

## Analysis and Modeling of the Relationship “Maintenance-Environment” Quantitative Experiments on Moroccan SMEs Samples

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**Abstract:** The Morocco has been engaged during many years in the sustainable development policies. Fitting this policies criterion constitutes one of the major factors which distinguish the enterprises and makes them citizenship ones. In this regard, organizations of different types look strongly to achieve and to prove a high level of environmental performance by controlling the impacts of their activities, products and services concerning the environment. If the maintenance role has been limited for several years to the availability and profit ability improvement, now a day this function is called over other aspects, particularly those concerning the environment respect. It is within this frame that our work is enrolled, in fact, it aims to establish the relationship between the maintenance and the environmental management. In this study, we analyze the relation “environment-maintenance” and we present the model resulting from this analysis. This model allows illustrating the impact of the maintenance over the performance improvement, then, the effects of the environment management over the maintenance. Also, we present in this study the experimental results of our model in the Moroccan context. The model validation is carried out through surveys from 7 companies, certified ISO 14001 in various sectors. The collected results have confirmed the assumptions expressed by our model.

**Key words:** Morocco, organizations, policies, profit, maintenance, validation

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### INTRODUCTION

Although, there is a large literature analyzing the relationship between environmental performance and financial performance (Chatterji and Levine, 2006; Konar and Cohen, 2001; Schaltegger and Synnæstvedt, 2002; Orlitzky *et al.*, 2003; Waddock and Graves, 1997; Griffin and Mahon, 1997), there are few studies examining the relationship between environmental performance and maintenance management performance. It is in this frame that our research work fits, it tries to analyze and model the relationship between maintenance and the environment.

In this study, we first define the concepts related to maintenance, green maintenance and the Environmental Management System (EMS). Then, we analyze the impact of maintenance on the environment and the impact of the EMS on the maintenance management and we deduce the global relationship “maintenance-environment” model. Finally, we try to validate, qualitatively, the model with 7 Moroccan companies in various activities sectors.

### Definitions

**Definition of the maintenance:** The definition and development of the maintenance concept has been addressed by numerous research studies (Monchy, 2003; Retour *et al.*, 1990). Also, the French standard gave several definitions of the maintenance function (the definition of NF X 60-010 standard and AFNOR NF X 60-000 integrating the economic aspect). As part of our research, we use the definition of standard NF EN 13306: maintenance is “the set of all technical, administrative and management tasks during the life cycle of an asset intended to maintain or restore it to a state in which it can perform a required function”. This definition introduces the maintenance concept throughout the whole life cycle of a material, this was missing in that of standard NF X 60-010.

Traditional definitions of maintenance focus on ‘good functioning’. Admittedly, the concept of ‘good functioning’ can also, include the respect of the environment (operation without any overconsumption of energy and matter, nor pollution of air, soil and water). But

it is clear that this notion refers more to the availability of a machine and the environmental dimension remains implicit if not absent. Thus, the integration of the criterion 'respect of the environment' in the definition of maintenance would help actually to respect the environment. Indeed, the integration of the environmental dimension in the definition urges maintenance managers to calculate and optimize the environmental costs and to integrate them into maintenance costs.

It is about the cost of penalties due to the environmental degradation provoked by the system. We cite in this regard the research work by Chouikhi (2012) which proposed to optimize the maintenance costs by integrating the cost related to the environment.

Finally, the integration of the environmental dimension into maintenance shows in our opinion, the concept of green maintenance. We have defined this concept as follows: "the set of all technical, administrative and management tasks during the life cycle of an asset intended to maintain or restore it to a state in which it can perform a required function in an environmentally sound manner". It means a healthy maintenance that ensures operation with the least breakdowns and limits any generation of negative impact on the environment.

**Definition of the Environmental Management System (EMS):** In the literature, several works have defined the EMS, for example, EMAS (Nash and Ehrenfeld, 2001). In the same sense, the International Standard ISO 14001, the most widely accepted by companies (Reverdy, 2005), defines the EMS as "the organization management system component used to develop and implement its environmental policy and manage its environmental aspects. A management system is a set of interrelated elements used to establish policy and objectives, also the means to achieve these objectives. It includes the organizational structure, planning activities, responsibilities, practices, procedures, processes and resources".

## **MATERIALS AND METHODS**

**Analysis and modeling of the relationship "maintenance-environment":** Research studies analyzing the impacts of a system (e.g., process, machine, etc.) on the environment or dealing with the relationship between environment and business are numerous, for example, Laratte (2013), Arari (2011), Mequignon (2011), Tahkamo (2013) and Ayed (2012). However, few works deal with the relationship between maintenance and environment, so, this relationship remains implicit in a context where the protection of the environment is a major stake.

