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Management Systems in Production Engineering

2023, Volume 31, Issue 2, pp. 191-196

Date of submission of the article to the Editor: 10/2022
Date of acceptance of the article by the Editor: 04/2023

DOI 10.2478/mspe-2023-0020

ANALYSIS OF THE IMPACT OF SIX SIGMA AND LEAN MANUFACTURING ON THE PERFORMANCE OF COMPANIES

Fatima Ezzahra Achibat, Ahmed Lebkiri, El mahjoub Aouane, Hanane Lougraimzi, Nabyl Berrid, Abdelaziz Maqboul
IbnTofail University

Abstract:
Moroccan companies seek to be competitive worldwide by improving quality, productivity, and customer satisfaction. Lean Manufacturing and Six Sigma are the most popular methodologies for continuous improvement in companies. The objective of this article is to determine the impact of Six Sigma and Lean Manufacturing on the performance of different companies. The data was collected by a questionnaire sent to the various companies and industries in Morocco. 45 companies responded to this study, divided into several sectors. The criteria of this study are based on two levels: Financial and operational performance. A statistical study is carried out by SPSS software to analyze and interpret the collected results. The results of this study show that companies using Six Sigma and Lean Manufacturing methodologies have a positive financial and operational performance compared to companies that only use Lean Manufacturing or companies that do not use Six Sigma or Lean Manufacturing. Therefore, the combination of Six Sigma and Lean manufacturing is the ideal and perfect approach for the continuous improvement of different companies.

Key words: *Six Sigma, Lean Manufacturing, SPSS, Quality Performance*

INTRODUCTION

Quality is a systematic improvement of the organization and the management of the performance, it plays a primordial role in the growth of the company in the sense of satisfy the needs and expectations of the customer. In recent years, the industrial world has experienced a progression in the field of quality because the main goal of each company is to satisfy its customers in terms of quality and cost and to have a continuous improvement of its organization, therefore all organizations seek to be competitive and evolving on a global scale in order to control costs, reduce the number of defects, reduce inefficiency, improve customer satisfaction and achieve a higher level of quality and productivity. The competition in the industrial sector forces various organizations to obtain relevant strategies to have products and services of sustainable quality and to stay ahead of this competition. Due to changing customer needs, organizations are improving the quality of their processes, In this sense, there are many approaches and methodologies used to improve the quality of the company, among these methods we cite Six Sigma (SS) and Lean Manufacturing (LM). Six Sigma and Lean Manufacturing methodologies have been proven to be relevant for problem-solving in the process and continuous improvement of organizations [1]. The purpose of this study is to analyze the quality improvement in the company following the Six Sigma approach (SS) and the concept of Lean Manufacturing (LM) in different financial and operational areas.

LITERATURE REVIEW

Six Sigma is a systematic and structured approach to improving quality, reducing defects, exceeding customer expectations, and improving process capability [2]. Six Sigma is a process improvement methodology adopted in Motorola by Bob Galvin and Bill Smith in the mid-1980's [3]. It is a process improvement methodology to improve process capability to 99.9997% [4, 5]. Six Sigma has a statistical performance goal of operating with only 3.4 defects per million opportunities [6]. It focuses on eliminating the causes of variations or defects in the business process [7]. This approach is considered a problem-solving

methodology based on statistical methods [8]. Most Fortune 500 companies have successfully used Six Sigma to improve their performance [9]. Six Sigma is used in various manufacturing industries such as automotive, textile, electronics, energy and other industries as well as service sectors such as banking, education and transportation [10]. This approch is more comprehensive than other process improvement tools such as Total Quality Management (TQM) and Internal Quality Control (IQC) [11]. This methodology is used in the manufacturing and service industries where these industries have achieved quality improvements as well as financial gains [10]. This procedure is generally known as the DMAIC method (Define, Measure, Analyze, Improve, and Control) [12, 13, 14], whose is used to identify the problem, identify the critical areas, identify the anomalies and malfunctions causing the problem, propose solutions and their implementation to eradicate or limit the causes of the problem and finally to control and evaluate the results of the implemented solutions [15].

