A Maturity Model For Assessing Industrial Performance Management. Case Study: a Painting Industry

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***Abstract*—Nowadays, manufacturing industries are challenged by the mass customization needs, the increase of market competitiveness, the volatility of a globalized market and the high technological evolution. In front of these complex and multiple issues, industries must adapt to remain performant and to follow the digital transformation that the market is experiencing. This study deals with the wide topic of industrial performance management and its evolution regarding Industry 4.0 specifications. Indeed, many questions are asked in this context that concerns the "digital transformation" of the industrial system, highlighting the need of maturity models, i.e., models that could assess, as a preliminary step, the readiness of such systems to this transformation, believing that such an assessment will be the point of departure of all the potential evolution that could be allowed by Industry 4.0 tools and paradigms. The presented work will focus in particular on maturity assessment of the performance management of industrial systems. The suggested idea is to be inspired by a maturity model that is commonly used in software engineering, namely the "Capability Maturity Model Integration CMMI". In this sense, after a brief recall of the industrial performance management basis, the CMMI is introduced as well as its adaptation to the industrial performance management characteristics. A case study concerning a Moroccan SME paint company, whose submitted problem concerns the quality improvement of their product and the link between the control of the production lines and the achieved compliance rates, is then carried out. Some concluding remarks are finally proposed, regarding the relevance of the use of the CMMI, among other maturity models, and the actions to carry out for the performance management transformation.**

Keywords: Industrial Performance, Performance management systems, Maturity models, CMMI, Industry 4.0 and Moroccan SME Introduction

I. INTRODUCTION

Industries are searching for productivity and efficiency by the continuous improvement of manufacturing operations. Certainly, this process is a complex industrial activity, namely from the beginning of the post-Taylorian period, and it became necessary to manage the associated performance by defining assessment tools for achieving the industries objectives. Indeed, these tools would translate the settled strategy goals into operational objectives and would work for measuring, controlling and set the path for attain the business goals. The performance management systems and performance indicators, which are a subset of this tools and represent an extension of the productivity/efficiency ratios [1][2], has commonly dealt with cost, quality, delivery time, among many others [3][4]. Nevertheless, the industrial monitoring has currently increased its complexity as it needs to deal not only with multicriteria indicators, but also with mixed qualitative and quantitative measurements such as sustainability indicators. Performance management systems essentially a process that comprise defining the industrial/operations goals, measuring the industrial performance, creating improvement action plans, selecting the best alternative, deploying the selected action, and measuring the action achievement measurement. Indeed, this process is strongly associated with the continuous improvement philosophies, such as Deming improvement cycle or lean management [5][6], and it is a critical practice to control, pilot and achieve the outcomes of the company operations [7][8].

In recent years, there has been renewed interest of performance management systems through the changes brought by the digital transformation revolution. This revolution, named Industry 4.0 in the manufacturing or production domain, is understood as a new industrial stage in which an integration between manufacturing operations systems and cutting-edge technologies significantly improves the efficiency, productivity and adaptability of industrial operations [9]. However, researchers and practitioners have not treated performance management systems on the industry 4.0 context in much detail [4][10]. The impact of Industry 4.0 on performance management systems promises to be beneficial for industries as it will improve the agility, flexibility and adaptability of industrial operations, enabling companies to offer customized

products, respond promptly to unexpected changes, and increase operations efficiency on a continuous improvement cycle [11].

Scientific and industrial literature have developed several maturity levels in the industrial context [11][12]. Companies are currently assessing their situation towards a digital transformation, but it is still limited the assessment of maturity level of the performance management system. In fact, most studies have only focused on the assessment of maturity levels on the utilization of the technological enablers [13][14], such as automation, artificial intelligences, robotics, analytics, cyber-physical systems, among others. Therefore, although some research have been carried out, it lacks a specific approach of maturity levels for performance management on the industry 4.0 context.

