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Diagnosis and Improvement in a Fresh Grape Agro-Exporting Company Using Management Techniques

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Abstract **-** This article focuses on the optimization of production areas in an agro-export grape company through the application of various management techniques and practical improvements. For this, a mixed methodology was used, which includes the analysis of quantitative and qualitative data, such as process flowcharts, diagrams, and records. Among the improvements implemented, the redesign of the conveyor belt was included, which reduced ergonomic injuries and work absences, with average adjustments between 92.82 and 105.6 m. In addition, the 5S methodology was implemented, which increased management by 89.1%. Concrete changes were made, such as the automation of pallet labelling and the relocation of staff, which allowed increasing productivity and recovering the investment in 5.2 months. As a result, productivity improved by 18.57% in women and 23.86% in men, and efficiency increased by 95.9%.

Keywords**:** Methods Engineering, Optimization, Agro-exporting Company, Efficiency, Ergonomics, Quality, and Process Improvement.

1. Introduction

The agro-export industry plays a crucial role in the global economy. "In terms of fresh grape exports, these amounted to US$ 1,745 million, representing an increase of 29.7% compared to 2022. It also showed a 16.9% increase in the volume exported, which was reflected in the months of September (+257%) and October (+85%). According to the Association of Table Grape Producers of Peru (Provid), this volume increase was due to an advance in the harvest of the 2023-2024 campaign, due to climatic conditions [1]. In this context, companies dedicated to the production and export of agricultural products, such as fresh grapes, face increasingly complex challenges in a globalized and competitive market environment [2].

Agro-export companies aim to be more competitive, and to optimize production processes, it is an excellent opportunity to consider the 5S methodology, which is applied in all types of companies [3]; in the maintenance areas [4] to avoid failures, prevent defects, facilitate cleaning [5], organize the workplace effectively [6], ergonomics is also considered based on the study of man in his work situation to improve the conditions in which he performs his activity [7], to design work tools that fit adequately and safely with the collaborators who use them [8] and the study of times to propose specific actions according to bottlenecks [9], with the reduction of unproductive times [10].

This article aims to analyze the diagnosis and improvement of a fresh grape agro-export company, answering the following question: How can we optimize its operations by applying various management techniques? It will be carried out through a multidisciplinary approach that combines business management principles and industrial engineering, in order to analyze and create a culture of continuous improvement [11]. The main stages of the process will be examined, problems will be identified, improvement strategies will be executed, and their impact on performance will be evaluated.

Given the above, it has become crucial to implement effective management techniques that improve efficiency and quality in the identified areas. It is expected that the findings of this study will not only contribute to improving efficiency and quality in production but will also serve as a basis for future research and applications in the field of the Peruvian agro-export industry and, by extension, in other similar sectors internationally.

2. Methodology

The research is experimental with a pre-test/post-test single group design. In other words, it provides information about what is inadequate and what is appropriate by applying a pre-test to the stimulus or experimental treatment. The treatment is then administered, and finally, a post-test is applied to the stimulus or study group [12] (pp. 202-225). The type of research is applied because it is based on generated knowledge [11]. It seeks the application on a circumstantial reality rather than the development of theories [12]. The scope of the research was descriptive, focusing on the process and application of methodologies through the current diagnosis. A mixed approach was adopted, as both quantitative and qualitative data were collected and analyzed. The instruments used were process flowcharts, diagrams, visits, and records.

The variables studied were management techniques (independent) and production (dependent). The participation of the staff working on a production line was taken into account, which consists of 26 collaborators, both men and women.

The process begins with the reception of the grape crates, verifying the quality of the input before unloading, then it is moved to the weighing area where it is coded. The crates continue the gasification process to disinfect and heal wounds, then it goes through a cooling process to ensure quality standards. Having a temperature of 18°C, it goes to the supply area where it undergoes a cleaning process using compressed air to be directed to the selection and packaging area. At this stage, the grapes are selected according to the calibers and categories established by the company, these selected grapes are packaged in bags and boxed to be transferred to the palletizing area, where they will be stacked in blocks of 114 boxes per pallet and strapped.

A thorough analysis of the process was carried out, which included the elaboration of an operations diagram, an analytical diagram of the process, a route diagram, and the collection of data on monthly production, as well as a time study. After this initial stage, a preliminary audit was carried out, which included a Pareto analysis to identify and prioritize the most significant problems within the area in question.