On the other hand, the production systems that constitute an important part of the capital of most industries are subject to the degradation related to the age and the use of such systems. This degradation affects not only the quality of the product but also that of the environment. In fact, the industrial systems degradation can have significant impacts on the environment.

To meet the requirements of environmental standards and regulations, companies and in particular their maintenance departments must develop and implement innovative methods and strategies that allows to improve their performance for one hand and to rationally exploit the available hardware resources on the other hand. This exploitation must be performed taking into account the impacts of industrial systems on the environment.

Perusing the literature on maintenance, the relevance of the maintenance management has been proven in several books (Lyonnais, 1992; Prickett, 1999; Jardine *et al.*, 1999). Indeed, a good maintenance management can help the company to remain competitive both nationally and internationally.

According to our bibliographic review, a properly implemented maintenance management has a positive impact not only on the infrastructure, the resources (human and material) and the company management (spare parts inventory, etc.) but also on the environment (Chouikhi, 2012; Zille, 2009; DeSimone, 1997; Aoufir, 2003; Halima *et al.*, 2015). The maintenance allows them to ensure the people safety and to limit the negative impacts of a material on the environment. Indeed, efficient maintenance interventions will:

- Extend the lifetime of assets
- Secure people and the properties
- Reduce noise (e.g., vibration of engines)
- Reduce consumption of matter and energy (e.g., water and electricity)
- Reduce solid and liquid waste (oil leakage)
- Reduce air pollution (gas leakage)
- Reduce environmental costs (the penalties cost due to the impact of the production system deterioration on the environment)

Thus, we can deduce that maintenance contributes to the environmental performance by reducing the environmental impacts. This positive impact of maintenance on the environment can be translated into an improvement of the environmental performance indicators (Fig. 1).

If maintenance management contributes to the environmental performance, the integration of the maintenance function into the design and operation of an

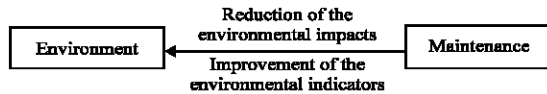


Fig. 1: The “maintenance-environment” relationship

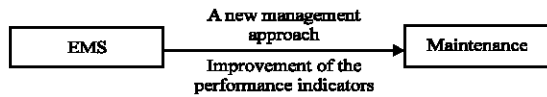


Fig. 2: The whole “environment-maintenance” relationship

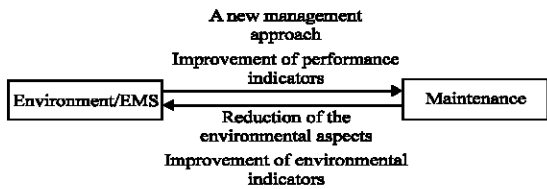


Fig. 3: The “maintenance-environment” relationship

EMS is then essential. This supports the consideration of maintenance as a requirement in ISO 14001 standard. We quote this sentence of Paragraph 4.4.1 entitled resources, roles, responsibility and authority: “management must ensure the availability of the essential resources for the establishment, implementation, keeping up-to-date and the improvement of the environmental management system. These resources include human resources, specific skills, organizational infrastructure, technological and financial resources”.

Responding to this requirement implies a specific organization of the maintenance service. This organization would result in an organizational performance at the maintenance function level.

In addition, environmental management requires defining for each process that includes the maintenance process, the environmental aspects and their impacts. The company is obliged in reduction of the environmental impacts improvement of the environmental indicators maintenance environment this sense to propose actions and procedures to control these aspects and limit their impacts on the environment. These actions and procedures will introduce a new management approach in the maintenance service.

We can thus, deduce that the environmental management requires a certain maintenance organization which in turn has a positive impact on maintenance performance indicators (Fig. 2 and 3).

The aggregation of relations 1 and 2 gives the global model explaining both directions of the relation “environment-maintenance”.

## RESULTS AND DISCUSSION

### Experimentation of the model

**Presentation of the sample and the survey:** In order to validate our model, we collected data from 13 Moroccan SMEs in various sectors of activities: agri-food, automotive, packaging, energy, agriculture and the rmomechanics sectors.

In each company, we tried to have the answers of the services concerned by our issue (the relationship maintenance and environment). The number of enterprises classed by sector of activity, the number of responses per company and the qualification of the respondent are summarized in Table 1.

