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Original Article

Productivity of the documentation process in railway maintenance in Lima

Productividad del proceso documental de mantenimiento ferroviario en Lima

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Abstract

Introduction: This study presents the adoption of an ISO 9001:2015 management model to increase the productivity of a document management process through planning, performance measurement and continuous improvement, thus meeting the established goal of the process in compliance with the indicators.
Objective: The main objective of this study is to analyze how the application of continuous improvement influences the productivity of the document management process of railway maintenance, through the use of an ISO 9001:2015 management model.
Methodology: The design of this research is quasi-experimental, since it will be developed in two moments pretest and posttest, longitudinal, quantitative, applied and explanatory because it will be demonstrated that one variable influences the other. A population of 150 workers was considered, with a sample of 63 employees at a confidence level of 95% and the population of documents analyzed was 1869, with a sample of 272 records.
Results: The application of the ISO 9001:2015 management model, through planning, performance measurement and continuous improvement, optimized the productivity of the document processing, achieving a 149.54% improvement.
Conclusions: It is concluded that by adopting the ISO 9001:2015 management model, the productivity of the document processing in railway maintenance was enhanced, increasing from 32.93% in the pre-test to 82.17% in the post-test, achieving a 149.54% improvement.

Keywords: Continuous improvement; productivity; performance evaluation; maintenance effectiveness; efficiency

Resumen

Introducción: Este estudio presenta la adopción de un modelo de gestión ISO 9001:2015 para aumentar la productividad de un proceso de gestión documental a través de la planificación, medición del desempeño y mejora continua, cumpliendo así con la meta establecida del proceso en cumplimiento de los indicadores.
Objetivo: El objetivo principal de este estudio es analizar cómo la aplicación de la mejora continua influye en la productividad del proceso de gestión documental del mantenimiento ferroviario, mediante el uso de un modelo de gestión ISO 9001:2015.
Metodología: El diseño de esta investigación es cuasi-experimental, ya que se desarrollará en dos momentos pretest y postest, longitudinal, cuantitativo, aplicado y explicativo porque se demostrará que una variable influye en la otra. Se consideró una población de 150 trabajadores, con una muestra de 63 empleados con un nivel de confianza del 95% y la población de documentos analizados fue de 1869, con una muestra de 272 registros.
Resultados: La aplicación del modelo de gestión ISO 9001:2015, a través de la planificación, medición del desempeño y mejora continua, optimizó la productividad del procesamiento documental, logrando una mejora del 149,54%.
Conclusiones: Se concluye que al adoptar el modelo de gestión ISO 9001:2015, se mejoró la productividad del procesamiento documental en el mantenimiento ferroviario, pasando de 32.93% en el pre-test a 82.17% en el post-test, logrando una mejora del 149.54%.

Palabras clave: Mejora continua; productividad; evaluación del desempeño; mantenimiento; eficacia; eficiencia.

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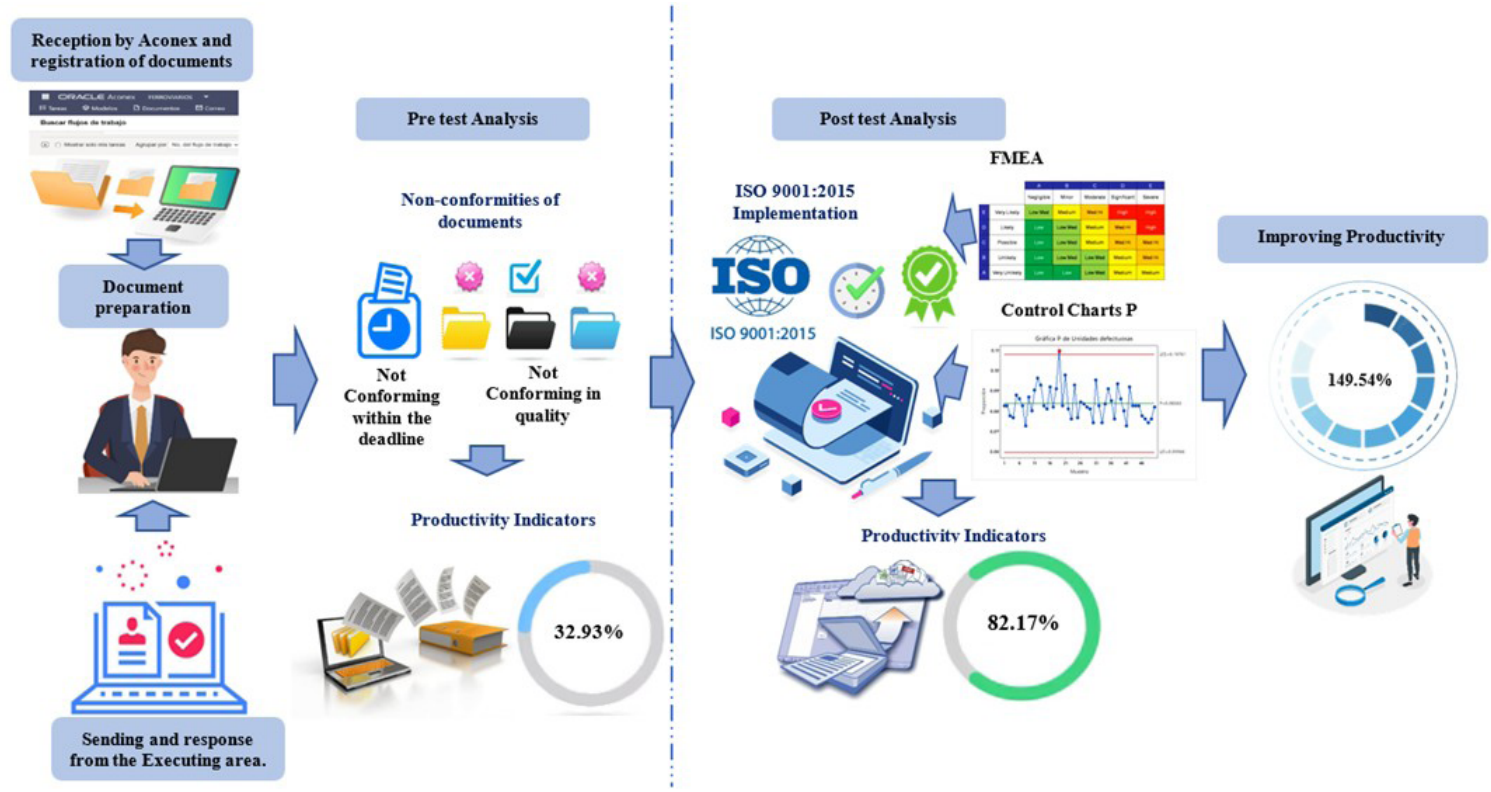
Spanish version

