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Maintenance policies for protection systems subject to two competing failure modes

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ABSTRACT

This work succinctly presents some contributions of a PhD thesis, highlighting the importance of protection systems in maintenance management. Unlike critical systems, protection systems fail silently, leading to potential disasters during unmet demands. The research developed models that consider competitive failure modes, incorporating both internal degradation and external shocks, inspired by real-world problems. Two new hybrid (inspections & preventive replacement) maintenance policy models are proposed. The first model addresses single-component systems with failures following a shot-noise process, where activation accelerates deterioration. The second model deals with heterogeneous populations (weak and strong components), using the delay-time concept, where the shock rate follows a non-homogeneous Poisson process. Numerical studies showed significant cost reduction potential compared to classical policies. Results indicate when inspections should be prioritized over age-preventive replacement, and vice versa, and when they should act together. In addition, user-friendly web applications were developed, allowing readers to explore the models.

KEYWORDS. Maintenance policies. Protection systems. Shocks.

Paper topics: POI – PO na Indústria; EST&MP – Estatística e Modelos Probabilísticos.

1. Introduction

Significant research has focused on optimizing maintenance policies to enhance operational efficiency and extend the life of critical assets [De Jonge and Scarf, 2020]. Well-designed strategies offer multiple benefits to organizations [Rodrigues et al., 2023a]. However, gaps remain in the literature.

First, few models were designed for protection systems, where failures are hidden until an emergency [Berrade et al., 2012]. These systems, such as circuit breakers, isolation valves, safety brakes, environmental protection barriers, airbags and defibrillators, have lower maintenance costs compared to unmet demand, which can lead to severe consequences [Rodrigues et al., 2023b]. Second, there is a significant gap in maintenance policies for systems in dynamic environments affected by shocks. Since systems fail due to internal degradation and external shocks, which accelerate degradation [Tavangar and Hashemi, 2022], ignoring these shocks leads to inefficient maintenance management.

Addressing these challenges, this thesis makes significant contributions by tackling various practical issues. First, it develops models for protection systems exposed to both observable and unobservable shocks. Second, it creates models for external catastrophic events, where a single shock can cause system failure, and for non-catastrophic events, where failure is due to cumulative shocks. Third, it considers scenarios in which activating the system to meet demands can itself be a shock. Fourth, it introduces a new approach by using the number of observable shocks as a preventive maintenance strategy. Lastly, it advances the integration of the delay-time concept with shocks, incorporating these concepts together for the first time for protection systems, while considering maintenance quality aspects such as imperfect inspections and heterogeneous populations.

Briefly, aiming to develop analytical models of maintenance policies for protection systems subject to internal degradation and external shocks, this work seeks to answer the following research question: since the operational (good or defective) or non-operational (failed) states of protection systems are hidden, how to manage these assets efficiently in order to ensure their readiness to meet demands?

2. Developed Models

The next two subsections provide a brief summary of the models developed in the thesis. The exclusion of detailed mathematical modeling and the focus on only two models are due to the content limitations of this document. The thesis also presents a third contribution for a two-component system with stochastic dependence, which is not covered here.

2.1 A hybrid maintenance policy for single-component protection systems subject to observable shocks

2.1.1 Practical motivation (Safety Break)

The motivation behind this study revolves around addressing a critical issue identified in steel mills: the safety and reliability of emergency brakes in overhead cranes. These cranes, essential for transporting molten steel at extremely high temperatures, handle significant loads—up to 50 tons—creating a hazardous work environment where accidents can result in catastrophic outcomes, including production interruptions, asset destruction, and loss of life.

To mitigate such risks, overhead cranes are equipped with emergency brakes installed in the steel cable drum, activated in case of hoist system failures. This safety system prevents the ladle from tilting or falling, ensuring safe operations as long as the brake system functions correctly. However, every activation of the brake subjects it to shock, leading to degradation and potential failure over time.