Lean Manufacturing was created by the Toyota company in Japan in the 1940's [16]. It is interpreted as a managerial system that integrates specific techniques to reduce internal and external process variability [17]. It aims to eliminate waste in the production process and improve efficiency [18]. Lean Manufacturing is a key approach to improving the production and competitiveness of an organization [19]. The basis of Lean Manufacturing is stability and standardization [20]. It was found that companies that had implemented Lean Manufacturing have a positive impact on business performance [21] as well as financial and environmental performance [22, 23]. Lean Manufacturing is an approach that encompasses different but complementary and coherent management techniques, these are Just-In-Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM), and Human Resource Management (HRM) [24, 25]. The indirect benefits of implementing Lean Manufacturing in organizations are: Improved quality and safety, reduced traceability time, positive company culture change, and reduced fatigue and stress [26]. There are different techniques and methods of Lean Manufacturing used by companies such as 5S, SMED, Kanban, Kaizen, Poka-Yoke, and other relevant tools [27].

RESAERCH METHODOLOGY

A survey was conducted to study the impact of Six Sigma and Lean Manufacturing methodologies within Moroccan companies. This study was done by developing a questionnaire sent to different industries and companies. This questionnaire was sent by email containing the link to the survey to the different managers of the companies, the questions asked are closed and open questions in order to determine the impact of the Six Sigma and Lean Manufacturing methodologies on the performance of companies. 45 companies responded to this questionnaire divided by several sectors: 38% Automotive, 23% Textile, 9% Food, 5% Aeronautics and 25% Other areas: Health, Building and Logistics, and others. This survey is analyzed by a statistical study using SPSS software, SPSS is a very complete software allowing to realize the statistical analyses to better determine and analyze the results collected. Statistical analysis, linear regression study, Spearman's rho correlation, and ANOVA were done to study the impact of Lean Manufacturing and Six Sigma methodologies on company performance.

The criteria of this study are based on: Improvement of Quality, Improvement of Productivity, Increase Revenue and Reduction in the Rate of Waste. These are measured by a Likert scale: Very important, Important, Good, Fairly good. These criteria are grouped into two performances: financial performance and operational performance. The objective of the data collection is to compare the use of Lean Manufacturing and Six Sigma according to the success factors, to know their impacts on the performance of companies.

RELIABILITY TEST

The reliability of the questionnaire results was tested by Cronbach's alpha coefficient. This coefficient is used to evaluate the internal homogeneity of a research instrument [28, 29].

Itvaries between 0 and 1. If the coefficient is greater than 0.8, it means that the internal consistency is strong.

A non-parametric test was used to determine the normality of the distribution, it is the Kolmogorov-Smirnov test [30], this is a test of adjustment which makes it possible to determine if a distribution corresponds to a normal distribution. In addition to linear regression analysis, Spearman's rho correlation and ANOVA were done to determine the impact of Six Sigma and Lean Manufacturing on company performance.

RESULTS AND DISCUSSION

The purpose of this study is to analyze the impact of Six Sigma and Lean Manufacturing methodologies on the performance of companies, it was made by the development of the questionnaire dedicated to the managers of companies distributed as follows: 56% quality managers, 40% production manager, and 4% maintenance manager. The companies that responded to this questionnaire were divided into several sectors: 38% Automotive, 23% Textile, 9% Food, 5% Aeronautics, and 25% Other sectors. The statistical study was done to analyze the collected responses by SPSS software, so the results indicate that our study is coherent, reliable, and follows a normal distribution.

Table 1
Reliability Test Results

Reliability statistics	
Cronbach's Alpha	Cronbach's Alpha based on standardized items
.899	.927

For our study, Cronbach's alpha coefficient is 0.89, which means that the study is reliable and consistent (Table 1).