Why was this study conducted?
The study was conducted to analyze the impact of continuous improvement, based on the ISO 9001:2015 management model, on the productivity of the document process in the Railway Maintenance area. It focused on key aspects such as activity planning and performance measurement, from which the need to optimize efficiency and effectiveness in document management was identified. This need arose from the goal of meeting the required quality standards, achieving the goals established in the process indicators, and achieving more efficient use of available resources..

What were the most relevant findings?
The most relevant results showed a significant increase in compliance with ISO 9001:2015 requirements, increasing from 46.17% to 92.48%, demonstrating the successful implementation of the quality management system. A notable improvement was also observed in document compliance, with a reduction in nonconformities from 42.44% to 6.55%, thanks to the use of continuous improvement tools, such as the Five Whys method. Finally, the productivity of the railway maintenance documentation process saw a substantial increase, increasing from 32.93% to 82.17%, representing an improvement of 149.54%.

What do these findings contribute?
These results contribute empirical evidence that the implementation of the ISO 9001:2015 model not only improves the quality and control of the documentation process, but also has a positive impact on the productivity of the railway maintenance operating environment. This contributes to compliance with high quality standards, resource optimization, and process efficiency, which, in turn, strengthens the railway company's overall performance and its ability to offer more reliable and safe services.



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Introduction

Due to the global environment, companies today must adapt and remain competitive in a rapidly changing market. They must continuously improve their processes by using the ISO 9001:2015 Quality Management System (QMS) as an important tool. According to (1), with ISO 9001 not only does the company benefit from the review and progressive improvement of processes through the PDCA approach (Plan, Do, Check, Act), but also its employees and customers. The ISO 9001 standard is an international QMS standard, which ensures that the organization will offer products or services that meet the needs of customers and relevant interested parties. The ISO 9001:2015 version highlighted the importance of the "process-based approach" and "risk-oriented thinking" to strengthen the process (2).

Currently, (3) indicates that a service is considered quality when it satisfies the expectations and technical requirements that the user needs, as well as achieving and maintaining a high degree of excellence and acceptance in society . For its part, (1) points out that the transparency of the process can be improved mainly by documenting procedures, standardization measures, control and monitoring.

It is indicated by (4) that ISO 9001 is used as a foundation to structure a quality management model, being a key practice to guarantee the adequacy and effectiveness of activities, processes, services, and products. According to (5), by adopting the set of requirements, organizations seek to recognize and meet the expectations of their customers, define quality criteria for their products and services, and achieve the objectives established in their management regulations. Similarly, (6) indicates that planning is a fundamental process for carrying out the study of the environment, risk assessment, and control. The implementation of the risk-based approach works best with a deepening of each step, emphasizing the requirements established by the ISO 9001:2015 standard. For both the strategic and operational levels, the model follows the PDCA cycle, emphasizing the need for consistent planning and, the analysis of the process carried out, identifying opportunities for continuous improvement (4).

Furthermore, the detection of non-conformities and corrective measures are essential for carrying out appropriate control and promoting continuous improvement. To do this, it is essential to identify the failures of the QMS to correct them and prevent their recurrence (7). As a result, productivity will increase, understood as the ratio between the production obtained and the inputs used in the process (8,9).

This study proposes to improve productivity, and according to (8), this can be defined as the relationship between the effectiveness and efficiency indices, that is, the results achieved by each resource unit used appropriately. According to (8), efficiency is measured as the relationship between completed work and planned work. In contrast, effectiveness refers to the results obtained that meet the objectives set by the organizations. Along the same lines, (10) mentions that high productivity indicates both effectiveness and profitability, while low productivity indicates the need to improve efficiency or reduce costs to improve profitability.

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Organizations often face errors in the management of their processes, which negatively impact productivity and the quality of the service they offer. According to (11), over the years, various strategies have been developed to overcome these difficulties, and one of them is obtaining a quality management system certification, the objective of which is to help companies implement more efficient processes, thereby improving their operational performance.

