tack	12.6	14.5	86.9		0.98	1.02	1
3	Collar notch turn	9	10	90.0		0.70	0.70	1
4	Facing iron	15	15.5	96.8		1.17	1.09	1
5	Facing fold After iron	8.4	9.5	88.4		0.65	0.67	1
6	Press Pocket around	32	32.4	98.8		2.49	2.28	2
7	Pocket, flap, patch mark	22	23.5	93.6		1.71	1.65	2
8	Set Pocket	42	45.6	92.1		3.26	3.20	3
9	Flap attach	24	27	88.9	3	1.87	1.90	1.5
10	Patch Iron	18	19.6	91.8		1.40	1.38	1
11	Patch Attach	24	27	88.9	4	1.87	1.90	2
12	Run Collar	23.2	25.4	91.3	3	1.80	1.78	1
13	Trim and Turn	7.2	13.8	52.2		0.56	0.97	1
14	Topstitch Collar	30	35.4	84.7		2.33	2.49	2.5
15	Collar Cut & Iron	12	13.5	88.9		0.93	0.95	2
16	Flap Iron	38	39	97.4		2.95	2.74	3
17	Flap Top stitch	30	33.2	90.4	5	2.33	2.33	2
18	B/Hole Flap	12	14.55	82.5		0.93	1.02	1
19	Sleeve rolling	13	14.5	89.7		1.01	1.02	1
20	Pair Sleeve	9	9.3	96.8		0.70	0.65	1
21	Excess Sleeve trim	18.6	20	93.0		1.45	1.41	1
22	Match body &parts	19.2	20.4	94.1		1.49	1.43	1
23	Join Shoulder	15	17	88.2		1.17	1.19	1
24	Shoulder Thread Trim	9.6	9.8	98.0		0.75	0.69	1
25	Attach sleeve	19	21	90.5	1	1.48	1.48	1.5
26	Label attach	21	23.5	89.4		1.63	1.65	2
27	Notch mark	16	19.8	80.8		1.24	1.39	1
28	Set collar & notch cut	25	27.6	90.6		1.94	1.94	2
29	Close collar with label	29	32	90.6	5	2.25	2.25	2
30	Sleeve tack	24	29.4	81.6		1.87	2.07	2
31	Trim Thread	12.6	12.8	98.4		0.98	0.90	1
32	Body arrange	6.6	7	94.3		0.51	0.49	1
33	Side seam	24	26.4	90.9	4	1.87	1.86	2
34	Trim bottom hem	14.4	15.35	93.8		1.12	1.08	1
35	Hem Bottom	30	32.4	92.6	2	2.33	2.28	2.5
36	Button hole Front	24	27.3	87.9		1.87	1.92	2
37	Sticker remove	28.5	29	98.3		2.21	2.04	2
38	Body bar tack	30	33.8	88.8%		2.33	2.38	2

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At 100% efficiency line target is 280 pieces of garments per hour. After that lay-out is done by sequencing the operations, randomly place worker at the workstations. Assembly line target is given at 100% efficiency which depends on efficiency, manpower, working hour and operation cycle times. Based on this CT(cycle time) theoretical total number of W/S (workstation) is calculated. Workers are assigned randomly in those workstations. Average cycle time and capacity of each operation are calculated. Efficiency of workers depends on FS (Factory standard) operation cycle time and average cycle time of the respective operations. Workers are ranked according to there efficiencies which is shown in table 1.

From table1 most efficient workers are found according to their rank which depends on their efficiencies. Bottle neck points are found based on more processing time taken operations. Most efficient workers placed at the bottle neck points whether his/her place occupied by less processing time taken worker. Then again identify the bottleneck points and continue until line efficiency decrease. Actual workstation is kept half or whole number based on theoretical workstation. From table 1 line standard minute value 12.87 minute and workplace 60 are found. In this study only 5 ranks are considered where higher the rank higher the efficient worker and it limits only on sewing operators. In figure 2 shows the bottleneck points with other sewing operations.