PRACTICE OF SIX SIGMA AND LEAN MANUFACTURING WITHIN COMPANIES

We have been able to know the companies using the Six Sigma method and the Lean Manufacturing methodology, according to Tables 2 and 3, we see that 82.2% of the companies use the Lean Manufacturing method, and 55.6% use Six Sigma, and based on the results, there are three different categories: 53% companies use both Six Sigma and Lean Manufacturing, 31% companies use just the Lean Manufacturing methods and 16% companies use neither Six Sigma nor Lean Manufacturing.

Table 2
The use of Six Sigma

	Frequency	Percentage
NO	20	44.4
YES	25	55.6
Total	45	100.0

Table 3
The use of Lean Manufacturing

	Frequency	Percentage
NO	8	17.8
YES	37	82.2
Total	45	100.0

Table 4 describes the relevant quality tools used in the Moroccan companies participating in this study.

Table 4
The use of quality tools

Quality tools	Numbers	Percentage
SMED	17	37.8
8D	20	44.4
Kanban	16	35.6
Poka-Yoke	16	35.6
PDCA	33	73.3
Kaizen	19	42.2
Ishikawa Diagram	29	64.4
5S	36	80
Pareto	32	71.1
QRQC	16	35.6
5 Whys	20	44.4
AMDEC	12	26.6

The PDCA, Pareto, 5S, 8D, and Ishikawa Diagram obtained the highest scores, which indicates that companies are looking for problem-solving in the process and continuous improvement of their organizations. In addition, there are other tools used by the companies participating in this study with a low score, such as Weighted Vote Methods, Total Productive Maintenance, VSM.

IMPACTS OF SIX SIGMA AND LEAN MANUFACTURING ON THE PERFORMANCE OF COMPANIES

Companies that have practiced Lean Manufacturing and Six Sigma are improved compared to other organizations resulting in the use of tools including PDCA, 8D, DMAIC, Ishikawa diagram, Poka-Yoke, Kaizen. In addition, the companies that have not reported implementing either Six Sigma or Lean Manufacturing are those that have practiced fewer tools such as 5S, Pareto, Ishikawa Diagram and have a low impact on the performance of these companies. The success criteria of this study are based on two main categories as follows: Financial performance contains the increase in revenue, operational performance contains the improvement in quality and productivity and the reduction in the rate of waste. These criteria are measured by a Likert scale: Very Important, Important, Good, and Fairly good. Figure 1 presents a general overview of the impact of Six Sigma and Lean Manufacturing methodologies on the financial and operational performance criteria of companies.

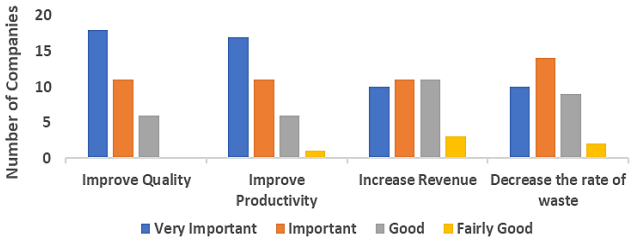

Fig. 1 The impact of Six Sigma and Lean Manufacturing on company performance

The results of linear regression, Spearman's rho correlation, and ANOVA are significant (R-two = 0.859, R = 0.927 and P value = 0.000). The results also show a significant correlation between the use of Lean Manufacturing, Six Sigma and Quality Improvement (P-value = 0.000, r = 0.770), Productivity Improvement (P-value = 0.000, r = 0.776), Turnover Increase (P-value = 0.000, r = 0.748), and Waste Rate Decrease (P-value = 0.000, r = 0.746). This means that Lean Manufacturing and Six Sigma methodologies have an important influence on the performance criteria of companies. Therefore, we can conclude that the more companies use both Six Sigma and Lean Manufacturing methodologies, the better the results and the more companies experience significant improvements in their processes.

