International Journal of Occupational Safety and Ergonomics (*JOSE*) 2010, Vol. 16, No. 3, 283–310

The Use of Tacit Knowledge in Occupational Safety and Health Management Systems

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A systematic approach to occupational safety and health (OSH) management and concepts of knowledge management (KM) have developed independently since the 1990s. Most KM models assume a division of knowledge into explicit and tacit. The role of tacit knowledge is stressed as necessary for higher performance in an enterprise. This article reviews literature on KM applications in OSH. Next, 10 sections of an OSH management system (OSH MS) are identified, in which creating and transferring tacit knowledge contributes significantly to prevention of occupational injuries and diseases. The roles of tacit knowledge in OSH MS are contrasted with those of explicit knowledge, but a lack of a model that would describe this process holistically is pointed out. Finally, examples of methods and tools supporting the use of KM in OSH MS are presented and topics of future research aimed at enhancing KM applications in OSH MS are proposed.

knowledge management tacit knowledge explicit knowledge knowledge exploration occupational safety and health OSH management OSH management system risk assessment risk management behaviour-based safety worker participation OSH performance OSH training narratives community of practice

1. INTRODUCTION

1.1. Concepts of Knowledge Management

A new management concept called knowledge management (KM) emerged in the world of business in the last two decades of the 20th century. Its aim was to improve business performance, competitiveness and innovativeness in the era of globalisation. Many socioeconomic and technological factors contributed to the creation of KM, including broadly spreading implementation of IT systems in enterprises, information overload and chaos, communication bottlenecks in computer networks, segmentation and specialisation of skills, mobility of the workforce and loss of intellectual assets as well as challenges resulting from competition in business environments [1]. The development of KM was also influenced by a search for new management concepts that could improve business performance, when the competitive potential of total quality management (TQM), business process re-engineering (BPR) or downsizing had been exhausted [2].

When the concept of KM was being developed, the notion of knowledge was distinguished from narrower terms like data and information. As data, we understand sets of numerical values, descriptions of facts, drawings, pictures, voice recordings, etc. Information is data presented in an organised, summarised and interpreted manner. Whereas the term knowledge currently does not have a single broadly accepted definition, in the field of business management it is understood mostly as "fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates from and is applied in the minds of its owners. In organisations it often becomes

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embedded not only in documents or repositories but also in organisational routines, processes and norms" (p. 5) [3].

An understanding of the process of creating organisational knowledge is the basis of KM in enterprises. Organisational knowledge (also known as organisational memory) is a result of the learning process within a given organisation. This notion includes information and knowledge processed by the organisation and defines processes by which its members can achieve, sustain, process and store knowledge [4].

Organisational knowledge is one of three types of knowledge, where the other two are individual and structural knowledge [5]. Individual knowledge can be found in human minds and is hard to grasp, whereas structural knowledge is a fairly easily accessible codified knowledge, the kind that can be found in various databases, reports, instructions, procedures, etc. Nonaka and Takeuchi [6] define structural knowledge as explicit or formal, whereas knowledge that is informal, hard to gain and codify is defined as tacit knowledge. Usually the management of enterprises concentrates mainly on explicit knowledge, whereas achieving higher management effectiveness requires accessing tacit knowledge resources and their conversion into formal and available knowledge. However, according to Davenport and Prusak "tacit, complex knowledge, developed and internalized by the knower over a long period of time, is almost impossible to reproduce in a document or a database. Such knowledge incorporates so much accrued and embedded learning that its rules may be impossible to separate from how an individual acts" (p. 70) [3]. Additionally, in the case of tacit knowledge its owners are often unaware of the knowledge they have and of its value to others and to the organisation for which they act. That is why acquisition of tacit knowledge and its use for the benefit of an organisation can be extremely difficult. Some estimates indicate that tacit knowledge makes up as much as 80% of the total vital knowledge, which may be useful for organisations to ensure their sustainable position on competitive markets [7].

Simultaneously with the development of KM concepts several models that describe the process of generating, processing, disseminating and using knowledge in organisations have been proposed. To support enterprises in implementing KM, suitable methods, technologies and informational tools have also been developed. Examples of such solutions are enterprise KM portals, data warehouses and data mining systems, methods of knowledge space visualisation, workflow-based business process management systems, e-learning tools, business intelligence applications and managerial decision support systems. These tools, however, allow us to manage mainly explicit knowledge. Reaching tacit knowledge and using it for the benefit of an enterprise remain very important issues in KM practice.

1.2. First Attempts at Adopting KM Principles to OSH Management

Regardless of the developments in KM discussed in section 1.1., since 1995 there has been a movement in several industrialised countries towards implementing a systematic approach to managing occupational safety and health (OSH) issues in enterprises. This development has involved setting voluntary standards that include OSH management system (MS) specifications based on the continuous improvement cycle Plan–Do–Check–Act (PDCA). When seeking new ways of making enterprises competitive and increasing their innovativeness, attempts were made to use the principles of KM not only to improve basic business processes (such as designing products and services, production, marketing or sales), but also to use those principles in OSH. According to literature applying KM principles has led to an improvement in the effectiveness of an environmental management system (EMS), which is based on a model similar to that in OSH MS. This approach allowed the enterprise to decrease energy consumption as well as emission of pollutants into the atmosphere and water [8, 9], proving at the same time that KM can increase the potential of the enterprise with regard to green competitiveness.

However, the literature specifically on OSH management does not yet provide sufficient evidence on similar successes in using KM in this area, though there have been a few attempts to adapt and use KM principles in OSH. In this article there is an overview of those selected KM applications in OSH management on the enterprise level (section 3). The most important common conclusions that can be derived from these few studies is the necessity of attributing high importance to acquiring and exchanging tacit knowledge that concerns different aspects of OSH. These processes should constitute a part of organisational learning and lead to effective OSH management in enterprises.

Taking this into consideration, the general objective of this article is to present a general overview of leading KM concepts and, on the basis of this review, to show the particular and potential role of acquiring and using tacit knowledge in OSH MS. Section 2 brings a brief overview of KM concepts and models, whereas in section 3 there is a review of literature on using KM in OSH management. Section 4 presents the results of an analysis of OSH MS specifications that identified sections of the system where the use of tacit knowledge is particularly important. On that basis, the potential roles of tacit knowledge in the system are described and contrasted with the use of various forms and contents of explicit knowledge. In section 5 there is an overview of practical methods and tools that can be used to stimulate, enhance and promote tacit knowledge in OSH MS in enterprises. The conclusions from those reviews and analyses are discussed in the last section, which also contains propositions of topics of further research necessary to explore further the potential, methodologies and practical aspects of the use of tacit knowledge in OSH MS. This section also underlines the need to develop a holistic model that would describe the role of KM processes within OSH MS, in particular processes related to creating, converting and transferring tacit knowledge.

2. BASIC CONCEPTS AND MODELS OF KM

In the last 20 years, several conceptual models have been developed that describe generating, processing, disseminating and using knowledge in organisations. The following three approaches were the most important ones in the initial stage of the development of the concept of KM:

- the Japanese model of creating knowledge [6, 10];
- the KM cycle [11, 12];
- the process-based model [13].

2.1. Japanese Model of Creating Organisational Knowledge

Nonaka and Takeuchi divided organisational knowledge into two categories, explicit and tacit [10]. This division was based on the assumption that organisational knowledge could not be seen only as a collection of explicit data and information gathered in the form of documents and computer databases. Organisational knowledge also contained some hard to capture individual and group values and beliefs as well as behaviours that resulted from nondocumented experiences of the members of an organisation.

An adaptation of the concept of tacit knowledge introduced by the contemporary philosopher Polanyi was the basis for this approach [14]. According to his theory, knowledge always contains a certain tacit and personal component. Some researchers (e.g., Hildreth and Kimble [15] and Grant [16]) claimed that Polanyi did not suggest a clear division of knowledge into explicit and tacit because knowledge is a continuum, in which sometimes explicit and sometimes tacit components dominate.

