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Improvement of Operational Performance through Value Stream Mapping and Yamazumi Chart: A case of Bangladeshi RMG Industry

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Abstract**: *To secure a competitive position in the global market, the Ready Made Garment (RMG) sector in Bangladesh has been facing various challenges including the improvement of industrial operational performance. Among the various operational issues, balancing the cycle time along the production line is felt to be a common and effective way for enhanced performance. There are numerous exact and approximate methods which have already been proposed and are available in literature for repetitive batch production. Unfortunately such approaches are rarely applied in the real RMG shop floor presumably due to the enormous efforts needed to align with the frequent changes of product lines. Compared to the exact and approximate methods, adoption of lean tools like VSM and Yamazumi chart is highly acclaimed for their simpler and wider applicability with superior capability in addressing and solving the balancing problems. So for balancing purposes of the RMG shop floor an attempt is made to frame and apply an integrated model combining the VSM and Yamazumi chart as presented in this article. Depending on the theoretical framework, operational performance of an RMG shop floor is evaluated upon balancing the cycle time. In doing so, firstly a current state map (CSM) and the corresponding Yamazumi chart are plotted to comprehend the existing operational procedure and analyse the workstation cycle time with respect to the takt time. Using the Yamazumi chart, the workstations are reorganized to reduce or eliminate the non-value added activities, to introduce parallel workstations, and to merge workstations so that a balanced production line is attained. Performance is then assessed by means of Overall Effectiveness of Equipment (OEE), Capacity Utilization and Efficiency. The results as obtained through testing a real life case study of RMG industry, ensure the effectiveness of the integrated system of VSM and Yamazumi chart to identify the wastes, restore the line balance and improve operational performance.***

Keywords: Value Stream Mapping, Yamazumi Chart, RMG industry, Line Balancing.

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I. INTRODUCTION

The Ready Made Garments (RMG) industries have been playing a crucial role for the socio-economic development of Bangladesh [1]. The Bangladeshi RMG industries started its journey in the late 1970s, grew significantly in 1980s and are identified as vital player for the socio development since 1990s. Within this short period of introduction, the RMG sector aids Bangladesh to transform itself from aid receiving nation to a trading nation. Nowadays, more than 83.49% of total export incomes of Bangladesh are earned directly from the RMG Sector and/or industries [2]. This RMG sector, comprising of more than 4,560 numbers of factories, are employing almost 4 million of Bangladeshi workers [3], [4]. Moreover, this sector is the first to provide the employment opportunities to women in a mass-scale within a country where women were traditionally not allowed to work outside home. Unfortunately, despite of having these tremendous opportunities, the Bangladeshi RMG sector is currently facing crucial challenges to keep and/or increase its share at international market. To compete and sustain in the global market, the RMG industries have to offer the high-quality product on time at lower price [5]. And for which, the industries have no option but to lessen the cycle-time of workstations, minimize the production lead time, enhance the efficiency, improve the OEE and increase the utilization. It is realized that, the cycle time reduction and/or the improvement of utilization and functional efficiency will help the RMG industries to gain the competitive advantages by means of cost leadership, differentiation and responsiveness. However, in practice, the production shop floors of most of the RMG industries in Bangladesh are suffering from the numerous commonly happening problems like uneven load distribution between the consecutive workstations and/or stages, large volume of inventories, quick changeover in production schedule, rejection of end items, interrupted flow of raw material and information. Among which, the uneven load distribution between the consecutive workstations makes the RMG industries incapable to satisfy the customer demand on time at low cost. One of the ways to approach this kind of intricate problems is to reduce the shop floor wastes like waiting time by balancing the cycle time of the workstations. In literature, a number of exact and approximate methods have already been proposed to solve this balancing problem. However, due to the lack in capabilities of reflecting real life situation, availability of case specific models, and less concern about the applied aspects, the exact and approximate methods are rarely adopted by the industries to configure their flow line [6], [7]. The adoption of lean Philosophy might help in this regard [6]. The term lean as defined in literature is a process that uses less of everything i.e. reduced human effort in shop floor, small shop floor space, low capital investment in machine tools, low engineering hours for new product development. This way of management also ensures fewer shop floor inventories, less numbers of defected products, and demonstrate the ability to produce wide varieties of products [8]. In literature the Lean is defined as a systematic way of upgrading the process by means of a set of principles and tools for continuous improvements [9]. Lean is also viewed as an integrated approach which incorporates various tools, approaches, and tactics for easing the product development process and managing the operations and supply chain in a comprehensive manner [10]. Even, Lean is considered as a classical management epitome where the human experts play a crucial role by extending their thinking to ensure the continuous improvements and agility in gratifying the consumer demand [11].Apart from this definition, Lean is also viewed management tactics to identify and eradicate the waste emerges throughout the entire value stream of any considered product [12]. Within the domain of Lean, the waste is described as anything that consumes resources (material, people, and equipment) without creating value from the context of customer [13]. In other words, from consumer's view point waste is something which does not add-value to end item but consume the time and cost [14]. In literature, from the context of lean, seven different types of wastes are commonly addressed which include overproduction, inventory, defect, transportation, waiting, movement of people, processing [13]. The researchers firmly believe that these wastes can be identified, evaluated and controlled by practicing five general lean principles. These principles are (1) identify the value, (2) map the value stream, (3) create flow, (4) respond to customer, and (5) pursue the perfection.