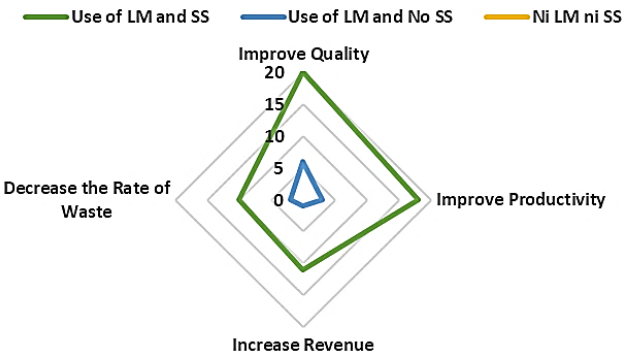

Fig. 2 Comparison of different companies in relation to the criteria for improving companies

Companies must constantly improve because if they neglect performance improvement, they risk disappearing since they no longer meet the needs and expectations of customers. Figure 2 illustrates a comparison of the

companies studied regarding the business improvement criteria (Improve Quality, Improve Productivity, Decrease the rate of waste, and Increase Revenue).
It is clear that companies using Lean Manufacturing and Six Sigma have more improvements in terms of these criteria than other companies. It is a perfect combination of these two methodologies for quality improvement within companies.

OPERATIONAL PERFORMANCE

It is found that companies using Lean Manufacturing and Six Sigma methodologies have achieved significant results on the criteria of quality and productivity improvement and reducing the rate of waste compared to companies that only use Lean Manufacturing or companies that do not use Lean Manufacturing or Six Sigma. These three Figures 3, 4 and 5 of the box plot diagrams illustrate a comparison of the different categories of firms in relation to the success criteria of the performance of the companies.

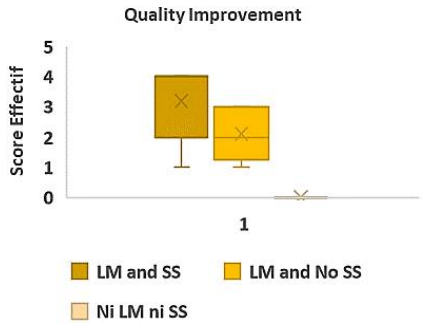

Fig. 3 Moustache Box Diagram for Quality Improvement

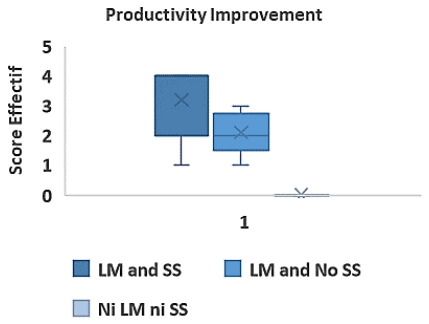

Fig. 4 Moustache Box Diagram for Productivity Improvement

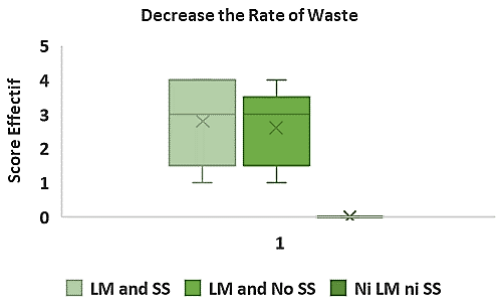

Fig. 5 Moustache box plot for Decrease the Rate of Waste

These results reveal that companies have significant performance when they use a combination of Lean Manufacturing and Six Sigma compared to companies that only use Lean Manufacturing and companies that do use neither Lean Manufacturing nor Six Sigma.

FINANCIAL PERFORMANCE

The box plot diagram shows that the use of Six Sigma and Lean Manufacturing have a positive impact on Increasing Revenue. The results present a comparison of different categories of companies, those who use both Six Sigma and Lean Manufacturing, those who just use Lean Manufacturing and others who do not use any of these methodologies. The companies using just Lean Manufacturing obtain moderate results in terms of financial performance, compared to companies using both Six Sigma and Lean Manufacturing. So, it is advantageous for companies to use Lean Manufacturing and Six Sigma to have relevant results in terms of financial performance (Figure 6).

