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Abstract

The today's competitive advantage of Ready-made garments (RMG) industry depends on the ability to improve the efficiency and effectiveness of resource utilization through proper adoption of industrial engineering techniques. RMG industries have historically adopted fewer technological and process advancement. This is especially true for less developed regions like East African Community (EAC) although significant amounts of textile and apparel products are produced in these regions. In most RMG industries, industrial engineering techniques have not been given enough attention even though they need to compete globally and survive in this extremely competitive and dynamic business environment. Presently, only very few garment industries have comprehended the functions of industrial engineering department. One of the basal reasons for this shortage is that the garment industries suffer much from substantial inadequacy of information and literature on the practical application of industrial engineering techniques in garment manufacturing. In this paper, the application of industrial engineering tools: ABC classification, process mapping, time study, and brainstorming were demonstrated in a garment manufacturing factory. The empirical data obtained were utilized to determine the standard minute value (SMV) and prepare operation bulletin for trousers. The results from the present study are very useful to the garment industry for setting up a realistic production target, and measure production capability of trouser assembly line as well as improving its efficiency.

Keywords: Industrial engineering, Time study, Garment industry, processing mapping, Standard minute value, Operation bulletin, Operation management, SAM

1. Introduction

Ready-made garment (RMG) industry is not only one of the oldest, largest, labor-intensive, low skilled, low value and most global industries but also the typical "beginner" industry for countries engaged in export-orientated industrialization (Abtew et al., 2019; Hamja et al., 2019). In 2016, the East African Community (EAC) pledged to phase out imports of second-hand clothing within three years to promote the development of the domestic garment sector (Wolff, 2020) (Calabrese et al., 2017). But that can be hardly achieved without proper implementing the industrial engineering (IE) and operation management (OM) functions in this sector.

The implementation of the IE and OM functions in RMG industry are very crucial for sustainability in the business and need proper monitoring of success (Islam et al., 2017). The OM aims at addressing problems related to low levels of sales and low turnover, over inventory and high manufacturing costs in textile-clothing companies in order to improve productivity and competitiveness (Maralcan & Ilhan, 2017). It mainly strategizes at promoting the supply chain integration, adequate demand forecasting methods, lean manufacturing principles, implementation of information technologies, and production planning techniques for the long, medium and short term (Cano & Zuluaga-mazo, 2019). On the other hand, IE focuses at reducing the production time which automatically reduces inventory cost to a minimum (Jana & Tiwari, 2018; Khatun, 2013). In RMG industry, the IE and OM functions are under IE department (Jana & Tiwari, 2018).

In previous studies, IE has been applied in RMG to harness better improvement in productivity (Khatun, 2013), and increase in agility of garment manufacturing (Khan et al., 2019). Baset & Rahman (2016) and Hossain et al. (2018) applied IE techniques in garments sector for reducing the cost of Standard Minute Value (SMV) and lead time to improve productivity by implementation of proper line balancing. Howard et al. (2019) applied IE as the strategies for determining the production cost and pricing of garments. Khan (2013) used lean manufacturing to achieve higher productivity in the apparel industry. Lean manufacturing has been increasingly used in RMG industry to increase productivity for reducing costs and lead time (Hamja et al., 2019; International Labour Organization, 2017; Khan, 2016). Furthermore, Bashar & Hasin (2019) studied the impact of Just in time (JIT) production on organizational performance in the apparel industry.

Tout ensemble, the key tasks of IE includes product analysis through determining optimum method of construction and establishing operation bulletin, production planning for effective and balanced flow of product, operator performance monitoring systems by hourly production monitoring and skill matrix, justify all changes based on analysis of work content, continuous improvement, taking cost saving opportunities, monitor operator performances and take action to improve performances and eliminate causes of underperformance (Islam et al., 2017; Rahman & Amin, 2016). In addition, implementation of 5S and six sigma are important task of IE in RMG (Khan, 2016).

The concept and functions of IE are indeed quite clear as they are the key to improve work nature and methods in RMG industry (Chandurkar, Kakde, & Bhadane, 2015). Surprisingly, very few RMG industry in EAC has comprehended the IE functions and has put in place the IE department in their firms. This is quite daunting, yet they need productivity improvement and sustainable competitiveness. But how can this be possible without proper IE department. Therefore, the present study aimed at demonstrating the important of IE and OM for determining realistic operation bulletin which is emblematic for productivity planning and improvement.

