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Organizational knowledge in the I4.0 using BPMN: a case study

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Abstract

In the context of industry 4.0, management of knowledge represents a real challenge, since the tacit knowledge acquired by the expert operators is not transferred quickly and easily to newly arrived operators. This sharing of knowledge could help in the faster adaptation of humans to workstations and could bring the more agile accommodation of artificial intelligence techniques to allow the self-learning. The Business Process Management (BPM) is a technique which enables the representation and analysis of processes, has been already mention in the literature as a useful tool that can facilitate the Knowledge Management. A process repository can be accomplished with BPM, thus promoting agile and fast knowledge transfer in a context where new skills emerge and must be quickly taken up. This paper intends to show the development of the working instructions maps, with workers' tacit knowledge, using the BPMN 2.0, in a chemical industry. This representation allowed the creation of a knowledge's repository which will help the company (in a I4.0 environment) to deal with the most existing workforce rotation, thus preserving most of the knowledge within the company itself.

Keywords: Knowledge Management; Industry 4.0; Business Process Management; BPMN 2.0; Organizational Knowledge

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1. Introduction

Nowadays, Industry 4.0 (I4.0) pretends to allow "smart decisions" for managing disruptive events via decentralized production control [1].

The management of knowledge is one of the achieve challenges of the industry, mainly in the context of industry 4.0. Expert operators acquire valuable knowledge about the manufacturing processes and the transference of this knowledge to new operators is a difficulty process in companies. This happens since this transference is sometimes not efficient or even does not take place, endangering the future of organizations [2].

Business Process Management emerges as a management discipline with the purpose of build a process-centric thinking [3]. Business process models can be useful to assess the limitations of current processes, while representing an As-Is model (that is a snapshot of the present process), and after a careful analysis, while representing a To-Be model (representation of the business flows that is intended to achieve). The Business process management as well as business process models can have an important role in knowledge management, since they can convert the informal knowledge of processes to formal knowledge [4, 5].

One of the tools that has been considered to be crucial for modelling business processes is the Business Process Model and Notation (BPMN) [6, 7].

Industry 4.0 has is core in implementing technologies which enable the creation of Cyber Physical Systems (CPS) [8]. This new context requires more flexibility and agility to meet customer needs. To achieve these both requirements companies will need faster decision-making processes and production systems self-adjusting and self-optimized [9]. This way, information and knowledge will have to move through the company more quickly. However, as already mentioned in Haldin-Herrgard [10], in organizations, knowledge resources have significantly been labelled as an iceberg, where the explicit knowledge is the observable top of the iceberg, and below the surface (where there is a significant part of this phenomenon), it is assumed that remains the tacit knowledge.

Therefore, it is essential to capture the tacit knowledge and place it in the smallest possible portion in relation to the explicit, in order to the company does not lose organisational knowledge when its employees leave. As cited in Jerman [11], "You do not only gain competence through formal education but also through life-long learning", and many organizations realize the promotion of competencies as the key to developing competitive advantage, having the same time an upgrading in company's performance, promoting knowledge at all organization's levels.

Currently, the loss of skills due to the turnover of the workforce is something to be avoided by companies, since the creation of value in industry 4.0 can be profitably achieved through the adoption of technologies that end up placing human beings at the centre of the innovation process [12].

The goal of this paper is to take advantage of business process models to represent the knowledge associated with the tasks of operators on the shop floor of an organization belonging to the chemical industry, thus transforming the tacit knowledge of these employees in explicit knowledge (creating a knowledge repository). Furthermore, through the analysis of these models we will be able to identify gaps and weaknesses in the enterprise 'processes. The Business Process Model and Notation (BPMN 2.0) is applied in this paper to promote the integration between organizational knowledge and business process management.

The present article is structured as follows: in the second section there is a literature review, where concepts such as knowledge management, business process management, BPMN and industry 4.0 are specified. Then, in the third section the case study is shown, where the context of the problem, methodology, results and discussion of them are presented. Finally, the conclusion intends to summarize the relationship between the concepts explained by the academy's analysis and the results taken in practice, in order to raise the need to apply the BPMN language to the manufacturing floor and how much it can favour the organizational knowledge.

