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INTEGRATED BPM-TPM MAINTENANCE MODEL TO REDUCE OVER-TIME ORDER RATE IN HEAVY-DUTY SECTOR SMES: A RESEARCH IN PERU

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Integrated BPM-TPM Maintenance Model to reduce over-time order rate in heavy-duty sector SMEs: A Research in Peru

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ABSTRACT

The heavy freight transportation sector has been positioning itself stronger in the sector as a result of the increase in imports and exports in Peru, which has generated a 5.6% increase in its GDP. According to the above, it is essential to identify the stages of the processes, maintenance plan, availability of trucks, as well as the quality of freight transportation. A fundamental part of these con- siderations is the maintenance management and the restructuring of the stages of the service process, the model proposed by this research is the use of tools such as VSM, BPM, and TPM, whose main objective is to reduce the current rate of orders delivered out of time of 4.78 %, generated by a poor organization of the adminis- trative and logistics area. After the implementation through a pilot plan within the company, a reduction of 0.72% was obtained.

CCS CONCEPTS

• **Software and its engineering, Software maintenance tools**;

KEYWORDS

Business Process Management, Total Productive Maintenance, Small-medium Enterprise, heavy truck

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1 INTRODUCTION

Nowadays, in an international panorama, the transportation sector has been gaining importance in industrialized, emerging, and de- veloping countries. In 2021, according to INEI, the transportation sector contributed to a gross value added of S/. 30,887,000, which meant a growth of 2.5% compared to the previous year in Peru 1. This resulted in an increase of 6.1% in the EAP rate for the same year compared to other years 2.

Likewise, the freight transportation industry has a growth pro- jection of 12% per year, which could continue to rise by improving factors such as unit availability, price comparison at the time of contracting, and access to the transportation community 3. In addi- tion, freight transportation since October 2020 is operating with a 70% capacity having as an obstacle the restrictions imposed by the GTL (Global Trade Logistic) for free movement on the roads 4. Due to the 30% gap in cargo transportation capacity, this directly affects the percentage of customer service level, since orders are not delivered on time.

On the other hand, one of the tools implemented to improve truck maintenance is TPM, according to a case study in an SME by applying TPM its percentage of total equipment effectiveness increased from 54.23% to 66.90% 5.

Another research identified as the main problem the scarcity of merchandise management strategies in progress, there is no database to help in the organization of the entry and exit of orders, in addition to the fact that data on delivery times frequency of mechanical failures of trucks, several drivers, among others, are not collected 6. A company in Hungary, to improve logistics processes, conducted an analysis of these processes, which helped to identify the processes that did not generate value which was eliminated and those of great importance were introduced in a simulation, resulting in a decrease in delivery time from 420 minutes to 315 minutes 7.

Under this context, the importance of implementing mainte- nance and logistics management techniques that provide greater profitability to trucking companies is evidenced. For this purpose, a small freight transportation service company in Peru will be evalu- ated. The main conflicts encountered were the deficient information on the data of orders received and delivered the delivery time of each order, and the inadequate capacity caused by truck failures. Both problems generate monetary losses of 20.76% of the annual net profit. To solve this problem, a combination of TPM and BPM tools was required.

2 STATE OF THE ART

2.1 Business Process Management

BPM is mostly used in management practices and business opti- mization approaches, which include planning, organizing, leading, and controlling business process management activities 8. Also, BPMS encompasses a wide variety of features from business simu- lation and analysis processes to legislation, monitoring, and control processes 9. On the other hand, BPMS is a process management tool, which serves a software-like function for workflow management, process redesign through the use of data collection, monitoring, and business intelligence 10.

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Table 1: Comparison table of the Proposal Components vs The Applied Studies

Scientific Paper	Reference	Analysis of the problem	Stabilization of the process	Improved maintenance management
Xiang & Feng, (2021)	5			Preventive and Autonomous Maintenance
Pinto, F. J. G. Silva, A. Baptista, Nuno O. Fernandes, R. Casais, C. Carvalho (2020)	15			Preventive and Corrective Maintenance
L. Alvarado, J. Santos, J. Quiroz, and J. Alvarez	11		SWIMLANE, SIPOC, AVA	
X. Wang (2015)	14	VSM		
In this investigation		VSM, Pareto	SIPOC, AVA	Preventive and Autonomous Maintenance

Therefore, the implementation of this tool has positively ben- efited companies that apply it. For example, the implementation of BPM in a construction company, helped in the redesign of the process, achieving a significant reduction of the problem found, improving it by 32.33% on the root causes identified 11.