2. Literature Review

2.1 RMG manufacturing challenges and opportunities

Garment manufacturing also known as apparel manufacturing is labour intensive which has led to the shifting of many apparel manufacturing facilities from developed countries to developing countries because of cheap labor force. Although there is cheap labor in developing countries, garment industries are facing the greatest challenges such as short production life-cycle, high volatility, low predictability, high level of impulse and quick market response (Rajkishore & Padhye, 2015). Inorder to survive, the garment industries in developing countries are betting big on reducing the cost of production by sourcing cheaper raw materials and minimizing delivery cost rather than labor productivity because of the availability of cheap labor.

Global and local competition is still a major challenge amongst apparel manufactures. Therefore, one can only survive on the market if all unnecessary costs are reduced, the range of production is expanded, and consumers are considered individually. However, the local apparel manufacturers are gradually reducing the production and focusing on performing only the entrepreneurial functions involved in apparel manufacturing such as buying raw materials, designing clothes and accessories, preparing samples and arranging for the production, distribution and marketing of the finished product (Rajkishore & Padhye, 2015).

Rapid technological changes and customer expectations have also imposed a great challenge to apparel manufactures especially in developing countries. Therefore, there is high demand from the manufacturers to improve the quality of fashion products constantly, and thus survive in the market (Karthik et al., 2017). In addition, the manufacturers are required to adjust their production system in order to meet market demand in that they have to set a flexible production model that is capable of quick and easy adjustment to modern requirements (Babu, 2012).

Another technological challenge facing apparel manufactures in developing countries is the differences that exist in the process of making clothes of different fashions, which in one way or the other requires a different organization of technological processes (Colovic, 2012). Therefore, this calls for the most economical ways of work and time required to perform work operations, change management, capacity and planning. Further, it is necessary to implement new solutions in manufacturing, information systems, management techniques, and design (Colovic, 2011).

The promising challenge facing the apparel industries in developing countries is the indispensability of scientific approach and engineering applications for apparel manufacturing. This implies that the apparel manufactures will find it very difficult to meet the cost of production unless and until manufacturing is done with scientific approach such as implementation of simulation model for line balancing and assembly line design, lean production, etc. (Babu, 2012). Generally, the apparel industries in the whole world especially in developing countries will not give any pleasing results to the management unless it strives for necessary improvements that will lead to productivity growth, more rational usage of all-natural resources and cost reduction. In most cases these companies do not see the necessity for changes in management, capacity and planning which are negatively impacting many apparel industries today (Karthik et al., 2017).

The disruption in textile and apparel industry triggered by digital transformation or industry 4.0, it is very likely that the RMG industry will undergo profound changes over the next few years. Smart Clothes, i. e. clothing characterized not only by its traditional protective and representational functions, but also by technological and digital features, have evolved as a promising opportunity for RMG industry well-known as fashion 4.0 or apparel 4.0 (Behr, 2018; Bertola & Teunissen, 2018).

2.2 Garment manufacturing systems

An apparel or garment production system is an integration of materials handling, production processes, personnel, and equipment that direct workflow and generate finished products (Babu, 2012). There are three types of apparel production system that are widely adopted in garment industry, these include; (i) group or modular production system (Sudarshan & Rao, 2014) (ii) progressive bundle production system and (iii) unit production system. In modular production system, operations are done in a contained and manageable work cells that includes a number of specialized resources such as an empowered work team, equipment and work to be executed. This production system has achieved the success of flexibility, however, very high initial capital and investment in training are still the major limitation to its adaptation to most apparel industries.

The progressive bundle production system normally referred to as conventional production system is still the most commonly installed production system till to date amongst other garment production system because of its cost effectiveness on high tech-machines. The operation in this system involves moving bundles of cut pieces manually to feed the line. Whereby, the operator inside the line drags the bundles by him/herself from the table and transfer the bundle to the next operator after completing his/her task. The major problem with progressive bundle system is the tendency of accumulating very large inventory which impose an extra cost of controlling and handling inventory. In order to overcome the limitation of material handling in progressive bundle system, a new system called unit production system was developed. In this system, the overhead transporter is used to move the garment from one workstation to another workstation for assembly which improves material handling. The success of unit production system is that it improves the production lead times, productivity and space utilization, however, this production system is extremely expensive. In general, the tradeoff of these production system depends on the production volume, product categories, and the cost effectiveness of high-tech machines (Karthik et al., 2017).

