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SECI Model Combined with ISO 9001 2015 to Support Organizational KM for Manual Assembly Manufacturing Operations

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ABSTRACT

In a large number of industrial sectors, manual assembly manufacturing operations highly engage tacit knowledge at an individual level. Companies in these sectors need to effectively manage organizational knowledge since it represents a real performance and sustainability lever. Although knowledge management (KM) specialists developed several models, these latter remain difficult to implement due to several barriers and limitations related to industrial reality and models ambiguity. This paper proposes an organizational knowledge management (OKM) framework for manual assembly manufacturing operations that is based on ISO 9001:2015 and SECI conversion cycle. This framework offers guidance for implementing a KM approach within the quality management system (QMS) allows to manage knowledge differently with regards to its tacitness level and overcomes many of the most common KM limitations. An experimental application based on a single case research design in an aeronautical assembly company is conducted to confirm the applicability and effectiveness of the framework suggested.

KEYWORDS

Explicit Knowledge, ISO 9001:2015, KM Barriers, KM Implementation, Manual Assembly Manufacturing Operations, Oragnizational Knowledge Management, SECI Cycle, Tacit Knowledge

INTRODUCTION

Assembly activities can be complex tasks that have manual operation processes. They develop and require a lot of expertise at the individual level. This accumulated expertise is knowledge that any company needs to convert from an individual to an organizational level. A company that loses its knowledge has little chance to register for performance and sustainability (Bibi et al., 2020; Zaim et al., 2019). The process that allows this conversion is called OKM.

Krafcik (1988) analyzed performance indicators at world auto assembly plants and admitted that an "experienced, well-trained, and well-educated workforce can be expected to perform at a higher level of efficiency" (Krafcik, 1988). Piotr Tworek (2011) conducted a study to analyze risk factors in the activities of large construction and assembly companies (Tworek, 2011). The study ranks

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employees' qualifications and experience in the eight main risk factors that construction and assembly companies may consider to master their activities. An analysis of the automation assembly industry in Japan stated that adapting to an aging workforce is the fifth objective of assembly automation (Fujimoto, 1992). Assembly companies have difficulties replacing senior, experimented workers. This may reveal that there is a difficulty in ensuring knowledge capture and transfer.

The OKM is not an easy task in the assembly field regarding the form of the knowledge concerned. While several studies confirm the close relationship between knowledge management, performance, and sustainability of companies (Nguyen & Prentice, 2020; López-Cabarcos et al., 2019; López-Torres et al., 2019; Rasula et al., 2012; Zack et al., 2009; Aaron, 2009; Darroch, 2005), others reveal the complexity of this process in the assembly field (Gavish et al., 2011; Gutierrez et al., 2010).

An interesting study states that industrial maintenance and assembly tasks "involve the knowledge of specific procedures and techniques for each machine" (Gutierrez et al., 2010). These techniques require cognitive memory and expertise to master "precise movements and forces" (Gutierrez et al., 2010). This technical description matches the definition that Nonaka and Takeuchi gave to tacit knowledge (Nonaka & Takeuchi, 1995).

Indeed, there are two forms of knowledge; tacit knowledge that refers to knowledge that resides in the human mind, behavior, experience, expertise, and perception; and explicit knowledge that can be readily articulated, codified, stored, and accessed on manuals, documents, procedures, videos, etc. (Nonaka & Takeuchi, 1995). The knowledge management approach can only be effective if it takes into account both forms of knowledge (Goh, 2002).

Tacit knowledge is the most difficult to manage in all sectors (Muthuveloo et al., 2017; Gubbins et al., 2012; Argote & Ingram, 2000; Nonaka & Toyama, 2015) and particularly in the assembly sector. The biggest challenge concerning this form of knowledge is the capture and sharing of knowledge (Agrawal & Mukti, 2020; Grant, 1996). While, this form of knowledge needs to be formalized and converted into words, numbers, or pictures that can be understood by others (Iqbal, 2017); it can be difficult in manual assembly to express, for example, the experience, manual dexterity, and cutting precision. Importing the tacitness of manual tasks to an organization is a real competitive advantage (Grant, 1996). Performance of assembly companies strongly depends on the organizational knowledge they develop (Gutierrez et al., 2010). The relationship between KM especially tacit KM and performance is no longer to be proven (Muthuveloo et al., 2017; Sousa, 2017).

Several studies observed one or some topics of knowledge management process in the field of maintenance and assembly (Parenmark et al., 1988; Ruiz et al., 2014; Webel et al., 2011; Yuviler-Gavish et al., 2013). Most of them were interested in training as a useful tool to share knowledge. Others looked for systems to capture knowledge through new information and communication technologies. Many systems are currently used to capture and transfer some parts of tacit knowledge like instruction manuals, diagrams, video tutorials, virtual or augmented reality, and many other tools (Westerfield et al., 2013). All these works deal with some aspects of knowledge management and not the whole process.

The literature in the field of knowledge management offers general models which are built in several stages, slightly different from each other (Heisig, 2009). Errors and omissions excepted, no study proposes a complete framework of organizational knowledge management specific to assembly activities.

No study counters the application of these general models for assembly operations, but a large number of these models face many difficulties when implementing KM actions (Agrawal & Mukti, 2020; Hong et al., 2011; Singh & Kant, 2008; Damodaran & Olphert, 2000) and some activities of KM process interact closely with other processes, such as Organizational Learning and Organizational Memory, which can be confusing for some organizations (Vasanthapriyan, 2022; Al Saifi, 2019; Jennex & Olfman, 2002).