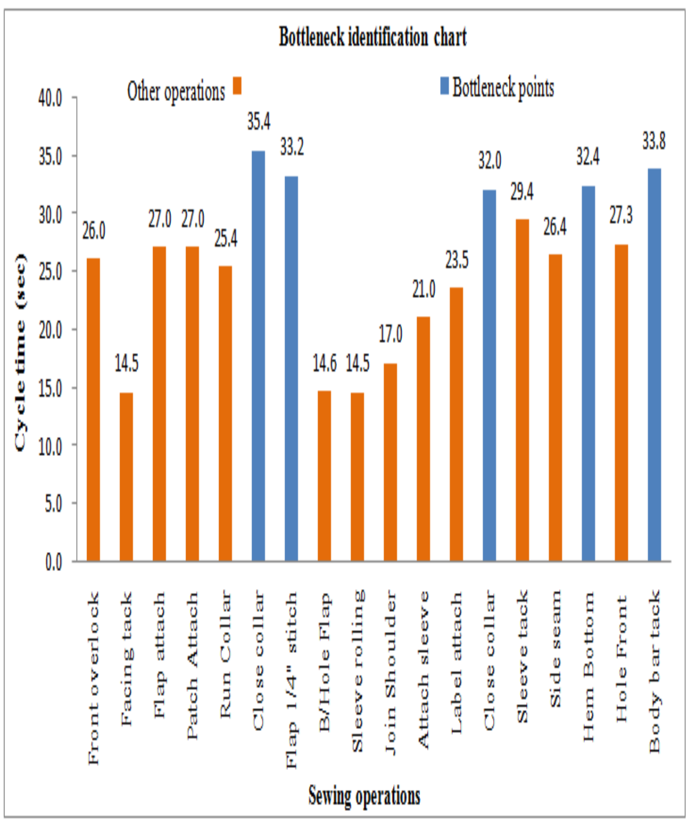

Figure 2: Identification of bottleneck poins

Table 2: Ranks, efficiencies and new bottleneck points with operation CT in various iterations (Iteration 1 to 3)

Worker Number	Operation description	FS CT (sec)	Line CT (sec)	Efficiency (%)	Rank 1 to 5	Iteration(1)		Iteration(2)		Iteration(3)	
						Bottle neck point	CT (sec)	Bottle neck point	CT (sec)	Bottle neck point	CT (sec)
1	Front & pocket over lock	24.1	26	92.8	1		26		26		26
2	Facing tack	12.6	14.5	86.9			14.5		14.5		14.5
9	Flap attach	24	27	88.9			27		27	5	26
11	Patch Attach	24	27	88.9			27		27	5	27
12	Run Collar	23.2	25.4	91.3	3		25.4		25.4		25.4
14	Topstitch Collar	30	35.4	84.7		1	33.0	1	32.6	1	31.8
17	Flap Top stitch	30	33.2	90.4		4	32.0	2	31.8	3	31.2
18	B/Hole Flap	12	14.55	82.5			14.6		14.6		14.6
19	Sleeve rolling	13	14.5	89.7			14.5		14.5		14.5
23	Join Shoulder	15	17	88.2			17		17		17
25	Attach sleeve	19	21	90.5			21		21		21
26	Label attach	21	23.5	89.4			23.5		23.5		23.5
29	Close collar with label	29	32	90.6	5	5	31.0	3	30.9	4	30.1
30	Sleeve tack	24	29.4	81.6			29.4	4	27	5	27
33	Side seam	24	26.4	90.9	4		26.4		26.4		26.4
35	Hem Bottom	30	32.4	92.6	2	3	32.0	2	32	2	31.8
36	Button hole Front	24	27.3	87.9			27.3	5	27	5	27
38	Body bar tack	30	33.8	88.8		2	32.0	2	32	2	32

Table 2: Ranks, efficiencies and new bottleneck points with operation CT in various iterations (Iteration 4 to 6)