Among these principles, mapping the Value stream is very crucial step as it helps to identify and evaluate the waste, and to improve the stream by creating a structured image of the material and information flow. Value Stream Map (VSM), specifically the current state map (CSM) is designed to identify the sources of the wastes and thereby, helps to formulate the remedial policies to reduce and control the waste and/or improve the operational performance. The current state map exhibits all the process flows in stepwise manner, by which it is possible to understand what necessary action have to take to improve the process. Whereas, the future state map (FSM) of the VSM exhibit the possible improvement that can be attained by adopting the suggested procedure.

As evident in literature, the researchers adopted the VSM to identify the wastes and recognize the outcomes obtained by the proposed remedial policies. For instance, Saleeshya, Raghuram & Vamsi [15] have explored and analysed the current state of VSM to identify the wastes and evaluate the operational performance of the shop floor of a textile industries. The identified wastes lead the researchers to suggest for the incorporation of 5S in work place and practice the kaizen, poka-yoke, quality circle, and Kanban system for the improvement. Whereas, Mohammad, Ahmad and Iqbal [16] adopted the VSM as tool for identifying and portraying the operational performance and existing wastes of the shop floor of the Ready Made Garments (RMG) industry. Depending on their plotted CSM, the researchers recognized the changeover as one of the main causes which increases the waiting time. As a remedial policies, by characterizing the realized benefits through the plotted FSM, the authors proposed to incorporate the Quick change-over system like Single Minute Exchange of Dies (SMED), the 5S method in work place, ensure total preventive method, develop Multi-skill worker, adopt total quality management system and the Kanban system for the cutting and sewing sections.

Kumar [17] also adopted the VSM to identify the causes of waste generation in the sewing line of an apparel industry. Depending on the plotted VSM, the researcher identified the layout problem and the structure of materials flow as the root causes behind the emergence of the waste like longer lead time. As a consequence, by characterizing the realized benefits from the plotted future state map, the author proposed to adopt the cellular layout structure, keizan and single piece flow principles as the remedial policies. Whereas, Behnam, Ayough and Mirghaderi [18] used the VSM to identify the Mudas in the manufacturing flow line of a natural fibre clothing industry and suggested to reduce the batch size, increase the workers, ensure the continuous flow and change the sequence of operations as the key policies for waste reduction. The VSM is also incorporated to identify the wastes of Textile shop floor by Carvalho, Carvalho & Silva [19]. In their work, the researchers recognized that the shop floor waste like inventory can be reduced significantly by adopting the Kanban system as well as formulating the master production schedule.

Even though, as evident in literature, an extraordinary effort is made to evaluate the wastes and formulate the remedial policies for improving operational performance by using several lean tools, a systematic way depending on the context of the problem is required to ease the path for solving the problem [20]. In this context, the usage of Yamazumi chart along with the VSM is realized to be a prominent approach to balance the work station cycle time and thereby improve the operational performance [21]. However, as best of our knowledge, regardless of its labour intensive mass production structure the RMG shop floor has not been thoroughly examined to balance the cycle time for improving the operational performance through the combination of Yamazumi chart and VSM. Hence, to fill this research gap and explore the benefits of real life application of an integrated lean approach, an attempt has been made to streamline the cycle time and improve the operational performance of the sewing line of a Bangladeshi RMG industry. The remaining sections of the paper are organized with a wide literature review, research methodology, case study, discussion and conclusion.

II. LITERATURE REVIEW

Value Stream Mapping (VSM) is a visual process which helps an analyser to comprehend the operational performance of the flow line or the shop floor, identify the non-value added activities or the wastes and exhibit the eventual benefits to be secured through adoption of any improvement policies. With the VSM it is also possible to articulate the entire manufacturing systems beginning from the sourcing of raw ingredients to the supply of end items along with the shop floor wastes [22]. Agarwal and Katiyar [23] believe that the VSM helps the manufacturers to reduce the waste by ensuring fewer defects, less scraps, low energy usage, etc. Whereas, Forno et al. [24] recognized that the VSM would help an organization to identify the value-adding activities, the flow of information and the people. More specifically, the current state map (CSM) helps to identify the complications within the shop floor, explore the causes of the obstacles and formulate the strategies for its reduction. Besides, Saraswat, Sain and Kumar [25] noted the VSM as an effective tool for identifying the shop floor wastes and easing the way of policy making to improve the overall effectiveness and efficiency. As a consequence, nowadays, the VSM is widely adopted in various manufacturing and service industries including textiles, automobiles, ceramics, and electronics, logistics, services, healthcare, product development, banks, and even in agribusiness [24].