Further more, Jennex claims that there are a lack of studies that focus on shifting the discussion from KM theory to practical implementation for organizational performance (Jennex, 2005). In addition, the SECI model has not seen much development that explains how it works (Patriotta, 2004) or that proposes tools for operationalizing its four modes (Irma Becerra-Fernandez, 2001;

Lee & Choi, 2003; Nonaka et al., 1994). Indeed, to date, there is still a real need for practical OKM frameworks using the SECI model (Farnese et al., 2019; Gourlay & Hill, 2022).

Organizational knowledge may succeed if it is managed very carefully. OKM cannot be done, in manual assembly manufacturing operations, without distinction between tacit and explicit knowledge (Goh, 2002). OKM is only effective when the four conversion modes are managed at the organizational level so that the conversion cycle is fully completed (Nonaka et al., 1994). Thus, it is not only a question of modeling and codifying; it is a question that combines codification and socialization. In knowledge, digitalization cannot replace socialization (Kreiner, 1999).

Based on these findings, the authors focus on OKM for manual assembly manufacturing operations by integrating the SECI knowledge conversion model and introduce a practical framework based on the knowledge management process proposed by the ISO 9001: 2015 standard and integrating the work of Nonaka to deal with the complexity of knowledge management in the assembly sector. The main objective of this study is to guide companies that have assembly activities in the management of their organizational knowledge while overcoming classical barriers to KM.

This paper is organized into eight sections. The overview of KM models, found in the second section, discusses some research available in the knowledge management area, particularly for manual assembly manufacturing operations. The third section describes the research methodology followed for this study. The OKM framework based on ISO 9001:2015 et SECI conversion cycle is presented in the fourth section. Then, the paper presents an application of the framework to the operation process of an aeronautical company. The results of this application are then discussed to evaluate the proposed framework and discuss its limitations. Implications of the study are also discussed. This study ends with a conclusion and a list of consulted references.

OVERVIEW OF ISO 9001 OKM MODEL AND SECI CONVERSION CYCLE

Organizational knowledge is frequently discussed in the literature as a mechanism for capturing and disseminating knowledge that exists within the organization (Huang, 2013). It represents the ability of members of an organization to integrate individual knowledge into a collective creation process (*Organizational Knowledge*, 2015). OKM is considered as “the practice of selectively applying knowledge from previous experiences of decision making to current and future decision-making activities with the express purpose of improving the organization’s effectiveness” (Jennex & Olfman, 2006). This formulation captures the spirit of any OKM approach and its direct link to performance.

Heisig (2009) states that “KM framework should be composed of at least five core KM activities such as identify, create, store, share and apply knowledge” (Heisig, 2009). But, as explained above, most of KM approaches face multiple barriers in their implementation cycle.

To overcome these barriers, an interesting Delphi work on the future of KM states that there is a need to develop research on three main categories: people, process and IT (Bibi et al., 2020; Scholl et al., 2004). Concerning the process issue, which is one of the twelve success factors of a KM system (Jennex & Olfman, 2004), It is suggested that KM initiatives should be integrated with common business processes that are executed anyway (Scholl et al., 2004). Another research recommends to explore integration with processes as Total Quality Management (TQM) or business process Reengineering (Zaim et al., 2019) especially since KM undeniably implies the implementation of a process that will ensure that knowledge requirements are continuously reviewed (Jennex & Olfman, 2002).

One of the most common and mandatory processes to industrial and assembly companies is the Quality Management System (QMS) (Probst, 1998). A recent literature review, covering 169 research articles from 1992 to 2018, highlighted the close relationship between TQM and KM processes (Agrawal & Mukti, 2020; Mendes, 2017). The most widely used and known standard in quality management is ISO 9001 standard. This standard has also been studied in its positive correlation with KM initiatives (Demir et al., 2021).

Following Zaim and colleagues' recommendations, it would be interesting to take advantage of this KM-ISO 9001 correlation (Zaim et al., 2019). This is a good choice since the latest version of ISO 9001 has integrated, for the first time, in the new 2015 version, an OKM requirement which should help companies to implement actions within the process of the QMS.

OKM Model Proposed by ISO 9001:2015

The technical committee ISO/TS 176 which developed ISO 9001:2015 standard chooses its own OKM model, in four steps, which are common to the different models proposed by KM specialists and very particularly to the one described by Alavi (Alavi & Leidner, 2001). This simple model allows companies that have never taken an action in this direction, to take their first steps and improve thereafter (in the logic of the Plan, Do, Check, Act (PDCA)).

Indeed, the clause 7.1.6 for the management of organizational knowledge is one of the biggest challenges of this new version of the standard (Fonseca & Domingues, 2017; Sari et al., 2017).

The ISO 9001: 2015 standard defines the OKM as "the knowledge specific to the organization, usually acquired through experience. This is information used and shared to achieve the goals of the organization".

The process proposed to achieve managing this knowledge can be extracted from the clause 7-1-6 as follows:

- The organization shall determine the necessary knowledge.
- This knowledge shall be maintained.
- This knowledge shall be made available.
- The organization shall acquire or access any additional knowledge.

Wilson and Campbell (2020) studied the clause in depth and made the correspondence between the steps recommended by the standard and those proposed by the classical KM models (Wilson & Campbell, 2020). They, then, translated the OKM process of ISO 9001:2015 into 4 steps corresponding respectively to those described above: 1. application, 2. capture and storage, 3. distribution, and 4. creation and acquisition.

The use of this terminology in the suggested framework could be relevant, but for simplicity reasons, authors will remain faithful to the terms used by the ISO 9001 standard.