Several approaches have been proposed as performance management systems for industries. These are the Balanced Score Card [15], the Integrated Performance Management System [16], the Performance Prism [17], and the Performance Pyramid [18]. These approaches consist of a set of procedures and indicators that precisely measure the performance of activities, processes and the whole organization, and is a vital aspect in regard to the management of companies. In our opinion, one of these approaches might be particularly beneficial for the industry 4.0 context. From the software engineering domain, the capability maturity model integration or CMMI is a process that helps organizations to improve productivity and efficiently in the development of products, services, and software programs [12]. Indeed, some authors have examined the potential for adapting the CMMI model as a process improvement paradigm to help decision-making and resolve any performance issue at any level of the organization [20][22]. From a general point of view, companies can implement several performance management systems adapted to their activities. However, for those who aspire to integrate the new industrial revolution, the acknowledgement of the maturity level on the industry 4.0 contact is fundamental towards digital transformation.

For these reasons, this research explores the use of the capability maturity model integration to assess the performance management of industrial systems. The methodological approach of this study was divided on three sequential phases: a) a review of critical drivers on the design of a set of performance management systems, b) the construction of a proposed performance management system adapted from the CMMI model, and c) a validation of the proposed system on a Moroccan painting industry from Morocco. This paper is organized as follows. Section 2 introduces the notion of performance management systems for industries and identifies the key drivers in the design of these performance measuring systems. Section 3 introduces the proposed performance management system, comprising specifically the maturity levels to assess the performance on the industry 4.0 context. A preliminary validation of the proposed model is presented by conducting an assessment instantiation of the ma-turity level on a painting manufacturing industry from Morocco. Finally, section 5 states the preliminary conclusions and the future work to follow this research.

II. PERFORMANCE MANAGEMENT SYSTEMS FOR THE INDUSTRIAL SECTOR

This section reviews the performance management systems to identify the scope and characteristics towards the industry 4.0 context. Undoubtedly, industries must have a performance management system in order to assure the fulfillment of the company objectives. A performance management system, also known as performance measurement control system, is defined as the management process of business activities that states a set of metrics to quantify the efficiency and effectiveness of business operations, and it states an improvement path for improving the company actions to be aligned to strategic, operations and commercial objectives [21]. It consists in cascading the company objectives into achievable goals and providing the managers with the tools for reaching the stated goals. For this paper, performance management system is considered a decision support system that aims to drive actions within the company operations to achieve a set of objectives [22][23].

The performance indicators reflect the critical success factors of the company by providing a performance management system PMS that includes quantifiable and strategic measures. To take the turn of digitalization of manufacturing, and meet their needs, in terms of definition of Performance Indicators PI [1] and implementation of Performance Measurement System PMS[10][2].
Even if performance management systems have undergone several evolutions over time, currently, they have to be adapted to the industry 4.0 concept and take into consideration new technologies allowing real-time measurements and preventive decision-making.

The requirements of digitalization force to adapt the performance management systems, imposing to have a quick and clear overview of the current situation, so as to react efficiently, one is not satisfied with measuring and controlling the performance, but rather with predicting it using new technologies [24]. The improvement of performance is currently a challenge to be overcome by organizations that aim to be more productive and agile [25]. This is certainly explained by the evolution of performance measurement and management systems. Indeed, the possession of an adequate performance management system is a lever of differentiation and competitiveness because it allows an evaluation of the effectiveness and efficiency of the actions carried out by the organization, as well as a better understanding of the progress and gains made [26]. However, even if there are many initiatives, it is often difficult to find the right way to measure the expected results in the context of Industry 4.0 [16][18].

