A MULTI-SITE CASE STUDY OF HUMAN FACTOR CONSIDERATIONS AND MACHINERY UTILIZATION IN FOOD PRODUCING INDUSTRY

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ABSTRACT

This study evaluated ergonomics consequences of maximizing industrial machinery usage on the operators. The main objective was to establish a relationship between human factor considerations and machinery utilization (MU). The MU, over a period of one year, was computed for 45 Bundling Food Packaging Machine (BFPM) in 6 sausage roll producing industries located in Southwest Nigeria. Machine hazard/safety checklists were used inform of questionnaire to carry out machinery inspections and the subjective perceptions of operators of the machinery with respect to work loads and exposures to machine related hazards. 82.2% of the BFPM had MU rated above 90%. 92.8% of the operators were affected by environmental load, 91.1% affected by physical load and81.8% by mental load. The statistical test result showed a weak relationship between the MU and the operators' ergonomics perception ratings (OEPR) (r = 0.025, p=.870). The independent sample t-test showed that MU had statistically significantly higher means of good percentage ratings (92.9 ± 4.8) compared to that of the OEPR (39.187 ± 17.07), t (88) = 20.321, p = 0.001. The result showed that the groups' calculated/response means were significantly different. The study concluded that the ergonomics factors maintained around the machinery were rated below the emphasis placed on its high production and quality.

Keywords: ergonomics, machinery, operators, safety, production

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Introduction

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system. It applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics is concerned with the 'fit' between the user, equipment and their environments. In machine designs, ergonomics aspects considerations include among others, integral lighting, danger signals, operating manual, handling of loads, postures, design of machine parts, graphical user interface, actuators and displays (Jan *et al.*,, 2012; Ashrafi and Khan, 2005; Mason, 1984*)*. Design ergonomics however adapts machine to the user.

Ashraf *et al.*, (2003) stated that some machinery in the industries is never assessed in terms of ergonomics, whereas one of the main causes of most industrial accidents is inadequate user-machine interaction and that unless the ergonomics lessons relating to machine usage are fully learned, disaster could still continue to occur. If *human factors considerations* important in machine usage are not adequately provided, it will cause physical and emotional stress. This will also affects machine operator performance that will result into low productivity and poor quality of work. Ergonomic improvements in machinery handling will enhance operators' productivity while ergonomically designed equipment and proper safety training can significantly reduce high level of industrial

accidents most especially among machinery handlers (Munipov, 1992; Brian *et al.,* 2015; Arun *et al.,* 2013).

Machinery is considered central to production process among the consumer goods industry. Therefore most industrialists strive to optimize assets and measure their ability to help meet overall goals. Fast-moving trends in production are adopted to reduce the time interval between the design of a product and delivery to the point of sale. Hence high-speed machining has been touted as a solution for maximizing machine efficiency in this direction (Alesa, 2009). The benefits to achieve are numerous. It helps to maintain high production, product quality and helps the line operate at peak performance among others. According to Melis (1989), in other to achieve an optimal balance between performance, quality and cost, machinery optimization is a main concern of food producing industry.

Subramaniam *et al.* (2009) mentioned that humans play a major role on the industrial shopfloor. He is typically actively involved in the decision-making process, *operates semi-automatic machines help greatly to* meeting management targets. Usually personnel directly working with machines involve in one manual handling or the other. Meanwhile biomechanics has obvious direct relevance to manual handling work on machine. Muscles must move to carry out tasks and how much physical work a worker can do depends on the biomechanical criterion (how much can be handled without damage to the body), physiological criterion (how much can be handled without over exerting the lungs) and psychophysical criterion (how much can be handled comfortably). It is however very difficult to set definitive criteria for repetitive work, because even very light levels of work may cause increase in intramuscular pressure, which may sometimes lead to swelling of muscle fibres, pain and reduction in muscle strength (Stellman, 1998). Postures at work can also be influenced by individual differences, age and sex. It was mentioned by Wolfgang and Joachim (1998) that a “best” posture in manual handling is largely fiction. Hence there are a number of alternative “best” postures from the standpoint of different criteria.