For instance, by plotting the CSM Belokar et.al [26] identified the waiting time as a waste for their considered automobile industry and proposed to introduce the new welding machine and change the layout plan for reducing this waste. The eventual benefits as exhibited through the plotted FSM, the researchers recognized a 67% reduction in cycle time. However, the cost of investment in attaining this improvements is not discussed in their work. Whereas, Singh & Singh (2013), adopted the VSM to identify the shop floor wastes in an auto-part manufacturing company [27]. After evaluating the operational performance through CSM, the researchers provoked to introduce single minute exchange die (SMED) method, drilling and CNC boring instead of boring through lathe, and work instruction sheets to reduce the wastes. As a subsequent effect, by means of the FSM, the researcher observed that for the case of replacement ball product the cycle time is converged by 69.4%, Work in Process (WIP) inventory by 18.26 % and manufacturing lead time by 24.56%. Whereas, for the end product of Weldon ball the researchers perceived that an improvement of 51.87 % in cycle time, 21.51% in WIP, 25.88% in manufacturing lead time are possible to secure through the incorporation of VSM. Nallusamy [28] used the value stream map to identify the wastes and adopted the work standardization as well as manual line balancing approach for establishing balanced workload among the staffs and increasing the employee's utilization of a CNC machining chamber. By doing so, the researchers were able to reduce the cycle time by 153 minutes.

Besides Singh, Singh, Singh & Singh (2017) adopted the concepts of value stream map (VSM) in a casting organization to identify the shop floor waste and improve the operational performance [29]. By bringing some of the operational changes in the unmoulding, painting and packing section, the researchers were able to reduce the non-value added time by 14.28%. While, the net cycle time of operation is also found to reduce from 12 to 9 minutes. Whereas, to increase the productivity of MCCB manufacturing assembly line, Pambhar and Pambhar [30] adopted the VSM technique and identified the unnecessary movement, inadequate skill, long waiting for transfer and cooling time as non-value added activities. By means of some operational changes to control the non-value added activities, the researcher observed a considerable reduction in throughput time from 1230 to 890 seconds.

Apart from these approaches of remedial policy formulation, the Yamazumi chart is also found to be adopted along with the VSM in the form of a line balancing concept to act as a potential lean tool [31], [32]. In literature, the Yamazumi chart is defined as a tool which exhibits all the components of time for accomplishing an activity. Usually, the bar chart is used in this regard to reflect the information through the variation of colors [21]. Whereas, according to Sabadka, Molnár, Fedorko and Jachowicz [33], the Yamazumi chart refers to a bar chart which demonstrates the required cycle time for each of the workstations or operator to accomplish their jobs. Nowadays, by featuring its reliability and ease of use, the researchers adopt the Yamazumi chart along with the VSM, line balancing technique and work measurement system to control the shop floor wastes and improve operational performances.

For instance, Buranasing and Choomlucksana [34] have shown that by the integrated effort of VSM, work measurement and Yamazumi chart, it is possible to control the shop floor wastes and thereby, reduce the waiting time through line balancing. Molenda, Biernot & Cierna [35] have demonstrated the possibilities of improving the line efficiency of car manufacturing company through the integrated effort of the VSM, work measurement and Yamazumi chart. Whereas, for the automotive assembly line, Czifra, Szabó, MÍkva & Vaňová [21] have also shown the possibilities of reducing the shop floor waste by the integrated effort of VSM, Work measurement approaches, Yamazumi chart and line balancing concept. Even though being similar to the automotive companies in respect of the labor intensive mass production system architecture, no such attempts of the integrated approach of VSM and Yamazumi chart are reported for controlling the shop floor wastes like waiting time and improving the operational performance of RMG industries.

III. RESEARCH METHODOLOGY

In this research an effort has been made to balance the cycle time for improving the operational performance through an integrated ~~lean~~ approach of Yamazumi chart and VSM. To secure the research goal, the methodology is structured in three distinct stages i.e. (A) Preparation of Current State Map (CSM) (B) Construction of the Yamazumi chart to balance the production line (C) Development of Future State Map (FSM). In this process the shop floor wastes are identified in the first stage through CSM. Whereas, the Yamazumi chart and line balancing approach are adopted to mitigate the wastes and improve the operational performance. Finally, the FSM is framed to realize the achievable improvements in the last stage. A brief discussion on each of these stages is given in the following subsections.