Based on real observations and discussions with industry workers, several potential triggers for emergency brake activation were identified: operator intervention during hazardous situations, power outages, steel cable ruptures, and lifting drum shaft failures. These demands

degrade the brake, necessitating a preventive inspection and replacement policy to ensure brake readiness and safety. Faced with this situation, a preventive inspection and replacement policy is proposed, which can handle meeting demands.

2.1.2 Maintenance policy and mathematical model

Scheduling inspections are conducted at regular time intervals (iT for $i = 1, 2, \ldots, M$) in order to determine whether the system is good or failed. However, inspections can be prone to misclassification, leading to false positives (probability p) and false negatives (probability q). False positives occur when the system is operational but judged as failed, while false negatives happen when the system is actually failed but deemed operational [Cavalcante et al., 2019]. In addition, the system will be replaced preventively at $M.T$ if it survives to this age.

As shocks are observable, additional inspections are triggered immediately upon each demand to reduce the impact of immediate failures. Without these extra inspections, the system may fail and be unable to respond to other emergencies. On-demand inspections help identify failures before new demands arise, combining fixed and opportunistic inspections.

The policy also turns its attention to the number of demands experienced by the system. Since shocks come via demand, and this is a damaging event, it is crucial to consider that after K met demands, the system is replaced (note, when $s = K$, an additional inspection is not performed). Additionally, the arrival of a demand process is interrupted during any maintenance action (corrective, preventive or inspection). Thus, the system is replaced when a scheduled inspection or additional inspection indicates that it has failed, immediately after the Mth inspection, immediately after the Kth met demand, or immediately after an unmet demand – whichever comes first. Any replacement renews the system. Figure 1 illustrates the proposed policy.

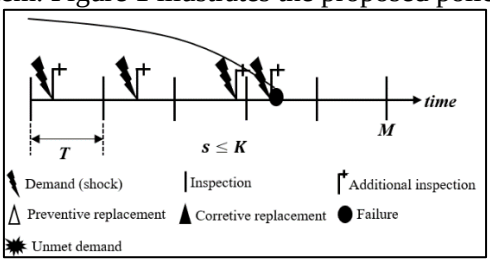


Figure 1: KMT$^+$policy representation (with scheduled and additional inspections).

Therefore, the decision variables are: K: Maximum number of met demands (shocks) until preventive replacement; M: Maximum number of inspections until preventive replacement; and T: Time interval between two consecutive scheduled inspections.

The mathematical development of the maintenance policy was based on constructing the probabilities of occurrence of seven different renewal cycle scenarios (or cases) (see Figure 2), so that the set of these scenarios must be mutually exclusive and exhaustive. The decision criterion (cost-rate) is $C_\infty(K, M, T) = \sum_{i=1}^{7} EC_i(K, M, T) / \sum_{i=1}^{7} EL_i(K, M, T)$, where EC and EL represent the expected cost and expected length of a renewal cycle for each scenario, respectively.

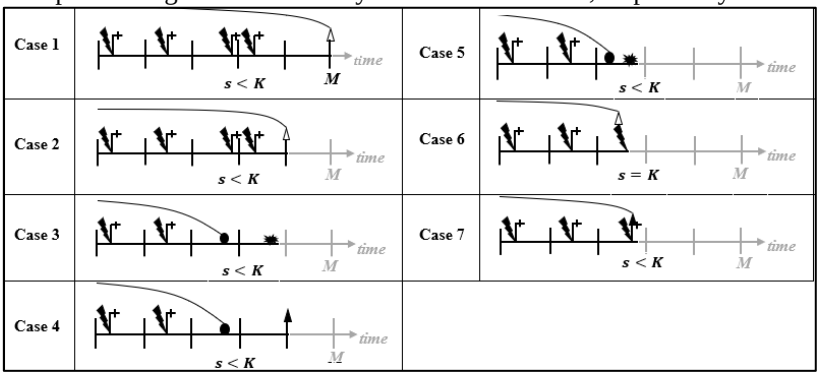


Figure 2: Pictorial representations of the renewal scenarios (Model 1).

