Risks of Contractual Fines for Failures in the Industrial Production Process and the Relation with the Importance of the Qualification of the Work in the Maintenance

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Abstract. Industrial failures are associated with poor maintenance planning, directly affecting organizational productivity. When equipment failures occur, established contracts allow fines to be imposed on organizations, sometimes due to delivery delays or product failures due to poor quality. The aim of this paper was to perform a literature review on the elements that cause risks of contractual fines due to equipment unavailability. To perform this work, a literature review was made based on published scientific articles on topics of predictive maintenance, preventive maintenance and corrective maintenance, production planning and control (PPC), financial risks for contractual fines and availability of machinery in industrial processes, as well as maintenance workforce qualification. Maintenance and operation, as the most important administrative and operational functions of production, are responsible for meeting the following requirements: quality, speed, reliability, flexibility and cost. As a result, it was found in the literature that a well-trained and motivated maintenance team performs higher quality short-term tasks, reducing machine repair times, and reducing the number of fines for failure to meet contractual deadlines. These results were corroborated by verification in four supply chain companies in the agricultural and construction machinery sector.

Keywords: Maintenance planning · Contractual risks · Maintenance workforce

1 Introduction

Industrial failures are associated with poor maintenance planning, directly affecting organizational productivity. When production equipment failures occur, the established contracts allow fines to be imposed on organizations due to possible delivery delays or product failures due to poor quality, leading to possible downtime due to poor maintenance planning. This can negatively affect customer demand, requiring operations

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managers to make emergency decisions to reinstate downtime for corrective maintenance.

The aim of this paper was to review the literature on the elements that cause contractual fines risks due to equipment unavailability, as well as a brief description of four cases of companies that supply parts and material parts.

The justification for this work was the difficulty of finding enough literature to address why many companies fail to meet contractual deadlines and its correlation with the qualification of the labor used in the maintenance of machinery and equipment of the production process, resulting in fines contractual.

As a hypothesis, verify if, in the literature, the availability of equipment can guarantee the fulfillment of the required demands, through a synergy of the workforce qualification between production planning and control (PPC) and maintenance planning and control (MPC).

2 Research Design

This article was structured based on a literature review based on published scientific articles on predictive, preventive and corrective maintenance, production planning and control, quality, financial risks by contractual fines and machine availability in industrial processes, as well as the qualification of maintenance workforce. These elements are represented in Fig. 1.

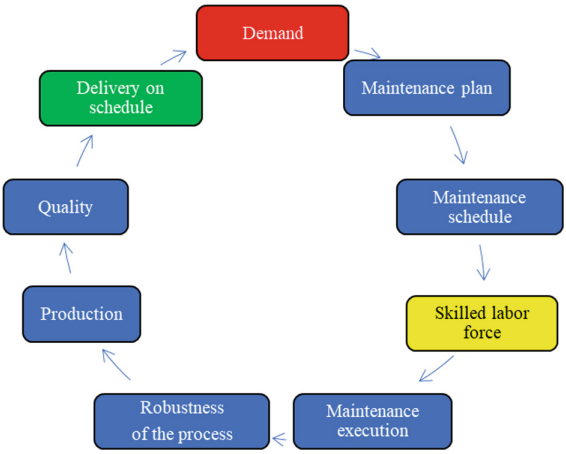

Fig. 1. Research structuring and its central elements.

The first step was to establish a theoretical basis with material that addressed the concepts needed to support the research. For this, the searches were made with keywords divided into groups:

- Group 1: maintenance planning and contractual risks;
- Group 2: contractual risks and maintenance workforce.

The keywords were searched in the Scopus database. The justification for the use of this database is the fact that it makes available the largest range of qualified scientific articles with access made available to researchers. The research was limited to scientific and review articles published since 2001. In all 520 articles were found. The second step consisted of deleting repeated articles and restarting the selection process. The first selection was made by reading the titles of the articles. The second selection occurred from reading the abstracts, selecting only those that fit the research theme. The third selection occurred from the complete reading of the full text of the articles.

Most of the articles found were not aligned with the research theme, as they did not address maintenance planning, contractual risks and maintenance workforce. Some articles dealt with maintenance planning only, but not contractual risks or maintenance labor.