2.3 Industrial engineering tools

2.3.1 ABC classification

Traditionally, ABC analysis has been used to classify various inventory items into three categories A, B, and C based on the criterion of dollar volume. In the current globalized hyper-responsive business environment, a single criterion is no longer adequate to guide the management of inventories and therefore, multiple criteria have to be considered (Sibanda & Pretorius, 2011). Other criteria that can be considered for ABC analysis include; lead time, item criticality, durability, scarcity, reparability, stockability, commonality, substitutability, the number of suppliers, mode and cost of transportation, the likelihood of obsolescence or spoilage and batch quantities imposed by suppliers. Consequently, ABC analysis has been adopted amongst researches to make decision on selection of products, machines, production lines, etc. For instance, Pinho & Leal (2007) used ABC analysis to prioritized a production system for their study based on productivity per day criterion. Therefore, in the current situation, ABC analysis tool was also adopted to prioritize the product model and assembly line to be used in this study.

2.3.2 Process mapping

Process mapping is an exercise of identifying all the steps and decisions in a process in a diagrammatic form, with a view to continually improve that process. In literature, two commonly used types of process mapping are; process flowchart (outline process map) and deployment charts. The former is useful for capturing the initial detail of the process. For instance, Kursun & Kalaoglu (2009) , Kitaw et al. (2010), Bahadır (2011) and Yemane et al. (2017) used process flowchart as conceptual model in their simulation study with the aim of analyzing and understanding the current state of the studied system. While the latter not only provide a basic overview but also shows who does what along with the interactions between people and departments. This one has been used as a standalone method amongst studies for process improvement. Uddin (2015) improved production process using value stream mapping as a standalone method. Since then, the present study adopted process mapping as tool for conceptual modeling, the process flowchart method was best suited for this study.

2.3.3 Fishbone diagram

Cause-and-effect diagram (fishbone diagram) is another method that has been widely used amongst studies (Barton, 2004). It is an analysis tool that provides a systematic way of looking at effects (performance measures) and the causes (factors or independent variables) that create or contribute to those effects (Hekmatpanah, 2011). One of the underlying benefits of this method is that, it has nearly unlimited application in research, manufacturing, marketing, office operations and so forth. One of its strongest assets is the participation and contribution of everyone involved in the brainstorming process (Hekmatpanah, 2011). The ability of cause-and-effect diagram to clearly identify and categorize factors that affect the performance of the system is one of the major reasons for its adoption in this study.

2.3.4 Time study

The definition of time study was first coined in the early 20th century in industrial engineering, referring to a quantitative data collection method where an external observer captured detailed data on the duration and movements required to accomplish a specific task, coupled with an analysis focused on improving efficiency (Lopetegui et al., 2014). Time study has been considered to be accomplished before any design of assembly line, which involves timing and observing motion of the work associated with building the product. Collecting times data are absolute requirements to improving the assembly operations in the facility (Ortiz, 2006). The advantages of time study method over other work measurement techniques include (Babu, 2012); (i) helps in developing a rational plan (ii) helps in improving productivity (iii) helps in balancing assembly lines (iv) provides the time data for process design (v) helps in determining operator skill levels. Nevertheless, conducting time study is time consuming and very tiresome especially when the system has many elements to be measured.

However, time study has been the most commonly used amongst studies as it determines accurate time standards, and it is economical for repetitive type of work. Vast number of researches have been done using time study method. For instance, Senthilraja et al. (2018) applied time study technique for improving the operators' productivity in rubber industry. While Khatun (2014) studied the effect of time and motion study on productivity in garment sector. The author postulated that the target productivity can be achieved by time study. Based on the fewer limitations of time study than other work measurements methods such as activity sampling, predetermined time standards (PTS), structured estimating, etc. (Babu, 2012) and its applicability showed by many researchers have motivated the present study.

The basic time study equipment consists of stop watch, study sheet and time study board (Ortiz, 2006). Steps for conducting time study have been presented as shown in figure 2.1 (Babu, 2012; Russell & Taylor, 2011).