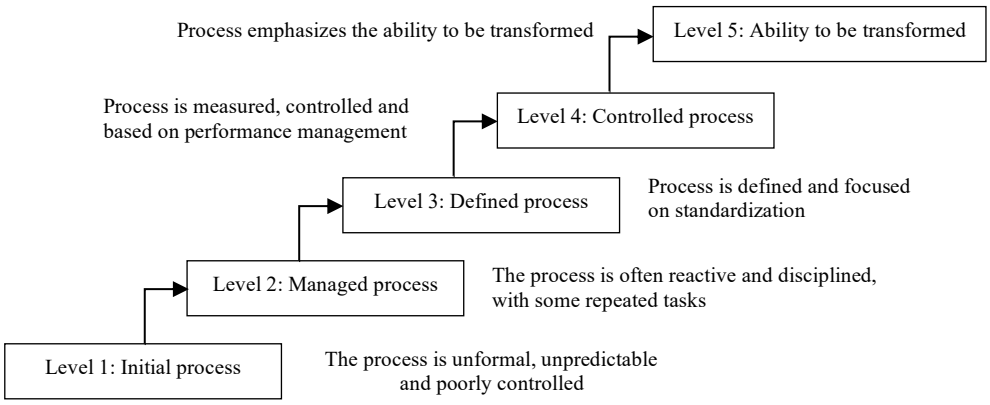

Fig. 1. maturity levels industrial performance management

III. THE CMMI MODEL FOR PERFORMANCE MANAGEMENT MATURITY ASSESSMENT:

A. Generalities:

The Capability Maturity Model Integration (CMMI), as defined by CMMI institute, is a capability improvement model, generally used in software engineering, that can be adapted to solve any performance issue at any level of the organization in any industry [19]..

The CMMI model defines the different levels of maturity of computer systems and aims to control the development processes of these systems, which guarantees the quality of the products and services resulting from these processes. Generally, we find five levels: (1) Initial; (2) Managed; (3) Defined; (4) Quantitatively Managed; and (5) Ability to be transformed.

According to ISO 9004: 2018, The maturity of an organization is defined by the effectiveness and efficiency of the functioning of the organization in order to obtain lasting performance [29][29]. Therefore, it can be considered among the means that allow to achieve industrial performance.

B. The adapted CMMI model

The adaptation of the maturity model eventually allows companies to make a de-scription of their processes, their culture and their strategies, in order to identify and operationalize the strengths and weaknesses of its system and achieve a state of attainable perfection thanks to a continuous improvement approach. The main purpose of industrial performance management is to increase the efficiency and effectiveness of an organization and provide products that meet the criteria requested by the client.

In this study, we worked with the five levels of maturity, inspired from the CMMI model proposed by CMMI Product Team [19]. The model proposes maturity levels of the industrial process which gives a global vision on the performance and shows the priorities and the center of interest of the organization.

These maturity levels are numbered from 1 to 5 (Fig. 1):

- Maturity level 1: Initial process;
- Maturity leve12: Managed process;
- Maturity level 3: Defined process;
- Maturity leve14: Controlled process;
- Maturity leve1 5: Transformed process.

1) Maturity level 1:

In this level of maturity, the company adopts an inadequately controlled production process and sometimes disorganized. While, the expertise and knowledge are restricted to one or more person over the others, what makes decision making difficult. The companies that are at this level are proficient at producing and marketing their product but, however, they lack commitment and respect for deadlines, which lead them to additional production costs and sometimes to products of minimum quality. In general, companies at this level of maturity lack efficiency and find it difficult to manage performance because there is no exact operational strategy.

2) Maturity level 2

This maturity level is characterized by a good management level with monitoring of costs, deadlines and functionality. A well-qualified staff having adequate knowledge and resources are involved. Yet a process of monitoring, control and evaluation of pre-defined practices. Pilots have the main responsibility of managing and adapting the industrial performance management system to meet customer requirements. The operational objectives are represented globally by non-standardized indicators allowing to control the industrial performance.

3) Maturity level 3

In a level of maturity 3, the production process is accurately described in internal standards or references. Thus, the company is strategically managed and takes into account risks, the instructions and enhancing process are precisely pre-defined. the industrial performance indicators are well defined, standardized and presented in the form of a dashboard, which

provides better visibility to employees. In contrary to the level 2, the leaders are not the major responsible. However, the employees are continuously trained, and they are aware of their responsibilities and duties towards industrial performance.

4) Maturity level 4

This level of maturity is characterized by a quantitative management based on a statistical collection and analysis of the industrial performance data. That allows for predicting of the productivity, adjusting the process in advance, and applying quality improvement measures for a better industrial performance.

5) Maturity level 5

The companies adopt a proactive, opportunistically, and innovative management based on a continuous improvement process. The productivity and quality are both the priorities of the companies. They are interested in the overall performance of the organization while using innovation and research as a source of differentiation.