2. Theoretical Background

2.1 Knowledge Management

The combination of data and information to which is added expert opinion, skills and experience is called knowledge [13]. It may be explicit or tacit, the latter being associated with the minds of knowledge holders, and therefore difficult to communicate, share and put into a document or database [13, 14]. On the other side the explicit one is typically

structured and retrievable, and should often being in repositories, embedded in documents, organizational routines, processes, practices and norms [4, 5, 13, 14].

As cited in Ebrahimi, Ibrahim, Razak, Hussin, & Sedera [15], an organization's competitiveness depends on its specialized knowledge, its diversity and the way it is integrated effectively in the company. Rules and directives, routines and self-managing teams are the mechanisms for integrating knowledge, and the last one (self-managing teams) is the most adequate for integration of knowledge for non-routine and complex organizational tasks that include uncertainty and novelty. Knowledge is a vital resource for obtaining competitive advantage, converted into quality improvement and more efficient business processes [16].

Knowledge management is as a strategy of getting the right knowledge to the right people at the right time, facilitating sharing of information between people, putting it at the same time into action providing the organizational performance improvement [5]. Its lifecycle has four core tasks, knowledge creation, knowledge storage/codification, knowledge transfer/distribution and knowledge application [17, 18]. Knowledge must be transferred or shared to have a wide organizational impact, representing the knowledge embedded in the organization's processes one of the main components of knowledge management (having for that a process oriented perspective) [18–20].

Nowadays, KM is one of the biggest challenges for organizations. For small and medium enterprises (SMEs), this practical is more important because they usually cannot afford the investment needed to achieve a credible business value from knowledge management. This group of enterprises end with erosion of knowledge due to the leaving of key employees [18].

2.2 Business Process Management and Business Model and BPMN

According to [21] "Business Process Management (BPM) is valued as a means to gain and sustain competitive advantage", since this methodology allows companies a faster organizational adaptation to the continuously changing requirements of the market and its customers, enabling development and continuous improvement of corporate strategies [22, 23].

BPM is also a subject that is strongly tailored to the modelling of organizational processes and the subsequent implementation of process models in executable software [24]. From a lifecycle point of view, this subject includes activities such as "identification, definition, modelling, implementation, execution, monitoring, control and improvement of processes" [25]. It promotes cross-functional processes synchronization and facilitates companies to focus on what is believed value from the customer's perspective [26].

The BPMN is already the de-facto and widely accepted standard language among others for most business experts to model processes [7, 27]. It offers the advantages of a graphical language, simplicity, standardization and provision for execution processes [27, 28]. Besides, it is capable of unify the way business analysts and technical developers see process models [3, 6].

2.3 Industry 4.0 and Organizational Knowledge

The emergence of new technologies such as cloud computing, Internet of Things, Cyber Physical Systems (CPS) and Big Data is encompassed by the concept of Industry 4.0 [29]. These new tendencies have their role in improving the transmission of information throughout the entire system [30]. Therefore, the Industry 4.0 'execution system' is based on the interrelations between CPS building blocks. This kind of blocks can be seen as embedded systems with decentralized control and advanced connectivity [31].

In the growing of Industry 4.0 environment it is perceived that there is a lack of knowledge sharing, control on data management practices, as well as lack of understanding of how companies should integrate 4.0 technologies, in order to improve the workflow in businesses [32].

This transition in the industrial sector establishes new challenges and requirements to the knowledge management in enterprises. Smart factories can enjoy, from knowledge management systems, the possibility of implementing and organizing newly value creation networks more efficiently and successfully. Beyond that, these systems support the unification of these networks within internal manufacturing processes and resources [33].

In any organization, individuals draw and behave according to a corpus of generalizations that are summarized in own experiences, specific knowledge, procedures and routines, and this is called the organizational knowledge [34].

Some companies promote the development of organizational learning (OL) capabilities and this influences knowledge, beliefs and behaviours within the organization which allow business growth and innovation. In the literature appear that OL can occur based upon trial and error situations or consists of work procedures and routines established from stored knowledge in organization's memory employed in successive situations like those that initially offered the experience [35, 36]. If I4.0 allows a faster and richer understanding about products, processes and services, the OL development may be expected to have their learning and information sharing catalysed by 4.0 technologies [36]. The adoption of Cyber-Physical Systems (CPS) dominates the I4.0 context and aims at increasing the flexibility and adaptability of production system, although the human factor must be considered [37].