In addition to the literature review on maintenance planning, contractual risks and maintenance work, we also searched for articles on predictive maintenance, preventive maintenance and corrective maintenance, PPC, quality and availability of machines in industrial processes. Finally, there were 14 articles that stood out in the research and followed the desired search terms. Thus, Sect. 3 will present the results obtained, as well as a brief case report of supplier companies and their characteristics regarding the theme presented in this paper.

3 Results and Discussions

3.1 Literature Review Results

From reading the articles, Table 1 was prepared, presenting a chronology of the evolution of the discussion of the subject by the most cited authors, highlighting the title and journal where they were found on the topics researched in Sect. 2.

Table 1. Most cited authors in the survey conducted at the Scopus.

Author	Title	Journal	No. of citations
Hui *et al.* [1]	Optimal machining conditions with costs of quality and tool maintenance for turning	Int. J. Prod. Res.	30
Ahmad and Schroeder [2]	The impact of human resource management practices on operational performance: recognizing country and industry differences	J. Oper. Manag.	972
Khan and Haddara [3]	Risk-based maintenance (RBM)	Process Saf. Prog.	90
Alsyouf [4]	The role of maintenance in improving companies' productivity and profitability	Int. J. Prod. Econ.	321
Al-Najjar [5]	The lack of maintenance and not maintenance which costs: a model to describe and quantify the impact of vibration-based maintenance on company's business	Int. J. Prod. Econ.	136

(*continued*)

Table 1. (*continued*)

Kans [6]	An approach for determining the requirements of computerised maintenance management systems	Comput. Ind.	85
Lee and Scott [7]	Overview of maintenance strategy, acceptable maintenance standard and resources from a building maintenance operation perspective	J. Build. Apprais.	73
Ma *et al.* [8]	A survey of scheduling with deterministic machine availability constraints	Comput. Ind. Eng.	329
Simões *et al.* [9]	A literature review of maintenance performance measurement: a conceptual framework and directions for future research	JQME	160
Peng *et al.* [10]	Competitive priorities, plant improvement and innovation capabilities, and operational performance. A test of two forms of fit	Int. J. Oper. Prod. Man.	85
Jabbour *et al.* [11]	Environmental management in Brazil: is it a completely competitive priority?	J. Clean. Prod.	107
Choudhari *et al.* [12]	Configuration of manufacturing strategy decision areas in line production system: five case studies	Int. J. Adv. Manuf. Tech.	21
Fitouhi and Nourelfath [13]	Integrating noncyclical preventive maintenance scheduling and production planning for multi-state systems	Reliab. Eng. Syst. Safe.	97
Lu *et al.* [14]	Integrated production and preventive maintenance scheduling for a single machine with failure uncertainty	Comput. Ind. Eng.	42

Maintenance planning decisions need to be linked to production and quality plans [6]. Strategically designed maintenance planning can improve machine availability and reliability by reducing the failure rate and potential threats to meet demand. As soon as equipment defects are detected, the repair will be minimal and at the lowest cost to get it back to normal operation [1].

If, on the one hand, managers are concerned with meeting required demand and managing costs to avoid potential contractual fines, it is necessary to identify how this can be avoided and monitored in order to achieve planned results. In this context, the integration of maintenance performance information systems with the organization's overall performance management information system can facilitate the necessary alignment [9, 15].

Competitive priorities such as cost, quality, delivery performance, flexibility and reliability are the basis for developing distinct production system capabilities [3, 10, 12, 16]. Although many studies have been conducted to identify competitive priorities in different countries [2, 17–20] there is still some consensus on six priorities that should be considered in the operating system: cost, quality, delivery, flexibility, service and environmental protection [11, 21, 22].

Daily production activities, such as planning, scheduling, procedure assignment, and quality control, have been improved through the effective integration of maintenance activities to increase process reliability. On the other hand, production, procedures and

policies such as the quality management approach can help improve maintenance performance and, consequently, deliveries within the customer's desired timeframe [4, 7, 13, 14, 23–26].

Failure to execute the request received or planned by maintenance may result in the risk of wasted hours beyond the planned or even production of non-compliant parts, directly affecting the demand fulfillment performance. Market conditions force organizations to have fewer and fewer raw materials inventories, work in process inventories and finished goods inventories. In some cases, the customer requires the supplier to maintain a small security inventory to avoid potential recurring service threat issues. The size of this stock is scaled by the history of reliability of its suppliers' machines and equipment. This safety stock is not financed by the customer but is also a determining factor when signing the supply contract for a certain period. Inventory is a contractual requirement to ensure supply accuracy as planned and may be reduced or increased as equipment and process reliability maintain a desired level of performance [3].