A. Current State Mapping

The CSM exhibits the shop floor and/or the flow line scenario by means of operational parameters like Overall Equipment Effectiveness (OEE), Effective Capacity, Takt Time, Utilization, Lead time, Efficiency for each of the consecutive stages. Numeric value for each parameter is outlined depending on the data collected through time study by means of videos, taking the mean of three observations and, computed by the usage of following mathematical interpretation provided by King and King (2015).

$$OEE = Availability * Performance * Quality \quad (1)$$

$$Availability = Actual\ operating\ time / Planned\ operating\ time \quad (2)$$

$$Performance = Actual\ Output / Planned\ Output \quad (3)$$

$$Quality = Accepted\ Product / Actual\ Output \quad (4)$$

$$Effective\ Capacity = Maximum\ Capacity * OEE \quad (5)$$

$$Takt\ time = Available\ time / Number\ of\ Batch \quad (6)$$

$$Utilization = Takt\ time / Effective\ Capacity \quad (7)$$

$$Lead\ Time = Order\ Size / Effective\ Capacity \quad (8)$$

$$Efficiency = Total\ task\ Time / (Number\ of\ WS * Largest\ WS\ Time) \quad (9)$$

B. Yamazumi Chart and Line Balancing Technique

Yamazumi chart is viewed in literature as a folded column graph which exhibits the cycle time for each of the work stations as well as their balances. To plot a Yamazumi chart, every single detail of the operational process are necessary to be identified. More specifically, a comprehensive and careful time study including the motions and waiting times of the employees are required to outline. In Yamazumi Chart these motions and/or the operations are represented by means of different colour labelling. For instance, the green labelling represents the value added works, orange labelling reflects the required works without added values, red labelling exhibits the non-value added activities, yellow labelling reflects the optional works (not performed on each product), blue labelling represents the associated works which is necessary but varies depending on the specification. These comprehensive representation and analysis as reflected through the Yamazumi chart paved the ways of controlling the wastes and incorporating the concept of line balancing to enhance the efficiency as well as the productivity.

The primary aim of line balancing is to reduce the deviation between the station cycle time and the Takt time. In this regard the researchers found that the usage of Yamazumi chart is extremely beneficial (Pakdil and Leonard 2017). As the line balance can be attained either by balancing the time or the work content or the material, the Yamazumi chart can help in this context by controlling and rearranging the tasks within the workstations (Ortiz 2009). In other words, by means of Yamazumi chart it is possible to rearrange or reassign the tasks among the workstations so that the cycle time matches with the takt time as much as possible. However, for the purpose of balancing a task having too small processing time in comparison to takt time is not suggested to be assigned in an individual workstation. Because such inclusion is to increase the workers' waiting time. Whereas, a task having processing time greater than the takt time can be manged by introducing parallel workstations. But in both the cases the precedence relationship should be maintained (Cannas, Pero, Pozzi and Rossi, 2018).

C. Future State Mapping

The future state map exhibits the improved scenario of the shop floor and/or the flow line which is possible to be attained by adopting the proposed modifications. As similar to the current state map, the future state map also exhibits the improved scenarios through several operational parameters like Overall Equipment Effectiveness (OEE), Effective Capacity, Takt time, Utilization, Lead time, Efficiency for each of the consecutive stages. The numeric values for these parameters are computed through (1) – (9).

IV. CASE STUDY

To carry out this research study a real life case of trouser sewing line of an RMG industry in Bangladesh was selected. For this sewing line, the production planning department aims to produce nine batches in a nine-hour shift in which a batch consists of 95 end items. The sewing line consists of a total of 38 workstations which are operated under three different stages and an end item has to pass through each of the workstations. An operator engaged in a workstation has to perform multiple tasks. Some of the tasks and their associated times as performed in five workstations within stage - 1 are provided in Table 1and two tasks are exhibited in Fig. 1. It is to be noted that due to non-disclosure agreement all the data are not revealed. Moreover, due to the differences in required distance and motion, the similar pickup operations consume different time at different work stations.Based on the time study and the collected relevant data, the Overall Equipment Effectiveness (OEE), Effective Capacity, Takt Time, Utilization, Lead time, Efficiency are computed for all the three stages by means of Eq. (1) - (9). The plotted current state map (CSM) is shown in the Figure 2.