The questionnaire we proposed consists of two types of questions, closed questions and open ones and it proposes to evaluate two dimensions: the first dimension aims to assess the impact of maintenance management on the environmental performance. The questions asked in this way make it possible to evaluate for the companies that have an EMS, if the maintenance management contributes to:

- Extend the equipment lifetime
- Reduce the noise disturbances (e.g., vibration of an engine)
- Reduce the consumption of materials and energy (e.g., water and electricity)
- Reduce the solid and liquid waste (leakage of oil) and air pollution (gas leakage)

The second dimension aims to assess the impact of the EMS on the maintenance performance. The questions asked in this sense are intended to evaluate whether the implementation of an EMS impact maintenance management or not. If this impact is felt in the company, our questionnaire can easily situate it within the 5 M of maintenance (machines, methods, materials, man power and mother nature).

As part of the impact assessment of the EMS on maintenance management, we asked a question relating to the Life Cycle Cost (LCC). This question allows assessing whether the implementation of EMS has reduced the LCC (by reducing the costs related to penalties resulting from the non-respect of the environment).

### Presentation of the results

**The impact of maintenance on the environment:** All answers to the questionnaires have confirmed that maintenance can extend the life of the equipment and reduce the consumption of material and energy. In addition, 93% of responses emphasized the positive

Table 1: Recapitulation on sample data

Activity area	No. of companies in the sector	No. of responses	Qualification of the repondent
Agri-food	1	3	Maintenance manager/QSE manager/production manager
Packaging	1	1	Responsible Integrated Management System (IMS)
Thermomechanics	1	1	Production department manager
Automotive	3	7	Environment responsible/maintenance manager/production department manager
Agriculture	1	1	Group maintenance department responsible
Energy	2	2	Maintenance manager/QSE manager
Mines and hydrometallurgy	1	1	maintenance manager
Submersible electropumps/surface electropumps/pump stations	1	4	Production manager/methodology office manager/quality control manager
Concrete poles/water and Electric meters	1	3	Production manager/maintenance manager/technical controller
Electricity/water/Electromechanical	1	7	Production manager/maintenance manager/technical controller/method manager/technical coordinator
Total	13	30	

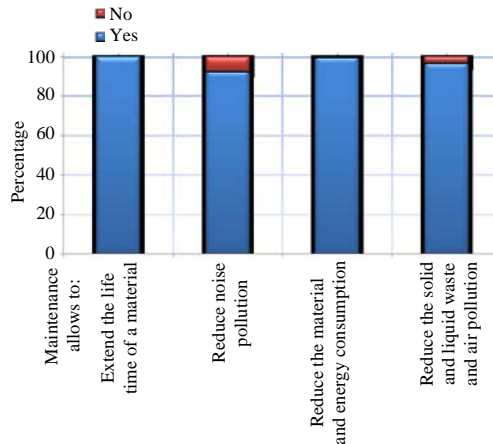


Fig. 4: Assessment of the impact of maintenance management on the environment

impact of the maintenance on reducing sound pollution, also, 97% of those interviewed agreed that maintenance actions can decrease solid and liquid waste and air pollution (Fig. 4).

Responses to the questionnaires are often based on the field observations. Tangible data to support these answers may not be available. Moreover, the maturity level of the SMEs and interviewed companies does not objectively answer certain questions such as “the impact of maintenance on the extension of the equipment lifetime”.

Overall, we will estimate the impact of maintenance on the environment by calculating the total score (SC total) obtained for all questions taking into account all respondents.

The total score of this dimension (SC total) is calculated basing on the score obtained for each question (SC qst), the number of questions asked (nq) in this dimension and the number of respondents (nr). Thus, total SC is computed as follows:

Table 2: The impact of EMS on the maintenance

Implementation	Percentage of responses confirming the impact of EMS on 5 M maintenance	Percentage of the responses confirming that the impact of EMS is not felt
Did the implementation of the EMS have an impact on the maintenance department functioning?	97%	3%

$$SC \text{ total} = \sum_{j=1}^{j=nr} \sum_{i=1}^{i=nq} (SCqst)$$

(SC qst) can take two values: 0 when the answer is ‘no’ and 1 when the answer is ‘yes’. All respondents have the same weight. Knowing that  $0 \leq SC \text{ total} \leq 120$ , we will consider:

- The impact is low if  $0 \leq \text{total SC} \leq 30$
- The impact is average if  $30 \leq \text{total SC} \leq 60$
- The impact is significant if  $60 \leq \text{total SC} \leq 120$

The scoring of the questionnaires gave:  $SC \text{ total} = \sum_{j=1}^{j=30} \sum_{i=1}^{i=4} (SCqst) = 117$ . This means that the impact of the maintenance management on the environment is significant.