Furthermore, the standard 9001:2015 indirectly referred to both forms of knowledge in the text of clause 7-1-6 without clear notification of tacit knowledge (Wilson & Campbell, 2016). By focusing towards knowledge "generally acquired by experience" (ISO 9001 2015, 2015), the standard invites companies to put more interest on tacit knowledge. Note 2 of the clause 7-1-6 supports this by specifying the examples of knowledge that the standard recommends to manage: "undocumented knowledge sharing".

The ISO 9001:2015 model of OKM seems to be a good solution to overcome some of the KM barriers. However, some studies reported few guidance concerning its implementation (Rybski et al., 2017; Wilson & Campbell, 2016) and others pointed out the lack of precision in relation to tacit knowledge (Dooley, 2000; Linderman et al., 2010). There is a real need for research that guides organizations to incorporate the knowledge clause (Wilson & Campbell, 2020). Indeed, the standard specifies the steps to be followed for the knowledge in a general way. However, as illustrated by a study on KM practices (Rechberg & Syed, 2014), tacit knowledge does not apply to all the steps (See Figure 1).

It is clear that both classical KM models and ISO 9001:2015 model may have some difficulties to be implemented and, at the same time, they offer different advantages.

Table 1 summarizes strengths and weaknesses of the two categories as discussed above. This comparison is obviously not exhaustive but it sums up the principal arguments discussed in this paper.

SECI KM Conversion Cycle

Nonaka et al. (2000) distinguish between tacit and explicit knowledge, stating that "knowledge is dynamic since it is created in social interactions amongst individuals and organizations" (Nonaka et

Figure 1. Links between KM forms and KM processes ifferng to Rechberg and Syed (2014)

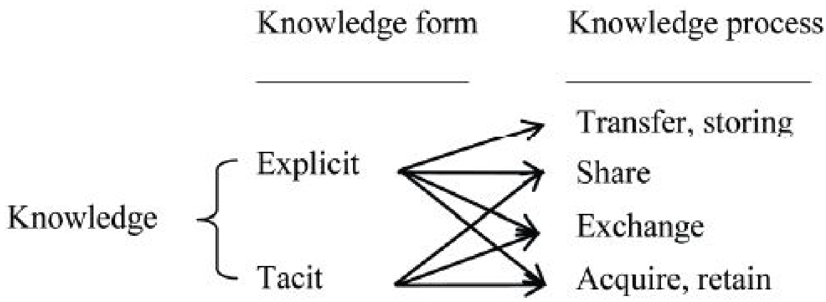
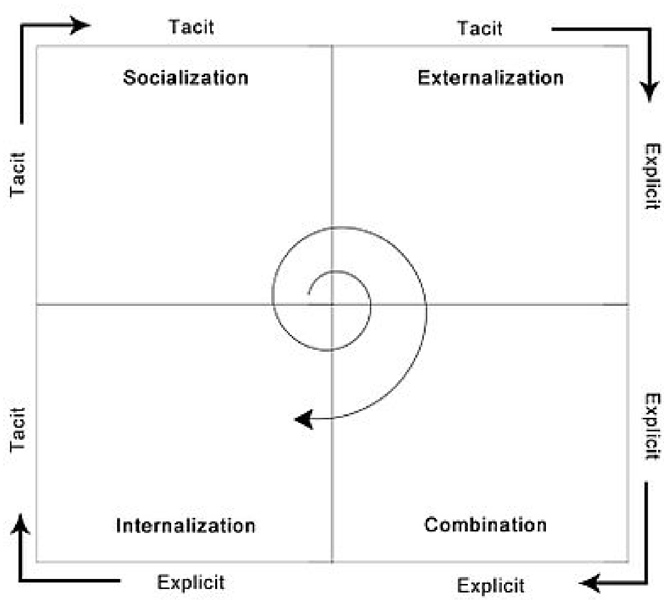


Table 1. A brief comparison between KM models offered by the KM field and KM model proposed by ISO 9001: 2015

	Strenghts	Weaknesses
KM models	Big choices of models and frameworks.	Several barriers reported
	Focus on both explicit and tacit knowledge.	Require dedicated resources.
ISO 9001:2015 model	One simple model on four steps.	No specific guidelines to implement.
	KM integrated with QMS process.	Do not distinguish between tacit and explicit knowledge.

al., 2000). They observed that knowledge follows four phases during its transformation: tacit-tacit, tacit-explicit, explicit-explicit, and explicit-tacit (Nonaka et al., 2000). These transformations (see Figure 2), also known as the SECI model, represent the four following modes of knowledge conversion: socialization, externalization, combination, and internalization.

Figure 2. SECI Knowledge conversion cycle of Nonaka



Socialization is "the process of converting new tacit knowledge through shared experiences" (Nonaka et al., 2000). Tacit knowledge is difficult to formalize because it is often unconscious. Socialization promotes informal environments where knowledge is unconsciously shared and acquired. Problem-solving approaches have already proven to be effective in the process of managing knowledge based on practical experience (Liu & Jiang, 2021) and are an interesting tool for the socialization mode. In such approaches, each participant comes with its knowledge (tacit and explicit), and the interaction between theifferrent participants can lead to the creation of new tacit knowledge.

Externalization is the transformation of tacit knowledge to explicit knowledge. This transformation allows knowledge sharing and storage (Balconi, 2000). In aeronautical assembly activities, an assembler lists the steps to follow to assemble two components. Moreover, it is this knowledge that is formalized in the instruction manuals or the manufacturing ranges. The whole challenge of knowledge management is on the formalization of tacit knowledge (Simard, 2017). This is why Nonaka (2000) described this process in the expression: "When tacit knowledge is made explicit, knowledge is crystallized" (Nonaka et al., 2000). Unfortunately, this is not always possible. In the example of the formalization of aeronautical assembly instructions, assemblers list all steps in detail but probably do not think of specifying some handling details that make one assembler faster than another. These can take place as a force applied by the hand to master the tightening tool or the position of the arm, which allows the rivets to be placed more rapidly. When the capture of this form of knowledge is successful, the knowledge is then made explicit, and, thus, its sharing is possible by the direct provision. When this externalization is not possible, it is then most suitable to use internalization tools to share knowledge.