BPM has six phases for its implementation. The first phase is to identify the main problem and the processes that are related to it; then follows the discovery phase, in which the current state of the process and relevant data is seen, then there is the analysis phase, all the strengths, and weaknesses that impact the process are seen to continue with the next stage which is the redesign process is responsible for the changes to be made to solve the problems identified, the future processes to be performed. Finally, there are the last two stages, which are the implementation and control, and monitoring to collect and analyze data to see the performance of the new process 12, 13. Also, VSM is necessary in BPM because this tool is primarily used to diagram the process flow and have a visual map to help identify the activities that generate the most delay in the process and thus be able to eliminate the activity 14.

2.2 Total Productive Maintenance

Total Productive Maintenance (TPM) its objective is to remove wastes, decrease downtime and minimize the costs. This approach is based on a well-defined maintenance program. Therefore, has been used widely over the last two decades across the industry and shown outstanding achievements 15. TPM is not considered a short-term activity, but instead a program of implementation and continuous optimization 15.

Maintenance tasks, such as cleaning, greasing, lubrication, tight- ening nuts and replacing oil, must be performed by operators during the time that operational maintenance personnel are occupied in other scheduled tasks. This is called autonomous maintenance, which is one of the basic pillars of TPM 16. What differentiates preventive maintenance, which consists of a set of actions focused on improving system performance, is that this maintenance is per- formed before an actual failure occurs 17. Therefore, modern main- tenance strategies focus on two aspects of improving employee competencies: the first is to improve the competence of the per- sonnel responsible for operational maintenance. Another aspect is the involvement of the personnel of maintenance works in the operations and the assignment of duties for a more efficient usage of the skills they have, reinforcing their sense of value and their participation in the achievement of the company's objectives 18.

The implementation of this tool was carried out in a company SME manufacturer of hydraulic parts, which after simulating the operation of TPM in their maintenance processes, it was obtained as a result that in the long term the equipment or machines studied will increase their OEE, overall effectiveness of productive equipment, to 75%. In addition, the average availability per machine increased by 9.88%. And an approximate 55,440 RMB is saved per year, which in dollars is $ 8,564.81 5.

The references according to each author mentioned in the state of the art are summarized in Table 1, classified according to the tools that have been implemented in this article.

2.3 MODEL PROPOSED

The suggested model is focus on the combination of two techniques: TPM and BPM. These tools aim to provide solutions to the prob- lems that have been found in the company under study. The first technique, BPM, will be used in planning, organizing, leading, and controlling the process management activities 5. The next tool to be used is Total Productive Maintenance (TPM) its objective is to re- move wastes, decrease downtime and minimize the costs. Based on well-defined maintenance plans, this methodology has been used widely over the last two decades across the industry and shown outstanding achievements 11TPM is not considered a short-term activity, but instead a program of implementation and continuous optimization 19.

Maintenance tasks such as cleaning, greasing, lubrication, nut tightening, and oil replacement must be performed by operators dur- ing the time that operational maintenance personnel are occupied in other scheduled tasks. This is called autonomous maintenance, which is one of the basic pillars of TPM 15.

Another aspect is the involvement of the personnel of mainte- nance works in the operations and the assignment of duties for a