The organization is particularly interested in solutions based on research and innovation in industrial performance management to anticipate unforeseen changes and customer expectations, it monitors advanced technological innovations and developments in the market or among competitors, and defines their ability to take on the digital transformation to become a smart factory.

Each level of maturity is defined by specific characteristics (**Table *1***) and limits, which allows the organization to position itself and implement an action plan to move to a higher level of maturity.

An increase in maturity levels can be achieved by relying on self-assessments of industrial performance management systems. The process is mainly made by exploiting quantitative and qualitative data, which promises mature decision-making

Table 1. Characteristics of the process of performance management system in function of maturity levels

Levels	Definition	Characteristics
Level 1	Initial	– The efficiency of the process is necessarily measurable – Quality objectives are specific and represent the strategic vision – Management techniques are often implemented and drive the process – The profile of the employees is in line with the responsibilities entrusted
Level 2	Defined	– Customer needs and requirements are taken into account and reviewed during the production phase so that the performance of the production tool is improved and sustained – The quality management system is defined by production managers based on the needs of customers and demonstrates a certain efficiency – The functioning of the manufacturing process is defined in a formalized manner – The quality and performance objectives are consistent with the aims of the organization
Level 3	Managed	– Ability to adapt to unforeseen changes is possible but not always – Problem solving is made by effectives methods and allow to capitalize the experience – The management techniques used demonstrate repetitive success and can be reused and improvement plans are institutional – Quantitative techniques monitor the manufacturing process
Level 4	Quantitatively controlled	– The operation of the process is optimized and reviewed regularly – Measurements are made to detect anomalies that could affect the process's ability to achieve performance – The quality and performance of the manufacturing process are analysed statistically – Goals for quality and performance in manufacturing processes exceeded
Level 5	Able to be transformed	– Integration of advanced technologies in the majority of operations – Ability to take on the digital transformation and become a smart factory – All process employees, from all hierarchical levels, are involved and integrated into performance management – Corrective actions for anomalies are planned, taking into account the impact of unforeseen changes on the performance of the production process and efficiency measures are carried out.

IV. THE PAINT COMPANY CASE

A. Context :

The considered case study takes place in a chemical paint plant, multinational leader in its sector of activity and installed in the Moroccan market since 1994.

The current situation of Moroccans industries is marked at the same time by the invasion of digital platforms, the increase of competitiveness and the instability of the markets. In front of these complex and multiple constraints, Moroccan SMEs, in particular, find themselves lost between improving industrial performance and continuing the digital evolution. Moroccan industry have started to give more importance to the Industrial

Revolution that the whole world is experiencing [30]. The Industrial Acceleration Plan established by the Moroccan Ministry of Industry, Trade and the Green and Digital Economy plans to integrate Moroccan industry at the heart of technological transformations, and affirms that Industry 4.0 is an exceptional opportunity to be seized by Morocco to access a new level of development [31][32]. However, according to the Organization for Economic Cooperation and Development (OECD) observations, Moroccan industries, and SMEs in particular, are currently suffering from problems related to the organization, competitiveness and performance management of production systems which is translated by a kind of unreadiness to face the invasion of new technologies, the development of smart products and services, lading thus to the immaturity of the actions taken in this sense [33][34].

In our study, the manufacturing process of Polyvinyl Acetate, which is used in fast drying paints or as an adhesive in solution in various solvents, has been chosen, because according to factory managers, this process is characterized by an increased rate of non-compliance. The objective is to apply our maturity assessment model according to pre-established criteria, in order to define the level of maturity of the Polyvinyl Acetate production process and subsequently make proposals to improve its degree of maturity.

B. Maturity assessment criteria

The adapted CMMI model takes into account industrial performance criteria, as it is presented at **Table *2*Erreur ! Source du renvoi introuvable.**. To verify the suitability of these criteria in our case study, interviews were carried out with plant managers. The choice of interviewees is based on their level of decision-making and their experience in managing industrial performance.

The imposed criteria constitute a performance lever for our studied factory and prove to be complementary, since they affect all the processes related to industrial performance. To move from a lower level of maturity to a higher one, the piloting process must meet the corresponding criterion. For each level of maturity, we have set a criterion (**Table *2***).