Figure 1 shows the use of the Ishikawa diagram to identify the causes of the problem, leading to the identification of three main problems that required solutions. The first focuses on improving the selection area, as the staff faces physical difficulties when transporting the boxes to the conveyor belt. In addition, the noise generated by the blowers causes discomfort among the collaborators. Lastly, the handling of the raw material results in disorder and unsanitary conditions, leading to some collaborators taking breaks during the workday, which affects production. These problems were addressed through corrective measures.

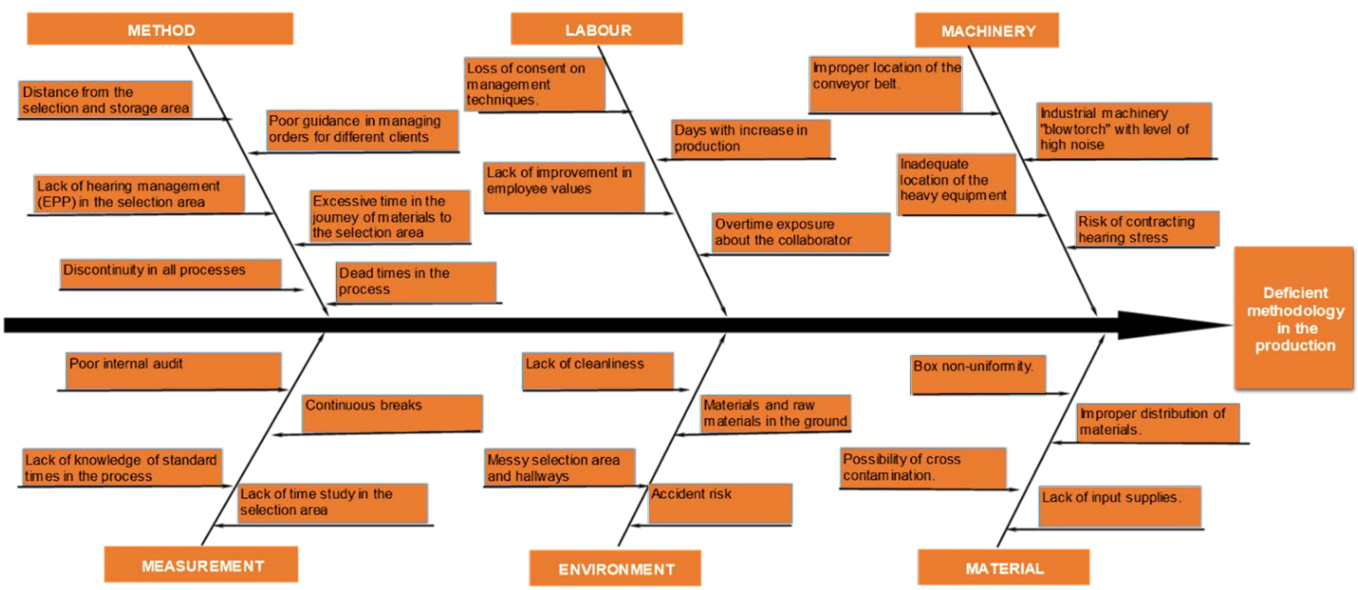


Fig. 1: The Ishikawa Methodology Diagram (Cause - Effect).

The first corrective measure begins with the 5S methodology, which consists of five stages: sort (Seiri, stage 1), set in order (Seiton, stage 2), shine (Seiso, stage 3), standardize (Seiketsu, stage 4), and sustain continuous improvements (Shitsuke, stage 5) [13], [14].

In the first phase, color cards were used to mark within the workplace (production area and warehouses) and see if there there were unnecessary materials/tools, in order to take corrective action. Yellow was used to indicate a contamination problem, and red if it was not related to work, such as food containers, scissors, cell phones, etc. In the second phase, the route diagram analysis was used to evaluate the process flow and subsequently redistribute the areas; the third phase was marked by cleaning and monitoring its compliance. In the fourth phase, earplugs were purchased for the selection area workers and a Zebra ZT400 Series industrial label printer, to increase efficiency and effectiveness in the traceability area with the aim of optimizing resources. In the final phase, training was carried out and a 5S committee was appointed, responsible for presenting future recommendations and suggestions. With respect to physical strain, the study of ergonomics (anthropometry) will redesign the conveyor belt with adjustable support, currently the belt measurement is 118 cm. Therefore, to determine the height of the adjustable support of the belt, the min. and max. values of the elbow height measurements of men and women were found, adjusting to a Hispanic industrial population.