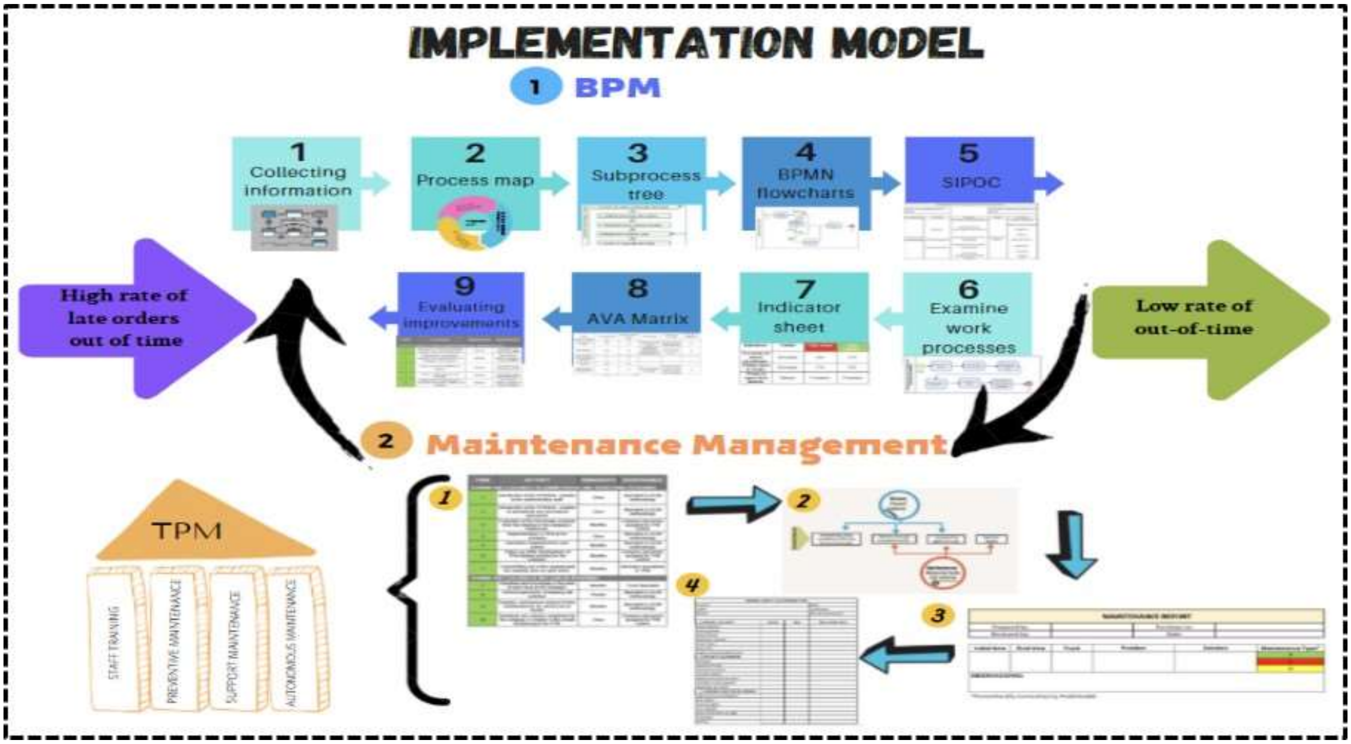

Figure 1: Implementation Model

more efficient usage of the skills they have, reinforcing the feeling of their value and their involvement in achieving the company's goals [18]. In figure 1 are the two principal tools that are going to be used in this investigation.

3 COMPONENTS OF THE MODEL

The proposal is divided in three phases, as mentioned below.

3.1 Phase 1: Problem Analysis

The first step to implement this component will be the realization of a VSM according to the data collected about the operation times that the company must follow when a customer wants the service of transporting heavy cargo, thus analyzing each of the times and activities that do not generate value but a delay in the functions of workers and delay in generating the order. The use of indicators is essentials to measure our improvements and maintain them over time. This tool is primarily used to diagram the process flow and have a visual map to help identify the activities that generate the most delay in the process and thus be able to eliminate the activity 14.

3.2 Phase 2: Process stabilization

The BPM tool will be applied, the purpose of which is to redesign the processes. The first step is the collection of data, which will be obtained from the first phase with the help of the VSM and the template to track the receipt of orders. After this, the main problems and the processes that are related to this will be identified and the AVA matrix will be used to identify the processes that do not generate value, give value to the customer, and value to the process.

3.3 Phase 3: Improved maintenance management

Analyzing and defining the main problems and their causes of maintenance are carried out, to eliminate or reduce them depending on the degree of affectation. The VSM tool was used to analyze the flow of information to the client and the timing of each activity in order to determine the reasons for the high level of the indicator. The Ishikawa diagram was also used to identify the sub-causes of each of the problems found, and with these results, the use of Pareto was required in order to calculate the severity of the impact of each of them on the development of the company. The main causes of this conflict were (a) Poor communication between the logistics area and the carriers, (b) Incorrect data storage, (c) Truck failure.