The operator of the future, already mentioned on the literature as Operator 4.0, will have to have news skills related to KM. In order to aid humans at workplaces, the dissemination of information and knowledge becomes important and this dissemination is has to be with and among operators and managers [38, 39]. It is also essential assure that information reaches its target in a way that is perceivable by the end user, helping him to perform its operations and make decisions [37, 39].

ICTs will accelerate the collection, storage and retrieval of knowledge, however they still strive to express the so called tacit knowledge [40, 41]. In fact, ICT is a key element in knowledge management, since it is capable of integrate fragmented knowledge, eliminating at the same time barriers to communication within the organization. Therefore, ICT-support can improve work and businesses efficiency, which will allow the increase of overall organization's performance [42]. However, in order to integrate knowledge in ICT, in a paradigm of rapid knowledge change such as that characterizing I4.0, it is important to ensure the mapping of work instructions, as well as the management of these processes. It is also essential to establish new points of connection between the human operators and the digital systems in manufacturing, in the sense of providing them with technical information or updating production databases with information concerning the status of production. It is believed that the operator's productivity will be stimulated by the increased flexibility of the workplace and the ability to more easily learn [37].

3 Case Study

3.1 Problem contextualization, objectives and methodology

This case study has its main goal in showing how organizational knowledge can be obtained and facilitated using for that the representation of the working instructions through the BPMN 2.0. The company where the case was developed produces flush toilets. The production area is the core task, with about 80% of the employees working there (a total of about 400 employees) in two distinguished areas: injection and assembly areas. The injection area works almost only with injection moulding machines and the main actors that intervene in this section are the *Injection Operator*, *Injection Technician*, *Logistics*, *Injection Team Leader*, *Quality*, *Planning* and *Maintenance.* The assembly area is mostly stocked by injection area, being that there are isolated manufacturing cells and others that are in stream with injection machines.

For all manufacturing cells there are standard processes, notably for filling OEE sheets, which aim to check cell and operator efficiency, the declaration process of productions in the company's ERP (IS transversal to all the departments) and how to proceed when downtime results from malfunctions, shortages or even non-conformities. The Kanban (a card that assures the supply of parts to the production line as needed, increasing efficiency) is used in this side of the enterprise and lean tools here implemented, such as sequencing, batching and levelling boards. These instruments work similarly to any cell. Here the main actors in the processes are the *Assembly Operator, Mizusumashi Operator, Supplier, Assembly Team Leader, Area Manager, Planning* and *Logistics Team Leader*.

This paper presents a shop floor tasks' mapping repository (of the main figures evidenced above), using the concepts of BPM and BPMN 2.0. This repository aims at knowledge management in an unstable environment that characterizes the I4.0 environment, since it will make available know-how to manage the rotation of the workforce of employees, preserving knowledge inside doors, without losing it with the departure of key workers.

Having in account the Business Process Management life cycle described by [43], the strategy that was followed is settled in the three first stages, Process Identification (PI), Process Discovery (PD) and Process Analysis (PA). In the first phase –PI – the most relevant processes are identified. The second phase, in the PD, detailed about processes are identified and documented through the AS-IS Models (using BPMN 2.0). In the third one, the main problems are

identified and analysed and subsequently the TO-BE models are mapped.

3.2 Results and Discussion

As mentioned, the aim of this work is to map the working instructions normally present in workers' tacit knowledge and therefore knowledge which is difficult to transmit, causing organisational problems, in particular loss of knowledge when workers rotate or leave from the organisation. In short, it is intended to convert tacit knowledge using by workers in the execution of different tasks in a company's shop floor into explicit knowledge, by usage of BPM concepts.

As can be observed in Figure 1, in the injection area the process initiates with the execution of the Daily Mold Change Plan. The *Injection Technician* has in his power the injection moulding machine monitoring through Andon lights, the box supply for parts coming out of injection machines and the mold change preparation and assistance. Furthermore, the operator controls the parts quality, dimensionally and functionally. The *Injection Technician* solves malfunctions that can happen in injection machines and carries out mold changes. The *Injection Team leader* is a point of contact with other entities like the maintenance technician, the planning and the quality. He solves some problems that the Operator cannot solve and furthermore he opens work orders in the company' Enterprise Resource Planning to Maintenance.

Given the limited space, in this work only the maps related to the work of the *Injection Technician* (Fig. 1) and the *Assembly Operator* (Fig. 2) will be explained and graphically explained.