An area called pre-cooling has been identified where the fruit is allowed to rest so that the pulp reaches a temperature of 18 -23 °C when entering the supply chamber. To achieve a much more efficient process, the law of least distance was applied, placing the next process closer to the other.

Continuing with the time analysis in the selection and weighing area, it has been observed that these activities consume a significant proportion of the total cycle time (CT), representing 47.98%. This is because they are carried out manually by a single operator, resulting in delays. Data on breaks, expressed as percentages of normal operating times for men (-16) and women (-21), have been analyzed, identifying intermittent and strong auditory strain as the most influential factor in performance. As for the total operation time in the selection area, it is observed that it is 464.519 seconds for women and 464.87 seconds for men. The Westinghouse system was used to determine the duration of activities, using production indicators such as CT, workstations (WS), idle time (IT), station time (ST) and efficiency. For the practical purpose of the study, a daily production of 3 containers (6840 boxes), with 80 boxes per person and an observed process time of 10.9392 minutes was considered.

$$CT = \frac{Production\ time\ per\ day}{Daily\ demand\ or\ production} = \frac{480\ min}{80\ boxes} = 6\frac{min}{box} \qquad (1)$$

$$WS = \frac{\sum Task\ time}{CT} = \frac{10.94}{6} = 1.82 = 2 \qquad (2)$$

$$IT = WS * CT - (ST_1 + ST_2\ ) = 2 * 6 - (5.52 + 5.42) = 1.06\ min \qquad (3)$$

$$Efficiency = \frac{\sum Task\ time}{WS * CT} * 100 = \frac{10.94}{2 * 6} * 100 = 91.17\% \qquad (4)$$

3. Results

After a week of implementing the previously mentioned measures, a survey was conducted as a final audit, which showed a significant improvement compared to the first audit; the values in weak areas such as "Sort" and "Set in order" improved by 100% and 92.5% respectively.

Figure 2 shows that the daily cleaning plan was applied, detailing cleaning procedures for the designated staff to follow when cleaning, improving by 87.5%.

(a) (b)

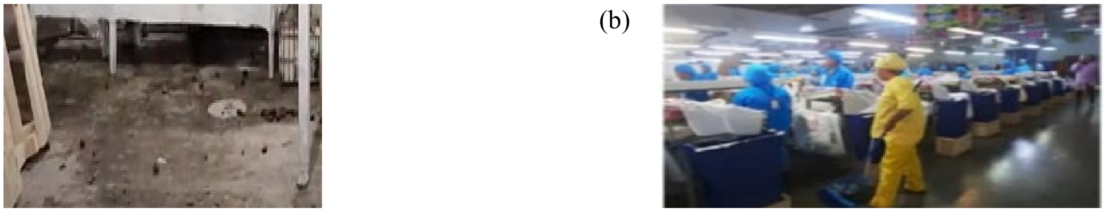


Fig. 2: Application of the third "S" (a) before, (b) after.

In standardizing, there was a 75% improvement. According to the data shown in Table 1, the cost of the machine and the monthly savings are described, recovering the investment in a short period of 5.2 months. Additionally, the activity of the worker in charge of strapping was increased to perform the labeling system with the Zebra ZT400 Series industrial label printer, allowing the traceability person to be relocated to another area where they can be more useful - such as the selection and weighing or packing area, thus increasing production.

Table 1. Representation of cost-benefit.

Cost		Amount	Cost per day US$	Cost per month US$
Zebra ZT400 Series Industrial Label Printer	US$ 1441.95	1 worker days worked 26	10.65	276.81
Total invested	US$ 1441.95	Total saved per month		276.81

To conclude generally, in Figure 3, it can be seen that the company maintains an 89.1% in its current management. However, there are still possible improvements related to visual management and soft skills, although discipline increased by 80%, improvements are being supervised with the invitation to participate in new regulations as solutions to future problems, induction was given to the operating and administrative personnel on the 5S methodology and its benefits, in addition, the permanence of the 5S committee was assigned to the most experienced collaborator.