Nonaka claimed that KM should include not only processing of already existing knowledge but should also focus on creating new knowledge and its use within organisation together with previously acquired knowledge [2]. In the process of creating organisational knowledge there is an exchange of two complementary types of knowledge, tacit and explicit. This

exchange is possible due to dynamic interactions between members of an organisation, groups and organisational levels. There are four types of knowledge conversion (see Figure 1):

- socialisation: change of individual tacit knowledge into group knowledge co-perceptible by members of the organisation;
- externalisation: conversion of tacit knowledge of the group into formal (explicit) knowledge of the group;
- combination: systematic processing of fragmentary (segmented) formal knowledge into formal knowledge (connection of new blocks of knowledge with already existing blocks of formal knowledge into one body of knowledge);
- internalisation: conversion of formal knowledge into tacit knowledge within the whole organisation and at the level of its members. This conversion includes an embodiment of formal knowledge in concrete practices, processes, activities and strategic initiatives.

A spiral loop indicating a change of explicit knowledge into tacit knowledge on successive stages of its creation and recreation in an organisation is a very important element of Nonaka's model [2, 3]. In this way knowledge conversion should lead to a continuous expansion of knowledge resources in the organisation.

In Nonaka's model, the most critical and most difficult to realise is the stage of socialisation, because individualised tacit knowledge can remain in the organisation members' minds or demonstrate itself in their behaviours only. Despite its value, it can be partly subconscious [2, 3]. This is a constraint to Nonaka's model. Hildreth and Kimble argue that if tacit knowledge of a certain member of organisation cannot be articulated and it is not shared with other members, the tacit–explicit conversion stage simply cannot work [15]. Transfer of tacit knowledge from master to student in the course of apprenticeship is an example. It leads to the development of the student's individual knowledge, but it is still tacit and not explicit

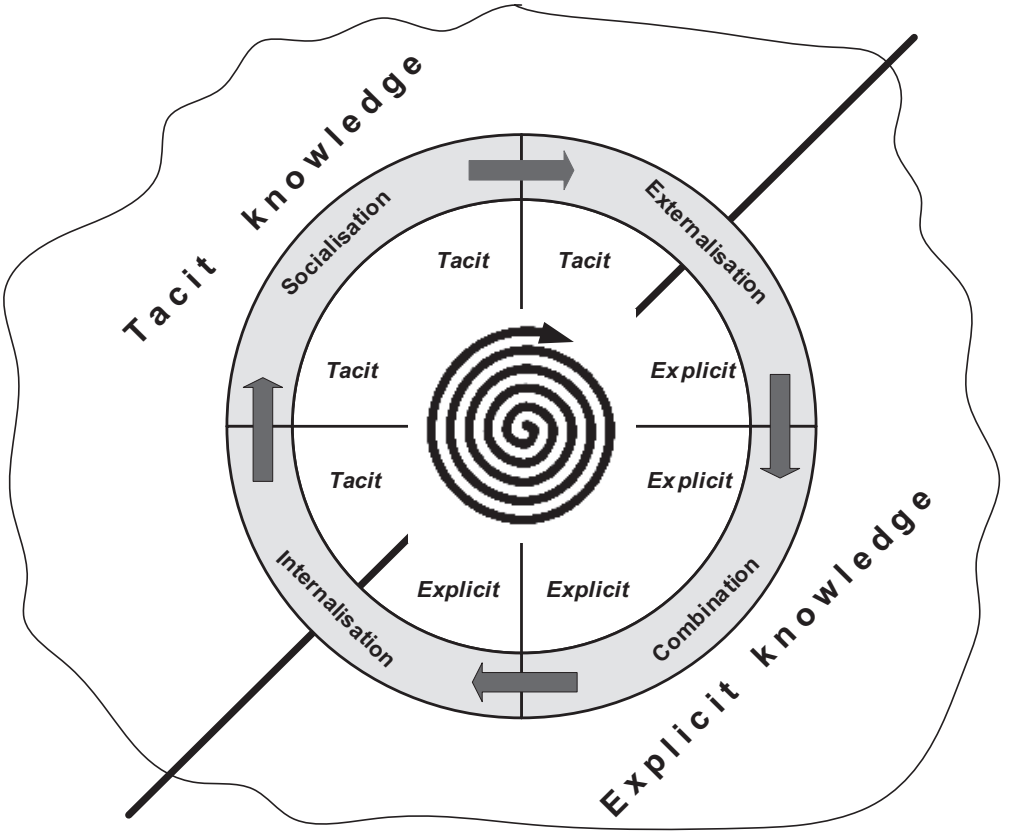

Figure 1. Japanese model of organisational knowledge creation (on the basis of Nonaka [6] and Nonaka and Takeuchi [10]).

knowledge. That is why a slightly different division of forms of knowledge into "hard" and "soft" was suggested [15, 17]. According to Hildreth and Kimble each body of knowledge is both hard and soft. Since both are inexorably and inextricably interwoven there is no clear division between these two forms [15].

Hard knowledge is codified and observable formal knowledge, the kind that can be found in textbooks, procedures, instructions, programmes, databases, etc. On the other hand, soft knowledge is tacit and takes the form of internalised experience, automated skills and internalised cultural knowledge embedded into practice [17]. Changing tacit knowledge into hard knowledge is in certain circumstances possible but only a part of this knowledge can be made explicit. Moreover, knowledge is embedded not only in habits and mental models of individual employees, but it is a result of current relations between certain members of working teams. Therefore, it is often subconscious and distributed across individual members of the organisation [18].

The following statement expresses well problems connected with management of tacit (or soft) knowledge, "people know more than they can say and more than it results from their common sense" (p. 205) [19]. That is why instead of focusing on changing tacit knowledge into explicit, and later on trying to manage it with methods suitable for formal knowledge, investing in soft KM techniques would be more efficient. Those techniques consist in developing informal methods of sharing this knowledge, without the necessity to externalise it [15].

2.2. Wiig's Model of KM Cycle

Creating and using knowledge in the enterprise can be made efficient by good organisation of acquiring and processing knowledge. Taking this into account, Wiig proposed an organisational KM cycle of four consecutive stages: (a) building, (b) holding, (c) pooling and (d) using knowledge [11, 12]. This cycle can be presented in linearly, but some activities within these stages can be performed simultaneously or in reverse.

Wiig's first stage (building knowledge) consists of obtaining, analysing, reconstructing, synthesising, codifying and modelling knowledge. At this point knowledge is acquired and built from various sources: experts and advisers, training courses, procedures and instructions, research, books, media, inspections and observations, as well as individual experience of members of the organisation.

Holding knowledge involves remembering it, accumulating and embedding it in repositories and archiving it. There are different forms of formal knowledge to be acquired, e.g., patents, research reports and technical documentation. This stage also includes holding tacit knowledge that can be found in company members' minds and which can be extracted in the form of practical tips and case studies, etc.

The third stage, pooling knowledge, assumes knowledge co-ordination that primarily relies on setting a knowledge resource network structure and on defining responsibility for making certain resources available. Other activities at this stage include collecting information about locating knowledge in documents, databases or expert networks (assembling knowledge) and providing access and retrieval of knowledge to all employees.

The last stage of Wiig's model, using knowledge, concerns ways of using practical knowledge within an organisation. For example, this can consist in using knowledge in routine tasks, production and services but mostly in any kind of decision-making processes conducted at various management levels. The latter includes using knowledge to identifying problems and their potential consequences, choosing knowledge suitable for solving these problems, searching for alternative solutions, assessing the advantages and disadvantages of those solutions, and planning and implementing selected solutions.

Wiig also proposed classifying manageable knowledge into three principal forms: (a) public knowledge, (b) shared knowledge (common for organisation members) and (c) personal knowledge [11]. Each of these forms was further divided into passive and active knowledge. Public

passive knowledge consisted mainly of books, standards and websites. Public active knowledge was made available by recognised experts, expert systems, etc. Written information on products, technologies, documented procedures, etc., was passive, shared knowledge. Informative systems used in an enterprise, including the intranet, were active shared knowledge. Whereas personal passive knowledge included information, facts and events stored in an individual's memory, personal active knowledge included skills, habits and an individual's interpretation of procedures.