Combination is the conversion of explicit knowledge to other explicit knowledge (Nonaka et al., 2000). Indeed, this mode is activated when combining explicit knowledge from different internal or external sources. For instance, synthesizing problem-solving analysis in a document, 8D for example, represents the creation of new explicit knowledge on the basis of other knowledge that already exists in the organization. A meeting report is also a good example of combination. Explicit knowledge is collected, combined, and edited into new explicit knowledge.

Internalization is the process that transforms explicit knowledge into tacit knowledge. Explicit knowledge is created or shared at an organizational level and is then integrated by individuals and converted into tacit knowledge. Nonaka et al. (2000) stated that "internalization is closely related to learning by doing" (Nonaka et al., 2000). Indeed, training is an opportunity to exchange explicit knowledge, but internalization can only occur when individuals invest some effort to integrate explicit knowledge received from other individuals or from the organization at the individual level. Understanding the corporate strategy and assimilating safety instructions are forms of internalization. This accumulation of knowledge can lead back to socialization again and so on.

In addition to the explanations given above, the literature also offers some matching efforts between the four conversion modes and the different KM tools (Marwick, 2001). Understanding the conversion modes makes the choice of the right tools easier to effectively manage each tacit and explicit knowledge (Eslamkhah & Hosseini Seno, 2019; Young & others, 2010), regardless of the context, especially since several studies have focused on the universality of the SECI model and its unconditional nature. Debates continue on this subject (Gourlay & Hill, 2022), but until the contrary is proven, the authors will rely on the universality hypothesis that the knowledge management community already claims (Von Krogh et al., 2000). There is even an empirical study specific to Morocco that confirms this conclusion in Moroccan companies (Talaskou & Belhcen, 2019).

THE OKM FRAMEWORK BASED ON ISO 9001:2015

OKM MODEL AND SECI CYCLE

The situation described above reveals a real need for assembly tasks companies to have a practical model suitable to the particularity of this sector. The following subsections present the SECI conversion cycle and the OKM framework proposed for manual assembly manufacturing operations.

The suggested framework in this article is based on the OKM model, described in clause 7-1-6 of the ISO 9001: 2015 standard, and on the SECI knowledge conversion cycle, proposed by Nonaka and Takeuchi for the creation of knowledge (See Figure 3). Knowledge cannot be managed in the same way, whether it is tacit or explicit. This framework distinguishes both. While companies may be familiar with explicit knowledge management, tacit knowledge cannot be maintained directly (Rechberg & Syed, 2014); it has to follow the appropriate conversion modes to make it easy to share and perhaps even to codify it afterward.

The requirements for OKM were introduced in the ISO 9001 standard and aimed to protect the organization from any loss of knowledge (such as departures and arrivals of staff) and encourage the organization to acquire knowledge (such as return on experience, sharing of experiences) (*ISO 9001 2015*, 2015). The proposed framework respects the four steps of ISO 9001:2015. The added value of this framework is at the level of the second stage.

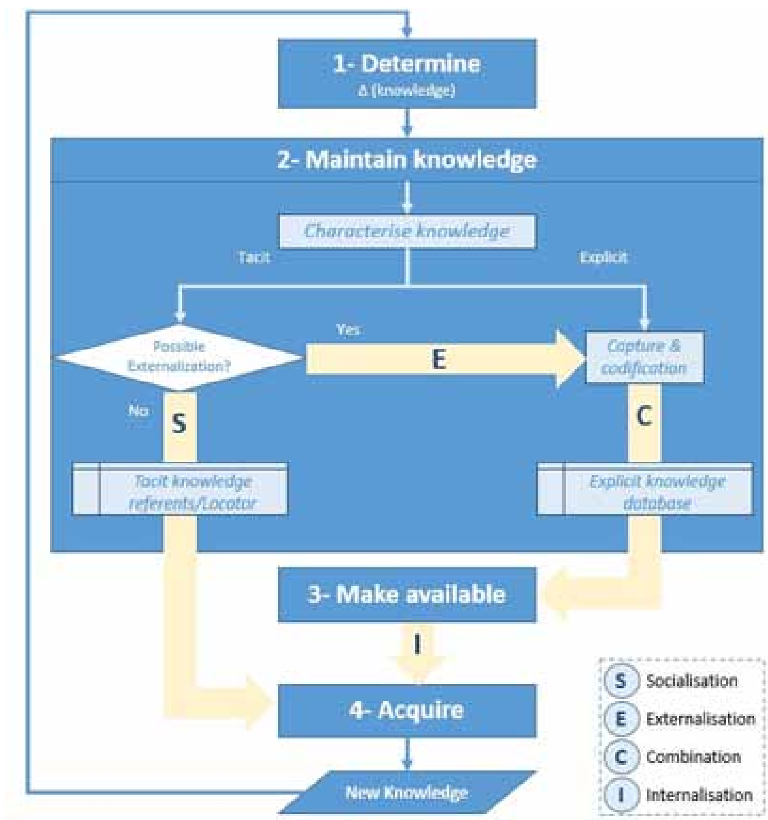
Step 1: Determine knowledge

This step consists of determining the knowledge needed to execute processes. In fact, it is done only once during a process. ISO 9001:2015 recommends updating it after each change of context, products, or services, focusing only on new knowledge required and not yet available in the organization.