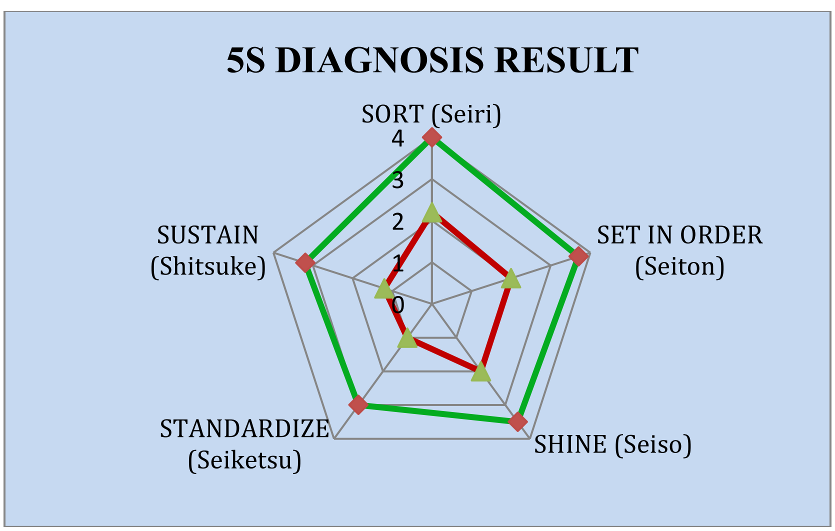


Fig. 3: Before and after the 5S diagnosis result.

Taking into account the anthropometric variable of elbow height, the adjustable measurement for men is 95.81 cm at its minimum and 115.39 cm at its maximum; for women, the measurement is 85.72 cm as a minimum and 99.91 cm as a maximum. The overall average is set at 92.82 cm at its minimum value and 105.6 cm at its maximum value. Finally, the formula is applied to find the belt height considering the ideal elbow height which was adjusted to 96 cm and with a work height of 12 cm plus the 5 cm that exist between the elbow height and the work height.

$$Conveyor\ belt\ heigh\ = elbow\ height - (work\ height + 5\ cm) \tag{5}$$

$$Conveyor\ belt\ heigh = 96\ cm - (12\ cm + 5\ cm) = 79\ cm \tag{6}$$

In Table 2, there is a history of absences due to occupational diseases averaging 8 days, which represents a payment to the worker for these non-working days of US$ 85.17. As a result of this change, there is a financial saving due to the overhead cost of labor and staff turnover for replacement.

Table 2. Economic savings.

Amount	Medical leave per month	Days not worked	Cost per day US$	Cost per month US$	Savings due to design improvement US$
4 individuals	2	8	10.65	85.17	85.17

In the current route diagram, the storage area in the supply area is overlooked, as there is currently storage in the cooling area because the bunches of grapes when they enter the process in the supply chamber are kept in a climate-controlled temperature range between 18 - 23 °C, applying the law of the shortest distance. Under the proposed method, the raw material goes directly to the cleaning and packaging area.

Changes are evident with respect to the current process, reducing the sequence of steps from 25 to 22.