Planned maintenance inspection activities have priority as they can reduce the risks of process reliability [27]. These inspections aim to answer the following questions like [28]: What could happen wrong? How can it go wrong? What is your probability of going wrong? What would be the consequences? Organizations determine strategies that aim to minimize the likelihood of failures and learn from failures when they occur [21]. The deterioration of machinery and equipment and the lack of quality in the maintenance workforce are the main causes of reduced production capacity and unreliability in production processes. As a result, this causes delays in customer order fulfillment and possible contractual fines in industries [29].

Therefore, using additional data to obtain detailed information on maintenance and production activities and thus maximizing the number of customer orders delivered within the customer's desired timeframe is a challenging problem. The importance of integrated MPC has been addressed, but modeling of integrated maintenance concepts for PPC is not as common in the maintenance literature [8].

Thus, as described by the main authors highlighted in Table 1, it can be inferred from the flow shown in Fig. 2.

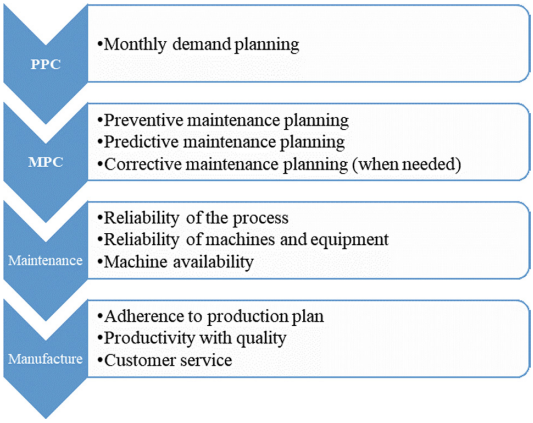

Fig. 2. Process systematization between PPC and MCP.

Figure 2 establishes a relationship between PPC and MCP to ensure demand. If production planning fails for corrective maintenance purposes, this will compromise all production planning. In addition, corrective maintenance presents some risks, including unpredictability of repair time, as well as sometimes difficulty finding spare parts or even emergency freight to restore equipment that is unavailable, and loss of equipment. planned production. Thus, the cost of corrective maintenance will be greater than the cost of preventive maintenance [30].

Production planning on bottleneck equipment does not foresee possible interruptions, beyond what has already been planned. If corrective maintenance due to unplanned shutdown occurs and this equipment is part of a continuous process, i.e. a process dependent on another, it will certainly result in losses, for which contractual fines for production delay may be imposed [30, 31].

3.2 Results of a Brief Study in Four Brazilian Companies

In Brazil, there is a competitive market in the manufacturing of parts and components for agricultural and construction machinery. Large automakers offer a one-month service warranty in their supply chain, expected to last 12 to 24 months. However, it requires delivery performance with targets of up to 95% and quality, 98% performance, with defined delivery and quality policies.

The desired delivery date criteria with a variation of about two days from the desired date by customers for situations when the supply chain fails to reach the desired goal, these customers establish a finished items safety stock so that any oscillation in the process and possible shortages of parts in the production lines of the automakers. Thus, safety stock is calculated based on the reliability and availability risk of the supplier's production process, as well as its capability.

For deliveries outside the agreed policy, a financial penalty is automatically imposed on the supplier, i.e. a rebate on the receivables the supplier has to the automaker. The non-compliance tolerance for each item is around 3 to 5% per year. Any deviation above this goal, authorships are performed in the production process in order to verify the capability, reliability and availability of the processes. Thus, positive or negative results directly influence the prospecting of new business.

All supply chain performance management studies are reviewed on a monthly basis and feedback from the indicators is sent throughout the supply chain. For this, a classification is made, in which the supplier is evaluated and, according to his performance, his classification, established in three levels, can be considered 3 as the worst and 1 as the best. In this way, the worst supplier rating is prevented from receiving new business opportunities or may even be disconnected from the supply chain.

Annually, a 3% cost reduction is required for each item. This reduction refers to the goal of improving the production process, whose value is automatically adjusted after 12 months. If, if the supplier fails to make the improvements mentioned above, the reduction is still required as agreed in the supply contract. Continuous process improvement is the sole responsibility of the supplier.