Therefore improving occupational health and safety (OHS) and workers' productivity are the major challenge of many industries, especially in the developing countries like Nigeria. Some of the industries not adequately designed as a proper workplace. There are other issues such as mismatch between worker abilities and job demands, poor human-machine system design and inappropriate management programs. These lead to workplace hazards, poor workers health, mechanical injuries, disabilities, and all these in turn reduces worker productivity, product/work quality and increases cost(Ashraf *et al.,* 2003). Because of the diversity in machinery usage in industries, there must be proper assessment of the risk involved to the personnel working with the machines. Workers must be aware of the risks and follow safe work practices that is attached to working with machines(Willy and Robert, 2006; Subramaniam, 2009; Mary, 2014).

This study investigated the ergonomics effect of maximizing industrial machinery on machine operators using some food producing (s*ausage roll*) machinery (Bundling Food Packaging Machine-BFPM) in some parts of southwest Nigeria. The objectives were to evaluate the machinery usage, effects on workers, management decision as it affects the machine handlers and establish a relationship between human factor consideration and machinery utilization (MU).

Significance of the study

The study measured the importance placed on industrial machinery operators in comparison with the attention given to utilizing the machinery. It helped the management identify the subjective perceptions of a group of their work force and the gap to bridge regarding ergonomics program(s) put in place and the efforts at promoting safe working environment.

Material and Methods

Subject selection

Bundling Food Packaging Machine (BFPM) common among the selected food processing industries was selected for the study. BFPM is widely used by many food industries. It can store huge quantity of foods before they wrapped as a single bundle. All personnel (operators) working directly with the machines who were adequately experienced on the job and have spent at least 365

days continuously on the machine were selected for the study. At least 2 operators (one on each shift) on each machine were assessed. In total 150 operators were involved. All potential volunteers agreed, and consents were obtained in written form to have the interview conducted after they were informed that their participation in the study was voluntary. The purpose of the study was stated and the confidentiality of the information provided were assured.

Study areas and the research tools

Six s*ausage roll* producing industries located within Lagos, Oyo and Ogun states, the Southwest Nigeria, were included in the study. Structured questionnaire, modified from machine checklists (Industrial Accident Prevention Association, 2008; Gorge Manson University, 2011) and other authors as guided by Gunnar (1990), Hollmann et al (1999) and Workplace Safety & Prevention Services (2013) were used and supplemented with face-to-face interviews. These were the research tools used for collection of information on the attitudes, needs and expectations of the machine handlers. The questionnaire construction addressed the subject areas as personal background, work background, typical workday/shift plan, current work, work organization, technical ergonomics and psychosocial factors. It measured the operators' physical load (such as body posture, repetitiveness), mental load (job stress) and environmental loads (machine speed, noise, vibration). The subjects were asked to assign numbers to stimuli of different intensities in such a way that the numbers given match their ergonomics perceptions and vary directly in proportion to them. Category ratio (CR) scale from 0 to 10 were used as shown in Table 1. Ten (10) is defined as the strongest effort and exertion a person experienced on the job.

Table 1: Category ratio scale and interpretations

Category ratio Scale	Interpretation
0	Nothing at all
0.5	Extremely weak
1	Very weak
2	Weak
3	Moderate
5	Strong
7	Very strong
10	Extremely strong

Source: Gunnar (1990)

Measurement of Machinery Utilization

Use of BFPM was common among the industries accessed. Hence machinery utilizations were calculated, for 45 BFPM, using the ratio of actual output to the output that could be achieved if a plant ran at its maximum capacity for 365 days per year while producing 100% quality product. The actual outputs of the machines over a period of one year were obtained from the managers' record while the maximum capacity were derived from the manufacturers' manual. Hence the MU was computed using (1) (Ellis, 1998).

$$Asset\ Utilization = \frac{(Average\ Production)}{(Production\ Capacity)} \times 100 \quad (1)$$

Data Analysis and Statistical tests

Statistical Package for the Social Sciences (SPSS) was used to analyse the collected data. The 45 MU results (in percentage) were compared with the operators' perception self-ratings (OEPR) (in percentage) for correlation strength. Spearman's rho was used for significance tests of correlation coefficients at a p-value of 0.05. According to Gerstman (2006), correlation quantifies the extent

to which two quantitative variables go together. Correlation strengths can be classified as weak, $0 < |r| < 0.3$; moderate, $0.3 < |r| < 0.7$; and strong, $|r| > 0.7$. The independent sample t-test was used to analyse the means of the unrelated groups at $p < 0.05$. According to Pagano (2004), the independent samples t-test evaluates the difference between the means of two independent groups. It appraises whether the means for two independent groups are significantly different from each other. The independent sample t-test is probably the single most widely used test in statistics (Matthew, 2004).