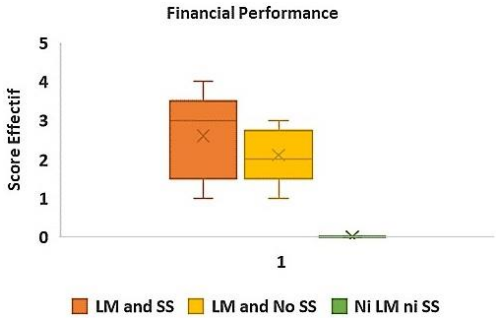

Fig. 6 Moustache Box Plot for Financial Performance

CONCLUSION

The study was made by developing a questionnaire sent to various Moroccan companies to analyze the impact of Six Sigma and Lean Manufacturing on the performance of companies. The main goal of each company is to satisfy its customers and improve the quality of its process, the results lead to the conclusion that these two methodologies make a perfect, ideal and complementary combination for the increase of the financial and the operational performance of he companies.
Companies using Six Sigma and Lean Manufacturing have achieved significant results in increased financial and operational performance resulting in improving quality, productivity, reduced waste and increased revenue compared to companies that only use Lean Manufacturing or companies that use neither Six Sigma nor Lean Manufacturing. Therfore the different companies should know that both Six Sigma and Lean Manufacturing methodologies lead to improved performance. The incorporation of these two methodologies six sigma and lean manufacturing allows to have a better production and good quality products and to satisfy the customers which is the main goal of every company in the world.
The effectiveness of the implementation of these two methodologies Lean Manufacturing and Six Sigma is revealed by an improvement in financial benefits and quality improvement. These performance results have been achieved through cost reduction, improved customer satisfaction, improved lead times, improved quality and productivity, and reduced waste. Future research must investigate and understand this perfect combination of six sigma and lean manufacturing and the success factors of this combination.

REFERENCES

[1] I. Alhuraish, C. Robledo, et A. Kobi, «A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors», *J. Clean. Prod.*, vol. 164, pp. 325-337, oct. 2017, doi: 10.1016/j.jclepro.2017.06.146.

[2] A. Trimarjoko, H. Hardi Purba, et A. Nindiani, «Management and Production Engineering Review», 2020, doi: 10.24425/MPER.2020.136118.

[3] V. Arumugam, J. Antony, et M. Kumar, «Linking learning and knowledge creation to project success in Six Sigma projects: An empirical investigation», *Int. J. Prod. Econ.*, vol. 141, n 1, pp. 388-402, janv. 2013, doi: 10.1016/j.ijpe.2012.09.003.

[4] R.G. Schroeder, K. Linderman, C. Liedtke, et A.S. Choo, «Six Sigma: Definition and underlying theory», *J. Oper. Manag.*, vol. 26, n 4, pp. 536-554, juill. 2008, doi: 10.1016/j.jom.2007.06.007.

[5] V. Gupta, R. Jain, M.L. Meena, et G.S. Dangayach, «Six-sigma application in tire-manufacturing company: a case study», *J. Ind. Eng. Int.*, vol. 14, n 3, pp. 511-520, sept. 2018, doi: 10.1007/s40092-017-0234-6.

[6] J. Wiley, «Forrest W. Breyfogle III», p. 1231.

[7] D.A. Desai, J. Antony, et M.B. Patel, «An assessment of the critical success factors for Six Sigma implementation in Indian industries», *Int. J. Product. Perform. Manag.*, vol. 61, n 4, pp. 426-444, avr. 2012, doi: 10.1108/17410401211212670.

[8] T. Pyzdek et P.A. Keller, *The Six Sigma handbook: a complete guide for green belts, black belts, and managers at all levels*. New York: McGraw-Hill Companies, 2010. Consulté le: 30 décembre 2021. [En ligne]. Disponible sur: http://accessengineeringlibrary.com/browse/six-sigma-handbook-a-complete-guide-for-green-belts-black-belts-and-managers-at-all-levels-third-edition

[9] P. Jirasukprasert, J. Arturo Garza-Reyes, V. Kumar, et M.K. Lim, «A Six Sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process», *Int. J. Lean Six Sigma*, vol. 5, n 1, pp. 2-21, févr. 2014, doi: 10.1108/IJLSS-03-2013-0020.