Step 2: Maintain knowledge

The ISO standard recommends updating the knowledge needed to execute products or services. This requires the storage of knowledge. Davenport et al. (year) propose having a knowledge map that represents the yellow pages of knowledge (Davenport & Prusak, 1998). The current framework

Figure 3. OKM framework based on ISO 9001:2015 and SECI conversion cycle



proposes to proceed first by a characterization of the knowledge identified in Step 1. This starts by determining the form of the knowledge concerned: tacit or explicit.

In the case of explicit knowledge, this knowledge can be codified and transferred in several ways. Knowledge first goes through a combination mode which allows it to be incorporated with other knowledge and reformulated in an appropriate format to the context of the company or that of the people expected to access this knowledge. Updating the knowledge databases and making them available can be done directly after this step. An internalization tool ultimately allows the acquisition of knowledge in an efficient manner.

In the case of tacit knowledge, it represents the expertise developed by individuals or groups of individuals. The socialization mode is needed for knowledge transfer. In such cases, the codification effort is “generally limited to locating someone with the knowledge, pointing the seeker to it, and encouraging them to interact” (Davenport & Prusak, 1998). The process owner has to identify the people who hold the knowledge in question. Tsoukas and Vladimirou (2001) suggested that practical mastery should be complemented by a quasi-theoretical understanding of what people do to exercise that mastery (Tsoukas & Vladimirou, 2001). Based on this observation, this framework proposes to apply regular externalization actions to capture what can be modeled. Indeed, organizational knowledge is “what people know about customers, products, processes, mistakes, and successes” and specifically “what resides in databases or through the sharing of experiences and good practices, or via other sources internal and external to the organization” (Penrose & Penrose, 2009). If this externalization is successful, the knowledge becomes explicit and therefore can be coded and saved with the rest of the explicit knowledge. If this knowledge remains difficult to code, then it has to be protected from any loss. Socialization tools should also be regularly applied to allow knowledge sharing in formal and informal ways.

Step 3: Make available

The characterization of knowledge facilitates and guides the current step. Explicit knowledge needs a combination of tools to make it available to others. Tacit knowledge may not be concerned with this step since this knowledge needs socialization tools to help sharing and acquisition. The choice of a transfer or sharing tool, in accordance with the conversion mode in question, is essential for the success of this stage. Training, for instance, being a widely practiced knowledge-sharing tool, can thus be carried out according to several methods or modalities depending on the form of knowledge. It is also possible to objectively evaluate the different possible training methods to make sure the most suitable method for the situation is selected (Jghamou et al., 2019).

Step 4: Acquire knowledge

Acquisition depends on the people who consume the knowledge. This stage involves the first focus of first-line workers compared to other facets of KM (Jin et al., 2020). Acquisition is also easier when the chosen conversion mode is suited to the form of knowledge in question. The acquisition of knowledge might generate the creation of new knowledge. This can trigger another cycle by determining and characterizing this new knowledge.

The application of the OKM framework related to ISO 9001:2015 is illustrated in the case study given in the next section.

EXPERIMENTAL RESEARCH METHODOLOGY

Context and Purpose of Study

To confirm the applicability and effectiveness of the developed OKM framework, the authors conducted an experimental study in a Moroccan manual assembly manufacturing company. This experimental research tests the framework’s applicability, checks its effectiveness, and evaluates its barriers.

Testing the Framework's Applicability

The ISO 9001:2015 OKM framework is a proven model regarding its applicability, and SECI's universality is confirmed. However, it is needed to question if their combination would be applicable for the specific activities of manual assembly manufacturing operations. Depending on whether the knowledge is tacit or explicit and what the modes are, the tools may be different. Companies already deal with explicit knowledge since it is easily identifiable and manageable via different forms. On the other hand, tacit knowledge is more difficult to identify and uses less conventional management tools. As a result, it seems necessary to verify that, in both forms of knowledge, it is possible to follow the four steps of the framework. Thus, the first question is:

Q1: Does the OKM framework applicable in manual assembly manufacturing operations?

Checking its Effectiveness

A KM approach is used to help companies improve their performance and guarantee their sustainability. Actions made following models must be more interesting than those taken without the KM approach. The authors rely on this fact to verify the effectiveness of the framework. A deep analysis of OKM actions and effects before and after the application of the framework is needed. The second question is:

Q2: Is the OKM framework more effective than singular KM actions?

Evaluating the Framework's Barriers

KM approaches may fail in different situations. A list of fifteen barriers identified in the literature is reported in Table 3 (Weber, 2007), and then the frameworks are compared according to each barrier. The third question is:

Q3: How does the OKM framework overcome the fifteen barriers to KM identified by Weber?

Experimental Design and Conditions

To answer the research questions identified above, it seems necessary to conduct a qualitative study with some actors in the field of manual assembly manufacturing operations. The review of research methodologies shows that the most appropriate method for testing theories is the case study (Denzin & Lincoln, 2005; Eisenhardt & Graebner, 2007; Gagnon, 2005; Yin, 2003). The authors choose to conduct a single case study to have the opportunity for an in-depth analysis of the results. The authors decided to apply the framework suggested to a Moroccan aeronautical company. The model is obviously applicable to all sectors that engage manual assembly manufacturing operations. More applications to companies from other sectors could be developed to support the model proposed.

Authors consider the case of a multinational company that specializes in the assembly of aircraft structures, fuselages, flight controls, wings, and nacelles in metallic and composite materials. The company is already AS9100 certified, which includes all the requirements of the ISO 9001 standard. The framework, being fully in line with the ISO 9001:2015 standard, will be very useful and suitable for this company.