Worker Number	Operation description	FS CT (sec)	Line CT (sec)	Efficiency (%)	Rank 1 to 5	Itera-tion(4)		Itera-tion(5)		Itera-tion(6)	
						Bottle neck point	CT (sec)	Bottle neck point	CT (sec)	Bottle neck point	CT (sec)
6	Front & pocket over lock	24.1	26	92.8	1		26		26		26
2	Facing tack	12.6	14.5	86.9			14.5		14.5		14.5
9	Flap attach	24	27	88.9			26		26		26
11	Patch Attach	24	27	88.9			27		27	5	28
12	Run Collar	23.2	25.4	91.3	3		25.4		25.4		26.5
14	Topstitch Collar	30	35.4	84.7		2	30.5	3	30.5	1	31
17	Flap Top stitch	30	33.2	90.4		4	30.4	4	30.4	3	29.5
18	B/Hole Flap	12	14.55	82.5			14.6		14.6		14.6
19	Sleeve rolling	13	14.5	89.7			14.5		14.5		14.5
23	Join Shoul-der	15	17	88.2			17		17		17
25	Attach sleeve	19	21	90.5			21		21		21
26	Label attach	21	23.5	89.4			23.5		23.5		23.5
29	Close collar with label	29	32	90.6	5	5	30	5	29.5	4	31
30	Sleeve tack	24	29.4	81.6			27		27	5	27
33	Side seam	24	26.4	90.9	4		26.4		26.4		27
35	Hem Bottom	30	32.4	92.6	2	3	31.3	2	30.5	1	30.5
36	Button hole Front	24	27.3	87.9			27		27	5	27
38	Body bar tack	30	33.8	88.8		1	31.8	1	30.4	2	31

Table 3: Efficient workers are replaced by bottleneck points in various iterations.

Rank	Efficient worker position						
	Ini-tial	Itera-tion-1	Itera-tion 2	Itera-tion 3	Itera-tion 4	Itera-tion 5	Itera-tion 6
Efficient 01	1	14	14	14	38	38	14/35
Efficient 02	35	38	17/35/38	35/38	14	35	38
Efficient 03	12	35	29	17	35	14	17
Efficient 04	33	17	30	29	17	17	29
Efficient 05	29	29	36	9/11/30/36	29	29	11/30/36

From table 3 in iteration 2 efficient worker 2 can be replaced by positions 17, 35, 38 and randomly we choose position 17. In iteration 3, efficient worker 2 and 5 replaced by 35 and 9 and in iteration 6 efficient worker 1 and 5 replaced by 14 and 11. From table 1 assembly line efficiencies are calculated. Efficient workers are interchanged and new bottleneck points are identified which we get from table 2. Line efficiencies are calculated through FS and cycle times collected from assembly line. In this study initially line efficiency is 88.8%, in iteration 1 efficiency is 90.2%, in iteration 2 efficiency is 90.8%, in iteration 3 efficiency is 91.5%, in iteration 4 efficiency is 92.2%, in iteration 5 efficiency is 92.7% and in iteration 6 efficiency is 91.8%. Through iterations initial to iteration 5 assembly line efficiency increases but in iteration 6 it decreases. Due to decreasing efficiency in iteration 6, the optimization process is stopped. In figure 3 efficiencies are shown in different iterations.

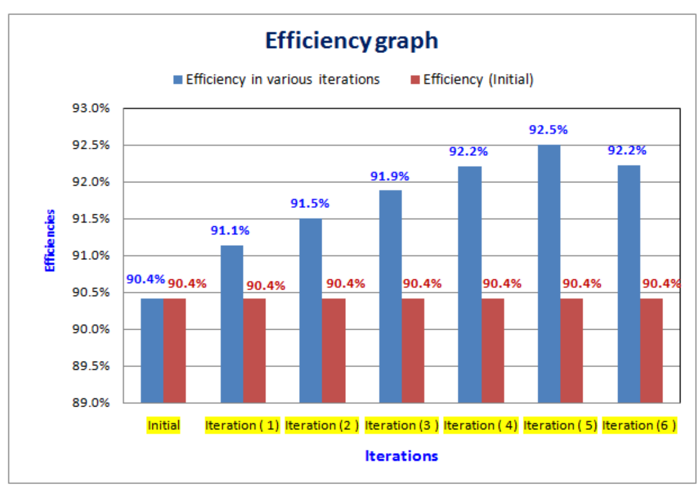

Table 4: Productivity loss, utilization (In percentage)