2.3. Process-Based Approach to KM

A process-based model of KM is used to describe all processes enabling creation, dissemination and use of knowledge to achieve the goals of the organisation. The six-block model of key processes (the building blocks of KM) is a frequently-used model based on this approach [13]. This model assumes that there are tight connections among all key KM processes; thus influencing one influences the other ones.

According to the said model, knowledge identification is the block that initiates overall KM in the organisation. The processes of this block should concern both knowledge existing within the enterprise and external knowledge that is available to that enterprise. These processes should lead to the transparency of knowledge resources so that an individual employee can localise them easily. An employee who is able to transform data into knowledge and use it for the benefit of an enterprise is a basic element of its knowledge resources. That is why identification of external knowledge includes collecting information about expert knowledge held by employees as well as creating knowledge maps (i.e., graphic representations of the organisational structure of intellectual assets and knowledge sources in an enterprise).

Identifying external knowledge primarily means locating all external experts working for an enterprise and making a list of relevant informational resources available on the Internet. All employees should have access to those lists and maps.

Knowledge acquisition is another block in process-based KM; its aim is to acquire necessary resources from outside of an enterprise. This knowledge can be derived from various contacts with clients, suppliers, partner firms or competitors. Acquisition can also involve purchasing databases or specialist software, acquiring intellectual property rights (e.g., patents), employing new workers with high competencies, employing external experts and taking over companies with innovative potential.

Knowledge development is the third block. It is to enlarge knowledge resources that already exist within an organisation as well as those acquired from the outside. This includes research, development and design of new products, acquisition of new skills by employees while they work, support for innovations, increase in employees' creativity and generation of group knowledge by delegating tasks to self-managed teams.

The next block, knowledge distribution, consists of processes aimed at transforming single and isolated pieces of information or skills into knowledge resources used by the whole organisation. These can be both centrally controlled processes of knowledge dissemination among certain employee groups as well as knowledge transfer processes between people and teams. The following techniques can be used to distribute knowledge: providing training on new work tools, new software, management methods, etc.; stimulating employees to share knowledge with their colleagues; publishing procedures, instructions, newsletters; using e-mail and the intranet; organising information meetings with employees; using computer expert systems and workflow-type systems; and organising contacts between employees and external experts. It is particularly important to create an organisational culture oriented at reducing psychological barriers involved in sharing knowledge.

Processes in the block of knowledge use should ensure an efficient use of knowledge held by and available to employees to benefit an enterprise. These activities are connected with reducing psychological and organisational barriers that

restrain both employees and managers from using new knowledge in practice. Methods supporting the use of knowledge include implementation of understandable forms of presenting knowledge (e.g., readable reports, pictures and figures instead of text and easy-to-use information management systems), training employees in a direct use of knowledge (so-called action learning), etc. In the process of knowledge assimilation it is also important to ensure a friendly working environment with a proper organisation of departments and location of workstations within an office.

The last block of the process-based KM model, knowledge preservation, includes activities aimed at preserving knowledge acquired in an enterprise and preventing the enterprise from losing useful knowledge resources in the future. The activities in this block should focus on selecting information that is worth keeping, and on storing and updating information that can be useful in the future. Storing knowledge should not consist of traditional methods of document filing or creating a company's electronic repositories only, but it should also involve storing tacit knowledge that is endangered especially if key employees leave. It is possible to encourage experts to work in the company for as long as possible, to have key experts prepare their successors and to create connection mechanisms with former employees.

Probst, Raub and Romhardt's KM model also includes a feedback loop that makes it possible to achieve KM goals established within the enterprise [13]. The goals should involve the overall vision and strategy of the company, its position on the market and challenges posed by ensuring innovativeness and competitiveness. On the other hand, KM goals should be realistic and take into account current conditions of knowledge resources in the enterprises as well as the degree to which KM processes have been implemented. Therefore, knowledge resources should be measured and assessed, so that KM processes can be adjusted on the basis of those measurements. Measurement of knowledge is not easy; however, there is information in the literature on knowledge measurement systems implemented in various enterprises (e.g., in consulting companies or enterprises focused on innovations). Still, there is no homogeneous approach in this area and indicators chosen to assess the level of knowledge vary. Probst et al. propose using, e.g., a Balanced Scorecard approach [20, 21], multidimensional knowledge measurement systems [22], assessment of organisational culture sensibility to knowledge, or strategic benchmarking.

2.4. Criticism of KM, and Its Successive Generations

At the end of the first decade of KM concept development, several publications criticised its usefulness and indicated its failure to fulfil the original expectations of business and scientific circles. For example, according to Pollard KM did not meet such expectations as innovation growth in enterprises, productivity and efficiency improvement, relations with clients, employee education and their retention as well as quality of managerial decisions [23]. This was so because of "the unrealistic expectation that human organizational behaviour could be changed, in all kinds of positive ways, by persuading people of the wisdom of capturing, sharing, and archiving knowledge" (p. 2).

Others suggested that KM would not bring revolutionary changes in business because it was in fact a management fad. According to Ponzi and Koenig, interest in management fads usually waned after an average of 5 years from the momentum of a given concept [24]. This was true for the quality circles' movement, TQM and BPR. Even though Ponzi and Koenig said KM was different, they claimed interest in KM-related topics peaked in business and scientific circles in 2002. Wilson, too, predicted that KM should be considered as a management fad that would go the same way as other fads in management; this concept was promoted mainly by consulting companies and business schools interested in having something new to sell to the business world, and also partly by IT companies and software houses that needed a good name for their IT products [25].

Grant and Grant analysed the criticism of the first phase of KM development; they saw excessive focus on applying IT to KM to be its main disadvantage. This resulted in KM turning into information management with no practical value [26]. Despite this criticism, support of the KM concept did not decrease; instead, there were a number of successful KM implementations in enterprises. There were also failures resulting from mistakes in KM implementation and not from the concept itself [27]. That is why KM researchers tried to improve the concept. As a result, new generations of KM were developed: McElroy's second-generation KM [28, 29, 30], Snowden's third-generation KM [31, 32] and Sveiby's [33] and Wiig's [34, 35] next generation KM (NGKM).

NGKM's main feature is its strong focus on human aspects. The basic differences among NGKM and previous generations of KM are the degree of integration between NGKM and enterprise philosophy, strategy, aims, practices and procedures, and the way in which this concept becomes a part of the employees' motivation and their everyday life [36]. The main characteristics of NGKM are (a) broad and proactive business philosophy and management beliefs; (b) knowledge-focused business strategies and practices; (c) intellectual capital stewardship mentality; (d) systematic, self-sustaining and self-renewing KM practices; (e) systems perspective of enterprise and environment; and (f) vigilant application of state-of-the-art KM practices and infrastructure capabilities [34, 35].

First generations of KM were more focused on technology, systems, or organisational culture, whereas NGKM is focused on how people learn, remember, make decisions, solve problems and act, and the connection between knowledge and workers' behaviour. When the NGKM principles were formulated, research results were used in mental models, narrative, conceptual blending, decision theory and sense-making.

According to Wiig, ensuring that all employees have access to necessary resources of professional, craft and navigational knowledge and metaknowledge is a significant success factor related to implementing KM principles in enterprises [35]. Employees must have requisite skills and attitudes (personality traits), which is strongly connected with the creation and transfer of components of tacit knowledge. Other success factors involve creating and maintaining a suitable organisational culture and work atmosphere, in which employees have the permission to act innovatively, to improvise and to step beyond established schemes and scopes of activities to serve the enterprise and it stakeholders as best as they can. Furthermore, it is very important to motivate employees to act intelligently by showing them that their actions will be valuable to the stakeholders, the enterprise and to themselves.

Wiig underlined that "KM must be people focused, not technology-centric, and must rely on people-related mechanisms such as storytelling, communities of practice (CoP), and social networking" (p. 229) [35]. The implementation of NGKM must be harmonised with culture and with joint values of the enterprise, employees and external stakeholders.