The framework focuses on the knowledge management of the assembly process. The latter directly impacts the efficiency of the operators working on these lines, which will, in return, impact the performance of the entire assembly line (Scott, 1994). This study used a qualitative approach to analyze empirical material collected. The data collection was carried out between January 2020 and March 2020, using a variety of sources, including structured interviews and internal documents.

The application of the framework required the organization to hold six workshops with a team composed of the operations director, who is the operations process owner, the operations Human Resources Business Partner (HRBP), the training manager, the quality manager, four team leaders, and two assembly-line workers that are recognized as high performers in operations. The project started with a training session to introduce the framework and explain the concepts of KM. Then, intersession actions took place within the company to monitor the implementation of the proposed framework. A working session was organized after the implementation of each step to analyze and validate the actions and conclusions. The project was closed with a final workshop to present and discuss the results of the study.

Data Collection Process

In order to answer question Q1, where the variable that the experiment seeks to observe is the ability and ease of the operations team to implement all the steps of the proposed OKM framework, authors used interviews and observations to collect the data for the experiment. Study participants were interviewed at the end of the experiment.

A structured and standardized interview protocol was used to obtain feedback from participants regarding the experiment (see Appendix). The interview schedule also contained rating scales asking each participant to rate on a scale of 1 to 10 their perception of the difficulty of the task they were assigned.

For the question Q2 and in absolute terms, it would be interesting to evaluate the relevance of the OKM framework through its impact on the performance of operational activities. In this sense, Aaron (Aaron, 2009) was inspired by Kirkpatrick's (Kirkpatrick & Kirkpatrick, 1998) model for evaluating training actions to develop a V-model for evaluating KM actions. Gubbins (Gubbins et al., 2012) tested it in a case study and proved its effectiveness. In the context of this study (shutdown of production during the COVID containment, slowdown of aeronautical activities in the world, restructuring plans and departure of a good number of operators...) it was not possible to use this form of evaluation. Authors then decided to evaluate the proposed framework by comparing the relevance of the resulting KM actions to those that the company had before the adoption of the framework. Since the company did not have an inventory of previous KM actions, this task was based on an analysis of the training summary for 2019 and individual feedback from the operations manager and the training manager regarding past KM practices.

To verify the third question Q3, the OKM framework suggested is compared to each barrier of the fifteen barriers of Weber. The question asked at each item is: did the OKM framework overcome this difficulty or not? The feedback is collected by observation in consultation between the authors and the operations manager.

The following section presents the detailed results of applying the proposed OKM framework during the six company workshops.

APPLYING THE OKM FRAMEWORK TO AN AERONAUTICAL ASSEMBLY COMPANY

The implementation of the suggested OKM framework followed the steps described in Figure 3 with respect to all details given in section three. Results of this application are presented as follows:
Step 1: Determine Knowledge

The operations manager listed 29 items of knowledge needed to complete the assembly process:

- K1: Security standards
- K2: Quality standards
- K3: Aviation standards
- K4: Foreign product standards
- K5: The basics of mechanics
- K6: Chemical products standards

- K7: Manufacturing instructions
- K8: Agile handling of assembly tools
- K9: Environment and workstation
- K10: Quality inspection
- K11: Corporate and professional working rules
- K12: Recurring quality problems
- K13: Administrative documents required
- K14: Installation of safetying devices
- K15: Static Testing-Metals, Composites, Adhesives, Renis, Sealants, Plastics, Rubbers, etc
- K16: Welding evaluation
- K17: Application of fluid resistant primer
- K18: Application of fluid resistant polyurethane
- K19: Cold Working of Holes
- K20: Manipulation of joining technologies (welding, riveting, press joining, etc.)
- K21: Installation of cold expanded rivetless nut plates
- K22: Drilling of composite and composite/metallic assemblies
- K23: Acid cleaning and deoxidizing aluminum alloys
- K24: Alkaline cleaning
- K25: Fluorescent penetrant inspection
- K26: Stress relief of metals
- K27: Heat treatment of aluminum & aluminum alloys
- K28: Chemical conversion treatment for aluminum alloys
- K29: Application of high temperature sealant

K denotes knowledge.

Step 2: Maintain Knowledge

At this stage, the framework distinguishes between tacit and explicit knowledge. For simplicity, authors present the results of characterization for only ten items and the process is applied to the rest of items in the same way (see Table 2).

Table 2. Characterization of knowledge required for assembly activities: application of Step 2 of the OKM framework proposed

Knowledge Item	Form of knowledge	Capture status	Knowledge location	Conversion mode
K1: Security standards	Explicit	Done	Procedures manual	Combination or/and Internalization
K3: Aviation standards	Explicit	Done	Procedures manual	Combination or/and Internalization
K7: Manufacturing instructions	Explicit	Done	Manufacturing ranges	Combination or/and Internalization
K8: Agile handling of assembly tools	Tacit	Not done	Assembler 1 and Assembler 2	Socialization
K12: Recurring quality problems	Tacit	Not done	All assemblers, team leader, quality coordinator	Externalization
K16: Welding evaluation	Tacit	Not done	Assembler 3	Socialization
K19: Cold working of holes	Tacit	Not done	Assembler 2	Socialization
K20: Installation of conventional rivets	Tacit	Not done	Assembler 4	Socialization
K24: Alkaline cleaning	Tacit	Ongoing	Training video	Socialization or/and Internalization
K25: Fluorescent penetrating inspection	Tacit	Not done	Assembler 5	Socialization

The table represents the cartography of the organizational knowledge necessary for the execution of the assembly process, in which all knowledge is identified. The storage location is also specified, either through a storage address, or through the name of the referent who holds it. The tools to be used for knowledge transfer are different depending on whether knowledge is tacit or explicit. In the case of explicit knowledge, that is already captured in the database, many internalization tools are possible to make the knowledge available to other users. Whereas, in the case of tacit knowledge, it is more suitable to use socialization to allow the acquisition of knowledge directly from the referents. To protect tacit knowledge, several tools of externalization are proposed in literature. In this study, the company chooses to apply the following tools: knowledge coffees, communities of practice and a mentoring program. The company, also, decided to explore the possibilities offered by augmented reality technology in order to model the performance of referents and capture the expertise that allows their performance.