(a) Sewing in WS-1 (b) Sewing in WS-3

Fig. 1. Two tasks performed in stage 1

Table- I: Name of the Table that justify the values

Stage	*Workstation*	*Task Notation*	*Task*	*Time*
1	WS-1	T1	Pickup from storage	3 sec
		T2	Folding and Placing to M/C	5 sec
		T3	Sewing	7 sec
		T4	Checking	2 sec
	WS-2	T5	Pickup from storage	7 sec
		T6	Folding and Placing to M/C	6 sec
		T7	Sewing	1 sec
		T8	Checking	1 sec
		T9	Pickup from storage	1 sec
		T10	Folding and Placing to M/C	1 sec
		T11	Sewing	2 sec
	WS-3	T12	Pickup from storage	2 sec
		T13	Attaching bone and pocket and Placing to M/C	2 sec
		T14	Sewing	6 sec
	WS-4	T16	Pickup from storage	6 sec
		T17	Attaching and Placing to M/C	3 sec
		T18	Sewing	6 sec
		T19	checking	1 sec
	WS-5	T20	Pickup from storage	5 sec
		T21	Attaching and Placing to M/C	6 sec
		T22	Sewing	7 sec
		T23	checking	3 sec

The values of OEE, utilization, lead time and efficiency of different stages of the considered flow line as delineated in Fig. 2 differ quite significantly. For instance, the utilization is found to be 1.47 for stage 1, 1.79 for stage 2 and 1.27 for stage 3. These numeric values on utilization reveal the incapability of current shop floor condition in satisfying the customer demand without overtime. This claim is further supported by the obtained numeric values for the OEE, Effective Capacity and Efficiency which are respectively for stage 1: 71%, 575 pcs and 49%; stage 2: 52%, 473 pcs and 49%; and stage 3: 72%, 597 pcs and 59%. Thus, a considerable variation is observed among the Utilization, OEE and efficiency which not only reveals the possibility of existence of wastes in the flow line, but also the presence of imbalance. Hence, to be firm on this realization as well as to identify and control these wastes and imbalances the Yamazumi charts are plotted for each of the stages as portrayed in Fig. 3.

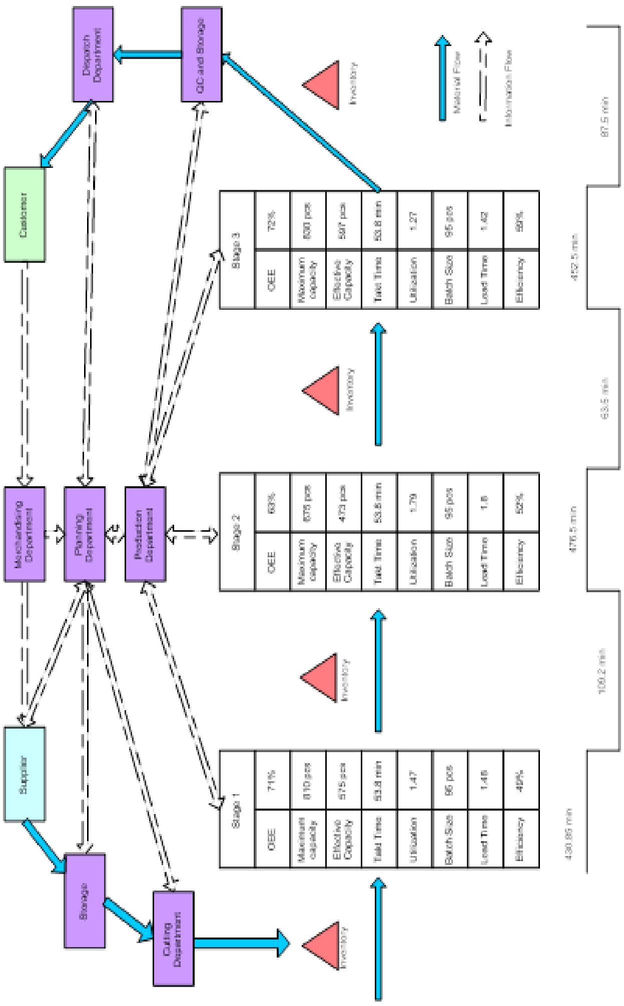
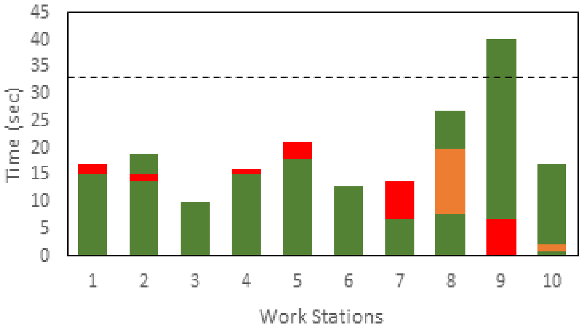
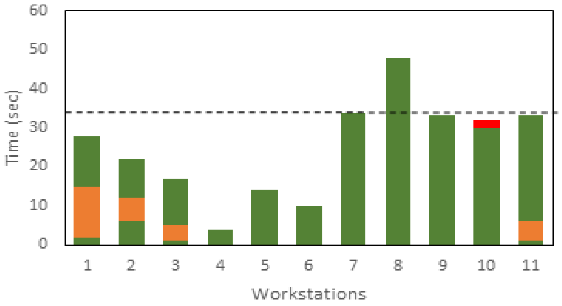