2.1.3 Results

In order to understand the policy, a comparison is made with two policies: a policy that does not consider the number of K demands (MT policy) and another with just that (K policy). These two policies were chosen to show the impact of making a decision based on more information (more decision variables).

Maintenance policies of this type are dependent on the elicitation of input parameters. So, the probability distribution of time-to-failure is given by a Weibull distribution with shape parameter $\beta = 2$ and scale parameter $\eta = 5$ un (units of time). Demands arrive according to an HPP with a rate $\mu = 1.5$ demands/un. Each shock increases the failure rate by $\xi = 0.025\ un^{-1}$. The probability of a demand causing immediate failure, of false negatives and false positives is, respectively, $\Omega = 0.1$, $q = 0.2$ and $p = 0.1$. Regarding the costs of maintenance actions, the cost of corrective replacement (after a failure event) is considered as a reference unit, so that $C_f = 1.5$ \$ (currency unit). Thus, $C_v = 0.05$ \$ (cost of an inspection), $C_{ai} = 0.07$ \$ (cost of an additional inspection), $C_p = 0.75$ \$ (cost of a preventive replacement) and $C_{ud} = 37.5$ \$ (cost of an unmet demand). Note that C_{ud} is twenty-five times greater than C_f, which reflects the drastic consequences of an unmet demand. The times taken to conduct scheduled and additional inspections are negligible. Preventive and corrective actions last for the following times: $T_p = 1 * (10^{-4})$ un, $T_f = 2 * (10^{-4})$ un, $T_{ud} = 1 * (10^{-3})$ un. Therefore, these are the parameters for the base case (BC).

Table 1 shows the results of the analysis conducted, which presents variations in several input parameters, in order to perform a sensitivity analysis. The KMT$^+$ policy has significant cost-saving potential in relation to both. But overall, the main findings are:

Table 1: Results of the sensitivity analysis

CASE	PARAMETERS									KMT$^+$				MT			K	
	β	η	Ω	p	q	C_v	C_p	C_f	C_{ud}	K	M	T	C_∞	M	T	C_∞	K	C_∞
BC	2	5	0.1	0.1	0.2	0.05	0.75	1.5	37.5	2	5	0.292	1.690	18	0.116	2.425	1	3.188
2	**1.5**	5	0.1	0.1	0.2	0.05	0.75	1.5	37.5	3	1	0.840	1.830	24	0.105	2.660	1	4.890
3	**2.5**	5	0.1	0.1	0.2	0.05	0.75	1.5	37.5	2	3	0.465	1.447	15	0.125	2.307	1	2.365
4	2	**4**	0.1	0.1	0.2	0.05	0.75	1.5	37.5	3	5	0.237	1.887	14	0.112	2.574	1	4.291
5	2	**6**	0.1	0.1	0.2	0.05	0.75	1.5	37.5	2	5	0.333	1.554	17	0.121	2.349	1	2.572
6	2	5	**0**	0.1	0.2	0.05	0.75	1.5	37.5	3	5	0.266	1.564	5	0.251	1.474	1	3.188
7	2	5	**0.15**	0.1	0.2	0.05	0.75	1.5	37.5	2	5	0.296	1.741	23	0.102	2.801	1	3.188
8	2	5	0.1	**0.05**	0.2	0.05	0.75	1.5	37.5	3	8	0.201	1.628	20	0.096	2.242	1	3.188
9	2	5	0.1	**0.15**	0.2	0.05	0.75	1.5	37.5	2	3	0.404	1.732	13	0.139	2.603	1	3.188
10	2	5	0.1	0.1	**0.15**	0.05	0.75	1.5	37.5	3	6	0.254	1.662	15	0.121	2.366	1	3.188
11	2	5	0.1	0.1	**0.25**	0.05	0.75	1.5	37.5	2	4	0.323	1.716	15	0.114	2.525	1	3.188
12	2	5	0.1	0.1	0.2	**0.03**	0.75	1.5	37.5	3	8	0.207	1.609	20	0.104	2.251	1	3.188
13	2	5	0.1	0.1	0.2	**0.06**	0.75	1.5	37.5	2	4	0.335	1.720	14	0.124	2.526	1	3.188
14	2	5	0.1	0.1	0.2	0.05	**0.5**	1.5	37.5	2	4	0.292	1.411	14	0.109	2.175	1	2.800
15	2	5	0.1	0.1	0.2	0.05	**1**	1.5	37.5	3	7	0.253	1.864	15	0.128	2.679	1	3.576
16	2	5	0.1	0.1	0.2	0.05	0.75	**1**	37.5	3	6	0.250	1.597	14	0.119	2.359	1	3.162
17	2	5	0.1	0.1	0.2	0.05	0.75	**3**	37.5	2	5	0.289	1.909	14	0.118	2.756	1	3.266
18	2	5	0.1	0.1	0.2	0.05	0.75	1.5	**30**	3	5	0.299	1.588	15	0.131	2.230	1	2.799
19	2	5	0.1	0.1	0.2	0.05	0.75	1.5	**45**	2	5	0.271	1.775	16	0.107	2.624	1	3.577