Step 3: Make Available

A collaboration between the operations manager and the training manager results on reviewing training programs for new assemblers. A consolidation action of new documents and their organization in practical and ergonomic storage files has been implemented and shared with concerned employees.

Step 4: Acquire Knowledge

The operations manager implemented some actions to capture new knowledge that can be created as a result of knowledge acquisition, following the designed framework. Indeed, knowledge coffees, after action reviews, new ideas rewards, problem solving reports are some of the tools implemented and that were positively adopted by this company.

The OKM framework proposed in this paper was successfully implemented to the assembly process of this aeronautical company. The next section discusses the results of this experimental research and analyses the three questions addressed in the previous section.

RESULTS AND DISCUSSION

The purpose of this experimental study was to test the framework proposed in this paper and verify its effectiveness in the case studied. It is important to point out that this is a qualitative study based on a single case. Therefore, the analysis combines the interpretations and perceptions of the stakeholders with the professional experience of the company's project team members.

As part of checking the first question, authors noted that tracking the four steps of the framework is feasible and easy in both cases (tacit and explicit knowledge). Moreover, the team that applied the framework did not feel any particular difficulty concerning its implementation. Indeed, OKM was linked to the operational process and did not need any special resources. The intervention of the owner process was sufficient to set up the framework and take the necessary actions to maintain and protect knowledge. Therefore, the OKM framework is applicable in manual assembly manufacturing operations.

To verify the effectiveness of the framework, authors applied it to the operations activities and discussed, with the company's team, the relevance of the results compared to those before the application of the framework. In fact, some of the knowledge transfer actions in the past were not necessarily adapted to the knowledge form. For instance, knowledge K12, "Recurring quality problems", was managed only by sharing the action with all members of the team. This is considered a socialization tool that is suitable to share tacit knowledge, but it is not sufficient to maintain it. With the application of the framework proposed, an externalization mode was added after the review actions to convert tacit knowledge to explicit. Indeed, a defect library has been elaborated and posters with the TOP defects of each workstation have been placed within the reach of the assemblers to better ensure the internalization process. Authors conclude that the framework is much more efficient because it guides managerial actions through a structured methodology. As a result, the OKM framework is more effective compared to previous KM actions.

To answer the third question, the authors analyzed the framework regarding the barriers reported by Weber (2007). Table 3 presents the fifteen barriers and explains how the developed framework overcomes each one. In addition, the mentioned framework resolves other barriers that may be found in similar studies (Durst & Zieba, 2019; McIver et al., 2019; Vuori et al., 2018). Thus, the OKM framework overcomes most of the fifteen barriers to KM identified by Weber. As a recommendation, the authors suggested the company conduct a long-term evaluation for the application of the present framework to validate its effectiveness regarding the 12 evaluation factors identified by companies to evaluate their KM projects (Loermans & Fink, 2005).

Table 3. How does the OKM framework proposed overcome KM barriers identified in the literature (Weber, 2007)

	KM Barriers	**How the framework overcomes the identified barriers**
	KM approaches may fail...	**The proposed framework...**
1	...when they attempt to create a monolithic organizational memory	...is interested in assembly operations and manual activities and it is not concerned by all the entities of the organization.
2	..when they do not integrate humans, processes, and technology	...engages humans within the QMS process and uses technology to support and facilitate the management of the process (without being technology-centric)
3	...when they are designed without input from all stakeholders	...is designed with the process community and maintained by its members.
4	...when contributors do not know the ideal specificity of knowledge	...is designed with the process community who is very familiar with the specifics of knowledge in their area.
5	...due to lack of leadership support	...is leaded by community leaders, which guarantees their commitment to the process.
6	...when users are afraid of the consequences of their contribution	Not applicable
7	...when they store knowledge in unrestricted textual representations	...favors the diversification of codification tools and the use of media adapted to the form of knowledge.
8	...when they rely on inadequate technology	...does not necessarily depend on a technology. Its application requires the use of a simple database for storing explicit knowledge. The choice of more sophisticated technology would not change the knowledge management process itself.
9	...when they are outside the process context	Not applicable
10	...when they ignore impediments to knowledge transfer	...takes into account the difficulty of making tacit knowledge available. The application of the adapted conversion mode favors the choice of transfer tools more suited to the form of the knowledge and its complexity.
11	...when they do not enforce managerial responsibilities	...takes up the responsibilities reported by the author in the stages of OKM.
12	...when they do not properly oversee the quality of stored knowledge	...considers knowledge management as a daily and continuous activity that is related to the daily operational activities. Assembly operations, being complicated, are also easier to understand by people already working on it.
13	...when they do not promote collaboration	...recommends a socialization mode concerning the transfer of tacit knowledge. Socialization tools use informal ways to promote collaboration between employees.
14	...when they are not able to show measurable benefits	...integrates OKM process into the QMS, this implies that the KM goals are consistent with the quality and operations goals and benefits may be observed in the operational results.
15	...because users do not perceive value in contributing	...allows consistency between KM goals, quality and operations goals; and benefits may be observed in the operational results.

The aim of this paper was to develop an OKM framework adapted to manual manufacturing operations by integrating the literature regarding the SECI model into the OKM requirement of ISO 9001:2015. Although the distinction between tacit and explicit knowledge was mainly addressed in coherence with Nonaka's framework, other dimensions could be considered to improve the construct.