3. REVIEW OF LITERATURE ON KM IN OSH MS

3.1. KM in OSH MS in High-Risk Industries

Mining, including hard coal mining, is a high-risk industry. Working conditions in this sector are very dangerous, which is reflected by a high ratio of occupational accidents and diseases in comparison with other industries and service sectors. Therefore, searching for efficient ways to improve working conditions in mining is of primary importance. That is probably why the first attempts to introduce KM principles in OSH management were made in this sector. To date there have been some studies and implementation efforts in this area, but few offer ideas on how KM concepts can be used in practice to manage OSH.

One of those studies used experience gained in developing OSH management in Australian mining to describe an example of a formal KM

process implemented to improve strategies of occupational risk management [36]. The most important steps of this process are (a) mapping knowledge in the organisation, (b) carrying out a KM audit, (c) identifying knowledge gaps and needs, (d) appointing project teams and initialising projects for acquiring and documenting knowledge and, after their completion, (e) overviewing and assessing the results in view of a reimplementation of KM processes in accordance with the principle of continuous improvement. This process is to be applied to various kinds of formal knowledge related to risk assessment and management, particularly to hazard and risk registers; the scope, completeness and application of safety-related policies and procedures; the effectiveness of current risk controls; investigation and identification of new controls; development of skills and knowledge inventories; risk communication methods, emergency management plans, etc. Cater proposed several methods and tools to support KM processes in practice in risk management, such as benchmarking, peer assistance, workshops and discussion groups, after-action reviews, corporate yellow pages and OSH knowledge websites; and the need to acquire tacit knowledge within risk management activities. However, there was no suggestion of any solutions that would ensure effective dissemination and the use of OSH-related tacit knowledge held by individual employees [36].

Vaught, Mallett, Brnich, et al. studied explorations of tacit knowledge in OSH management in the USA [37]. This research focused on acquiring tacit knowledge on specific behaviours of mine rescuers during mine emergency responses. Since some sources of useful tacit knowledge may exist outside of the consciousness of individual employees and may be distributed across the individuals [18], it was assumed that such knowledge was transferred among rescue team members and that the process was manageable.

Narratives (storytelling) were used in National Institute for Occupational Safety and Health's research to acquire and cultivate tacit knowledge. This method is increasingly used not only in the arts and literature, but also in medicine, or science, in general [38]. Thirty rescue veterans took part in the study. In the presence of researchers they told their stories about specific moments of rescue actions they took part in. Next, those stories were used to design scenarios of simulated rescue actions that were later used in training miners, rescuers and people responsible for emergency management in mines. Such field training sessions were organised in real conditions in a U.S. hard coal mine. As a result of this experiment, tacit knowledge hidden in the minds of the rescue veterans was transferred to the minds of a future generation mine rescuers. Additionally, the rescue veterans' recorded stories were used as explicit knowledge and a free publication for miners and rescuers was developed [39].

Many social sciences researchers have confirmed the success of storytelling as a natural method of knowledge sharing, especially with regard to tacit knowledge. Most people remember complicated relations and conditions better if they are structured and presented in the form of a story. Therefore, this method may be very useful for many aspects of KM applications in organisations; it influences both the ways in which knowledge is disseminated among workers, and in which it is acquired and institutionalised [33]. In enterprises that belong to high-risk industries, it has been proven that people learn safety rules faster when those rules are presented in the form of stories than in formal training or through instructions [40]. However, so far storytelling has not been appreciated or used widely by managers; formal and systematic approaches predominate.

According to Gherardi and Nicolini safety knowledge should be perceived as a collective competency or a culture developed within CoP [41]. Wenger, McDermott and Snyder define CoPs as informal "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4) [42]. Studies indicate that formal and model-based approaches are not

suitable in safety KM; it is necessary to include elements of a human inquiry perspective in the learning process and thus to attribute a greater role to socially accepted methods of tacit knowledge exchange [40].

3.2. KM Principles in OSH MS and Ergonomics

Sherehiy and Karwowski made the first attempt to include KM principles into an existing generic model of OSH MS [43]. The scope of this concept goes beyond traditional OSH boundaries because it also includes managing ergonomic interventions in an enterprise. That is why the whole area covered by the concept has been denoted as occupational safety, health and ergonomics (OSHE). To indicate the possibilities and the scope of applying KM principles to OSHE management, the ILO-OSH 2001 [44] organisational framework of the OSH MS model was adopted.

First of all, Sherehiy and Karwowski assumed that knowledge is a central resource that helps to achieve goals in OSHE management. However, the current approach to management in this area focuses on formal KM, i.e., on legal provisions, standards, guidelines, procedures and internal instructions, registers, etc., whereas to ensure efficient OSHE management in an enterprise it is necessary to explore tacit knowledge hidden in the minds of experienced employees at all organisational levels. This knowledge is strictly connected with the working context and is hard to verbalise, e.g., a safety engineer's experience, hazard recognition and its practical aspects, perceptual and cognitive skills, rules of thumb, intuition and syntheses of facts.

Sherehiy and Karwowski emphasised that KM is an important method that should allow achieving management goals in OSHE [43], although at present there are no validated models of KM applications in this area. KM should stimulate suitable conditions of knowledge exchange, innovative solutions application and the use of knowledge already existing in an organisation. Moreover, according to Sherehiy and Karwowski a future KM model for OSHE should include creating organisational knowledge; organisational learning (including knowledge transfer, sharing and consolidation); and knowledge revision, conceptualisation, reflection and acting. It is also important that it consider objective knowledge, especially tacit knowledge that all employees regardless of their position have.

3.3. Tacit Knowledge in EMS and OSH MS

The internal structures of OSH MS implemented on the basis of national voluntary standards or ILO guidelines [44] are mostly similar to those of EMS (Standard No. ISO 14001:2001 [45]). The generic models of those systems are based on the same concept, i.e., PDCA, and their formal specifications contain similar functional conceptions of their main elements. Therefore, it was possible that the exploration and use of tacit knowledge in EMS would throw light on the potential role and use of tacit knowledge in OSH MS.

The results of a study conducted in eight Canadian industrial enterprises implementing EMS provide some evidence for this thesis [8]. The study revealed the relevance of tacit knowledge in three areas of EMS: (a) identification of pollution sources, (b) proposals for preventive solutions and (c) management of emergency situations. These areas can be considered as analogical to the following elements of OSH MS: (a) hazard identification, and risk assessment and management; (b) prevention and control measures and (c) emergency prevention, preparedness and response. Moreover, this study showed that promoting and sharing tacit knowledge in EMS appeared within the framework of (a) consultation of the personnel, (b) empowerment, (c) training and (d) documentation and retention. The first three of these categories are essentially analogous with OSH MS sections on worker participation, and competency and training.

Research on tacit knowledge in EMS has also shown many other findings that can be adequate to view these issues from the perspective of OSH MS. First of all, it turned out that workers' personal knowledge greatly influenced the identification of environmental hazards. This

knowledge was based on routine work activities and physical proximity to those hazards. Tacit knowledge was also useful in seeking preventive solutions and solutions that would minimise those hazards. To use that knowledge, however, it was necessary to create a suitable climate and conditions in an enterprise, which would trigger workers' voluntary participation and commitment in those activities.

Boiral suggested a general framework for managing tacit knowledge in an enterprise. It consisted of four stages: creation, consultation, codification and implementation. These processes would work only if there were suitable structures and management habits that favoured consultations with employees, empowerment practices and creation of good climate for informal exchange of knowledge [8]. Codification of tacit knowledge could be difficult. Managers, especially those in formal management systems, tend to document all activities and thus codify relevant knowledge. Codification of tacit knowledge may be expensive and lead to bureaucracy and excessive documentation. It may also result in more importance being paid to formal knowledge; thus both managers and employees might overlook the advantages of tacit knowledge.