Result and Discussion

Workers Response to Interview

One Hundred and twenty-five (83%) of the entire one hundred and fifty (150) workers who participated in the study, completed the questionnaire. Table 2 showed the information about the subjects. The average age was about 27 years. Most of the workers were 25 years of age and 3 years on their current job.

Table 2: The statistic information about the workers studied in six food producing industries.

Description	Job Experience (years)	Age	Operating time (hours)
Mean	3.6	27	9.4
Mode	3	25	8
Standard Deviation	3.5	3.1	2.0

Reported effect(s) of machinery on workers

From Figure 1, more than 90% of the group of workers reported that the machines they operated were properly guarded (94.4%) and that oil spillages were cleaned up almost immediately (96.8%). About 90% also highlighted that machine vibrations were properly managed. However 92.8% of the operators reported that the speed of the machine was high for them and would have preferred working at a slower pace, while 68.8% of them complained of excessive machine noise. As 68.2% and 58.7% mentioned that emergency stop and warning labels respectively were put in place, 65% complained that the orientations of the machines did not permit keeping a natural posture during operations and that the arrangement of machinery limit their free movement.

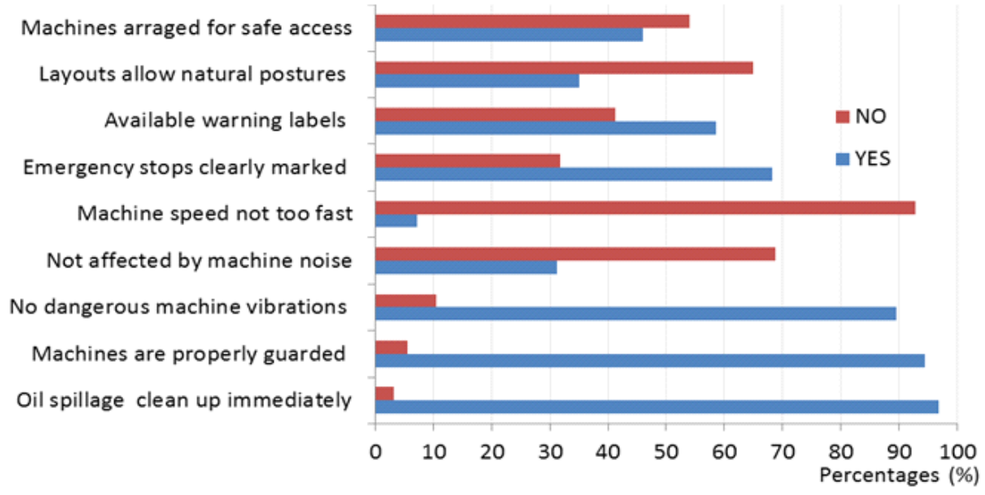

Fig. 1: Reported machine conditions as it affected the operators

Operators' reported management measuresat improving occupational safety

As shown in Figure 2, 72.5% of the workers mentioned that their management provided adequate free medical care. 64.2% believed they were given enough instruction on the machine they worked with but only 48% stated that they enjoyed regular direct trainings on safety related. 52.6% saidthey were provided with adequate PPE and that usage was enforced. However 75.2% complained that shift-work disturbed their normal rest while 71.2% desired for more recovery time.