The number of timing cycle for specific activity basically depends on end the use the time study data. For instance, if the time study data is to be used in probability distribution analysis then a greater number of timing cycle or measurements give better result. For each work element/task, processing time can be recorded 10 times (Kitaw et al., 2010), or 15 times (Sudarshan & Rao, 2014) , 20 times (Kursun & Kalaoglu, 2009) or more, the higher the number of measurement, the better the results. There are two common methods of measuring time with a stopwatch such as fly back and continuous method (Puvanasvaran et al., 2013; Starovoytova, 2017).

2.3.5 Brainstorming

Brainstorming or brainwriting is one of the most common techniques used to generate ideas from the individual or group of people. In most cases, it has been applied in both educational, industrial, commercial, and political field (Al-khatib, 2012). In the previous studies, brainstorming has been combined with other method such as fish bone diagram (cause-and-effect analysis tool) for analyzing the current state of production systems. For instance, Barton (2004) used brainstorming and fishbone diagram to analyze and identify factors the affect throughput of the production process. Many studies have shown the applicability of brainstorming as the problem solving techniques. Al-khatib (2012) confirmed the effectiveness of using brainstorming as a problem-solving tool. The ability of brainstorming method to generate as many ideas as possible without judgement, has motivated this study to use it for generating ideas on factors that influence the throughput of garment assembly line.

2.3.6 Observation

Observation is another method that has been used for analyzing the current state of the system amongst studies. However, it has been used alongside interview to capture more data on the current state of the system (Gebrehiwet & Odhuno, 2017). Observation is a very important tool when conducting process mapping and time study. For instance, in garment assembly line, two major areas that were observed on the sewing machines are; Machine working (positioning, sewing, and dispose) and Machine not working (waiting for repair, waiting for suppliers, personal need for workers and idle (Babu, 2012). The present study combined observation with process mapping for conceptual modeling of the garment assembly line.

3. Methodology

In this study, brainstorming and fishbone diagram were used to analyze the current of the garment assembly line. ABC classification method was employed to prioritize the product style and the assembly line for the study. In this case, trouser assembly line was given A- priority because of its complexity. Continuous stopwatch time study was conducted as according to the previous study (Puvanasvaran et al., 2013). The operation bulletin was developed following steps outlined in **Figure 1** (Babu, 2012). The standard minute value (SMV) or standard allowed minute (SAM) was determined after obtaining the observed times (Bongomin et al., 2020). The line target, target for an operation and manpower requirement were calculated using Eqn 1, Eqn 2 and Eqn 3, respectively.

$$Line\ target = \frac{Working\ time\ x\ Planned\ efficiency\ x\ Planned\ operators}{Total\ SMV} \tag{1}$$

$$Target\ for\ an\ Operation = \frac{Working\ time\ x\ planned\ efficiency\ x\ operator\ number}{SMV} \tag{2}$$

$$Manpower\ requirement = \frac{Line\ target}{Individual\ operation\ target} \tag{3}$$