According to (12), quality refers to offering the best possible services using a specific number of resources; along the same lines, (13) highlights that quality in the public sector is defined as that feature that allows achieving the objective of equity, which is currently the main goal of the State. For this reason, the QMS is presented as a strategic tool for the public sector, as it contributes to the achievement of the State's goals and corrects deviations in the processes.

In this context, in accordance with the regulation and evolution of quality, the X Conferencia Iberoamericana (10th Ibero-American Conference) of 2008 proposed adjusting the functioning of Public Administrations in the Ibero-American sphere to turn them into effective tools at the service of their societies, with the aim of improving the quality of public services and ensuring that governments are better prepared to face challenges. In this regard, following the recommendations and objectives set forth at the Conference, both the Ministerio de Transporte y Comunicaciones (Ministry of Transport and Communications of Peru, MTC) and the Organismo Supervisor de la Inversión en Infraestructura de Transporte de Uso Público (Supervisory Agency for Investment in Public Use Transport Infrastructure, OSITRAN) adopted the ISO 9001:2015 standard as a key tool to optimize the management of the public services they provide, thereby improving productivity and quality in their processes.

Aligned with these guidelines, the company under research, which is part of the private sector railway network, is responsible for providing preventive and corrective maintenance services to the train fleet and the railway infrastructure of a State-concessioned line, with an approximate length of 34.1 kilometers. During the period from June 2022 to June 2023, several issues arose in the documentary process related to railway maintenance, which affected productivity. These problems included poor planning in document management and handling, lack of optimization in service times, high incidence of errors in documents, and a high percentage of nonconforming documents. As a result, the established goal for the process was not achieved, which was to meet 85% in the process indicators._

Given this situation and considering one of the requirements established by the State to operate the transportation service, the company decided to implement the ISO 9001:2015 Quality Management System starting in July 2023. This system was evaluated before and after its implementation to measure its impact.

In conclusion, the relevance of this research lies in its ability to promote continuous improvement in the railway maintenance documentary process, through the application of the ISO 9001:2015 standard, with the aim of increasing the process' productivity.

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Methodology

The research is applied, with explanatory level, experimental design in its quasi-experimental category, and it was implemented in two phases: pretest and posttest, with the purpose of demonstrating the increase in productivity. The scope is longitudinal; data were collected from May 2022 to May 2024. A quantitative approach was used, employing a comparative analysis of efficiency and effectiveness indicators as a technique to evaluate productivity before and after the implementation of the ISO 9001:2015 QMS, to meet the established process goal of 85%.

The study population included the participation of 150 workers, with a sample of 63, and the document population consisted of 1869 records, with a sample of 272 documents, at a 95% confidence level. For data collection, survey methods were used, applied to the 63 workers through a questionnaire related to the ISO 9001:2015 standard and Productivity; using the Likert rating scale. In addition, a documentary review was carried out, based on the indicators recorded by the documents processed in the Oracle Aconex software between May 2022 and May 2023, which showed the low productivity of the documentary process.

Results

ISO 9001:2015 Quality Management Model

In the ISO 9001:2015 variable (X), three key dimensions extracted from the standard were used: planning, performance evaluation and continuous improvement with the aim of improving the productivity of the documentary process, in which, to carry out the initial and final diagnosis of the process, compliance with each of the standard's requirements was evaluated with the support of those responsible for the process, see results in Table 1.

Table 1. Percentage evaluation of compliance with the requirements of "X"

Requirements	% Pre test compliance	% Post test compliance
4. Context of the organization	75%	95%
5. Leadership	80%	93%
6. Planning	20%	93%
7. Support	52%	80%
8. Operation	42.86%	85.71%
9. Performance evaluation	33.33%	100%
10. Improvement	20%	100%
Compliance % average	**46.17%**	**92.48%**

According to the evaluation presented in Table 1, the pretest result was 46.17%, while, after implementing corrective actions to improve compliance with the standard, the posttest result reached 92.48%, which represents an increase of 46.31%. This increase indicates that the documentary process has met the criteria established by the standard, according to the rating scale described in Table 2, confirming the successful implementation of the Quality Management model.

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Table 2. Rating scale for the implementation of the Quality Management model

Acronyms	Description	Value
N	Unachieved implementation	0% to <= 15% achieved
P	Partially achieved implementation	>15% to <=50% achieved
L	Widely achieved implementation	>50% to <=85% achieved
F	Achieved implementation	>85% to <=100% achieved

Source. Regulations

Planning (X1)

To determine how planning is situated within the documentary process of Railway Maintenance, the process diagram was used, see figure 1.