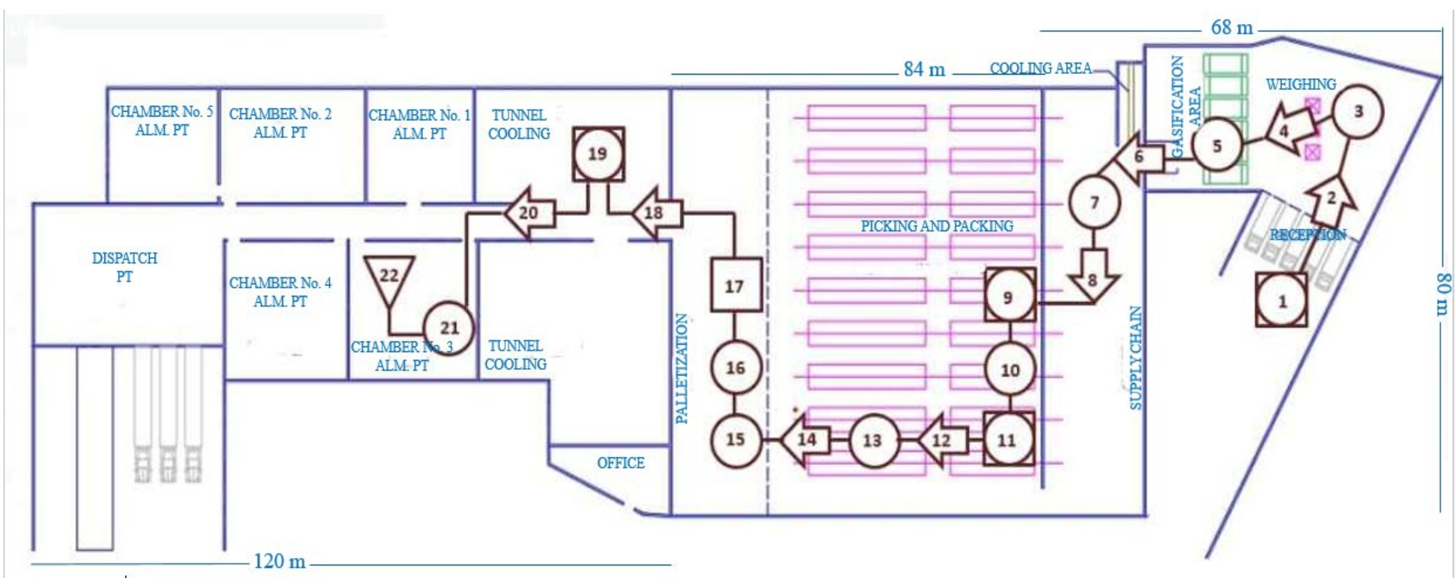


Fig. 4: Current layout diagram.

Table 3. Economic savings.

Symbology		Before	After	Economic
Activity		Operations	Operations	%
○	Operation	14	12	-14,29%
⇨	Transportation	09	08	-11,11%
□	Inspection	06	05	-16,67%
▽	Storage	01	01	0,00%
Distance		148	112	-24,32%
Time		97,332	84,149	-13,54%

The economic impact on operations; -14.29% less than what we had before, transport; -11.11% less, inspection -16.67% less, distance; we decreased by -24.32% the number of meters we should travel.

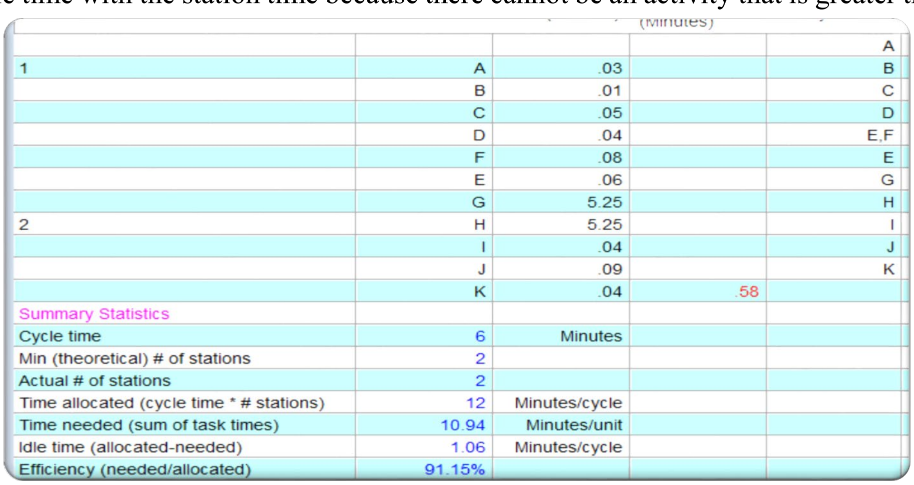
Study of Times and Movements: The improvement contemplates the description of auditory tension - intermittent and strong, it was proposed to use personal protective equipment (PPE) with earplugs and earmuffs that decreased this degree of tension by complex, optimization of 5 process elements, with the valuation factor using the Westinghouse system, reflecting as fundamental consistencies for element A) regular, B) good, c) Regular, D) excellent and E) good; the total operation time for women is 391.78 seconds and 375.32 seconds for men.

Time: -13.54% less compared to the initial state.