3.4. KM in OSH MS—a Summary

The overview of literature in sections 3.1 and 3.2 shows that research on the use of KM principles in OSH management is still fragmented and that it focuses on attempts to use a set of KM methods to support different components of OSH MS. The conclusion regarding the role of tacit knowledge in this system is that its acquisition and exchange require special attention. This type of knowledge may be important in hazard identification and risk control processes, in efficient training of workers, particularly rescuers in high-risk industries, etc.

The results of research on the role of tacit knowledge in specific areas of EMS (section 3.3) provided an indirect proof of the potential and importance of that knowledge in OSH MS. A comparison of these areas with their equivalents in OSH MS shows that acquiring and exploring tacit knowledge can improve the effectiveness of hazard identification and risk management, implementation of prevention and control measures, emergency prevention, preparedness and response, and of training and other forms of developing competencies. Tacit knowledge acquisition processes should support organisational learning and should lead to effective OSH management in enterprises. However, to achieve these goals it is necessary to develop and disseminate practical tools supporting enterprises in efficient knowledge exploration and management.

A search for literature on applications of KM produced several studies on applications of KM to improving the general safety of the public. However, most of them concerned issues outside the traditional scope of OSH and focused on societal concerns regarding the influence of industrial development. Thus, there were numerous attempts to apply KM principles in industrial safety [46], nuclear safety [47] and aviation safety [48]. Some KM applications in these fields include interesting concepts, models and tools, but there is no evidence that they will be applicable to OSH. That is why at present they might be considered as sources of ideas that may lead to future studies, rather than sources of any practical conclusions on the role of KM in OSH.

4. TACIT KNOWLEDGE IN OSH MS

4.1. Systematic Approach to OSH Management

The era of systematic management of OSH started in the mid-1990s. Since then there has been a significant transformation in strategies of improving working conditions. This process includes a radical change in the approach of all stakeholders from enforcing obligatory compliance with detailed technical provisions on OSH to voluntary implementation of system procedures aimed at continuous improvement. The latest stage of this transformation is reflected in voluntary national standards on OSH MS, e.g., BS 8800:1996 [49], AS/NZS 4804:1997/2001 [50] and PN-N-18001:1999/2004 [51]. At an international level, dissemination of a systematic

approach to OSH management was connected with the development of the OHSAS 18001 specification [52] and with the establishment of the ILO-OSH 2001 guidelines on OSH MS [44].

OSH MS models adopted in the aforementioned documents are based on the PDCA or Deming's cycle. Some of those models were developed for specific industries or activity sectors, e.g., an OSH MS for the construction industry as specified in Standard No. SAA HB53 [53]. However, most of those models are generic and can be used in enterprises regardless of the economic sector or type of activity.

Adoption of an OSH MS model based on PDCA in such international documents as OHSAS 18001 [52] or ILO-OSH 2001 [44] has caused domination of this model in applications all over the world. For example, in 2005 OSH MS certified according to OHSAS 18001 were in place in over 15000 enterprises in 82 countries[1]. The exact number of enterprises with OSH MS is not known at present, but as the market for certification services in OSH MS has grown by ~30–40% per year, the number of enterprises with this system in place could be estimated at ~50000 in 2009.

4.2. Behaviour-Based Safety in OSH MS

In recent years the behaviour-based safety (BBS) approach (sometimes called behavioural safety) has become increasingly popular within OSH management. BBS is commonly defined as a systematic application of psychological research on human behaviour to the problems of safety in the workplace [54]. This method assumes that people tend to take risky actions but these actions are not a result of an inappropriate approach towards safety but of a lack of experience. BBS has been successful because ~80% of accidents at work result from employees' inappropriate behaviour [55]. Moreover, BBS is focused on observable and measurable behaviours critical to occupational safety in a given enterprise.

Many consulting companies offer and promote BBS implementation programmes world-wide. Many studies provide a sufficient amount of scientific evidence that attests to the effectiveness of behavioural safety initiatives across a variety of industries in many countries [56, 57]. An implementation programme in an enterprise should cover identification and specification of employees' behaviours that are critical for their safety, observation of these behaviours and collection of data that concern their frequency and, finally, implementation of appropriate correction and prevention actions for ensuring improvement of workers' safety and health [58].

Implementation of BBS in an enterprise where a formal OSH MS already exists and is complementary with one of the previously described models does not require major changes in the system itself. New components that include BBS can be easily integrated with the existing management system and output from that system can be used as input into behavioural safety interventions and vice versa. In particular, BBS processes can be a part of a risk management subsystem; e.g., workstations or operations identified in a risk management process as related to significant hazards can be further analysed to identify critical behaviours that are needed for hazard prevention. Results of such analyses can be used for modifying employees' behaviours to prevent hazards and to reduce occupational risks [59].

4.3. Potential Use of Tacit Knowledge in OSH MS

Desk research was carried out to find the most important areas of OSH MS where processes of acquiring, processing, transferring or using OSH-related knowledge took place. It consisted in an analysis of the detailed specifications of all elements of this system and a review of the relevant literature on OSH management issues. The model and specifications of OSH MS laid down in ILO-OSH 2001 [44] were the

1 OHSAS Project Group, 2006, Results of the survey into the availability of OH&S standards and certificates, up until 2005-12-31 [unpublished document].

structural framework of this analysis. They were supplemented with a set of management system requirements connected with an implementation of BBS. Table 1 presents the results of this analysis. To demonstrate the potential role of tacit knowledge to be used in the individual sections of the system more clearly, its scopes are described and contrasted with the types of formal (i.e., explicit) knowledge relevant to these sections. Additionally, the scopes of the explicit and tacit knowledge determined in Table 1 for the different sections of the system have been divided into two parts, for managers (M) and for workers (W). Because of the different roles of those groups in the management system and with regard to work processes, the types and amount of knowledge possessed or transferred by managers and by workers differ considerably.

TABLE 1. The Use of Knowledge in Sections of an Occupational Safety and Health Management System (OSH MS)

A. Scope of knowledge useful for the Policy section

	Formal (Explicit) Knowledge	Tacit Knowledge
	A1. OSH policy	
M	Legal regulations and standards on OSH on employers' responsibility for OSH	Personal experience in managing an enterprise according to established policies and rules
	Other requirements (collective agreements, corporate social responsibility standards, labour inspectorate recommendations, etc.)	Sense of moral obligation for applying continuous improvement rules to OSH
	Specifications of OSH MS	
	Declaration of the enterprise's OSH policy	
W	Declaration of the enterprise's OSH policy	No OSH-specific tacit knowledge required
	Procedures and instructions implementing OSH policy and standards at the level of the workplace	
	A2. Worker participation	
M	Legal regulations on safety and health committees	Personal experience in consulting and/or involving workers in activities aimed at improving OSH
	Arrangements for workers and their safety and health representatives to participate actively in OSH management	
W	Arrangements for workers and their safety and health representatives to participate actively in OSH management	Concerns, ideas and other inputs on OSH submitted by workers to be considered within OSH MS

B. Scope of knowledge useful for the Organisation section

	Formal (Explicit) Knowledge	Tacit Knowledge
	B1. Responsibility and accountability	
M	Legal regulations on employer's responsibility for OSH in the enterprise	Personal experience and leadership skills in implementing OSH improvement activities
	Records on allocation of responsibility, accountability and authority for the development, implementation and performance of OSH MS	
	Definition of managers' responsibility and accountability in OSH MS	
	Arrangements and responsibilities to identify and control work-related hazards and risks	
W	Formal rules and procedures related to OSH established at the level of the workplace	No OSH-specific tacit knowledge required
	Scopes of individual workers' responsibility and accountability in OSH management	

TABLE 1. (*continued*).