After this, In the simulation, two types of maintenance were designed: First, autonomous maintenance was applied, which has an average time of 15 to 40 minutes. The drivers are in charge of performing the inspection, which is based on a general and quick check of the truck. In addition, it will be controlled by means of a technical sheet to be filled in by each driver and approved by the maintenance manager. The reason why this maintenance can be carried out quickly is because after a truck returns from a trip,

Table 2: Indicators Table

Indicator	Formula	Use
Out of time order rate (OTR)	$\frac{\#\ late\ orders}{\#total\ orders} x100$	The calculation of orders that were not delivered within the time agreed by the customer per month.
Percentage of non-conforming clients (PCI)	$\frac{NCI}{CE} x100$	In the present equation, NCI is the number of non-conforming clients and CE is the number of clients surveyed 21.
Meantime between failures (MTBF)	$\frac{Operation\ time}{\#\ of\ failures} x100$	The average time a truck operates between failures. Operating time is the difference between truck uptime, preventive maintenance time, and repair time.
Mean Time to Repair (MTTR)	$\frac{Time\ spent\ on\ repairs}{\#\ of\ reparations} x100$	Time spent to repair a failure and return the truck to its optimum condition
Availability Index (Ai)	$\frac{MTBF}{MTBF+MTTR} x100$	The calculation of this indicator is calculated using MTBF, mean time between failures and MTTR, mean time to recovery 20.

preventive maintenance is carried out in order to anticipate possible failures.

This maintenance is performed by specialized technicians, who are in charge of doing a general overhaul in an average time of 4 hours for each unit. The average maintenance times were col- lected from the company under study for a period of 2 months. Through this, random data were implemented and validated in Input Analyzer to determine the behavior of each one of them.

Finally, with the results obtained from the simulation, a compar- ison table will be made with the initial information, and improve- ments of preventive and corrective actions related to the TPM tool will be proposed 15, 20. The results are controlled by the table of indicators which is presented in Table 2.

Each of these indicators is essential to measure the improvement that is being implemented with the BPM-TPM tools. The main indicator being measured is the KPI of orders delivered out of time since the company's main objective is to reduce this indicator to provide a better service to customers.

4 VALIDATION

4.1 Initial Diagnosis

The results of the case study show a technical gap related to the rate of late orders. Currently, the SME has a monthly level of 5% of orders delivered after the due date, which leads to operating costs of around S/ 88,800.73 and penalties of S/ 7016.66 for such late delivery. The main causes of this conflict are: (a) Poor communication between the logistics area and carriers, (b) Incorrect data storage, (c) Truck failure. In table 3 are the results obtained along with the evaluation indicators.

4.2 Validation Design and Comparison with the Initial Diagnosis

The procedure followed to validate the model was to perform a simulation in the Arena program: first, specific information was requested from the logistics and maintenance area of the company for the months of July and August, these values were analyzed through Lean tools such as VSM to help determine variables such as number of orders out of time, number of unsatisfied customers, MTBF, MTTR, and Ai (availability). After that, the data will be entered into the simulation to verify that the applied tools provide the company with an improvement in its logistics and maintenance processes. The next phase to be introduced in the simulation is the BPM phase, in which the entire process that is followed from the time an order is issued until the customer receives the service will be introduced, and activities that do not generate value to the process will be eliminated. Finally, with regard to the TPM phase, the current maintenance system will be modified by adding the drivers of each unit to perform autonomous maintenance and the specialist mechanics will do preventive maintenance.

The optimal number to run the system was 30 replications be- cause this is the minimum needed to complete the central limit theorem or normality. In this simulation it was not necessary to use the output analyzer, since the half width has a high accuracy of 0.75 minutes, which indicates that the model is acceptable, and the data obtained are valid. As a result, the rate of orders delivered late is expected to be reduced by 4.06%.