Worker number	Operation description	FS CT (sec)	Productive time (sec)	Theoretical w/s	Initial w/s	Balanced w/s	Maximum production capacity	Initial line target	Balanced line target	Average Output	Loss (pieces)	Loss (%)	Utilization (%)
1	Front & pocket o/l	24.1	21.2	1.8	2.0	2	339	299	299	233	66	22	69
2	Facing tack	12.6	11.3	1.0	1.0	1	317	286	286	228	57	20	72
9	Flap attach	24	21.6	1.9	1.5	2	333	225	300	245	55	19	73
11	Patch Attach	24	21.6	1.9	2.0	2	333	300	300	249	51	17	75
12	Run Collar	23.2	20.4	1.7	1.0	2	353	155	310	267	44	14	76
14	Topstitch Collar	30	27.0	2.5	2.5	2	267	300	240	224	16	6.8	84
17	Flap Top stitch	30	27.0	2.3	2.0	2	267	240	240	231	9	3.9	86
18	B/Hole Flap	12	10.2	1.0	1.0	1	353	300	300	259	41	14	73
19	Sleeve rolling	13	11.7	1.0	1.0	1	308	277	277	247	30	11	80
23	Join Shoulder	15	13.2	1.2	1.0	1	273	240	240	213	27	11	78
25	Attach sleeve	19	16.7	1.5	1.5	1.5	323	284	284	253	31	11	78
26	Label attach	21	18.9	1.7	2.0	1.5	286	343	257	232	25	9.8	81
29	Close collar	29	26.1	2.3	2.0	2	276	248	248	245	3	1.2	89
30	Sleeve tack	24	21.6	2.1	2.0	1.7	278	300	251	243	7	2.9	87
33	Side seam	24	21.1	1.9	2.0	1.7	285	300	251	240	10	4.2	84
35	Hem Bottom	30	27.0	2.3	2.5	2	267	300	240	240	0	0.0	90
36	Button hole Front	24	20.4	2.0	2.0	1.7	295	300	251	245	5	2.1	83
38	Body bar tack	30	26.1	2.4	2.0	2	276	240	240	240	0	0.0	87

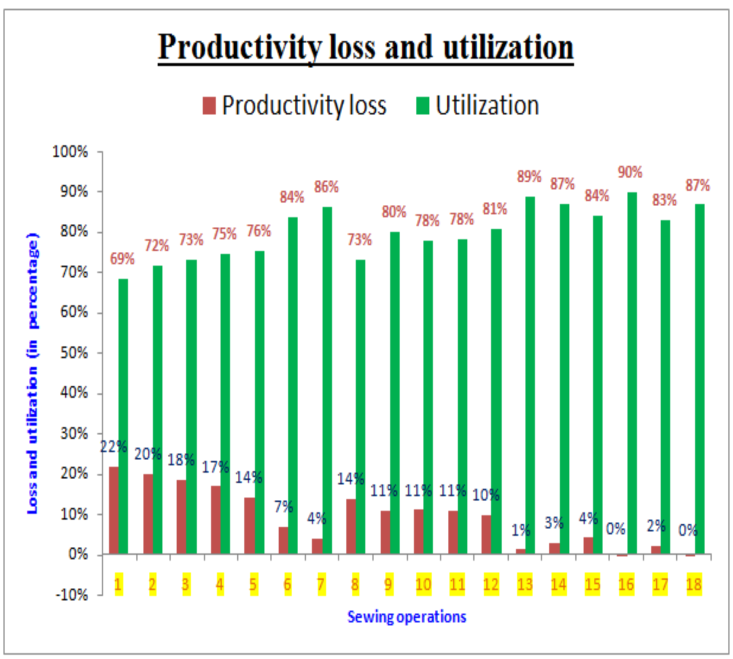

Figure 4: productivity loss and utilization (In percentage)