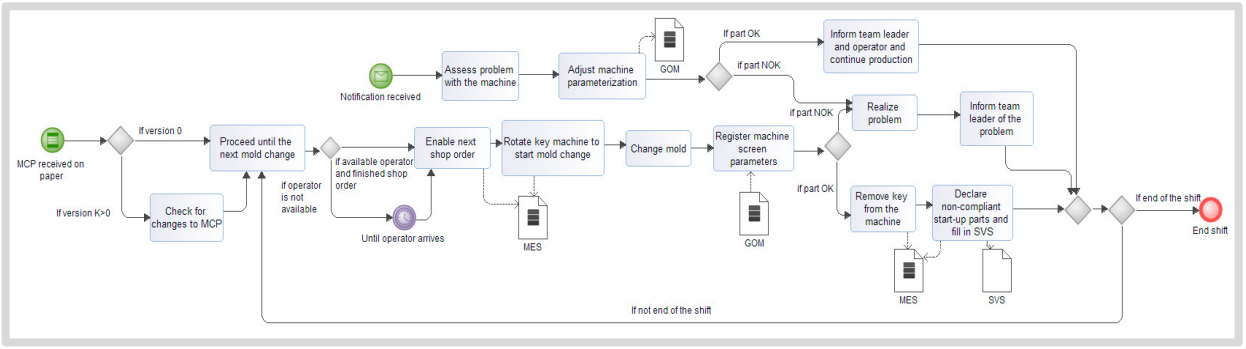

Figure 1- Map of working instructions of Injection Technician based on BPMN 2.0.

As shown in figure 2, in the assembly area the operator must, in addition to assembling the different components, fill in the OEE sheet, inform the team leader whenever something goes wrong (e.g. device breakdown), record production and at the end of the shift ensure the execution of the 5 S's. On the other side, the *Assembly Team Leader* is the person who update the Daily Kaizen Board Indicators as well as the allocation of operators by workstations.

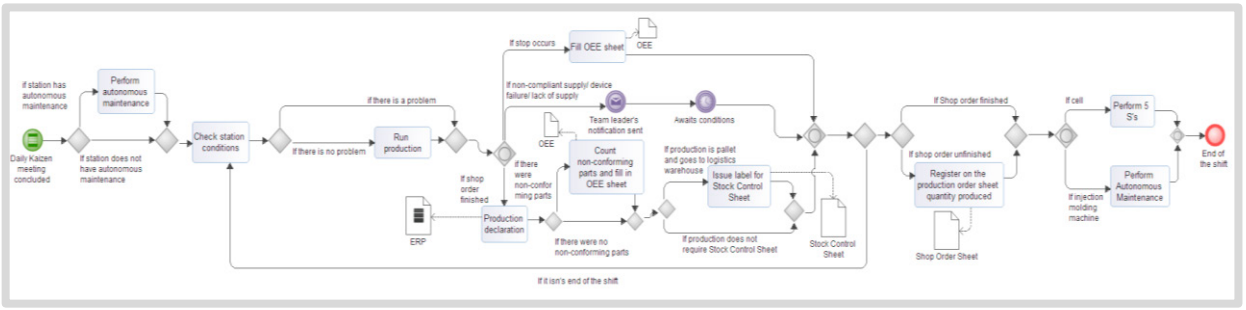

Figure 2- Map of working instructions of Assembly Operator based on BPMN 2.0.

This person must also monitor the working rate of each cell allocated to them and audit them according to safety

rules. It also controls the supply by *Mizusumashi* by placing the so-called query's in the levelling frames. And in this area, it is this person who opens work orders in the event of malfunctions in machines or mounting devices to maintenance. The *Mizusumashi Operator* is guided by the query's placed by the team leaders on the levelling board. It has its own supermarket where it supplies itself and then supplies the line edges of the cells that belong to it. Between the *Mizusumashi Operator* and the assembly operator there is always communication whenever there is supply in the cell so that the Mizusumashi knows what needs to be supplied and in what quantity. It is also this operator who executes the batch construction framework that controls what should be and when it should be removed from logistics by the logistics *Supplier Operator*. It is only at the end of the shift that the *Mizusumashi Operator* tends to write off consumables on the ERP by executing it by scanning the query's barcodes. Lastly, The *Supplier Operator* has three main tasks, supply the Mizu's supermarkets, collect finished product pallets and empty boxes pallets.