Table 3: Simulation Current vs Improved Situation

	Out-of-time order rate	Availability
Initial situation	4.78%	73.15%
Improvement situation	0.72%	81.25%

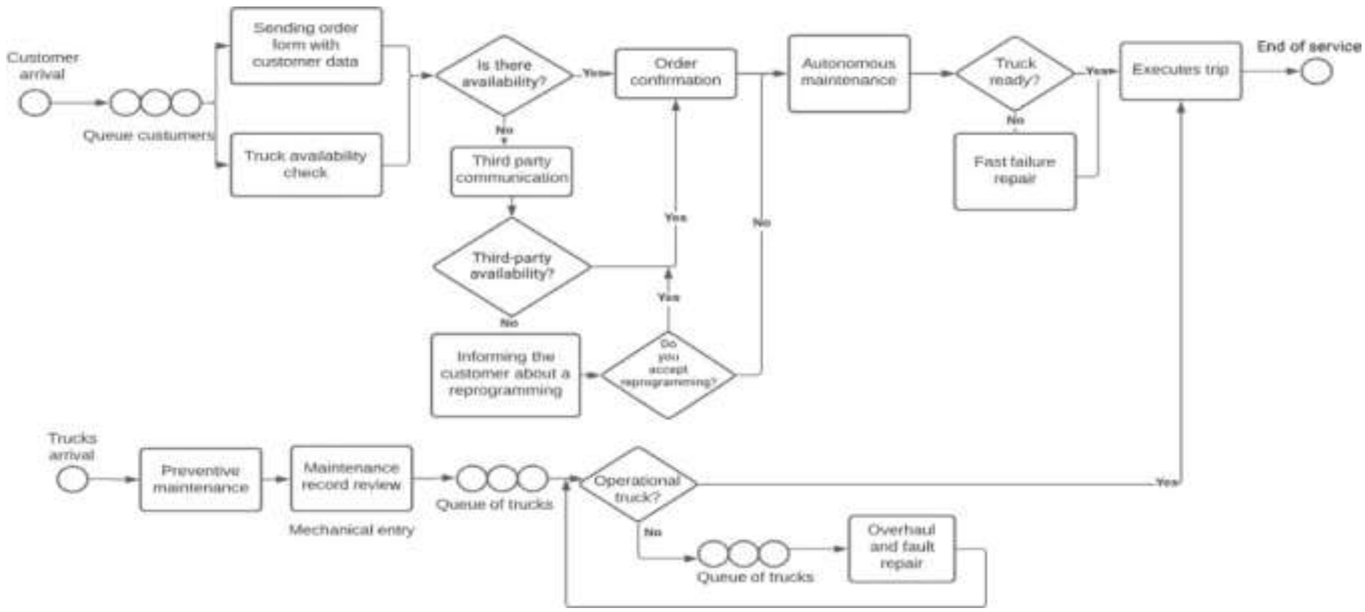

Figure 2: General View of the Process Model Proposed

4.3 Improvement-Proposal Simulation

An integrated simulation was developed using the Arena software to model the current situation and the improvement of the com- pany proposal. The main activity evaluated in the logistics area was the customer service time to confirm the order, while in the maintenance area the availability of trucks for the execution of the service was measured. For the simulation of the current situation, the data taken into account for the modeling were provided pri- vately by the company, information on the operations of the last 2 months. On the other hand, in the case of the modeling of the proposed model, the data to be considered will be aleatory. For this purpose, the Input Analyzer was used to validate the data entered in the program; the number of random variables considered was 19. Finally, the number of replications that the software must perform for the values presented to be significant was 30 because the central limit must be fulfilled and the half-width of the principal indica- tor is small, which means that the precision is high. The model of simulation proposed is in figure 2.

After running the program, the improvement results were ob- tained according to the indicators initially proposed. This was achieved thanks to the restructuring of the process carried out through the BPM tool, which meant a decrease of 4.06% of orders served out of time. Furthermore, an improvement was achieved in the maintenance area after implementing the TPM tool, which led to an increase of 8.1% in the availability of units in the company.

Once the percentage of off-time orders improved through the simulation, implementing the two improvement tools in parallel, the average amount that the company would save with the improve- ments was calculated. As shown in Table 4, the company would be saving S/ 6285.41 per month in operating costs.