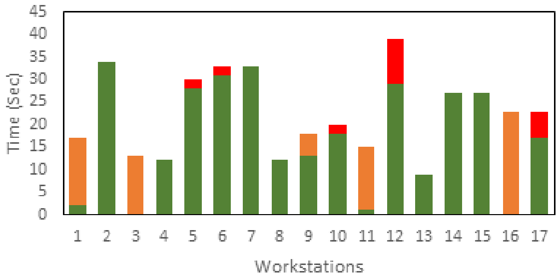
Fig. 2. Current state map (CSM)



(a) Stage 1



(b) Stage 2



(c) Stage 3

Fig. 3. Yamazumi charts for different Stages

It is observed that for all the three stages, some of the workstation times exceed the Takt time of 34 seconds (Takt time = Available Time/Number of end items in a batch). Due to the extra-long workstation cycle time (WS 9 in stage 1, WS 8 in stage 2, WS 12 in stage 3) the manufacturer basically becomes unable to gratify the demand on time by increasing the production lead time. While, for many of the workstations in stages 1, 2 and 3 the workstation cycle times are considerably lower than the Takt time. These imbalances in cycle time is one of the root causes for lower OEE and the required higher utilization. Though, it is often difficult to adjust the workstation time according to the Takt time due to the assignment and resource restrictions, there is no option to readjust the extra-long tasks according to the takt time to meet the customer demand. In this regard some modifications and/or remedial policies are proposed for improvement in the following subsections.

A. Proposed Modification for Stage-1

The extra-long time as recorded for the W/S-9 in stage 1 exceeds the Takt time by six seconds. The tasks that are performed in this workstation along with their task time are shown in the Table II. However, the time of 7 seconds for the first task in W/S-9 to pick up from storage appears to be due to the completion of previous two activities i.e. pocket matching and marking at the right side of the W/S-9 as shown in Fig. 4. By reorganizing the workstation for previous two operations or in other words completing this operation at the left side instead of right it would have been possible to reduce the non-value added activity time. Based on the proposed modification and the reengineered tasks, the processing times are shown in Table II.

Table-II: Task description and modification for WS-9

SN	*Tasks*	*Current Task Time*	*Task time after (improvement)*
1	Pickup from storage	7 sec	1 sec
2	Attaching and Placing to M/C	11 sec	11 sec
3	Sewing	22 sec	22 sec
	Total W/S time	40 sec	34 sec

Moreover, the tasks in W/S-7 and W/S-8 are performed manually by two individual operators. The task time and the description are given in Table III. The task of pocket matching as shown in Table III and performed in WS-7 can easily be avoided by following a First in First out (FIFO) system. Thereby, it is also possible to merge these two workstations and assign only one operator to perform the tasks. Thus based on the proposed modification, the reengineered tasks and their processing times are shown in table III.

Fig. 4. Organization of WS 9

Table-III: Task description and modification for WS-7 & 8

WS	*SN*	*Tasks*	*Task Time*
WS-7	1	Pickup from storage	7 sec
	2	Matching	7 sec
		Total W/S time	14 sec
WS-8	1	Pickup from storage	8 sec
	2	Preparation for Mark	12sec
	3	Marking	7sec
		Total W/S time	27 sec
WS (Modified)	*SN*	*Tasks (Modified)*	*Task Time (Modified)*
WS-7	1	Pickup lower part from Storage	7 sec
	2	Pickup upper part from Storage & placement	8 sec
	3	Preparation for Mark	12 sec
	4	Marking	7 sec
		Total W/S time	34 sec

B. Proposed Modification for Stage-2

As presented in Table IV the operator at WS-3 in stage 2 manually performs the tasks of opening. Since this task of WS-3 consumes only 4 seconds, it can be conveniently merged with the tasks in WS-4 without affecting the Takt time. The accumulated time due to the modification become 21 seconds which is also much lower than the Takt time. Hence, in this way, it is possible to free one of the operator who might be utilized to share task for any extra-long workstation. The proposed modification along with the description is shown in table IV.

In W/S-8 of stage-2 a single operator performs all the tasks as provided in Table V making it as extra-long work station. To reduce the workstation time, the freed worker as mentioned earlier modification is engaged here to create a parallel workstation. Thus, it is possible to bring down the workstation time below the Takt time. The proposed modification along with the description is presented in Table V.