[10] M. Patel et D.A. Desai, «Critical review and analysis of measuring the success of Six Sigma implementation in manufacturing sector», *Int. J. Qual. Reliab. Manag.*, vol. 35, n 8, pp. 1519-1545, sept. 2018, doi: 10.1108/IJQRM-04-2017-0081.

[11] Y.H. Kwak et F.T. Anbari, «Benefits, obstacles, and future of six sigma approach», *Technovation*, vol. 26, n 5-6, pp. 708-715, mai 2006, doi: 10.1016/j.technovation.2004.10.003.

[12] L.M. Gaikwad, S.N. Teli, V.S. Majali, et U.M. Bhushi, «An Application of Six Sigma to Reduce Supplier Quality Cost», *J. Inst. Eng. India Ser. C*, vol. 97, n 1, pp. 93-107, janv. 2016, doi: 10.1007/s40032-015-0200-2.

[13] K. Linderman, R.G. Schroeder, S. Zaheer, et A.S. Choo, «Six Sigma: a goal-theoretic perspective», *J. Oper. Manag.*, vol. 21, n 2, pp. 193-203, mars 2003, doi: 10.1016/S0272-6963(02)00087-6.

[14] M. Zhang, W. Wang, T.N. Goh, et Z. He, «Comprehensive Six Sigma application: a case study», *Prod. Plan. Control*, pp. 1-16, mars 2014, doi: 10.1080/09537287.2014.891058.

[15] P. D. Sutphin, S. P. Reis, A. McKune, M. Ravanzo, S. P. Kalva, et A. K. Pillai, «Improving Inferior Vena Cava Filter Retrieval Rates with the Define, Measure, Analyze, Improve, Control Methodology», *J. Vasc. Interv. Radiol.*, vol. 26, n 4, pp. 491-498. e1, avr. 2015, doi: 10.1016/j.jvir.2014.11.030.

[16] M.L. Emiliani, «Origins of lean management in America: The role of Connecticut businesses», *J. Manag. Hist.*, vol. 12, n 2, pp. 167-184, avr. 2006, doi: 10.1108/13552520610654069.

[17] R. Shah et P.T. Ward, «Defining and developing measures of lean production», *J. Oper. Manag.*, vol. 25, n 4, pp. 785-805, juin 2007, doi: 10.1016/j.jom.2007.01.019.

[18] Y. Goshime, D. Kitaw, et K. Jilcha, «Lean manufacturing as a vehicle for improving productivity and customer satisfaction: A literature review on metals and engineering industries», *Int. J. Lean Six Sigma*, vol. 10, n 2, p. 691-714, mai 2019, doi: 10.1108/IJLSS-06-2017-0063.

[19] J. Singh, H. Singh, et G. Singh, «Productivity improvement using lean manufacturing in manufacturing industry of Northern India: A case study», *Int. J. Product. Perform. Manag.*, vol. 67, n 8, pp. 1394-1415, nov. 2018, doi: 10.1108/IJPPM-02-2017-0037.

[20] R. EL-Khalil, Z.M. Leffakis, et P.C. Hong, «Impact of improvement tools on standardization and stability goal practices: An empirical examination of US automotive firms», *J. Manuf. Technol. Manag.*, vol. 31, n 4, pp. 705-723, mars 2020, doi: 10.1108/JMTM-08-2019-0289.

[21] M.G. (Mark) Yang, P. Hong, et S.B. Modi, «Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms», *Int. J. Prod. Econ.*, vol. 129, n 2, pp. 251-261, févr. 2011, doi: 10.1016/j.ijpe.2010.10.017.

[22] M. Dieste, R. Panizzolo, J.A. Garza-Reyes, et A. Anosike, «The relationship between lean and environmental performance: Practices and measures», *J. Clean. Prod.*, vol. 224, pp. 120-131, juill. 2019, doi: 10.1016/j.jclepro.2019.03.243.