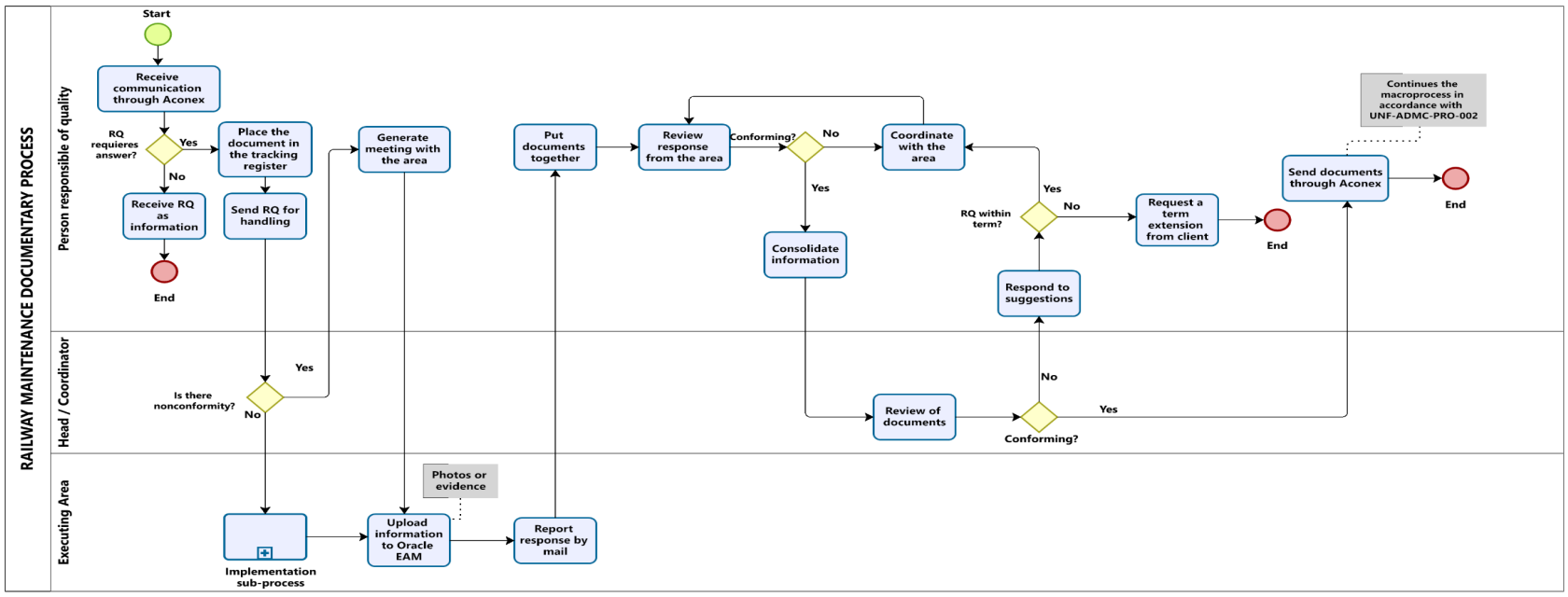

Figure 1. Process diagram in Bizagi Modeler.

In accordance with the steps of the process, existing risks were identified through the failure mode and effects analysis (FMEA) method, with each of these being evaluated according to the criteria of severity, probability of occurrence, and detection capability to establish the risk priority number (RPN). In which, out of the 11 existing causes, 3 causes were identified with high risk and 1 cause with moderate risk, resulting in an RPN of 654 out of a total of 809 for the entire process, representing 80.84%, see table 3. This indicates that most of the risk priority level is concentrated on high and moderate risk causes due to incorrect resources' planning (responsible parties, time, established schedule, and technological tools) for handling documents that enter through the Aconex platform. In the final situation, an acceptable risk level is shown for the first three causes, and the last cause shows a moderate risk level, which represents a total of 55.81%.

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Likewise, to calculate the percentage of RPN reduction and see if the corrective actions implemented have been effective, it was determined using equation 1.

$$\%\ RPN\ Reduction = \frac{Total\ RPN\ Before\ - Total\ RPN\ After}{Total\ RPN\ Before}\ x\ 100 \qquad (1)$$

$$\%\ RPN\ Reduction = \frac{654-129}{654}\ \text{x } 100 = 84.05\%$$

The equation indicates a reduction of the RPN by 84.05%, which means that the corrective actions implemented have been effective in reducing the risk priority level; given that in the initial situation the RPN presented a 654 total and in the current situation it shows an RPN of 129. Therefore, the planning and improvement measures in the documentary process have been effective in reducing the previously identified risks by 84.05%, detecting and preventing future risks in the process.

Table 3. Failure mode and effects analysis (FMEA) method

Process steps	Cause of the failure	Initial situation					Recommended actions	Responsible party	Situation afterwards				
		Control	SEV	OCC	DET	RPN			Actions taken	SEV	OCC	DET	RPN
Receive communication through the Aconex Platform.	Lack of proper mapping of incoming documents.	NO	10	6	5	300	Establish partial stops to receive incoming documents through the Aconex platform, in this way preventing a document from being sent late to the user area.	Quality Assistant and/or Coordinator	Document review by Aconex at eight thirty in the morning, twelve noon, and six in the evening.	6	1	5	30
Place document in the tracking register.	Lack of proper document registration.	YES	10	6	2	120	Implement the automation of data entry to save time, reduce errors, and improve system efficiency.	Quality Assistant and/or Coordinator	The tracking format was improved, and hyperlinks were created in the format's subject to direct to the Aconex platform.	3	1	5	15
Send Requirement (RQ) to the area responsible for the request.	Lack of clarity in the communication of the request.	NO	3	6	3	54	Train the staff to improve writing skills and convey a clear message.	Quality Coordinator	Training was conducted for the staff to improve writing and spelling.	3	1	4	12
Review technical document and/ or letter.	Lack of review criteria.	YES	6	6	5	180	Train staff to gather information from the document according to the criticality of each request.	Head of Quality	The staff were trained to conduct a questioning analysis whenever there is a risk in deviation or finding, and monitoring began each time the document was reviewed.	3	6	4	72
TOTAL						**654**							**129**

Note. SEV= Severity ; OCC= Occurrence ; DET= Detectability.

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Performance evaluation (X2)

For the performance evaluation of the Railway Maintenance documentary process, the indicators of the compliance level for handling documents from June 2022 to May 2023 were analyzed in the pretest, see table 4.