Table-IV: Task description and modification for WS-3 & 4

WS	*SN*	*Tasks*	*Task Time*
WS-3	1	Pickup from storage	1 sec
	2	Preparation for Opening	4 sec
		Opening	12
		Total W/S time	17 sec
S-4	1	Pickup from storage and Placing to Machine	1 sec

	2	Sewing	3 sec
		Total W/S time	4 sec

WS (Modified)	*SN*	*Tasks (Modified)*	*Task Time (Modified)*
WS-3	1	Pickup from storage	1 sec
	2	Preparation for Opening	4 sec
	3	Opening	12 sec
	4	Placing to Machine	1 sec
	5	Sewing	3 sec
		Total W/S time	21 sec

Table-V: Task description and modification for WS-8 & 9

WS	*SN*	*Tasks*	*Task Time*
WS-8	1	Pickup from storage	2 sec
	2	Placing to M/C	30 sec
	3	Sewing	16 sec
		Total W/S time	48 sec

WS (Modified)	*SN*	*Tasks (Modified)*	*Task Time (Modified)*
WS-7	1	Pickup from storage	2 sec
	2	Preparation for Placing to M/C	30 sec
		Total W/S time	32 sec
WS-8	1	Pickup from storage and Placing to M/C	6 sec
	2	Sewing	16 sec
		Total W/S time	22 sec

C. Proposed Modification for Stage-3

WS-12 in stage 3 is found to be an extra-long workstation in which the worker performs the checking in addition to the value added activities. However, the checking task can be divided into two and distributed among the two consecutive workstations: W/S-12 and W/S-13. Thereby with a slight increase in WS-13 time it is possible to shorten the time for WS-12 below the Takt time. The proposed modification along with description is shown in Table VI.

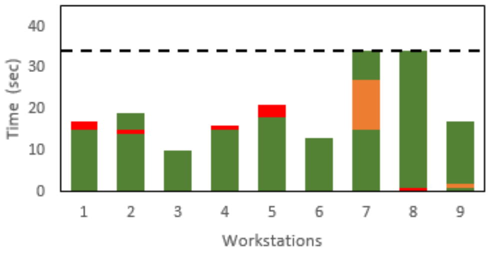
V. DISCUSSION

The modifications or remedial policies are proposed for the improvement of the operational performance of the trouser production shop floor. Based on those modifications, the Yamazumi charts are revised for the three stages of the production line and displayed in Figure 5. It is evident from the revised illustrations that the cycle time for all of the workstations would become lower or equal to the Takt time through adoption of the proposed changes or modifications. In other words it is envisaged that the customer demand should be possible to be satisfied on time if the necessary changes are implemented. However, the effect of this change on OEE, Utilization, Lead time and Efficiency needs to be worked out and reflected in the future state map (FSM).

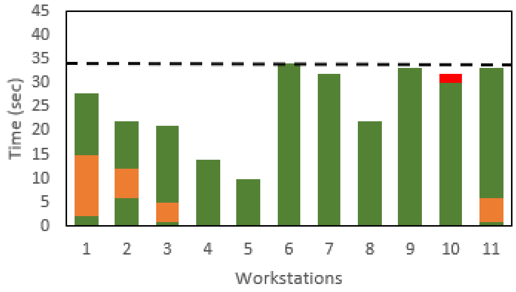
Table-VI: Task description & modification for WS-12 & 13

WS	*SN*	*Tasks*	*Task Time*
WS-12	1	Pickup from storage	1 sec
	2	Folding and Placing to Machine	4 sec
	3	Sewing	24 sec
	4	Checking	10 sec
		Total W/S time	39 sec
WS-13	1	Pickup from storage	1 sec
	2	Placing to Machine	3 sec
	3	Sewing	5 sec
		Total W/S time	9 sec

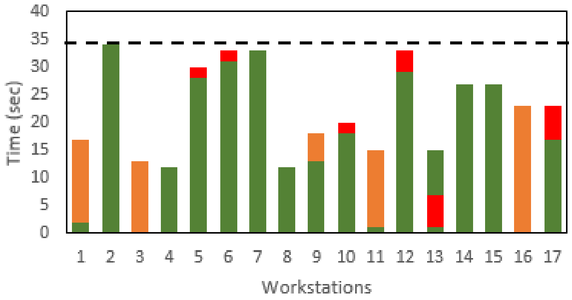
WS	*SN*	*Tasks (Modified)*	*Task Time*
WS-12	1	Pickup from storage	1 sec
	2	Folding and Placing to Machine	4 sec
	3	Sewing	24 sec
	4	Checking	4 sec
		Total W/S time	33 sec
WS-13	1	Pickup from storage	1 sec
	2	Checking	6 sec
	3	Placing to Machine	3sec
	4	Sewing	5sec
		Total W/S time	15 sec



(a) Stage 1



(b) Stage 2



(c) Stage 3

Fig 5: Yamazumi chart for different Stages after modifications

Therefore, a future state map is also drawn as shown in Figure 6. Depending on the Figure 2 and 6, the achievable improvements are summarized in Table VII. From the information as provided in Table VII, it is obvious that due to the proposed change the OEE is to be improved from 71% to 79% in stage-1, 52% to 79% in stage-2 and 72% to 79% in stage-3. The effective capacity is increased from 575 to 752 pieces in stage-1, 473 to 752 pieces in stage-2 and 597 to 752 pieces in stage-3.