The results confirm our assumption that the management of the maintenance improves environmental performance.

#### The impact of SME on maintenance management:

The assessment of the impact of setting up an EMS on the maintenance service operation is shown in Table 2. The 97% of responses confirmed the impact of environmental management on maintenance management.

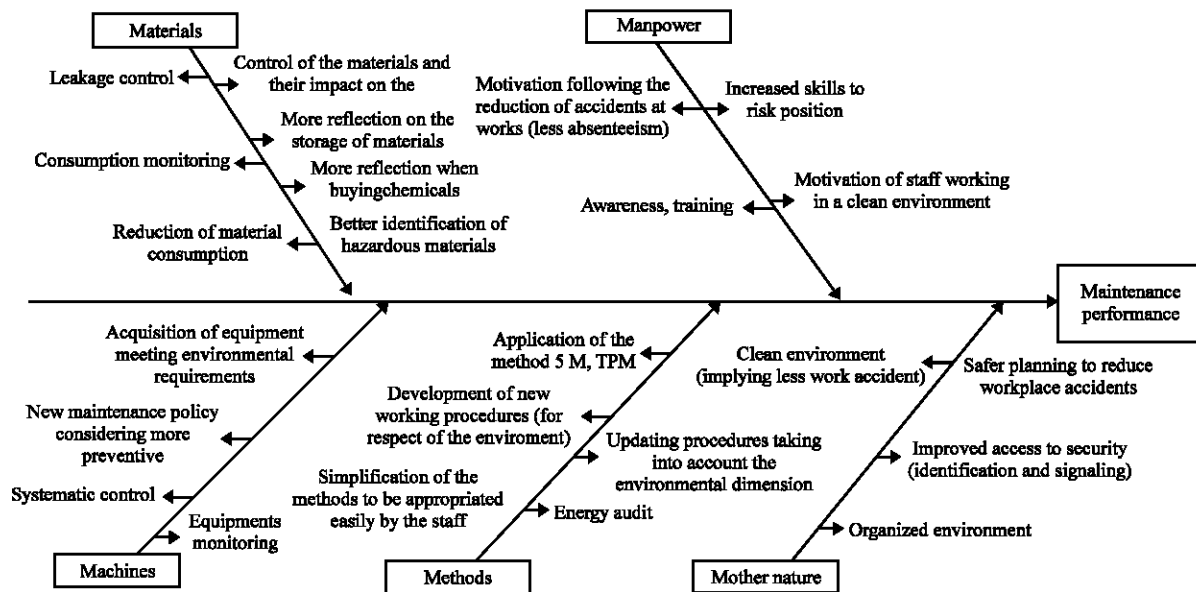


Fig. 5: The impact of the implementation of an EMS on the maintenance management according to the 5 M

The replies made it possible to situate this impact according to the 5 M represented in the form of an Ichikawa diagram (Fig. 5).

The answers concerning the impact of the EMS on the management of maintenance are based mainly on the field experience of the different respondents. These responses confirm our hypothesis that the EMS improves management mode and maintenance performance indicators.

Also, we received no response regarding the impact of the EMS on the Life Cycle Cost (LCC). This is reflected, on the one hand by the fact that the environmental law in Morocco is not yet applicable on the other hand, the information system of companies in our sample does not calculate the LCC and of course the integration of the costs relating to penalties due to non-respect of the environment has not yet been made. Finally, we did not receive a response on the question of the impact of the EMS on the reduction of maintenance costs for the same reasons mentioned before.

## CONCLUSION

If the negative impact of a production system on the environment and the impact of maintenance management on the production system seem obvious, the direct impacts between maintenance and the environment are not always evident. Our research fits into this framework and shows that maintenance management impacts environmental performance, so, good environmental

management within an industry influences the management of maintenance. At the end of this research we elaborated a model on the relation 'environment-maintenance'.

The experimentation of our model was carried out in 7 Moroccan companies certified ISO 14001 in various sectors of activity. This qualitative experiment confirms the relationship between maintenance management and the improvement of environmental performance and also, the relationship between environmental management and the improvement of maintenance performance. Quantitative experimentation with a Moroccan company in the agro-food sector is under way. The data collected up to now confirm the different relationships of our model.