Table 4. Document management compliance percentage – Pretest

Month	Number of documents					Final conformity rating	Final non-conformity rating
	Non-conforming - Quality and term	Non-conforming - Term	Non-conforming - Quality	Conforming – Quality and term	TOTAL		
Jun 2022	4	23	3	18	48	38%	62%
Jul 2022	15	17	0	15	47	32%	68%
Aug 2022	30	21	0	24	75	32%	68%
Sep 2022	4	8	8	24	44	55%	45%
Oct 2022	2	4	5	30	41	73%	27%
Nov 2022	8	3	10	34	55	62%	38%
Dec 2022	3	0	3	22	28	79%	21%
Jan 2023	0	11	3	20	34	59%	41%
Feb 2023	1	9	3	27	40	68%	32%
Mar 2023	2	8	3	35	48	73%	27%
Apr 2023	1	1	1	18	21	86%	14%
May 2023	1	3	7	25	36	69%	31%

According to the analysis conducted, it was identified that there is an average of 40% nonconforming documents and 60% conforming documents during the mentioned period, which means that the established conformity goal of 85% for the process is not being met.

Likewise, to improve the performance evaluation within the documentary process of Railway Maintenance, the process has been monitored using the FMEA method to prevent high risks from arising through actions adopted as indicated in table 3. For this, the indicators of the compliance level in handling the documents from June 2023 to May 2024 were analyzed, see table 5.

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Table 5. Percentage of compliance in document management – Posttest.

Month	Number of documents					Final conformity rating	Final non-conformity rating
	Non-conforming - Quality and term	Non-conforming - Term	Non-conforming - Quality	Conforming – Quality and term	TOTAL		
Jun 2023	3	2	1	43	49	88%	12%
Jul 2023	1	0	0	39	40	97%	3%
Aug 2023	1	1	2	36	40	90%	10%
Sep 2023	2	1	2	42	47	89%	11%
Oct 2023	1	1	1	45	48	94%	6%
Nov 2023	0	0	0	37	37	100%	0%
Dec 2023	3	1	1	50	55	91%	9%
Jan 2024	2	1	0	40	43	93%	7%
Feb 2024	1	0	1	39	41	95%	5%
Mar 2024	2	0	1	36	39	92%	8%
Apr 2024	0	0	1	41	42	98%	2%
May 2024	0	0	0	35	35	100%	0%
$\bar{X}$						**94%**	**6%**

According to the analysis conducted, it was identified that there is an average of 94% conforming documents and 6% nonconforming documents from June 2023 to May 2024, indicating that the established process goal of 85% has been exceeded during the mentioned period.

Continuous improvement (X3)

To identify if there is unusual variability in the process and determine whether it is within or outside the allowed control limits, a Statistical Process Control (SPC) analysis was conducted using p-charts to analyze the handling of documents: memos, minutes, and letters within the period from June 2022 to May 2023; given that on average there was a 40% rate of nonconforming documents during that period. This was done to identify the existence of out-of-control points and to address the causes of these points that lead to the presence of nonconformities in document handling, and based on this, implement corrective actions aimed at the continuous improvement of the document handling process. From the results obtained in table 6 for each type of document, an average nonconformity proportion of 42.44% was obtained, which indicates that, in the documents reviewed, a significant percentage does not meet the established target of 85% conforming documents.

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Table 6. Nonconformity proportion in document handling – Pretest

Month	Memos				Minutes			
	Conforming doc	Doc processed	Nonconforming doc	Nonconformity proportion	Conforming doc	Doc processed	Nonconforming doc	Nonconformity proportion
Jun 2022	5	23	18	0.783	4	10	6	0.600
Jul 2022	4	25	21	0.840	3	9	6	0.667
Aug 2022	12	40	28	0.700	2	11	9	0.818
Sep 2022	8	22	14	0.636	5	8	3	0.375
Oct 2022	12	21	9	0.429	6	6	0	0.000
Nov 2022	14	23	9	0.391	5	12	7	0.583
Dec 2022	8	10	2	0.200	5	7	2	0.286
Jan 2023	7	16	9	0.563	5	8	3	0.375
Feb 2023	11	20	9	0.450	5	7	2	0.286
Mar 2023	18	26	8	0.308	4	6	2	0.333
Apr 2023	7	8	1	0.125	4	5	1	0.200
May 2023	11	16	5	0.313	4	9	5	0.556
TOTAL	**117**	**250**	**133**	**0.532**	**52**	**98**	**46**	**0.469**

Letters			
Conforming doc	**Documents processed**	**Nonconforming documents**	**Nonconformity proportion**
9	15	6	0.400
8	13	5	0.385
10	24	14	0.583
11	14	3	0.214
12	14	2	0.143
15	20	5	0.250
9	11	2	0.182
8	10	2	0.200
11	13	2	0.154
13	16	3	0.188
7	8	1	0.125
10	11	1	0.091
123	**169**	**46**	**0.243**

Therefore, according to the final situation, there is a conformity proportion of 57.56%, with an existing gap of 27.44% compared to the set goal of 85% to achieve the objective. Likewise, to identify the root causes of the out-of-control points obtained mainly in the handling of memos and letters when making the p-charts during the period from June 2022 to May 2023, the five whys method was used to identify the main cause of the problem and thus apply corrective actions that contribute to improving the process. For this, nonconforming memos and letters in relation to quality and term, as well as those nonconforming in relation to term from the period of July 2022 for memos and August 2022 for letters, were considered, months where points outside the control limit were obtained.