6 Fatigue Data

Table 5: Productivity variation and fluctuation with time (Before lunch hour)

Worker number	Target	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:0	10:0-10:3	10:3-11:0	11:0-11:3	11:3-12:0	12:0-12:3	12:3-01:0
1	299	90	100	100	110	120	120	115	120	110	100
2	286	88	98	98	108	118	118	113	118	108	98
9	300	95	105	105	116	126	126	121	126	116	105
11	300	96	107	107	118	128	128	123	128	118	107
12	310	103	114	114	126	137	137	132	137	126	114
14	240	86	96	96	106	115	115	110	115	106	96
17	240	89	99	99	109	119	119	114	119	109	99
18	300	100	111	111	122	133	133	128	133	122	111
19	277	95	106	106	117	127	127	122	127	117	106
23	240	82	92	92	101	110	110	105	110	101	92
25	284	98	109	109	120	130	130	125	130	120	109
26	257	90	100	100	109	119	119	114	119	109	100
29	248	95	105	105	116	126	126	121	126	116	105
30	251	94	104	104	115	125	125	120	125	115	104
33	251	93	103	103	113	124	124	118	124	113	103
35	240	93	103	103	113	124	124	118	124	113	103
36	251	90	105	105	116	127	127	121	127	116	105
38	240	94	103	103	113	124	124	118	124	113	103

Table 5: Productivity variation and fluctuation with time (After lunch hour)

Worker number	Target	2:00-2:30	2:30-3:00	3:00-3:30	3:30-4:00	4:00-4:30	4:30-5:00	Average Output
1	299	100	110	130	130	130	140	233
2	286	98	108	127	127	127	137	228
9	300	105	116	137	137	137	147	245
11	300	107	118	139	139	139	150	249
12	310	114	126	149	149	149	160	267
14	240	96	106	125	125	125	134	224
17	240	99	109	129	129	129	139	231
18	300	111	122	144	144	144	155	259
19	277	106	117	138	138	138	148	247
23	240	92	101	119	119	119	128	213
25	284	109	120	141	141	141	152	253
26	257	100	109	129	129	129	139	232
29	248	105	116	137	137	137	147	245
30	251	104	115	136	136	136	146	243
33	251	103	113	134	134	134	144	240
35	240	103	113	134	134	134	144	240
36	251	105	116	137	137	137	148	245
38	240	103	113	134	134	134	144	240

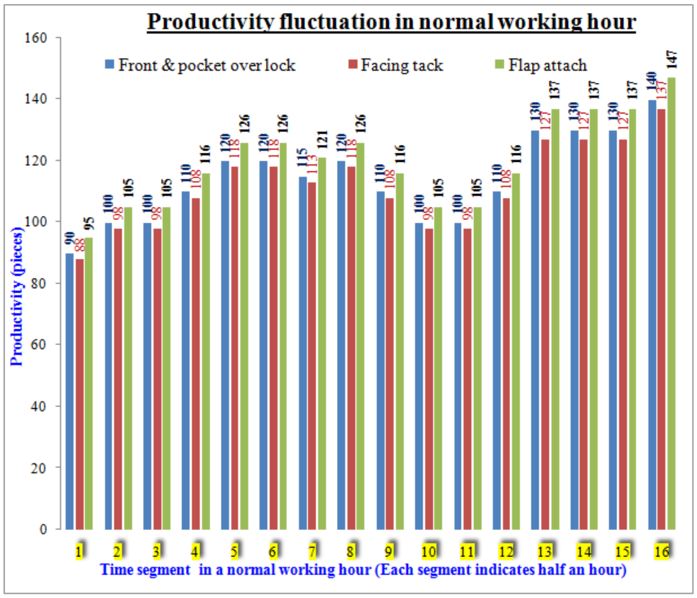

Figure 5: Fluctuation of productivity with time

In table 5, it is clear shown that for the same sewing operation productivity varies time to time due to fatigue and other resons. Data are collected for each operation in half hourly basis from start at 8:00 am and finished at 5:00 pm with one hour lunch break from 01:00 pm to 02:00 pm in a normal working hour.