I. Inspections are essential for protection systems. When there is any reason that induces an increase in the cost-rate, inspections are intensified and conducted more frequently;

II. Misclassification does not encourage inspections by making preventive replacement performed earlier. However, perfect additional inspections reduce the negative impact of these errors, thus allowing the life of the component to be extended;

III. When the rate of demands (shocks) per unit of time is very high, policies that consider the number of shocks as one of the decision variables for preventive replacement tend to be more effective. This is the only situation where time-based inspection actions do not make much of a difference;

IV. Due to all shocks being effective, when the jump in the baseline failure rate is very high, policies that perform scheduled inspections will always be more effective than policies based only on the number of shocks, even if the jump is associated with demands.

2.2 A two-phase maintenance policy for single-component protection systems subject to fatal shocks with state-dependent rate

2.2.1 Practical motivation (Circuit Breaker)

In real-world scenarios, numerous geographically dispersed substations are responsible for distributing electricity to millions of customers. These substations rely on extensive protection systems, including circuit breakers, which interrupt electrical current during abnormalities to prevent issues like overloads and short circuits. This rapid and precise action ensures the security and resilience of the power supply infrastructure.

Circuit breaker failures generally occur in two ways [Shahidehpour et al., 1994]: failing to operate when needed or false tripping. The former is more concerning due to its potential for significant environmental, social, and economic consequences. This concern serves as a strong motivation for the development of the second maintenance policy. Furthermore, there are other practical reasons not yet addressed in current literature that justify this study:

- Some maintenance policies address systems susceptible to observable shocks, but not all shocks are detectable. The policy in this study targets fatal shocks, making it suitable for systems with observable or unobservable shocks;
- Inspections can distinguish defective states from failure states in some systems, allowing the use of the delay-time concept to prevent failures. Zhang, Shen, and Ma [2021] proposed a policy for systems with hidden states and shocks, assuming perfect inspections. This study advances by considering inspection misclassifications;
- No previous studies have examined protection systems under shocks with components from heterogeneous populations.
- The modelling of this study will condition the shock rate on the state (good or defective) of the system.

2.2.2 Maintenance policy and mathematical model

By assumptions, it is considered that the system is subject to demands and external shocks. Demands, denoted by Z, follow an exponential distribution with a rate of 1/μ. External shocks are modeled by a non-homogeneous Poisson process (NHPP), $\{N(t), t \geq 0\}$, with shocks occurring more frequently in the defective state than in the good state, i.e., $v_1(t) < v_2(t)$.