Table 4: Operating Costs

Periocity	Actual	Improved	Savings
Monthly	S/7,400.06	S/1,114.65	S/6,285.41
Annual	S/88,800.73	S/13,375.84	S/75,424.89

Table 5: Penalty Costs

Periocity	Actual	Improved	Savings
Monthly	S/584.81	S/88.09	S/496.72
Annual	S/7,017.66	S/1,057.05	S/5,960.61

On the other hand, it has been observed that there has been a decrease in penalty costs because of the out-of-time orders, since the percentage of late orders had a high percentage reduction, as shown in Table 5.

5 DISCUSSION

The model implemented focused on 2 areas: logistics and main- tenance, which combined reach the main purpose on decreasing the number of late orders currently placed by the company. It is worth mentioning that the use of TPM can be used in the techno- logical equipment of the company, this autonomous maintenance can be performed by the same logistics personnel, these activities are cleaning activities performed before starting their activities. For the results obtained from the application on the model, shown in Table 6 below.

In where:

- O1: Out of time order rate

Table 6: A comparison between scenarios depending on the suggested targets.

	Objetives				
Situation	O1	O2	O3	O4	O5
E0	4.78%	13.30%	7.03 Hours per failure	7.35 Hours per failure	73.15%
E1	0.72%	10%	37.28 Hours per failure	6.764 Hours per failure	81.25%
Variation	4.06%	3.300%	30.25 Hours per failure	0.50 Hours	10%

Table 7: Applied Studies

Authors	**Reference**	**Results**	**Year**
Xiang & Feng,	[5]	The availability improved in 88.5% to 96.2%.	2021
Pinto, F. J. G. Silva, A. Baptista, Nuno O. Fernandes, R. Casais, C. Carvalho	[15]	The availability improved in 5%. There was a decrease in break due to failure by 23% and 38% for CNC lathes and TNC machine center.	2020
L. Alvarado, J. Santos, J. Quiroz, and J. Alvarez	[11]	The initial time yield was 67.23% and after applying the BPM the result was 92.35%.	2019

- O2: Percentage of non-conforming clients
- O3: Mean time between failures (MTBF)
- O4: Mean time to repair (MTTR)
- O5: Availability Index (Ai)
- E0: Initial Situation
- E1: Situation after the improvement

Analyzing the results obtained from the simulation of the pro- posed model, it can be seen that the main indicator, index of orders delivered out of time, decreased from 4.78% to 0.72%, which means for the company a great reduction in penalty costs, in addition to providing greater capacity to receive orders due to the increase in truck availability from 73.15% to 81.25%. The increase in forklift availability was due to the decrease in the occurrence of breakdowns at the organization, which were the result of the implementation of the autonomous maintenance plan, in charge of the drivers, be- fore the truck goes out to operate. As well as the improvement of preventive maintenance, where every time the truck returns to the plant, mechanics trained in TPM perform a complete check of the entire unit, and in some cases, defective or old parts of the truck are replaced to prevent it from being out of service on subsequent trips. The frequency of MTBF failures increased to every 37.28 hours, and the repair time (MTTR) decreased to 6.8 hours. Implementing the merger of both tools is not simple; it requires a great deal of commitment and perseverance from the company to implement it and maintain it over time, bringing, according to the predicted results, great benefits over time. After having performed an analysis of each article mentioned in Table 1, it can be observed that the results obtained in the simulation have a great resemblance to other similar studies. This can be seen in Table 7.

6 CONCLUSIONS

The implementation of both tools, TPM and BPM, in a heavy freight transportation company proved to be beneficial; since through simulation, it was possible to reduce the number of off-time orders by 0.72%.

In conclusion, it was possible to achieve the objectives of each indicator mentioned in this article, especially the call waiting time, which obtained a reduction of 82.98%, this was achieved thanks to the implementation of BPM by eliminating the activities of customer registration, replacing it by sending a card, which asks the new or frequent customer specifications about your order and in case of the new customer, the personal data of this.

This research was able to prove that the implementation of the TPM tool can be applied in the heavy load transportation sector, this is demonstrated in the improvement simulation where the number of failures presented before the trips was reduced, as well as the present availability of the trucks in the plant.

Finally, with this research that was carried out in a heavy load transportation company, the advantage of implementing both tools: BPM and TPM were demonstrated. It was shown that BPM helps to improve the process in the logistics area while TPM is responsible for increasing truck availability.

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