	Formal (Explicit) Knowledge	Tacit Knowledge
	B2. Competency and training	
M	Requirements for OSH competencies defined for all workstations and organisational levels Training programmes for managers (including safety managers) on general OSH issues and their roles in OSH MS OSH knowledge acquired by managers from consultants, journals, books, websites, etc. Risk management procedures and safety rules	OSH knowledge acquired by managers (including safety managers) by learning on the job, mentoring, etc. Personal experience in formal and informal methods of transferring OSH-related knowledge to workers
W	Training programmes for workers on OSH and their roles in OSH management OSH knowledge transferred to workers in training courses, and through procedures, instructions, publications, websites, etc.	OSH-related knowledge acquired by workers by learning on the job, apprenticeship, mentoring, etc. Personal knowledge and awareness of hazards, risks and safety rules acquired from co-workers
	B3. OSH MS documentation	
M	Documented OSH policy and objectives Arrangements, procedures, instructions, etc., within OSH MS Allocated key OSH management roles and responsibilities for OSH MS Results of hazard identification, risk assessment, and monitoring active and reactive OSH performance Records on workers' exposure, injuries, ill health, diseases, incidents, absenteeism, and on surveillance of workers' health	No OSH-specific tacit knowledge required
W	The same types of formal knowledge as for managers, but limited to the scope required for individual workers at their workstations	No OSH-specific tacit knowledge required
	B4. Communication	
M	Arrangements and procedures for receiving, documenting and responding to internal and external communications related to OSH OSH-related information transferred between relevant levels, managers and workers	Personal experience and skills in implementing OSH-related communication procedures
W	Arrangements and procedures for internal communication related to OSH Documented concerns, ideas and other inputs on OSH submitted by workers	Personal knowledge and awareness of hazards and risks (acquired by learning on the job) transferred between workers and managers Concerns, ideas and other inputs on OSH submitted by workers to their safety and health representatives and managers
	C. Scope of knowledge useful for Planning and Implementation* section	
	Formal (Explicit) Knowledge	**Tacit Knowledge**
	C1. System planning, development and implementation	
M	Arrangements and procedures for planning of OSH improvement activities Records on risk assessment, OSH monitoring, workers' exposure, injuries, ill health, diseases, incidents, absenteeism, etc., as a basis for OSH improvement plans OSH improvement plans adopted in the enterprise including criteria selected for measuring achievement of objectives	Personal experience and skills in preparing, establishing, implementing and evaluating OSH improvement plans

TABLE 1. (*continued*).

	Formal (Explicit) Knowledge	Tacit Knowledge
W	Tasks in OSH improvement plans relevant to individual workers' work and responsibility	Concerns, ideas and other inputs on OSH submitted by workers and considered in OSH improvement plans
	C2. OSH objectives	
M	Records on risk assessment, OSH monitoring, workers' exposure, injuries, ill health, diseases, incidents, absenteeism, etc., as a basis for OSH objectives and targets	No OSH-specific tacit knowledge required
	OSH objectives adopted in the enterprise	
W	OSH objectives and targets relevant to individual workers' activity and responsibility	No OSH-specific tacit knowledge required
	C3. Hazard and risk prevention: prevention and control measures	
M	Arrangements, procedures and instructions for identifying hazards and assessing risks (including checklists, software tools, etc.)	Personal knowledge on the effectiveness of preventive and protective measures for the elimination of hazards and reduction of risks (acquired by learning on the job)
	Regulations, standards and research reports with criteria for estimating risk for various factors (e.g., exposure)	Personal knowledge of dangerous work processes, workstations and work methods, where workers' behaviours may be critical for their safety
	Records of measurements of workers' exposure and results of risk assessment carried out periodically or occasionally at workstations	
	Knowledge of preventive and protective measures for eliminating hazards and reducing risks (technical standards, guidelines, handbooks, etc.)	
W	Knowledge of hazards and risks identified and assessed at individual workstations within formal risk assessment	Personal knowledge of hazards and risks at the workplace (acquired by learning on the job or transferred by co-workers within team work)
	Formal safety rules, instructions and technical requirements to be applied by workers when using protective or preventive measures for elimination of hazards and reduction of risks	Personal knowledge of safety-critical behaviours and safety rules (acquired by learning on the job or transferred by co-workers within team work)
	C4. Hazard and risk prevention: management of change	
M	Results of evaluation of the impact on OSH of internal changes (e.g., in staffing, new processes, working procedures and organisational structures) and of external changes (e.g., in national laws, OSH knowledge and technology)	Personal knowledge of the effectiveness of preventive and protective measures in eliminating hazards and reducing risks
	Results of identification of hazards and assessment of risks carried out before any modification or introduction of new work methods, materials, processes or machinery	Personal knowledge of dangerous work processes, workstations and work methods where workers' behaviours may be critical for their safety
W	Knowledge of new hazards and risks identified and assessed at individual workstations in the case of modification or introduction of new work methods, materials, processes or machinery	Personal knowledge of hazards and risks introduced by modification or introduction of new work methods, materials, processes or machinery (acquired by learning on the job)
	C5. Hazard and risk prevention: emergency prevention, preparedness and response	
M	Knowledge of potential hazards and OSH risks associated with storing, processing, producing and transporting dangerous materials and goods (inflammable, explosive, toxic, etc.)	Personal knowledge of potential impact of hazards and risks associated with storing, processing, producing and transporting dangerous materials and goods on workers' safety and health
	Procedures for identifying potential for major accidents and emergency situations within the enterprise and in the neighbourhood	Personal knowledge of emergency rules and evacuation plans acquired by participation in training courses and exercises in emergency procedures
	Emergency plans and procedures (including evacuation) and other arrangements for first aid, medical assistance, firefighting, etc.	
	Training programmes for all members on emergency procedures, including plans for regular exercises in emergency procedures	

TABLE 1. (*continued*).

	Formal (Explicit) Knowledge	Tacit Knowledge
W	Emergency plans and procedures (including evacuation) and other arrangements for first aid, medical assistance, firefighting, etc. Training programmes for all members on emergency procedures, including plans for regular exercises in emergency procedures	Personal knowledge of potential impact of hazards and risks associated with storing, processing, producing and transporting dangerous materials and goods on workers' safety and health Personal knowledge of emergency rules and evacuation plans acquired by participation in training courses and exercises in emergency procedures
	C6: Hazard and risk prevention: procurement and contracting**	
M	Legal regulations, standards and internal safety and health requirements for goods (machinery, equipment, tools, personal protective equipment, etc.) and services to be purchased by the enterprise Legal regulations, standards and internal safety and health requirements established in the enterprise for selecting contractors Contractors' reports on OSH, including identified hazards and risks, results of OSH monitoring, records of injuries, ill health, diseases, incidents, absenteeism, etc.	Personal knowledge of hazards and risks that may be associated with using goods (machinery, equipment, tools, personal protective equipment, etc.) and services to be purchased by the enterprise Personal knowledge of potential hazards and risks brought by contractors' workers
W	OSH procedures established by the enterprise for contractors' workers Training programmes on OSH provided for contractors' workers prior to commencing work	Personal knowledge of hazards and risks at the workplace (acquired by contractors' workers by learning on the job or transferred by co-workers) Personal knowledge of safety-critical behaviours and safety rules (acquired by contractors' workers by learning on the job or transferred by co-workers)
	D. Scope of knowledge useful for the Evaluation section	
	Formal (Explicit) Knowledge	**Tacit Knowledge**
	D1. Performance measurement and evaluation	
M	Procedures for monitoring, measuring and recording OSH performance of the enterprise Results of proactive OSH monitoring, including, e.g., systematic inspections of work systems, premises end equipment, surveillance of workers' health, achievement of OSH-related plans, and of compliance with national regulations and other commitments Results of reactive OSH monitoring, including, e.g., statistics on work-related injuries, ill health, diseases and incidents, data on damage to property and other losses, decisions of labour inspectors, and results of programmes of workers' rehabilitation and behaviour-based safety programmes	Personal knowledge of dangerous work processes, workstations and work methods, where workers' behaviours may be critical for their safety
W	Procedures for monitoring, measuring and recording OSH performance of the enterprise relevant to individual workers' at their workstations	Personal knowledge of hazards and risks at the workplace (acquired by learning on the job or transferred by co-workers within team work) Personal knowledge of safety-critical behaviours and safety rules (acquired by workers by learning on the job or transferred by co-workers within team work)

TABLE 1. (*continued*).