## REFERENCES

- Aoufir, E.H., 2003. [Contribution to maintenance cost management and decision support of maintenance strategies]. Ph.D Thesis, Ecole Mohammadia d'Ingenieurs, Rabat, Morocco. (In French)
- Arari, B.B.I., 2011. [Contribution to the evaluation of the supply chain for the textile industry: Definition of sustainable development criteria: Application of the PROMETHEE upgrade method to the life cycle analysis of a T-shirt]. Ph.D Thesis, Lille University of Science and Technology University, Villeneuve-d'Ascq, France. (In French)
- Ayed, B.R., 2012. Eco-design of a railway traction chain. Intl. Congr. Life Cycle Assess., 2011: 1-2.

- Chatterji, A. and D. Levine, 2006. Breaking down the wall of codes: Evaluating non-financial performance measurement. *California Manage. Rev.*, 48: 29-51.
- Chouikhi, H., 2012. [Optimization of green maintenance strategies for goods and services production systems]. Ph.D Thesis, UFR Mathématiques, informatique, mécanique, Metz, France. (In French)
- DeSimone, L.D., 1997. World Business Council for Sustainable Development (WBCSD) Eco-Efficiency. MIT Press, Cambridge, Massachusetts, USA., Pages: 306.
- Griffin, J.J. and J.F. Mahon, 1997. The corporate social performance and corporate financial performance debate: Twenty-five years of incomparable research. *Bus. Soc.*, 36: 5-31.
- Halima, T., M.E. Hammoumi and B. Herrou, 2015. Integration of the environmental dimension in maintenance decision support tool FMEA: Case of a Moroccan foundry. *Global J. Eng. Sci. Res. Manage.*, 2: 68-84.
- Jardine, A.K.S., T. Joseph and D. Banjevic, 1999. Optimizing condition-based maintenance decisions for equipment subject to vibration monitoring. *J. Qual. Maint. Eng.*, 5: 192-202.
- Konar, S. and M.A. Cohen, 2001. Does the market value environmental performance?. *Rev. Econ. Stat.*, 83: 281-289.
- Laratte, B., 2013. [Dynamic and cumulative assessment of environmental impacts as part of a life cycle analysis]. Ph.D Thesis, University of Technology of Troyes, Troyes, France. (In French)
- Lyonnais, P., 1992. Mathematical Maintenance and Method. 3rd Edn., Lavoisier Publication, France.,
- Mequignon, M.A., 2011. [How can the lifespan of buildings influence performance in terms of sustainable development?]. Ph.D Thesis, Institut national des sciences appliquées de Toulouse, Toulouse, France. (In French).
- Monchy, F., 2003. [Maintenance: Methods and Organizations]. Dunod Publisher, Paris, France, Pages: 513 (In French).
- Nash, J. and J.R. Ehrenfeld, 2001. Factors that Shape EMS Outcomes in Firms. In: *Regulating from the Inside: Can Environmental Management Systems Achieve Policy Goals*, C. and N. Jennifer (Eds.). RFF Press, Washington, D.C., USA., ISBN: 9781891853418, pp: 61-81.
- Orlitzky, M., F.L. Schmidt and S.L. Rynes, 2003. Corporate social and financial performance: A meta-analysis. *Organiz. Stud.*, 24: 403-441.
- Prickett, P.W., 1999. An integrated approach to autonomous maintenance management. *Integr. Manufac. Syst.*, 10: 233-243.
- Retour, D., M. Bouche and V. Plauchu, 1990. [Where is the industrial maintenance (In French)]. *Probl. Economiques*, 2: 7-13.
- Reverdy, T., 2005. [Environmental standards in business: The eventful trajectory of a managerial mode (In French)]. *Sociologies Pratiques*, 1: 97-119.
- Schaltegger, S. and T. Synnestvedt, 2002. The link between green and economic success: Environmental management as the crucial trigger between environmental and economic performance. *J. Environ. Manage.*, 65: 339-346.
- Tahkamo, L., 2013. Life cycle assessment of light sources-case studies and review of the analyses. Ph.D Thesis, Paul Sabatier University, Toulouse, France.
- Waddock, S.A. and S.B. Graves, 1997. The corporate social performance-financial performance link. *Strat. Manage. J.*, 18: 303-319.
- Zille, V., 2009. [Modeling and evaluation of complex maintenance strategies on multi-component systems]. Ph.D Thesis, University of Technology of Troyes, Troyes, France. (In French).