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Then, after identifying the root causes of the problem in the out-of-control points of mainly the memos and letters, monitoring was resumed to check for any unusual variability in the Railway Maintenance documentary process between June 2023 and May 2024 and to determine whether the process is within or outside the established control limits during that period. For this purpose, an SPC analysis was conducted using p-charts to analyze the handling of documents: memos, minutes, and letters within the aforementioned period, thereby achieving continuous improvement in the document handling process, see table 7.

Table 7. Nonconformity proportion in document handling – Posttest.

Month	Memos				Minutes			
	Conforming documents	**Documents processed**	**Non-conforming documents**	**Non-conformity proportion**	**Conforming documents**	**Documents processed**	**Non-conforming documents**	**Non-conformity proportion**
Jun 2023	25	28	3	0.107	7	8	1	0.125
Jul 2023	22	23	1	0.043	9	9	0	0.000
Aug 2023	19	20	1	0.050	8	10	2	0.200
Sep 2023	20	22	2	0.091	8	9	1	0.111
Oct 2023	26	28	2	0.071	9	9	0	0.000
Nov 2023	19	19	0	0.000	8	8	0	0.000
Dec 2023	26	28	2	0.071	9	10	1	0.100
Jan 2024	20	20	0	0.000	7	7	0	0.000
Feb 2024	18	18	0	0.000	8	9	1	0.111
Mar 2024	12	15	3	0.200	8	8	0	0.000
Apr 2024	18	18	0	0.000	9	10	1	0.100
May 2024	16	16	0	0.000	8	8	0	0.000
TOTAL	**241**	**255**	**14**	**0.055**	**98**	**105**	**7**	**0.067**

Letters			
Conforming documents	**Documents processed**	**Non-conforming documents**	**Nonconformity proportion**
11	13	2	0.154
12	12	0	0.000
9	10	1	0.100
14	16	2	0.125
10	11	1	0.091
10	10	0	0.000
15	17	2	0.118
13	16	3	0.188
13	14	1	0.071
16	16	0	0.000
14	14	0	0.000
11	11	0	0.000
148	**160**	**12**	**0.0750**

Therefore, according to the final scenario, there is a conformity proportion of 93.45% and a nonconformity proportion of 6.55%. In this case, the established goal of 85% conformity was exceeded, which indicates good performance of the process.

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Productivity (Y)

Productivity - Pretest

To measure productivity, effectiveness and efficiency were used. Efficiency was measured using the number of theoretical and actual documents from the period June 2022 to May 2023 for the pretest, as shown in Table 8. From which it was concluded that there was inadequate resource management and poor technique in handling the documents, which negatively impacts the quality and term of their processing.

Table 8. Efficiency by document type - Pretest

Month	Memos			Minutes			Letters		
	Theoretical	Actual	Efficiency	Theoretical	Actual	Efficiency	Theoretical	Actual	Efficiency
Jun 2022	29	23	79.31%	12	10	83.33%	18	15	83.33%
Jul 2022	31	25	80.65%	11	9	81.82%	17	13	76.47%
Aug 2022	47	40	85.11%	13	11	84.62%	28	24	85.71%
Sep 2022	29	22	75.86%	10	8	80.00%	18	14	77.78%
Oct 2022	28	21	75.00%	8	6	75.00%	19	14	73.68%
Nov 2022	29	23	79.31%	13	12	92.31%	24	20	83.33%
Dec 2022	15	10	66.67%	9	7	77.78%	15	11	73.33%
Jan 2023	25	16	64.00%	10	8	80.00%	15	10	66.67%
Feb 2023	26	20	76.92%	9	7	77.78%	18	13	72.22%
Mar 2023	33	26	78.79%	10	6	60.00%	20	16	80.00%
Apr 2023	15	8	53.33%	9	5	55.56%	16	8	50.00%
May 2023	24	16	66.67%	12	9	75.00%	20	11	55.00%
TOTAL	**331**	**250**	**75.53%**	**126**	**98**	**77.78%**	**228**	**169**	**74.12%**

Likewise, the effectiveness in the pretest was determined, considering the number of conforming documents and planned documents in that period, considering each type of document: memos, minutes, and letters, see table 9.

Table 9. Effectiveness by document type - Pretest

Month	Memos			Minutes			Letters		
	Conforming documents	Planned documents	Effective-ness	Conforming documents	Planned documents	Effective-ness	Conforming documents	Planned documents	Effective-ness
Jun 2022	5	29	17%	4	12	33%	9	18	50%
Jul 2022	4	31	13%	3	11	27%	8	17	47%
Aug 2022	12	47	26%	2	13	15%	10	28	36%
Sep 2022	8	29	28%	5	10	50%	11	18	61%
Oct 2022	12	28	43%	6	8	75%	12	19	63%
Nov 2022	14	29	48%	5	13	38%	15	24	63%
Dec 2022	8	15	53%	5	9	56%	9	15	60%
Jan 2023	7	25	28%	5	10	50%	8	15	53%
Feb 2023	11	26	42%	5	9	56%	11	18	61%
Mar 2023	18	33	55%	4	10	40%	13	20	65%
Apr 2023	7	15	47%	4	9	44%	7	16	44%
May 2023	11	24	46%	4	12	33%	10	20	50%
TOTAL	**117**	**331**	**35.35%**	**52**	**126**	**41.27%**	**123**	**228**	**53.95%**