Table 2. Criteria for each maturity level

Maturity level	Criteria
Maturity level 1	C1: Management involvement and strategic vision
Maturity level 2	C2: Customer orientation and filling the need
Maturity level 3	C3: Risk management and adaptations to change
Maturity level 4	C4: Optimization of action plans, measurement and control systems
Maturity level 5	C5: Integration of new technologies to assist in performance management

For maturity level 1, we have set the criterion "C1: Management involvement and strategic vision". In a production industry, it is normal for management to demonstrate its involvement in the performance management system. This involvement is characterized by support for the quality approach, marked by the appointment of process pilots and the monitoring of action plans according to the company's strategic vision. The responsibility of process pilots, the development of customer culture and operating procedures are implemented and respected in order to ensure governance of the processes.

The criterion imposed for level of maturity 2 is "C2: customer orientation and filling the need". At this level, the company adapts its industrial performance management system to meet or even anticipate the needs of customers and stakeholders and / or interested parties. Customer needs, in terms of production quality, are exploited as a source of innovation and differentiation, they are taken into account during the implementation of the industrial strategy, converted into requirements, respected during production, and help to meet customer expectations. The degree of satisfaction is measured and customer complaints are identified.

The criterion defined for maturity level 3 is "C3: risk management and adaptations to change". Industries at this level manage to control the risks linked to production and performance management, risk governance is integrated into the performance management system, it makes it possible to benchmark, control and manage risks. Corrective actions are planned whenever necessary, taking into account the impact of unforeseen changes on the industrial performance management system and the production process, when the latter does not go as planned and does not achieve the expected results.

For maturity level 4, we applied the criterion "C4: the optimization of action plans and measurement and control systems". Managers rely on quantitative and statistical steering techniques to detect anomalies and malfunctions in the process and assume decision-making. A performance management information system is put in place, thus making it possible to control the functioning of the processes and to set down the improvement objectives by relevant indicators which are measured and measurable.

The criterion imposed at level 5 of maturity is "C5: Integration of new technologies to assist in performance management". The company is focused on continuous improvement and demonstrates its leadership in terms of innovation and research. Industrial performance management is done proactively, always seeking to improve efficiency by integrating advanced technologies to assist in industrial performance, in order to reach strategic objectives in advance. All actors are collaborated and integrated in the continuous improvement process, which ensures incremental progress in industrial performance.

V. DISCUSSION

A survey was carried out with plant managers for validating our model. To meet a criterion, the process to be studied must

justify a complete, documented, available and shared approach. The findings of our diagnostic show that the vinyl production process exceeds the two criteria 1 and 2 and is positioned in the level of maturity 3 of industrial performance management.

The directors and managers implement an approach which makes it possible to control and master the risks exposing the process. Corrective actions are planned whenever necessary, taking into account the impact of anomalies on the industrial performance management system and the production process, when the latter does not go as planned and does not achieve the expected results.

The performance management system formalizes strategic decisions and controls operational decisions. Its purpose is to align the company's operational strategy. In this sense, it seems interesting to evaluate the maturity of the PMS, to define their adaptability in the context of industry 4.0, to support companies in their digital transformation.

Industrial performance management systems are considered among the decision support tools, which include performance indicators presented in the form of a dashboard, thus allowing managers to react better. The objective is to quickly analyze and verify a set of information at a given moment, taking into consideration related elements, in order to propose the most relevant solution. In the context of Industry 4.0, the decision-making process is supported by artificial intelligence, which is the next IT revolution for companies. It impacts its functioning, its organization and its teams, but more globally its governance.

VI. Conclusion

This work was carried out as an initiative to encourage SMEs to embark on the process of digitalization and smart manufacturing by taking into account the improvement of industrial performance. Our industrial performance management maturity assessment model has enabled us to position the studied process according to several pre-established criteria which correspond to maturity levels, and subsequently to propose a tool to help in taking decisions, that allows to collect all the necessary data and provide managers with useful information for effective decision-making. Our next contribution will attempt to integrate this system into all production processes and to provide a complete tool that exploits new technologies as solutions for improving industrial performance.

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