Table 4. Valuation method - Westinghouse System.

	ABILITY		EFFORT		CONDITIONS		CONSISTENCY		TOTAL
A	D	0.00	D	0.00	C	0.02	E	-0.02	0.00
B	C2	0.03	C2	0.02	D	0.00	D	0.00	0.05
C	C2	0.03	D	0.00	E	-0.03	D	0.00	0.00
D	C1	0.06	E1	-0.04	C	0.02	D	0.00	0.04
E	C2	0.03	D	0.00	D	0.00	E	-0.02	0.01

In Figure 5, the data is verified in the QM FOR WINDOWS software, where we observe that there is an incongruity with respect to the cycle time with the station time because there cannot be an activity that is greater than the cycle time.



		(Minutes)		
				A
1	A	.03		B
	B	.01		C
	C	.05		D
	D	.04		E,F
	F	.08		E
	E	.06		G
	G	5.25		H
2	H	5.25		I
	I	.04		J
	J	.09		K
	K	.04	.58	
Summary Statistics				
Cycle time	6	Minutes		
Min (theoretical) # of stations	2			
Actual # of stations	2			
Time allocated (cycle time * # stations)	12	Minutes/cycle		
Time needed (sum of task times)	10.94	Minutes/unit		
Idle time (allocated-needed)	1.06	Minutes/cycle		
Efficiency (needed/allocated)	91.15%			

Fig. 5: Data verified in the QM FOR WINDOWS software.

The comparison of before and after has been obtained through the time study. Table 5 shows a time saving of 1.2123 min in women and 1.4925 min in men. This time saving allows us to produce more boxes in a day per worker and considering considering that there are 4 workers in this operation, table 6 shows the increase in boxes and the increase in percentage variation.

Table 5. Times used per box and savings per box.

	Times used per cash and savings per cash			
	Before (s)	**After (s)**	**Saving (s)**	**Saving (min)**
Women	464.519	391.7837	72.7353	1.2123
Men	464.87	375.3222	89.5478	1.4925

By performing calculations with the new base time: 9.59 min (10.94 min - 1.35 min). The fresh grape production line has an efficiency of 95.9%.

$$Efficiency = \frac{\sum Task\ time}{WS * CT} * 100 = \frac{9.59\ min}{2 * 5\ min} * 100 = 95.9\% \quad (7)$$

Table 6. Increase in production and percentage variation.

	Number of boxes per day					
	Before	**After**	**Before**	**After**		
	Q. Boxes per day	**Q. Boxes per day**	**Q. Boxes / 4 Workers**	**Q. Boxes / 4 Workers**	**Production increase (Boxes)**	**Variation %**
Women	61.9996	73.5099	247.9985	294.0398	46.0413	18.57%
Men	61.9528	76.7341	247.8112	306.9363	59.1251	23.86%

4. Discussion

Applying the 5S methodology, time study, and Ergonomics, the results of the study indicate that the proposed interventions have been effective in optimizing operational processes and improving efficiency in economic and time terms. Additionally, the focus on gender equity and ergonomics demonstrates a commitment to a fair and safe work environment. However, it is important to continue monitoring and evaluating these improvements to ensure their long-term sustainability and look for additional optimization opportunities. Regarding the line balance with the new demand, when corroborated with the software, there is an incongruity between the cycle time and the selection and weighing station time. Given this situation, the increase in personnel for activities in selection and weighing should be considered, this to reduce the minutes per task, since there cannot be an activity that is greater than the cycle time; remember that by decreasing the cycle time, the number of stations increases, and this leads to saturation.

5. Conclusion

The implementation of the proposed method has improved the efficiency of the production process, eliminating storage in the pre-cooling stage, and optimizing the sequence of steps. The reorganization of the workflow has reduced idle time and improved resource utilization, minimizing the distance traveled by raw materials, leading to greater energy efficiency and lower operating costs. A reduction of 14.29% in operating costs has been achieved, especially in transport and inspection. The implemented measures have improved the total operation time by 13.54%, recommending greater gender equity in terms of workload and efficiency. Production per box has been increased for both genders, improving overall efficiency without the need for more labor. The study proposes ergonomic measures and highlights the importance of maintaining a clean, orderly, and efficient work environment. The importance of continuous supervision and the maintenance of long-term improvements is underlined.

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