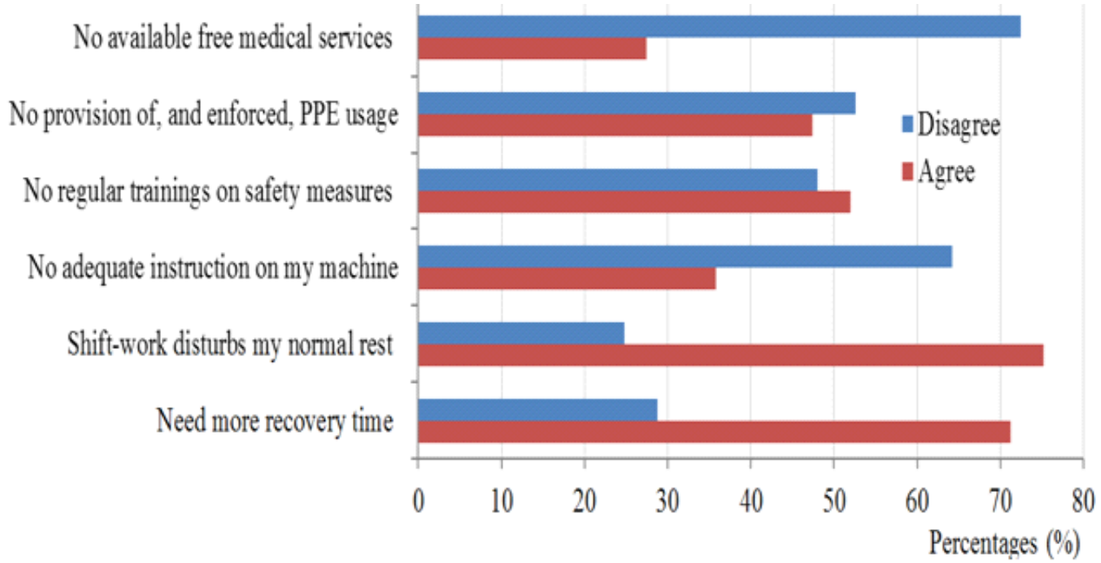

Fig. 2:Operators' reported management decisions as it affected their works on machine

Subjective perceptions of operators regarding workload elements

Figure 3 showed the measure of some selected workload elements affected by the group of workers and the ratings' interpretation as aforementioned (Table 1). A total of 92.8% of all the operators mentioned that they were affected by environmental load. An average category ratio scale of 8.8 (88%) was allotted to work pace, 7.5 (75%) for job demand, 6.8 (68%) for noise disturbance and 5.0 (50%) for job control.

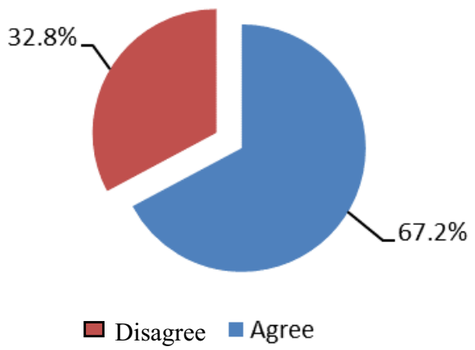

Fig. 3: Operators' perceptions and responses to workload element

About ninety two percent (91.9%) of the subjects complained of physical load influence. In this category, an average rating of 5.75 (57.5%) was assigned to manual lifting on the job, 9.63 (96.3%) for repetitiveness and 7.82 (78.2%) to awkward posture.

Almost 83% of the operators were afflicted by mental load. Of this percentage, an average scale of 8.75 (87.5%) was allocated by the workers for fatigue after daily work, 8.18 (81.8%) allocated to job stress while 2.05 (20.5%) was for job satisfaction.