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Considering the efficiency and effectiveness results of the three types of documents in the pretest, productivity was calculated using equation 2, obtaining an average of 32.93%, see table 10. This result indicates the existence of significant inefficiencies in the term and quality handling of documents, resulting in low performance indicators within the document management process of railway maintenance.

$$Productivity = Effectiveness\ x\ Efficiency \quad (2)$$

Table 10. Documentary process productivity - Pretest

Indicators	Document type			Average
	Memos	Minutes	Letters	
Efficiency (%)	75.53%	77.78%	74.12%	**75.81%**
Effectiveness (%)	35.35%	41.27%	53.95%	**43.52%**
Productivity (%)	26.70%	32.10%	39.99%	**32.93%**

Productivity - Posttest

In the posttest case, the number of theoretical and actual documents from the period June 2023 to May 2024 was used to determine efficiency. Of which, an improvement is shown for each type of document, see table 11.

Table 11. Efficiency by document type - Posttest

Month	Memos			Minutes			Letters		
	Theoretical	Actual	Efficiency	Theoretical	Actual	Efficiency	Theoretical	Actual	Efficiency
Jun 2023	30	28	93.33%	9	8	88.89%	14	13	92.86%
Jul 2023	22	20	90.91%	9	8	88.89%	13	12	92.31%
Aug 2023	23	20	86.96%	10	10	100%	11	10	90.91%
Sep 2023	24	22	91.67%	10	9	90.00%	17	16	94.12%
Oct 2023	32	28	87.50%	10	9	90.00%	11	11	100%
Nov 2023	19	19	100%	9	8	88.89%	11	10	90.91%
Dec 2023	32	28	87.50%	10	10	100%	18	17	94.44%
Jan 2024	22	20	90.91%	8	7	87.50%	16	16	100%
Feb 2024	20	18	90.00%	9	9	100%	15	14	93.33%
Mar 2024	15	15	100%	9	8	88.89%	17	16	94.12%
Apr 2024	19	18	94.74%	10	10	100%	15	14	93.33%
May 2024	16	16	100%	8	8	100%	11	11	100%
TOTAL	**274**	**252**	**91.97%**	**111**	**104**	**93.69%**	**169**	**160**	**94.67%**

Then, in terms of effectiveness, the number of conforming documents and planned documents for the period from June 2023 to May 2024 were used, considering improvement for each type of document: memos, minutes, and letters, see table 12.

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Table 12. Effectiveness by document type - Posttest

Month	Memos			Minutes			Letters		
	Conforming documents	Planned documents	Effective-ness	Conforming documents	Planned documents	Effective-ness	Conforming documents	Planned documents	Effective-ness
Jun 2023	25	30	83.33%	7	9	77.78%	11	14	78.57%
Jul 2023	22	22	100%	9	9	100%	12	13	92.31%
Aug 2023	19	23	82.61%	8	10	80%	9	11	81.82%
Sep 2023	20	24	83.33%	8	10	80%	14	17	82.35%
Oct 2023	26	32	81.25%	9	10	90%	10	11	90.91%
Nov 2023	19	19	100%	8	9	88.89%	10	11	90.91%
Dec 2023	26	32	81.25%	9	10	90%	15	18	83.33%
Jan 2024	20	22	90.91%	7	8	87.50%	13	16	81.25%
Feb 2024	18	20	90%	8	9	88.89%	13	15	86.67%
Mar 2024	12	15	80%	8	9	88.89%	16	17	94.12%
Apr 2024	18	19	94.74%	9	10	90%	14	15	93.33%
May 2024	16	16	100%	8	8	100%	11	11	100%
TOTAL	**241**	**274**	**87.96%**	**98**	**111**	**88.29%**	**148**	**169**	**87.57%**

Considering the efficiency and effectiveness results of the three types of documents in the posttest, productivity was calculated using equation 2, obtaining an average of 82.17%, which demonstrates efficient and effective performance in handling documents within the required term and quality. This indicates that the Railway Maintenance documentary process is being managed optimally, with minimal waste of resources and a remarkable ability to approach the established goal of 85%. Table 13.

Table 13. Documentary process productivity - Posttest

Indicators	Document type			Average
	Memos	Minutes	Letters	
Efficiency (%)	91.97%	93.69%	94.67%	93.45%
Effectiveness (%)	87.96%	88.29%	87.57%	87.94%
Productivity (%)	80.89%	82.72%	82.91%	**82.17%**

Likewise, a comparison was made between the average productivity before and after the test, see figure 2.

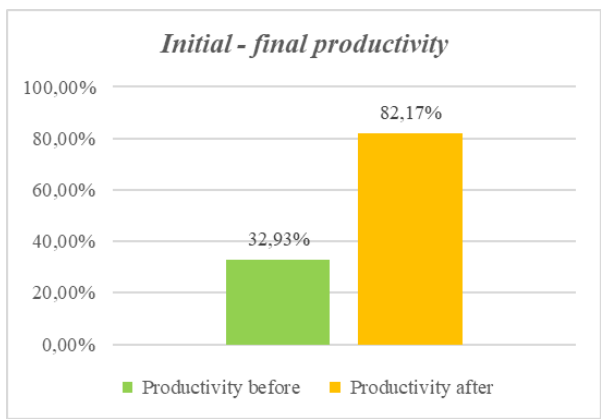

Figure 2. Comparative analysis of productivity in document management

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When comparing the overall average productivity, in the pretest the average estimate was obtained at 32.93%, which, once the application of planning, performance measurement, and continuous improvement was executed, the posttest productivity was obtained at 82.17%, resulting in an improvement percentage of 149.54%, as shown in equation 3.

$$\%\,Improvement = \frac{Final\ productivity\ - Initial\ productivity}{Initial\ productivity} \quad (3)$$

$$\%\,Improvement = \frac{82.17\% - 32.93\%}{32.93\%} = 149.54\%$$

Discussion

The results of the study reveal a 149.54% improvement in productivity, comparing the pretest and posttest results of the documentary process in railway maintenance. This improvement is attributed to the efficiency and effectiveness achieved in increasing productivity after implementing the ISO 9001:2015 QMS, optimizing the management of documents entered through the Aconex platform. In particular, a significant improvement was observed in the FMEA, which is consistent with previous research in various business sectors.