	Formal (Explicit) Knowledge	Tacit Knowledge
	D2. Investigation of work-related accidents, diseases and incidents	
M	Reports from internal investigations on the origin and underlying causes of work-related injuries, ill health, diseases and incidents Reports of external OSH investigative agencies, e.g., labour inspectorates and social insurance institutions Results of investigations communicated to the safety and health committee and to responsible persons for corrective actions	Personal knowledge of and experience in methods and techniques of carrying out internal investigations on the origin and underlying causes of work-related injuries, ill health, diseases and incidents
W	Reports from internal investigations on the origin and underlying causes of work-related injuries, ill health, diseases and incidents (relevant to individual workers' at their workstations)	Personal knowledge of the origin and underlying causes of work-related injuries, ill health, diseases and incidents reported by individual workers
	D3. Audit	
M	Arrangements, programmes and procedures related to conducting periodic audits of all components of OSH MS Reports from periodic audits of OSH MS with conclusions for persons responsible for corrective actions	Personal experience and skills in methods and techniques necessary to carry out periodic audits of OSH MS
W	Reports from periodic audits of OSH MS with conclusions for persons responsible for corrective actions (relevant to individual workers' workstations)	Personal knowledge of failures and deficiencies in OSH MS Workers' ideas for corrective and preventive actions to improve OSH MS
	D4. Management review	
M	Analysis of the effectiveness and compliance of OSH MS, including results of investigations of work-related injuries, ill health, diseases and incidents; results of monitoring performance, measurements and audits; and other internal and external inputs and organisational changes, that could affect OSH MS and OSH policy Findings of OSH management review communicated to persons responsible for relevant elements of OSH MS, to the safety and health committee, workers and their representatives	No OSH-specific tacit knowledge required
W	Findings of OSH management review communicated to persons responsible for relevant elements of OSH MS, to the safety and health committee, workers and their representatives	No OSH-specific tacit knowledge required

	E. Scope of knowledge useful for the Action for Improvement section	
	Formal (Explicit) Knowledge	**Tacit Knowledge**
	E1. Preventive and corrective action	
M	Arrangements, procedures and plans for preventive and corrective actions resulting from OSH monitoring, OSH MS audits and management reviews Analysis of root causes of OSH MS nonconformities with their specifications and documentation, with OSH regulations and OSH policy Reports on implementation and effectiveness of the preventive and corrective actions	Personal knowledge and experience in methods and techniques for investigation of root causes of OSH MS nonconformities with its specifications and documentation, as well as with OSH regulations and enterprise OSH policy

TABLE 1. (*continued*).

	Formal (Explicit) Knowledge	Tacit Knowledge
W	Results of analysis of root causes of OSH MS nonconformities with their specifications and documentation, and with OSH regulations and OSH policy (relevant to individual workers' workstations)	Personal knowledge of workers on failures and deficiencies in OSH MS Workers' ideas for corrective and preventive actions to improve OSH MS procedures
	E2. Continuous improvement	
M	Arrangements and procedures for continuous improvement of elements of and whole OSH MS	Sense of moral obligations for applying rules of continuous improvement to OSH
	Recommendations from comparing OSH enterprise's performance and processes in OSH with others (benchmarking)	Personal knowledge and experience in methods and techniques of implementing principles of continuous improvement at the level of enterprise or department
W	Instructions for implementing principles of continuous improvement at the level of the workstation	Personal knowledge and experience in methods and techniques of implementing principles of continuous improvement at the level of the workstation

Notes. M—managers, W—workers. *—the provisions of ILO-OSH 2001 [44] in area C contain specifications for the Initial Review section (clause 3.7). This section was not analysed here, since it includes activities carried out before OSH MS is implemented; **—specifications for Procurement and Contracting are presented separately in the ILO-OSH 2001 guidelines (clauses 3.10.4 and 3.10.5, respectively). For the purpose of simplification, they were analysed jointly here.

An overview of Table 1 shows that the right column (tacit knowledge) has fewer descriptions of scopes of knowledge than the left column. However, this does not mean that processing and transferring tacit knowledge are less important in managing OSH; tacit knowledge is difficult to grasp, define, explore and describe, because it is stored and distributed in the minds of the members of the organisation. Therefore, it is hard to unequivocally assign it to individual elements of OSH MS.

4.4. Tacit Versus Explicit Knowledge in OSH MS

The overall aim of the study on the possible and actual applications of KM principles in OSH MS was to determine how the management of tacit knowledge might contribute to such a system and, as a consequence, how it might potentially benefit the enterprise that has implemented that system. A literature review on that issue (section 3) and a desk analysis of the detailed specifications of OSH MS components (section 4) resulted in an identification of the main roles of tacit knowledge in this system, particularly in contrast to the usually well-defined scope of the use of explicit knowledge. Figure 2 is a graphic representation of the results of this study.

The right part of Figure 2 contains a complete list of the consecutive sections of OSH management incorporated into the model of the system according to the concept and structure in ILO-OSH 2001 [44]. The left part represents Nonaka's cycle of creating organisational knowledge [6, 10], which is widely used in literature to explain the difference between tacit and explicit knowledge and to introduce the concept of mutual conversion of those two types of knowledge (see section 2.1). The spiral loop within this model shows the direction of subsequent steps in the creation and recreation of knowledge within OSH MS. Therefore, this cycle may be considered as a kind of engine driving the whole OSH MS towards substantial improvement by injecting new amounts of vital organisational knowledge.

The links and arrows running from left to right do not represent a flow of any real knowledge. Both tacit and explicit already exist and/or are being created within the sections of OSH MS. The purpose of the dark and light grey arrows is to indicate the sections where relevant bodies of tacit and explicit knowledge are particularly important for ensuring the overall effectiveness and improvement of the whole system.