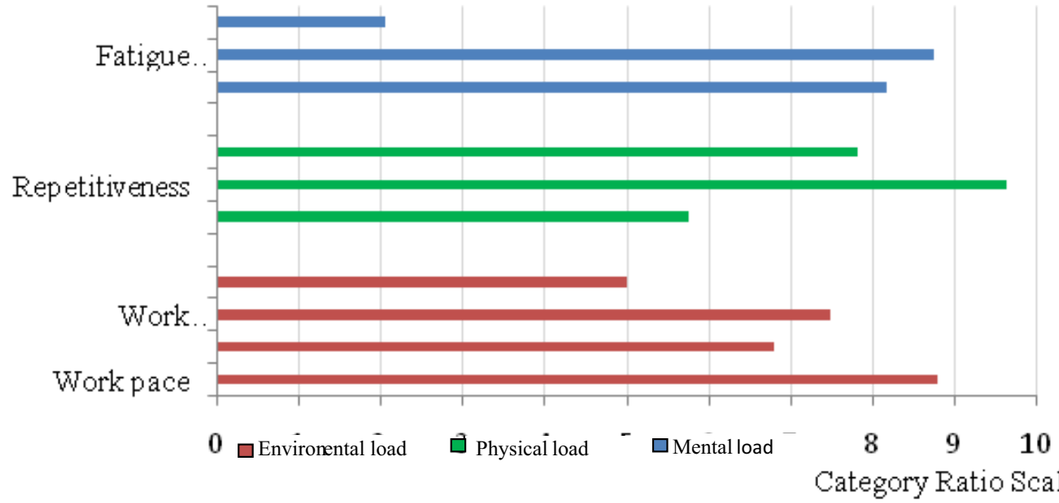

Fig. 4:Workers'perceptions on management position on production and/or quality and the human factor consideration

Average total reported on the job ergonomics criteria enjoyed by the operators

About 32.8% of all the BFPM operators opined and reported that their safety and health were the priority of the management as against 67.2% of their equals in the task who perceived that their managers placed greater emphasis on high production and quality more than meeting their ergonomics related demands.

Machinery Utilization

Using the formular as presented in equation (1) earlier, the 45 MU were calculated and some parts of Figure 5a and Figure 5b showed the outcomes. Nineteen (19) out of 23 representing 90.5% in Fig 5a had MU, over a period of one year, above 90% while 18 out of 21 representing 85.7% in Figure 5b had its AU above 90%. In general 37 out of 45, representing 82.2%, were above 90% and the production were rated good.

Ergonomics considerations versus machinery utilization

Comparing operators' ergonomics perception self-ratings (OEPR) with machine MU

Figure 5 also compared the MU which were rated good and the operators on the job comfort self-ratings. About 32.8% of all the operators were well satisfied with the ergonomics measures put in place and enjoyed on the job, while 82.2% of the machines they operated were rated high in terms of MU.

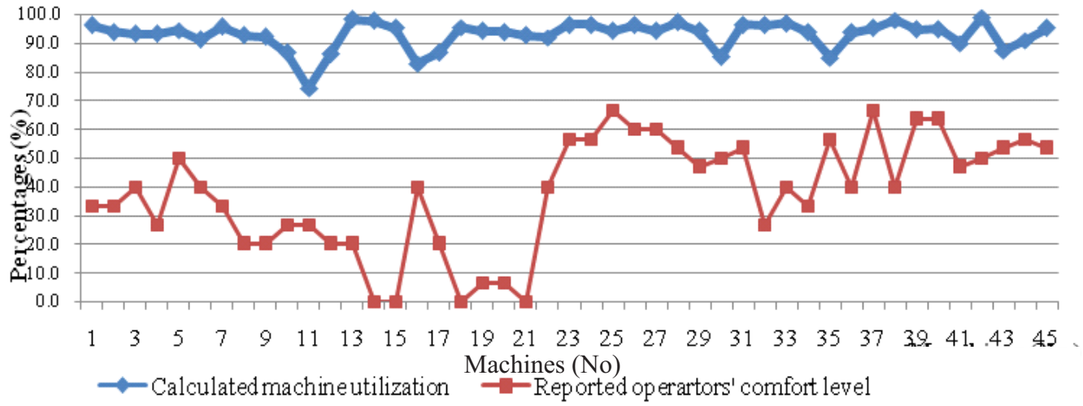

Fig. 5:Machinery utilization level for the studied BFPM and the reported operators' on the job comfort self ratings

Spearman's Rank Correlation coefficient Statistics test between *MU and OEPR*

After comparing the result of MU with that of OSPR for correlation strength using Spearman's rho, r = 0.025 and p= .870, hence the correlation is not significant. The coefficient of determination of 0.025 suggests 97.5% variability.

***Independent samples t-test between MU and* OEPR**

The t-test to determine the mean difference between MU and OEPR found that MU showed a statistically significantly higher means value (92.9 ± 4.8) compared to OEPR (39.187 ± 17.07), $t(88) = 20.321$, $p = .000$. However, the groups' means were significantly different because the value of "Sig. (2-tailed)" was lower than 0.05.