[23] M. Dieste, R. Panizzolo, et J.A. Garza-Reyes, «A systematic literature review regarding the influence of lean manufacturing on firms' financial performance», *J. Manuf. Technol. Manag.*, vol. 32, n 9, pp. 101-121, déc. 2021, doi: 10.1108/JMTM-08-2020-0304.

[24] B. Resta, S. Dotti, P. Gaiardelli, et A. Boffelli, «Lean Manufacturing and Sustainability: An Integrated View», in *Advances in Production Management Systems. Initiatives for a Sustainable World*, vol. 488, I. Nääs, O. Vendrametto, J. Mendes Reis, R.F. Gonçalves, M.T. Silva, G. von Cieminski, et D. Kiritsis, Éd. Cham: Springer International Publishing, 2016, pp. 659-666. doi: 10.1007/978-3-319-51133-7_78.

[25] R. Shah et P.T. Ward, «Lean manufacturing: context, practice bundles, and performance», *J. Oper. Manag.*, vol. 21, n 2, pp. 129-149, mars 2003, doi: 10.1016/S0272-6963(02)00108-0.

[26] S. Gupta et S.K. Jain, «A literature review of lean manufacturing», *Int. J. Manag. Sci. Eng. Manag.*, vol. 8, n 4, pp. 241-249, nov. 2013, doi: 10.1080/17509653.2013.825074.

[27] S. Nallusamy, «Lean Manufacturing Implementation in a Gear Shaft Manufacturing Company Using Value Stream Mapping», *Int. J. Eng. Res. Afr.*, vol. 21, pp. 231-237, déc. 2015, doi: 10.4028/www.scientific.net/JERA.21.231.

[26] E.C. Davenport, M.L. Davison, P.-Y. Liou, et Q.U. Love, «Reliability, Dimensionality, and Internal Consistency as Defined by Cronbach: Distinct Albeit Related Concepts: Reliability, Dimensionality, and Internal Consistency», *Educ. Meas. Issues Pract.*, vol. 34, n 4, pp. 4-9, déc. 2015, doi: 10.1111/emip.12095.

[29] R. Eisinga et B. Pelzer, «The reliability of a two-item scale: Pearson, Cronbach, or Spearman-Brown?», p. 6.

[30] T. Otsu et G. Taniguchi, «Kolmogorov-Smirnov type test for generated variables», *Econ. Lett.*, vol. 195, p. 109401, oct. 2020, doi: 10.1016/j.econlet.2020.109401.

Fatima Ezzahra Achibat (corresponding author)
ORCID ID: 0000-0002-4643-802X
Laboratory of Advanced Materials
and Process Engineering
Faculty of Sciences
Ibn Tofaïl University, PB 133-14000, Kenitra, Morocco
e-mail: fatimaezz.achibat@uit.ac.ma

Ahmed Lebkiri
ORCID ID: 0000-0003-0593-0074
Laboratory of Advanced Materials
and Process Engineering
Faculty of Sciences
Ibn Tofaïl University, PB 133-14000, Kenitra, Morocco
e-mail: ahmed.lebkiri@uit.ac.ma

El mahjoub Aouane
ORCID ID: 0000-0001-5356-2240
Laboratory Biotechnology Environment and Quality
Faculty of Sciences
IbnTofail University, PB 133-14000, Kenitra, Morocco
e-mail: aouane_mahjoub@yahoo.fr

Hanane Lougraimzi
ORCID ID: 0000-0003-1897-4340
Laboratory Biotechnology Environment and Quality
Faculty of Sciences
IbnTofail University, PB 133-14000, Kenitra, Morocco
e-mail: hanane.lougraimzi@uit.ac.ma

Nabyl Berrid
ORCID ID: 0000-0002-5195-861X
Laboratory Biotechnology Environment and Quality
Faculty of Sciences
IbnTofail University
PB 133-14000, Kenitra, Morocco
e-mail: nabyl.berrid@uit.ac.ma

Abdelaziz Maqboul
ORCID ID: 0000-0002-3575-0691
Laboratory of Animal Ecology
Faculty of Sciences
IbnTofail University, PB 133-14000, Kenitra, Morocco
e-mail: maqboul2012@gmail.com