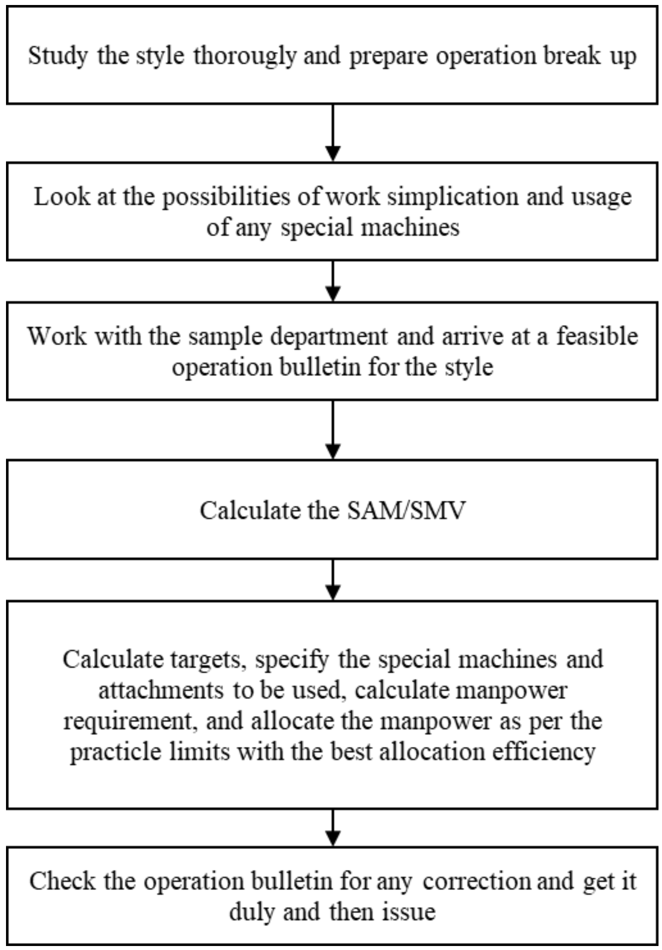

Figure 1. Operation bulletin construction approach

4. Results and Discussions

The operation bulletin was developed based on the following line specifications: the total SMV (41.763), planned efficiency (75%), total machine SMV (37.712), helper SMV (4.051), and minutes per day (480). The trouser assembly line with 65 operations and 61 planned operators was considered. The target and manpower calculations were done for each operation and presented in Table 1. From the calculated manpower, the required manpower numbers were determined.

$$line\ target = \frac{480\ x\ 0.75\ x\ 61}{41.763} = 525\ pieces\ per\ day$$

$$Target\ for\ operation\ 1 = \frac{480\ x\ 0.75\ x\ 1}{0.312} = 1142\ pieces\ per\ day$$

$$Manpower\ requirement\ for\ operation\ 1 = \frac{525}{1142} = 0.46$$

Table 1. Operation bulletin for Trouser

OP	Task description	Resource	OT (mins)	SMV/ SAM	Target (pieces/day)	MPC	MPR
1	Buttonhole on flybox	Buttonhole machine	0.309	0.315	1142	0.46	1
2	Front rise overlocks	Overlock machine	0.243	0.283	1270	0.41	1
3	Knee patch attach	Single needle lockstitch	0.885	0.929	388	1.35	2*
4	Side pocket flatlock	Flatlock machine	0.255	0.352	1023	0.51	1
5	Side pocket overlock	Overlock machine	0.154	0.198	1816	0.29	1
6	Right flybox overlock	Overlock machine	0.259	0.334	1078	0.49	1
7	Side pocket attach	Single needle lockstitch	0.550	0.577	624	0.84	1
8	Side pocket topstitches	Single needle lockstitch	0.658	0.691	521	1.01	1
9	Right flybox attach	Single needle lockstitch	0.668	0.701	513	1.02	1
10	Fly attach	Single needle lockstitch	0.663	0.695	518	1.01	1
11	Front prep bundling	Helper	0.448	0.373	965	0.54	1
12	Back marking	Helper	0.227	0.214	1681	0.31	1
13	Back patch pressing	Iron press	1.659	1.356	266	1.98	2
14	Back patch attach	Single needle lockstitch	0.455	0.534	674	0.78	1
15	Hip pocket cutting	Automatic wallet machine	0.170	0.247	1460	0.36	1
16	Hip pocket overlocks	Overlock machine	0.800	0.927	388	1.35	2*
17	Hip flap folding	Helper	0.229	0.216	1666	0.32	1
18	Buttonhole on hip flap	Button hole machine	0.184	0.187	1923	0.27	1
19	Hip flap runstitch	Single needle lockstitch	0.316	0.331	1087	0.48	1
20	Hip flap turning	Turning machine	0.255	0.240	1499	0.35	1
21	Hip flap topstitches	Single needle lockstitch	0.402	0.421	854	0.61	1
22	Hip pocket finish	Single needle lockstitch	0.695	0.730	493	1.06	1
23	Hip flap attach	Single needle lockstitch	0.554	0.582	619	0.85	1
24	Back prep bundling	Helper	0.381	0.359	1001	0.52	1
25	F&B matching	Helper	0.458	0.432	834	0.63	1
26	Side seam overlock	Overlock machine	1.196	1.531	235	2.23	2
27	Side seam topstitches	Feed of arm machine	0.771	1.091	330	1.59	2
28	Knee pocket marking	Helper	0.384	0.362	995	0.53	1
29	Knee pocket folding	Helper	0.249	0.235	1532	0.34	1
30	Knee pocket hemming 1	Single needle lockstitch	1.108	1.163	310	1.70	2
31	Knee pocket tacking	Single needle lockstitch	0.532	0.558	645	0.81	1
32	Knee pocket overlock	Overlock machine	0.204	0.238	1514	0.35	1
33	Knee pocket hemming 2	Single needle lockstitch	1.210	1.270	284	1.85	2
34	Knee pocket ironing	Iron press	1.867	1.652	218	2.41	2
35	Knee pocket attach	Single needle lockstitch	1.192	1.251	288	1.82	2
36	Knee flap folding	Helper	0.427	0.403	894	0.59	1
37	Buttonhole on knee flap	Button hole machine	0.198	0.202	1783	0.29	1
38	Knee flap runstitch	Single needle lockstitch	0.211	0.221	1625	0.32	1
39	Knee flap turning	Turning machine	0.370	0.349	1033	0.51	1
40	Knee flap topstitch	Single needle lockstitch	0.373	0.392	919	0.57	1
41	Knee flap attach	Single needle lockstitch	1.639	1.721	209	2.51	3*
42	Bar tacking	Bartack machine	1.493	1.560	231	2.28	2
43	Back rise overlocks	Overlock machine	0.514	0.658	547	0.96	1
44	Back rise topstitches	Double needle lockstitch	0.408	0.576	625	0.84	1
45	Big loop part matching	Helper	0.081	0.076	4711	0.11	1