Discussions

More than 80% of the total group of workers (operators) involved in the study complained of one level of discomforts or another from environmental, physical and mental load. Repetitiveness, too fast work-pace,fatigue after work and job stress were leading among all other complaints. Other significant discomfort rated between 'strong' and 'extremely strong' by the subjects included job demand, noise disturbance, lifting, inability to maintain natural postures at work among others. On the response to management's efforts at improving their on-the-job comfort and/or safety and health level, less than 50% mentioned to have regularly enjoyed direct on-the-job trainings on safety. Whereas more than 70% complained that the shift-work characterized by their job disturbed their normal rest and craved for more recovery time. In their opinions, majority of the group of workers (about 70%) opined that their enhanced comfort demands did not make the priority list of their managements but rather believed that greater emphasis was placed on meeting daily production targets and qualities than they were concerned about their desired enhanced comfort level on the job. The findings established the view earlier reported by Ashraf *et al.* (2003) that most industrial machinery do not meet ergonomic criteria of their handlers.

Machinery utilization (MU) as used in this study was a metric that focused on how the efforts of managements translated to high production targets. More than 80% of all the BFPM evaluated had their utilization ratio above 90% and the assets were rated properly functioning. The result showed a closed gap between what the machines were capable of producing and what they actually produced. However when the MU results were compared with the operators' ergonomic perception ratings (OEPR), the correlation is not significant and the groups' calculated/response means were significantly different. Hence the efforts in place at making the BFPM yield high level of production were not the same as the one in place to enhance the machine operators' on the job comfort level.

Both manpower utilization and machine efficiency are said to be the leading major factors contributing to production line efficiency (Subramaniam, 2009).

As observed from this study, the industries, at least for a period of one year, were able to properly utilize their production assets but the manpower directly involved seemed not satisfied ergonomically, going by the concerned workers' opinions. However, it is to be emphasized that in meeting targets, human play a vital role in the production floor and machine operators are valuable help in achieving management targets. However man is prone to environmental changes. When the performance of a machine handlers is reduced as a result of either a mechanical or other form of injury (mental, physical or environmental), the production quantity and/or quality also drops.

From the group of workers responses, it can be deduced that the operators were aware of the importance of ergonomics factors to their health and safety and expected the ergonomics criteria to be highly captured in their work space and/or efforts at meeting the set target. It seemed that the operators were not satisfied with the second hand information/trainings received from their supervisors. They wanted a direct training program from qualified Health and Safety professionals. Therefore efforts at enhancing the comforts level and/or health and safety of workers attached to production machinery is worth investing on. The feedback will be high standards of production and enhanced profits. This will reduce complaints of not been able to cope with the rate at which the work is expected to be performed. When emphasising efficiency, two goals should be paramount–the quality use of manpower and the engagement of appropriate MU.

There is therefore the need for a better mechanism that will take into account the state of the operators while optimizing the MU. The mechanism should be equipped to suggest how the operation of the machines should be optimally adjusted, relevant trainings to be administered on the operators, optimal review of allocation of job to individual and stress relief package for workers.

One of the limitations of the present study is the sample and subject sizes were relatively small and the effects may under estimate the real-world opinions of the entire group of workers. Future efforts may however consider a wider coverage and other industries different from food producing. Lack of baseline information gathering is also an issue.

Conclusion

The study investigated the ergonomics effect of maximizing machinery usage on operators using some sausage roll producing industries in some parts of Southwest Nigeria. From the study, more than 80% of all the bundling food packaging machine evaluated had their utilization ratio above 90% and the performance of the assets were rated good. However, repetitiveness, too fast work-pace, fatigue after work and job stress were leading among all other complaints by more than 80% of the group of the operators directly manning the machines. Other significant discomforts rated at least 'strong' included job demand, noise disturbance, frequent manual lifting, inability to maintain natural postures at work. While more than 50% of them craved for direct relevant trainings, 70% complained that the shift-work disturbed their normal rest and craved for more recovery time. In their opinion, about 70% opined that their desired enhaced comfort level on the job was not part of the priority list of their managements as greater emphasis were placed on meeting daily production targets and quality. Machinery utilization (MU) results compared with the operators' ergonomics perception self-ratings showed that the correlation is not significant and the groups' calculated/response means were significantly different. The study suggested development of a better mechanism that will take into account the state of the operators while optimizing the MU. This will help to sustain and/or enhanced the level of occupational safety and health advocated by International Labour Organization standards among the groups of workers.

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