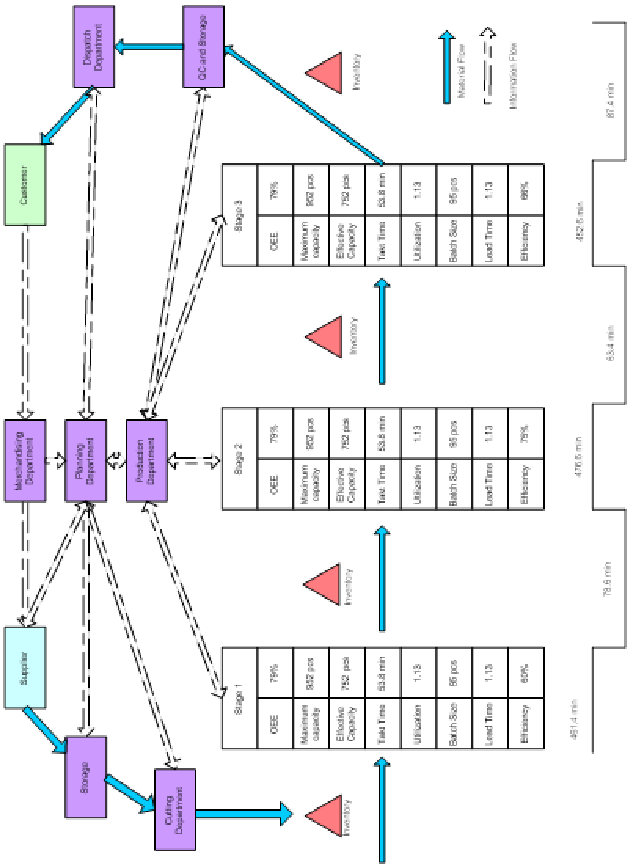


Fig 6. Future State map

Table-VII: Evaluation of change in performance measures

SN	Measures	Stages	Current State	Future State
1	OEE	1	71%	79%
		2	52%	79%
		3	72%	79%
2	Effective Capacity	1	575units	752 units
		2	473units	752units
		3	597units	752units
3	Utilization	1	1.47	1.13
		2	1.79	1.13
		3	1.27	1.13
4	Efficiency	1	49%	60%
		2	52%	75%
		3	59%	66%

Whereas, the utilization changes from 1.47 to 1.13 in stage-1, from 1.79 to 1.13 in stage-2 and 1.27 to 1.13 in stage-3. Moreover, the efficiency is to improve from 49% to 60% in stage-1, 52% to 75% in stage-2 and 59% to 66% in stage-3. However despite this improvement, the efficiency cannot be reached up to 100% due to the assignment and resource constraints. It is also true that due to the rejection caused by the poor workmanship and other reasons, utilization can never be levelled as 1 or 100%. So because of the possibility of rejection or rework, a small amount of overtime is still required to be maintained to satisfy on-time customer demand by the modified configuration.

VI. CONCLUSION

The research study was aimed at investigating the prospects of balancing the cycle time with a view to enhancing the operational performance of RMG shop floor through application of an integrated lean approach using the VSM and Yamazumi chart. A real-life case with a three-stage sewing line of a Bangladeshi local RMG industry was studied to evaluate the approach performance. Required numerical data were gathered by means of time study. Depending on the collected data, the current state map was framed to comprehend the existing operational performance of the shop floor. Analysis was extended further through incorporation of Yamazumi chart which aided to investigate the non-value added activities as well as the possible ways of balancing the workstation cycle time with respect to the takt time. Yamazumi chart is found to be conducive to define some policies for reducing and/or eliminating the non-value added time, creating the parallel work stations, merging multiple work stations into one, and improving the operational performance of the flow line. Consequently, a future state map (FSM) was also developed to reflect the possible benefits of the proposed modification and/or improvement policies. From the FSM it was realized that the line efficiency, capacity, and OEE could be improved respectively by 22.4%, 30.7% and 11.26% in stage 1, 44.23%, 58.9% and 51.9% in stage 2 and 11.8%, 25.9% and 9.7 % in stage 3. Whereas, utilization was reduced by 23.1% in stage 1, 36.8% in stage 2, and 11.02% in stage 3. This reduction in utilization is due to the decrease in the requirement of over time. In future, the integrated scheduling and the work-in-process (WIP) inventory management issues would be studied from the context of lean manufacturing. Moreover, Maynard Operation Sequence Technique (MOST) could also be incorporated for standardizing work and time to assess the operational performances.

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