Some limitations exist related to the proposed framework and others related to the nature of the experimental study performed. Despite the fact that the framework was implemented without major obstacles, it should be noted that, during the study, the authors observed that the company's teams tend to confuse knowledge and skills. In this case, the authors addressed this by organizing a training session before the implementation work began. The authors believe there may be a way to further simplify the model to guide users to knowledge without confusing it with skills. For the experimental part, the objective of this research was to verify the effectiveness of the OKM framework proposed through questions Q2 and Q3. The case study answered these questions using multiple sources of evidence. However, the data collected and analyzed are relative to the immediate period of the framework's implementation. A longitudinal study over a longer period of time could provide a follow-up to measure the impact of the model on the performance of the operating process and to compare these results with other empirical studies conducted in this area strategies over time.

Also, and as with most case studies, the external validity of the research remains to be proven (Yin, 2003). The experimental research and conclusions are based on a single case study and could limit the generalizability of the findings due to local social practices (Nonaka & Von Krogh, 2009). Therefore, the authors cannot state that the answers to the three research questions are valid for all manual assembly manufacturing operations. Thus, research would benefit from replications in other national or multinational contexts to extend the applicability and effectiveness of the framework proposed in this paper. Overall, this study presents encouraging results that may stimulate further interesting research.

RESEARCH AND PRACTICAL IMPLICATIONS

The findings of this study have some interesting theoretical and practical implications. The starting point of this study is based on (Krafcik, 1988), (Tworek, 2011), and (Gutierrez et al., 2010), which state that assembly operations are very complex tasks depending on the knowledge held by individuals and by the organization. For manual assembly manufacturing operations, the management of tacit knowledge represents a real challenge. The main effort made during this study was to find a relevant model of knowledge management that can be adapted to the tacitness of assembly operations. The framework developed in this article is intended to be specific and more effective than the one presented by the ISO 9001:2015 standard. It is also easier to set up than those offered by the KM field. In addition, this framework overcomes the majority of the limitations identified in other knowledge management models (Weber, 2007).

The framework presented in this paper brings practical added value to the manual assembly manufacturing operations field. The literature offers several models that have been followed up by several studies. However, applications and adaptations to some sectors or activities have attracted more research than others, especially when explicit knowledge dominates. Given the diverse models in the literature, practitioners can be lost, and the choice of one model over others may not be suitable for the manual assembly manufacturing operations sector where tacit knowledge represents a real challenge.

At this point, the practical implication is added to the theoretical one. The framework of OKM aims precisely at helping practitioners better manage their organizational knowledge with suitable methods regarding the form of the knowledge concerned. The proposed OKM framework also builds on previous studies and addresses some of their recommendations by adding more research on how to implement KM approaches or initiatives in organizations seeking performance and by increasing efforts to operationalize and put the SECI model into practice.

CONCLUSION

This article focuses on the management of organizational knowledge in manual assembly manufacturing operations. There are a lot of tacit knowledge in this kind of activities which directly influences the performance of organizations. Several KM models are proposed in literature; however, they present some limitations related to their implementations.

The purpose of the study was to develop a framework that can help assembly companies effectively manage their organizational knowledge overcoming common KM barriers. This framework suggests a unique approach that combines the four steps of OKM proposed by ISO 9001:2015 and SECI conversion cycle given by Nonaka. An experimental case study was presented to illustrate the application of the designed OKM. It concerns the operation process of an assembly aeronautical company in Morocco. The results of this application demonstrated that this framework is applicable and relevant in the case of aeronautical assemblies. Indeed, this combination allows to overcome a high number of limitations reported by the literature review concerning KM models.

Linking knowledge management with the quality management system personalizes the knowledge management according to the process in question. It also removes the necessity to have resources completely dedicated to the knowledge management process. Also, entrusting the operational teams with the knowledge management of their perimeter empowers them and engages them in a spirit of sharing. In the same sense, the framework encourages recognition of the effort to acquire and create knowledge through the identification of knowledge referents.

The results of this paper have real practical and theoretical implications and open several perspectives for future research that have been discussed in the last section. This study allows the improvement of the OKM process in manual assembly manufacturing operations sector. The outlined objectives of this study were successfully met and the suggested questions were answered.

CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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APPENDIX A

The experiment interview schedule used for study data collection is composed of the following items:
1- Did you find it difficult to distinguish between tacit and explicit knowledge? On a scale of 1-10 (10 representing difficult)
2- To what extent do you think it is necessary to distinguish between the two forms of knowledge in the management mode? On a scale of 1-10 (10 representing necessary)
3- What is the level of difficulty that you have encountered when carrying out the actions that have been allocated to you? On a scale of 1-10 (10 representing difficult)
4- What level of difficulty do you feel you will have in maintaining the OKM framework in the future? On a scale of 1-10 (10 representing difficult)
5- How relevant would you say the OKM framework is to your daily work? On a scale of 1-10 (10 representing relevant)

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Jamal Echaabi is a full time professor of higher education in the mechanical engineering department of the National Higher School of Electricity and Mechanics, Hassan II University in Casablanca since 1987. In 1986, he holds a Doctorat in solids mechanics from Loraine University and in 1994 a PhD from polytechnic school, university of Montreal in the field of composite materials. In addition to the various positions of responsibility he has held, Professor ECHAABI is the founder and responsible of a research team (1997-2021) and is active in the fields of solid mechanics, failure and damage of composites, LCM composite manufacturing, educational engineering and industrial engineering. Pr. Echaabi has supervised several masters and PhD theses and published over than 100 articles in international scientific journals and conferences.