In figure 5, three operations are selected to show the fluctuation of productivity with time to time. The operations are front and pocket overlock, facing tack and flap attach.The same color bar chart indicates variability of productivity in the normal working hour with half an hour time interval.

7 Conclusion

Because of increasing competition in apparel products in the global market, it is very important for apparel manufacturing industries to maintain the demand and deadline of shipments. In most of the assembly lines in the apparel industries, workers are not placed based on their skill which reduces productivity and deteriorates deadline of shipments with increasing costs. This work is carried out for the purpose of analysis and development a frame work for improving productivity based on the performance of the workers. To develop the framework time study, fatigue study, worker performance has been studied. Bottleneck point's time can be reduced by placing efficient workers at the bottleneck points. Number of total workers required in the assembly lines can be reduced by placing efficient workers at the bottleneck points. Productivity loss due to fatigue only depends on the nature of performance of workers assigned at the bottleneck points and it can not be reduced after a certain limit. Maximum production capacity can be found with lowest loss in the bottleneck points. It is clear that worker's physical fatigue can be reducing to an extent by improving source of physical fatigue such as lighting, ventilation, sufficient space allocation, keeping lower label of noise etc. It incurs some additional cost to the product and the main goal of any apparel industries are not only to provide service but also profit. If the additional cost is very high compare to the improvement of productivity, it is not wise to expense to develop the environment of workplace. It is necessary to examine the relationship between improvements of productivity and increase in the costs. To compensate for the fewer workers, overtime hours worked by industrial hourly workers have been on a steady increase for years which increases in physical fatigue can lead to a decrease in the quality of the produced goods. A future study can be carried out to find the profitability comparing the productivity, additional costs and quality.

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References

[1] Shepard.E and Clifton.T, "Are longer hours reducing productivity in manufacturing?", International Journal of manpower, Vol.21, pp.540-533

[2] Savage. M and Pipkins. D,"The effect of Rest Periods on Hand Fatigue and Productivity"Journal of Industrial Technology, Vol. 22, pp.1-6

[3] Fallentin. N, Viikari-Juntura. E, Waerested. M and kilborn. A,"Evaluation of physical workload standards and guide lines from a Noradic perspective"Scand J work eviron health, Vol 2, pp.3-53

[4] Tanabe. S, Nishihara. N and Heneda. M,"Indoor temperature, productivity and fatigue in office task" HVAC & R Research, Vol 10, pp.120-135

[5] Leilanie. J,"Perceived Job Stress of women workers in Diverse Manufacturing Industries", Wiley Periodicals. Inc, Human Factors and Ergonomics in Manufacturing, Vol.15(3), pp.257-291

[6] Dragcevic. Z, Zavec. D, Rogale. D and Gersak. J,"Workloads and standard time Norms in Garment Engineering", Journal of Textile and Apparel, Technology and Management, Vol 2(2), pp.1-8

[7] Hanna. A, Chang. C, Sullivan. K and Lackney. J,"Impact of Shift Work on labor Productivity for Labor Intensive Contractor", J. Constr. Engrg. And Mgmt. 134, 197; doi:10.1061/(ASCE)0733-9364;134:3(197)

[8] Harris. A, Thomas. S and William. B,"Do Long Workhours Impact health, Safety and Productivity at a Heavy Manufacturer", Journal of Occupational and Environmental Medicine, Vol 49, No. 2.

[9] Thomas. R and raynar. K,"Quantitave analysis on scheduled overtime and lobor productivity", Journal of construction Engineering and Management, vol. 123, No.2. Allen, Harris M. Jr Ph D; Slavin, Thomas MS, MBA; Bunn, William B. III MD, JD, MPH