For example, studies, such as that of (14), analyzed the impact of the supply chain network on business performance under the ISO 9001 standard, concluding that it improves productivity and provides a standard for optimizing processes, ensuring that products reach the market efficiently and in a timely manner. In contrast, the current study specifically focuses on improving the handling of documents in relation to quality and terms, thus ensuring a quality and safe service for all users of the railway line.

Similarly, research on (15) examined the effects of the ISO 9001:2015 standard on accounting management, highlighting benefits such as improved staff training, more efficient documentation, more effective control of risks and opportunities, and the promotion of a culture of continuous improvement. In contrast, with the railway maintenance documentary process, adequate management of the documents was achieved, aligned with quality standards in the handling and control of their monitoring. This contributed to reducing risks in the process, promoting an environment of continuous improvement throughout the operation and generating significant benefits, such as the reduction of penalties for contractual breaches with the State, since the supervision led by OSITRAN seeks to ensure that a quality and safe service is offered to all users.

On the other hand, these results are consistent with the study of (16), which showed that the QMS implementation contributed to an increase in the profitability levels of clinical laboratories in the periods before and after its adoption, positively impacting their financial indicators. This finding contrasts with the study in question, which managed to improve the documentary

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process, surpassing the objective indicator of 85% as the established goal, which in turn resulted in a significant improvement in productivity. Similarly, they align with the findings of (17), who determined that the QMS implementation based on the ISO 9001:2015 standard improved the productivity of San Gabriel, going from 64.97% to 79.83%, and reducing the number of defective water cans by 28 daily units. Thus, it achieved an increase of 14.86%. and a 23% improvement in productivity through optimization of product quality and supply chain management, while the documentary process benefited from a more structural transformation in document management and quality, which allowed for improved document service indicators and exceeded the established process goal. Although both cases show improvements in productivity, the percentage increase in the documentary process is considerably greater than in the case of the water cans. This is due to the starting point of each process; since the documentary process began with a lower productivity level (32.93%) compared to the production of water cans (64.97%). Therefore, the documentary process achieved a greater margin of improvement, which allowed for a higher percentage increase. However, this difference does not imply that the process of the water cans was less successful; it simply reflects that each context started from a different level of initial inefficiency.

These results reinforce the relevance of the ISO 9001:2015 Quality Management model as a key factor for increasing productivity in processes. In this regard, this study applies the ISO 9001:2015 QMS in documentary management within the railway sector, providing an innovative approach to document handling.

Conclusions

The research study aimed to determine the influence of the ISO 9001:2015 Quality Management model to increase the productivity of the documentary process of Railway Maintenance. To this end, compliance with the standard's requirements was measured in the pretest, obtaining 46.17%, and in the posttest, reaching 92.48%. This increase reflects the system's effectiveness in optimizing processes and improving compliance with established standards. As part of the planning, the FMEA method was used, obtaining a result of 80.74% in the pretest, and after the measures were adopted, a 55.81% was obtained in the posttest. Regarding the performance evaluation, the initial diagnosis showed 60.50% of conforming documents, while in the final evaluation this percentage increased to 94%, thus exceeding the established process goal of 85%, which underscores the improvement in the quality of the processed documentation. Furthermore, regarding continuous improvement, a nonconformity proportion of 42.44% was obtained in the pretest, and 6.55% in the posttest through corrective measures taken by identifying values that are outside the control limits in the p-chart._These results reflect a remarkable increase in productivity, which went from 32.93% in the pretest to 82.17% in the posttest, representing an improvement of 149.54%. This demonstrates that the implementation of the ISO 9001:2015 model has been fundamental in significantly optimizing the productivity of the process. Likewise, on a qualitative level, the results obtained through a questionnaire based on the Likert scale confirm that the implementation of the ISO 9001:2015 QMS has a significant influence on the productivity of the documentary process. This demonstrates that this model not only improves productivity but also ensures the operability and safety of the service provided by the railway company.

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In this context, the QMS implementation based on the ISO 9001:2015 standard represents an effective strategy to improve productivity in other maintenance and operations processes within the railway sector. Its application can also be extended to other lines of research related to production processes, storage techniques, sustainable organizational management, among others, demonstrating its positive impact on other industries.

CRediT authorship contribution statement

Conceptualization – Ideas, Data Curation, Formal Analysis, Funding Acquisition, Research, Methodology, Project Management, Resources, Software, Supervision, Validation, Visualization – Preparation, Writing – original draft – Preparation, Writing – review and editing – Preparation: Marycruz Lyly, Huanca Trejo y Edgar Cruz, Ruiz Lizama.

Financing: does not declare. Conflict of interest: does not declare. Ethical aspect: does not declare.

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