OP	Task description	Resource	OT (mins)	SMV/ SAM	Target (pieces/day)	MPC	MPR
46	Big loop runstitch	Single needle lockstitch	0.248	0.260	1386	0.38	1
47	Big loop turning	Turning machine	0.160	0.151	2385	0.22	1
48	Big loop topstitches	Single needle lockstitch	0.222	0.233	1545	0.34	1
49	Big loop button hole	Button hole machine	0.093	0.095	3795	0.14	1
50	small loop runstitch	Loop stitch machine	0.141	0.149	2412	0.22	1
51	S&B loop, W.B attach	Single needle lockstitch	1.964	1.819	198	2.65	3
52	Waist band topstitch	Single needle lockstitch	1.076	1.129	319	1.65	2
53	Waist band closing	Single needle lockstitch	1.405	1.474	244	2.15	2
54	Small loop tacking	Single needle lockstitch	1.605	1.685	214	2.46	3*
55	Inseam overlock	Overlock machine	0.473	0.548	657	0.80	1
56	Trouser turning	Helper	0.376	0.355	1015	0.52	1
57	Inseam topstitch	Feed of arm machine	0.483	0.671	536	0.98	1
58	Adjustable prep	Helper	0.151	0.142	2535	0.21	1
59	1st adjustable attach	Single needle lockstitch	1.193	1.252	287	1.83	2
60	Button hole on bottom	Button hole machine	0.513	0.523	689	0.76	1
61	Adjustable hemming	Single needle lockstitch	0.156	0.164	2198	0.24	1
62	2nd adjustable attach	Single needle lockstitch	0.655	0.688	524	1.00	1
63	Bottom Rope attach	Helper	0.937	0.884	407	1.29	2*
64	Bottom hemming	Single needle lockstitch	0.870	0.913	394	1.33	2*
65	Final bar tacking	Bartack machine	0.856	0.895	402	1.31	2*

S-Small, B- Big, W.B- Waistband, OT- Observed time, WS-Workstation, OP- Operation, MPR- Manpower requirement, Mins-Minutes, MPC-Manpower Calculated

The manpower requirement with (*) for an operation means that the exact number can further be determined after observing the level of work in progress (WIP) and idle time at the workstation. Most likely they represent the bottleneck workstations, therefore, this might result into increment of manpower in case of high WIP or reduction of the number of manpower required in case of high idle time in the workstation. To this end, for the line to perform to the expectation: 2 ironing operations require 4 ironers, 51 machine operations need 63 operators, 12 helper operations require 13 helpers.

Conclusions and Recommendations

The present paper has demonstrated the function of IE for developing operation bulletin that can be used for production planning. This operation bulletin can be applied for trouser of different styles. It can further be enhanced after practical implementation to observe the WIP at the workstations. The further study on line balancing is needed to reduce the number of workstations or cycle time which will improve the productivity and minimize the resource cost.

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