To deal with this, periodic inspections are performed at $i\Delta$ time intervals ($i = 1, 2, \dots, K$) in order to determine whether the system is good, defective or failed. After $K\Delta$ there are no further inspections, but there is a scheduled preventive replacement at T, if the component survives until there (see that $K\Delta < T$). Additionally, false positives occur if the system is classified as defective while it is good (p_1). False negatives occur if the system is classified as good, while it is defective (q_1) or failed (q_2). Finally, any replacement renews the system completely.

Therefore, this is a hybrid (imperfect inspection and replacement) policy (also called KΔT policy) for heterogeneous protection systems subject to fatal shocks and internal degradation, in which the decision variables are: K: Maximum number of inspections; Δ: Time interval between two consecutive inspections; T: Age for scheduled preventive replacement.

The maintenance policy was developed mathematically by constructing probabilities for 42 different renewal cycle scenarios. Due to the significantly larger number of renewal scenarios, especially compared to the previous model, pictorial representations will not be included. For detailed illustrations, please refer to [Rodrigues, 2024]. The decision criterion (cost-rate) is given by: $C_\infty(K, \Delta, T) = \sum_{i=1}^{42} EC_i(K, \Delta, T) / \sum_{i=1}^{42} EL_i(K, \Delta, T)$.

Table 2: Parameters for sensitivity analysis. For $p_1 = 0.08, q_1 = 012, q_2 = 0.1, v_1(t) = 0.001t^{0.8}, v_2(t) = 0.002t^{0.5}$. BC: Base case.

Case	Parameters										
	η_1	η_2	β_1	β_2	α	λ	μ	C_I	C_p	C_C	C_{UD}
1 (BC)	5	15	2	3	0.1	0.5	0.1	1	10	40	1000
2	4	15	2	3	0.1	0.5	0.1	1	10	40	1000
3	6	15	2	3	0.1	0.5	0.1	1	10	40	1000
4	5	13	2	3	0.1	0.5	0.1	1	10	40	1000
5	5	17	2	3	0.1	0.5	0.1	1	10	40	1000
6	5	15	1.5	3	0.1	0.5	0.1	1	10	40	1000
7	5	15	2.5	3	0.1	0.5	0.1	1	10	40	1000
8	5	15	2	2.5	0.1	0.5	0.1	1	10	40	1000
9	5	15	2	3.5	0.1	0.5	0.1	1	10	40	1000
10	5	15	2	3	0	0.5	0.1	1	10	40	1000
11	5	15	2	3	0.2	0.5	0.1	1	10	40	1000
12	5	15	2	3	0.1	0.3	0.1	1	10	40	1000
13	5	15	2	3	0.1	0.7	0.1	1	10	40	1000
14	5	15	2	3	0.1	0.5	0	1	10	40	1000
15	5	15	2	3	0.1	0.5	0.2	1	10	40	1000
16	5	15	2	3	0.1	0.5	0.1	0.5	10	40	1000
17	5	15	2	3	0.1	0.5	0.1	1.5	10	40	1000
18	5	15	2	3	0.1	0.5	0.1	1	8	40	1000
19	5	15	2	3	0.1	0.5	0.1	1	12	40	1000
20	5	15	2	3	0.1	0.5	0.1	1	10	35	1000
21	5	15	2	3	0.1	0.5	0.1	1	10	45	1000
22	5	15	2	3	0.1	0.5	0.1	1	10	40	900
23	5	15	2	3	0.1	0.5	0.1	1	10	40	1100

Table 3: Results of the sensitivity analysis.