To illustrate the relevance of this work, four companies from the southern region of Brazil were surveyed. These companies are suppliers to assemblers of agricultural

machinery, producing tractors and harvesters, construction machinery, used in earth-moving and tractor, backhoe and loaders.

Of the four companies surveyed, two have been suppliers to automakers for over ten years, one of them eight years old and one the fourth company for nine years. Regarding the area of activity, the four companies supply only to the Brazilian market, with an average annual revenue of approximately 12 million dollars each company.

Companies have safety stock with finished parts. However, one of the companies has a smaller safety stock because its maturity level is higher. Technologically, they all have modern two- and three-dimensional laser cutting machines and equipment, welding machines such as robots. But one of the companies stands out for having a welding robot in three dimensions. Both companies provide laser cut parts, folds, and welded assemblies.

The supply policy for automakers is based on Kanban and deliveries are scheduled according to the demand of the automakers. It was also found that automakers keep their stocks for only three days of production. However, it requires the four companies to have an inventory of finished and semi-finished parts internally. Suppliers receive daily updated Electronic Date Interchange (EDI) orders from the automakers, ensuring the four weeks of confirmed orders. However, in some cases, automakers require some deliveries within four weeks. To avoid paying fines, this is negotiated between the planning areas in advance.

For certain types of assembled assemblies, welding or forming tools or devices are required. The automakers pay for the manufacture of this tooling in the development of the samples. It has been evidenced in the 24-month history that at some point all companies paid for any quality or deadline failure, and these penalties provided for in the supply agreement are automatically made to suppliers' receivables.

4 Conclusions

Operations and production managers are constantly concerned about the reliability and availability of processes and equipment. It was observed that a well-trained and motivated maintenance team performs higher quality short-term tasks, thus ensuring that the equipment is restored, leaving it in its normal operating condition. This ensures the productivity, quality and demand required.

Increasing competitive pressure requires reliable processes from organizations, which helps them increase their own competitiveness in their market. This confirms the proposed hypothesis, evidencing in the literature that the availability of equipment can guarantee the required demands, through a synergy of workforce qualification between PPC and MCP, based on the works mentioned in Table 1.

Therefore, it is considered that the objective of this work was achieved by the literature review, which presented the elements that cause risks of contractual fines due to the unavailability of equipment and how this can be avoided in order not to generate contractual fines and possible damages to companies and your image. This corroborated with a brief account of how it happens with some organizations mentioned in the study.

Robust processes help maintain stable productivity, reducing operating and maintenance costs. These processes can also contribute to a reduction in material inventory in processes and finished products, thereby reducing the need for safety stocks to support eventual unavailability in the production process. It can also reduce operating and maintenance costs.

For future work, a possibility of theme to be explored is related to process reliability and flexibility in operations due to demand volatility.

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References

1. Hui, Y.V., Leung, L.C., Linn, R.: Optimal machining conditions with costs of quality and tool maintenance for turning. Int. J. Prod. Res. **39**(4), 647–665 (2001)
2. Ahmad, S., Schroeder, R.G.: The impact of human resource management practices on operational performance: recognizing country and industry differences. J. Oper. Manage. **21** (1), 19–43 (2003)
3. Khan, F.I., Haddara, M.: Risk-based maintenance (RBM): a new approach for process plant inspection and maintenance. Process Saf. Prog. **23**(4), 252–265 (2004)
4. Alsyouf, I.: The role of maintenance in improving companies' productivity and profitability. Int. J. Prod. Econ. **105**(1), 70–78 (2007)
5. Al-Najjar, B.: The lack of maintenance and not maintenance which costs: a model to describe and quantify the impact of vibration-based maintenance on company's business. Int. J. Prod. Econ. **107**(1), 260–273 (2007)
6. Kans, M.: An approach for determining the requirements of computerized maintenance management systems. Comput. Ind. **59**(1), 32–40 (2008)
7. Lee, H.H.Y., Scott, D.: Overview of maintenance strategy, acceptable maintenance standard and resources from a building maintenance operation perspective. J. Build. Apprais. **4**(1), 269–278 (2009)
8. Ma, Y., Chu, C., Zuo, C.: A survey of scheduling with deterministic machine availability constraints. Comput. Ind. Eng. **58**(2), 199–211 (2010)
9. Simões, J.M., Gomes, C.F., Yasin, M.M.: A literature review of maintenance performance measurement: a conceptual framework and directions for future research. JQME **17**(2), 116–137 (2011)
10. Peng, D.X., Schroeder, R.G., Shah, R.: Competitive priorities, plant improvement and innovation capabilities, and operational performance: a test of two forms of fit. Int. J. Oper. Prod. Manage. **31**(5), 484–510 (2011)
11. Jabbour, C.J.C., da Silva, M.E., Paiva, E.L., Almada, F.C.: Environmental management in Brazil: is it a completely competitive priority? J. Clean. Prod. **21**(1), 11–22 (2012)
12. Choudhari, S.C., Adil, G.K., Ananthakumar, U.: Configuration of manufacturing strategy decision areas in line production system: five case studies. Int. J. Adv. Manuf. Technol. **64** (1), 459–474 (2013)
13. Fitouhi, M., Nourelfath, M.: Integrating noncyclical preventive maintenance scheduling and production planning for multi-state systems. Reliab. Eng. Syst. Saf. **121**(1), 175–186 (2014)
14. Lu, Z., Cui, W., Han, X.: Integrated production and preventive maintenance scheduling for a single machine with failure uncertainty. Comput. Ind. Eng. **80**(1), 236–244 (2014)
15. Tavares, L.A.: Business Centered Maintenance. NAT, Rio de Janeiro (2005)