During the analysis of the tasks performed in the two main areas of the company, some problems were identified: (i) performing redundant tasks; (ii) lack of communication between systems; (iii) manual records (high paper traffic); (iv) outdated information in the computer system; and (v) low level of real-time machine state interpretation.

The understanding of business processes is claimed in academia as the survival of the organization and currently, the business process modelling is a fundamental part of many companies, since document and redesign complicated organizational processes [23]. Regarding the KM, the essential goal of this practice is to transform implicit or tacit knowledge into an explicit one (representing in a formal way). Besides, after this representation, the distribution throughout the organization is a target, contributing to enterprise knowledge availability and re-usability, building internalized pragmatic expertise [19]. In fact, the representation of tacit knowledge through process maps using BPMN in this work, as well as the subsequent analysis to identify potential sources of waste, has not only made it explicit and more easily transmissible, but has also boosted the creation of a repository of useful knowledge when moving or leaving employees. The amalgamation of KM into business processes has become a potential feasible and theoretical task in KM [23] and BPM is capable to offer procedures for "knowledge capturing, externalization, formalization, structuring and re-use" [19].

Cyber-physical systems have been predicted as facilitators of knowledge services in smart systems [16], since they are constituted by digital technologies which are able to create and share knowledge [41]. These technologies offer connectivity among activities and stakeholders at all levels, creating an enterprise integration

When a company implement a KM practices, a main subject having into account is how this KM assist the accomplishment of organization's goals. In that way, the alignment between the KM strategy and the business strategy is essential [44].

Although, a whole work must be done in capturing what is already in people's minds, and a collaborator strategy needs to be aligned. In smart factory complex system the human element is an often forgotten piece [11], although the I4.0 paradigm brings the obligation to educate collaborators with new curricula in order to cope with the growing necessities of the factories of the future [12].

The Operator 4.0 must have access to information and knowledge, in an effort to make decisions, learn faster new tasks or just to monitor the current operational state [39]. A knowledge cycle must be created in enterprises, where all begins in capturing tacit knowledge that could be stimulated by the sharing of formalized and documented knowledge (explicit).

4 Final Remarks and Future Work

The Business Process Modelling is a crucial tool to represent and to analyse processes in an organization's environment. The resulting maps allow the visualization of connections between processes and systems which helps to identify gaps and think which processes should be automatized.

In this paper the BPMN 2.0 was used to represent human tasks in an organization in order to achieve an organizational knowledge repository. It was concluded that almost the entire shop floor is excessively dependent on the human hand and that the processes are nonetheless very manual. Considering the information systems that the company has, it stands out as a suggestion of future work, the modelling of these same systems and their updating in order to contemplate the processes highlighted in this paper. Only after a good process stabilization in the factory MES is there, as a second suggestion of future work, a feasibility analysis of the introduction of AI techniques that consider Process Mining.

Moreover, even though the existing business process modelling tools support the modelling and execution of

business processes, they lack some assistance in knowledge dimension, having some authors that have already proposed extensions to the language (BPMN 2.0) for this purpose [23].

There are some issues making difficult to transfer and share of knowledge, such as the struggle for operators in putting their knowledge into words, the absence of standardization to capture and document knowledge, the considered extreme time recognized by employees to spend on documentation and, above all and most importantly, the use by workers of their knowledge as a guarantee to remain relevant and indispensable in their workplace [45].

From a knowledge point of view, process orientation is vital to deliver task appropriate knowledge in the organization's operational business processes context [20]. Furthermore, knowledge is broadly well-known for being the enhancer of long-term growth, development and existence of competitiveness in any enterprise. And nowadays, there is a great amount of information and knowledge that is extremely valuable and is not made externalized or formalized, resulting in not being used by other individuals and sometimes it can even be lost for the enterprise [19].

To conclude Business Process Modelling can be applied in order to establish the knowledge management in a company. Furthermore, it also serves as a tool to study all the gaps in the enterprise's processes. With the perception of these gaps BPM can help improving organization's industry 4.0 environment, as well as to facilitate the acquisition and transfer of knowledge. Although it is important reveal the difficulty in applying changes in organization's processes. The documentation of these processes it is important in order to facilitate people adaptation to workstations. Knowledge management can mitigate the revolt to change felt by people in general by creating a more transparent and balanced climate in which everyone can know everything.

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