Case	KΔT Policy				KΔ Policy ($K\Delta = T$)			T Policy ($K = 0$)	
	K^*	Δ^*	T^*	$C_\infty(K, \Delta, T)$	K^*	Δ^*	$C_\infty(K, \Delta)$	T^*	$C_\infty(T)$
1 (BC)	5	1.403	8.150	3.682	8	1.235	3.769	3.793	4.184
2	6	1.311	8.978	3.744	8	1.238	3.816	3.578	4.446
3	4	1.546	7.367	3.611	7	1.301	3.719	3.961	4.010
4	4	1.441	6.857	3.824	6	1.291	3.942	3.693	4.245
5	6	1.391	9.538	3.566	8	1.323	3.633	3.864	4.145
6	5	1.399	8.173	3.666	6	1.780	3.938	3.747	4.438
7	5	1.400	8.137	3.681	8	1.237	3.766	3.852	4.016
8	5	1.346	7.836	3.837	9	1.160	3.909	3.611	4.338
9	5	1.454	8.451	3.573	7	1.340	3.662	3.910	4.113
10	1	3.757	5.651	3.236	4	1.813	3.429	4.632	3.478
11	8	1.137	10.101	4.005	10	1.106	4.054	3.313	4.702
12	5	1.483	8.632	3.507	7	1.383	3.589	4.005	3.979
13	5	1.353	7.848	3.815	8	1.187	3.906	3.667	4.330
14	1	∞	∞	0	1	∞	0	∞	0
15	8	1.212	10.869	3.850	11	1.158	3.890	3.448	4.742
16	9	1.031	10.064	3.294	11	0.986	3.323	3.793	4.184
17	1	3.138	4.951	3.908	5	1.613	4.125	3.793	4.184
18	3	1.611	6.061	3.369	6	1.306	3.496	3.470	3.658
19	6	1.387	9.446	3.946	8	1.305	4.012	4.091	4.664
20	5	1.431	8.337	3.585	8	1.266	3.660	3.831	4.123
21	4	1.509	7.233	3.775	7	1.277	3.870	3.758	4.244
22	5	1.447	8.398	3.592	7	1.343	3.679	3.929	4.060
23	5	1.364	7.935	3.767	8	1.203	3.852	3.677	4.300

2.2.3 Results

The behavior of the maintenance policy (KΔT policy) was investigated against two other classic policies, which are: the periodic inspection policy, where after K inspections the component is replaced preventively (KΔ policy), and the age-based policy (T policy). Table 2 summarizes the

specification of input parameters, while Table 3 presents the result of the sensitivity analysis. The costs of maintenance actions are constant and known, being $C_I < C_P < C_C \ll C_{UD}$. Maintenance times are negligible. In addition, the cumulative distribution function of the defect is a mix of Weibull distributions, where η_i and β_i represent the scale and shape parameters, respectively (with $i = 1$ for weak components and $i = 2$ for strong components).

The KΔT policy has significant cost-saving potential in relation to both. But overall:

I. Flexible multi-phase policies are useful for dealing with components with different characteristic lives;
II. Inspections are essential to ensure the readiness of protection systems. However, at the level of the minimum desired inspection quality. Investing in qualifications, adequate material or in a specialized team to prevent misclassification should be taken into consideration;
III. Inspections must be directly proportional to the demand rate;
IV. When there are only long-lived components, age-based policies tend to be more useful. This recommendation is also valid for high misclassification probabilities.

3. Concluding remarks

This document presented contributions from a PhD thesis, focusing on the development of maintenance policy models for protection systems. The thesis introduced maintenance policies that integrate shock models with maintenance quality parameters, resulting in more realistic and effective strategies. By proposing flexible and adaptive maintenance approaches, such as hybrid policies, the research provides valuable guidance on when to prioritize inspections or preventive maintenance based on cost-rate criteria. These contributions enhance the readiness of protection systems and offer the literature a comprehensive approach to modeling competitive failure modes, including both internal degradation and external shocks. The development of practical maintenance tools further demonstrates a commitment to societal benefit, enabling the widespread application of these policies in managing various systems.

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4. Statement on scientific contributions during the PhD

This section describes the scientific papers, awards, and technological products developed during the PhD period (March 2020 – March 2024).