16. Díaz, E., Martín, M.L.: Un análisis de las configuraciones genéricas de la estrategia de producción de empresas industriales españolas. CEDE **10**(32), 149–176 (2007)
17. Burgess, C.J.C.: A Tutorial on support vector machine pattern recognition. Data Min. Knowl. Disc. **2**(2), 121–167 (1998)
18. Calantone, R.J., Cavusgil, S.T., Zhao, Y.: Learning orientation, firm innovation capability, and firm performance. Ind. Mark. Manage. **31**(6), 515–524 (2002)
19. Cárdenas Aguirre, D.M., Castrillón Gómez, Ó.D., Becerra Rodríguez, F., García, A., Giraldo García, J.A., Ibarra Mirón, S., Zapata Gómez, A.: Gestión de la Producción: Una Aproximación Conceptual. Universidad Nacional de Colombia, Unibiblos, Bogotá (2008)
20. Kathuria, R., Porth, S.J., Kathuria, N.N., Kohli, T.K.: Competitive priorities and strategic consensus in emerging economies: evidence from India. Int. J. Oper. Prod. Manage. **30**(8), 879–896 (2010)
21. Slack, N., Lewis, M.: Operations Strategy. Harlow, England (2017)
22. Longoni, A., Cagliano, R.: Environmental and social sustainability priorities: their integration in operations strategies. Int. J. Oper. Prod. Manage. **35**(2), 216–245 (2015)
23. Maletič, D., Maletič, M., Gomišček, B.: The impact of quality management orientation on maintenance performance. Int. J. Prod. Res. **52**(6), 1744–1754 (2014)
24. Luo, W., Cheng, T.C.E., Ji, M.: Single-machine scheduling with a variable maintenance activity. Comput. Ind. Eng. **79**(1), 168–174 (2015)
25. Ishizaka, A., Nemery, P.: Assigning machines to incomparable maintenance strategies with ELECTRE-SORT. Omega **47**(1), 45–59 (2014)
26. Robson, K., Trimble, R., MacIntyre, J.: Creating and sustaining a maintenance strategy: a practical guide. J. Bus. Adm. Res. **2**(1), 77–84 (2013)
27. Brown, S.J., May, I.L.: Risk-based hazardous protection and prevention by inspection and maintenance. Trans. ASME J. Press. Vessel Technol. **122**(3), 362–367 (2003)
28. Arendt, J.S.: Using quantitative risk assessment in the chemical process industry. Reliab. Eng. Syst. Saf. **29**(1), 133–149 (1990)
29. Kaufman, D.L., Lewis, M.E.: Machine maintenance with workload considerations. Nav. Res. Logist. **54**(7), 750–766 (2007)
30. Garza-Reyes, J.A.: From measuring overall equipment effectiveness (OEE) to overall resource effectiveness (ORE). JQME **21**(4), 506–527 (2015)
31. Mhada, F.A., Hajji, R.M., Gharbi, A., Pellerin, R.: Production control of unreliable manufacturing systems producing defective items. JQME **17**(3), 238–253 (2011)