- AWARDS (4):
- 2024: Motion of Applause, City Council of Tuparetama – PE;
- 2023: Best Publication (PhD Category), ANPEPRO (EPPGEP);
- 2023: Honorable Mention (Academic Work Category), Academia Brasileira da Qualidade – ABQ;
- 2022: Recognized by the PPG as an outstanding student (Technological Product Category), ANPEPRO (EPPGEP).

- PAPERS IN JOURNALS (7):
- **Rodrigues, A. J. S.**, Motta, F. A., Alberti, A. R., and Cavalcante, C. A. V. (2023). A hybrid policy for inspecting and replacing safety brakes subjected to shocks. *Quality Technology & Quantitative Management*, 1–31. https://doi.org/10.1080/16843703.2023.2257974.
- **Rodrigues, A. J. S.**, Cavalcante, C. A. V., and Alberti, A. R. (2023). A multicriteria model to support the selection of inspection service providers based on the delay time model. *International Transactions in Operational Research*, 30:3554-3577. https://doi.org/10.1111/itor.13274.
- **Rodrigues, A. J. S.**, Cavalcante, C. A. V., Alberti, A. R., Scarf, P., and Alotaibi, N. M. (2023). Mathematical modelling of mission-abort policies: a review. *IMA Journal of Management Mathematics*, 34(4):581-597. https://doi.org/10.1093/imaman/dpad005.
- Scarf, P., Alotaibi, N., Cavalcante, C. A., **Rodrigues, A. J. S.**, and Melo, Y. R. (2024). On periodic maintenance for a protection system. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, ahead-of-print. https://doi.org/10.1177/1748006X241254420.

- Alotaibi, N. M., Scarf, P., Cavalcante, C. A., Lopes, R. S., Silva, A. L. D. O., **Rodrigues, A. J. S**., and Alyami, S. A. (2023). Modified-opportunistic inspection and the case of remote, groundwater well-heads. *Reliability Engineering & System Safety*, 237:109389. https://doi.org/10.1016/j.ress.2023.109389.
- Scarf, P., Alotaibi, N. M., Cavalcante, C. A., Melo, Y. R., and **Rodrigues, A. J**. (2024). Modified age-based replacement. *Reliability Engineering & System Safety*, 245:110022. https://doi.org/10.1016/j.ress.2024.110022.
- Cavalcante, C., Scarf, P., Ribeiro, Y., **Rodrigues, A**., and Alotaibi, N. (2024). Planning maintenance when resources are limited: a study of periodic opportunistic replacement. *IMA Journal of Management Mathematics*, dpae015, ahead-of-print, https://doi.org/10.1093/imaman/dpae015.

▪ CONFERENCE PAPERS (3):
- **Rodrigues, A. J. S**., and Cavalcante, C. A. V. (2023). A hybrid policy for protection systems subject to internal degradation and external shocks. In: *VIII EPPGEP 2023*. https://anpepro.org.br/wp-content/uploads/2023/10/DOUTORADO-UFPE.pdf.
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- **Rodrigues, A. J. S**.; Cavalcante, C. A. V. A web application for maintenance planning of protection systems subject to shocks. 2023. Patente: Programa de Computador. Número do registro: BR512023001410-9, data de registro: 23/05/2023, Instituição de registro: INPI - Instituto Nacional da Propriedade Industrial. Disponível em: https://augustojsrodrigues-kdt-kdt-ar-cwc2un.streamlit.app/.
- **Rodrigues, A. J. S**.; Alberti, A. R.; Cavalcante, C. A. V.; Motta, F. A. KMT Policy Software. 2023. Patente: Programa de Computador. Número do registro: BR512023001857-0, data de registro: 04/07/2023, Instituição de registro: INPI - Instituto Nacional da Propriedade Industrial. https://augustojsrodrigues-kmt-kmt-ot-an-l6wr74.streamlit.app/.

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