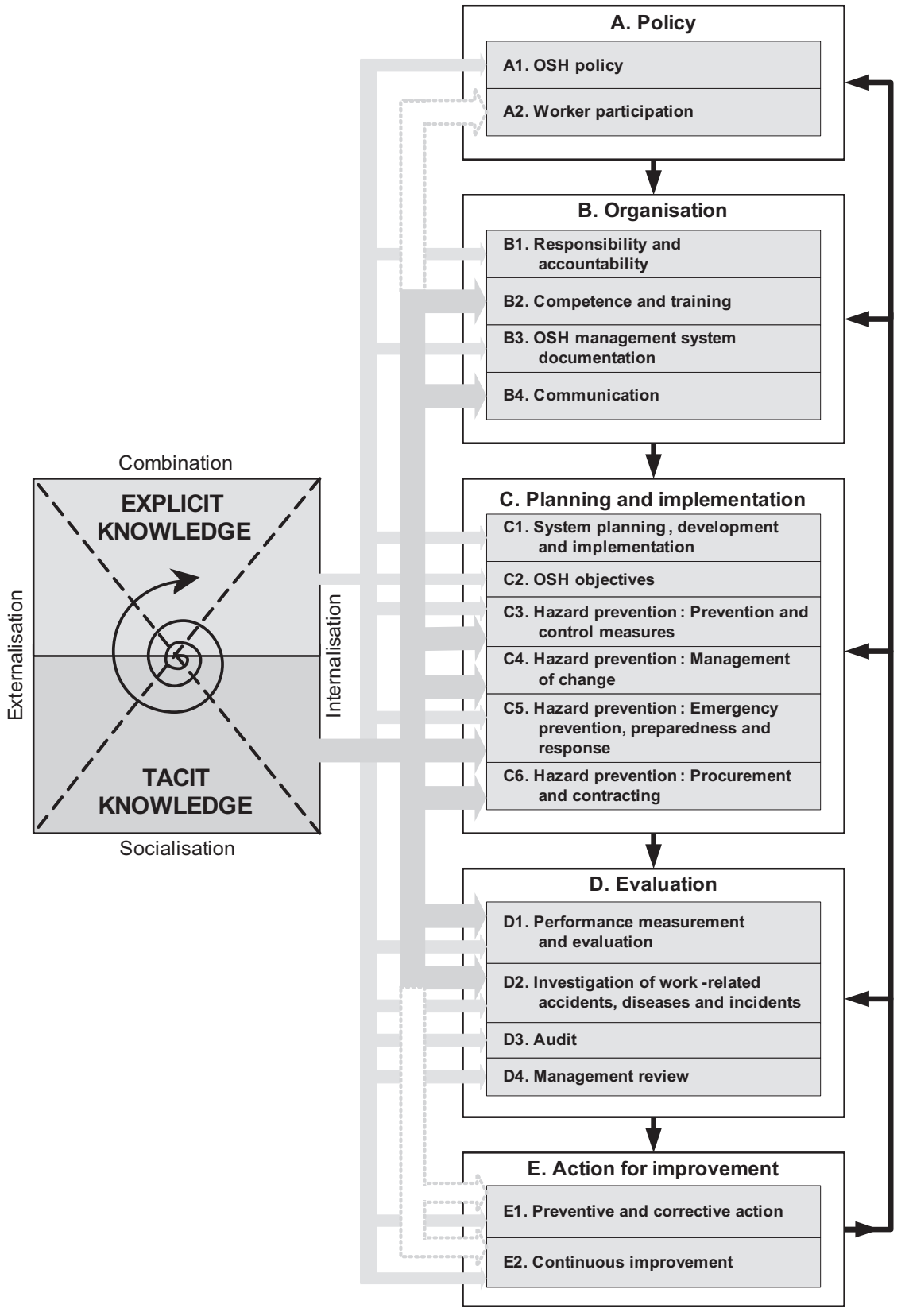

Figure 2. The main roles of tacit and explicit knowledge in an occupational safety and health (OSH) management system.

4.4.1. Tacit knowledge

First, tacit knowledge plays an important role in those activities within OSH MS that focus on building individual workers' and managers' awareness of hazards and risks in the workplace, disseminating efficiently OSH knowledge and shaping safety culture (B2 and B3 in the system). Second, the exploration of tacit knowledge may significantly contribute to the quality of hazard identification and risk assessment carried out at individual workstations, preferably in consultation with and participation of workers and their safety and health representatives. Next, tacit knowledge is necessary for appropriate selection and application by workers of preventive and protective measures and, in consequence, it may significantly influence their effectiveness in eliminating and/or reducing hazards and risks (C3, C4, C5 and C6).

Workers' tacit knowledge in the form of awareness of hazards and risks at their workstations may be a valuable input into measuring and evaluating OSH performance of enterprises, particularly in the scope of proactive and reactive OSH monitoring (D1) and in investigating work-related accidents, diseases and incidents (D2). The profound knowledge obtained in this way will be useful in developing and implementing OSH improvement plans, including planning and implementing preventive and corrective actions. Those actions will be better adapted to dealing with real irregularities, nonconformities and other failures identified within OSH MS.

Figure 2 also shows directions of the potential use of tacit knowledge, which are not directly linked with assessing and preventing occupational risks, but with assuring efficient functioning and improving overall OSH MS (the relevant sections of the system are indicated with dotted arrows). In A2, tacit knowledge is embedded in concerns, ideas and other inputs on OSH matters that are generated by workers for inclusion into OSH MS activities. Exploring and using this tacit knowledge may bring good results in the short term: proposals for OSH improvements submitted by workers will better reflect their real needs and demands with regard to OSH and, in consequence, actions for OSH improvement imposed by managers to fulfil those needs and demands will be better received and implemented by workers.

Similar roles are assigned to tacit knowledge in E1, where using this knowledge to identify root causes of any inconsistencies or nonconformities within OSH MS will lead to better reaction to and more efficient correction of those failures. In E2, the role of tacit knowledge relies on its contribution to shaping durable habits and skills of routine application of continuous improvement principles by all members of the enterprise. This can apply to work processes as well as to other activities, e.g., improving operating machinery or other production devices, and improving management procedures or OSH administration. Tacit knowledge in E2 may thus substantially benefit the enterprise by increasing the scope and efficiency of all activities aimed at continuous improvement of OSH MS.

4.4.2. Explicit knowledge

Table 1 and Figure 2 show that explicit knowledge is important in almost all sections of OSH MS. This observation is evident since the whole concept of implementing OSH MS in the enterprise is based on a systematic acquisition and use of explicit knowledge. This knowledge is strictly codified and disseminated in various documents, procedures, instructions, etc., according to specifications of OSH MS used in an enterprise (e.g., ILO-OSH 2001 [44]). In principle, explicit knowledge in OSH MS can be divided into three categories: (a) external explicit knowledge that influences managing OSH in the enterprise, (b) internal explicit knowledge on the operation of OSH MS and (c) practical knowledge on identifying hazards, assessing risk and using preventive and protective measures.

The forms of explicit knowledge listed in Table 1 are mostly passive sets of information, records and formal data. They are necessary to run OSH MS and to provide evidence to external OSH surveillance bodies or certification companies that the system is in place and complies with relevant specifications. However, this knowledge will be of little or no use for

OSH if it is not converted and embedded in the workers' and managers' minds as awareness of hazards and risks in the workplace and as their internal motivation to act pro-safety. This conversion belongs to the domain of tacit knowledge and attests to its dominant role in OSH MS.

5. TACIT KNOWLEDGE IN OSH MS; PRACTICAL METHODS AND TOOLS

Results of literature reviews and analyses in sections 3 and 4 demonstrate, discuss and evaluate the actual and potential roles of tacit knowledge in OSH MS, and particularly indicate those sections of OSH management where this type of knowledge might be useful and beneficial for the enterprise. Unfortunately, as attempts to use KM principles in OSH management have been rare (see section 3), this concept is not yet very popular among managers. There is little experience and scientific evidence to provide practical support to enterprises willing to manage OSH knowledge, and particularly to explore the potential of OSH tacit knowledge. These concepts should be actively promoted among employers, managers, consultants, OSH authorities, etc. However, to fulfil this objective it is necessary to provide enterprises with knowledge on practical methods and tools for acquiring, exploring, transforming and disseminating tacit knowledge.

5.1. Training in OSH, and Acquiring Tacit Knowledge

Training in and development of competencies in OSH are important components of OSH MS. The employer should implement and maintain organisational solutions that would guarantee all people to hold competencies necessary to fulfil their duties and responsibilities [44]. This component should also include acquisition and dissemination of tacit OSH-related knowledge. However, research on the use of tacit knowledge shows that a systematic and formal approach to employees' learning and training is not a good solution; it may even lead to a deterioration in OSH conditions since it hinders an informal exchange of tacit knowledge and leads to an increase in unsafe behaviours.

Effective teaching of safe work is based on acquiring practical experience and on using all senses rather than on acquiring cognitive knowledge [60]. Newly employed workers on construction sites learn better to recognise hazards and to behave according to certain rules through observing, listening, talking, feeling and acting than through formal training with traditional educational methods. Efficient OSH training of new workers should include transfer of tacit knowledge. This could be an element of an apprenticeship, in which experienced masters indicate hazards and risks at work and show how to avoid them. They may even use work-related accidents to successfully instruct apprentices about their mistakes and the real consequences of breaking rules and provisions of safe behaviours [61].

With regard to introducing training methods and passing on OSH tacit knowledge it is useful to refer again to narratives (section 3.1.). People tend to learn safety rules better while listening to stories than in formal training courses or by reading instructions [41]. Stories help to pass on tacit knowledge holistically, in a way that is easily understood and remembered. People like listening to stories; this is a useful method in creating a sense of community and in building interpersonal relations.

Moreover, traditional OSH training courses do not usually take into account local culture of the workplace and concentrate on cognitively acquired competencies rather than on transferring knowledge on the conditions of a specific workplace [62]. To create conditions that will facilitate informal but successful methods of transferring OSH knowledge it is useful to use the social learning concept of CoP [60, 63]. Such communities can exist within a single organisation, within a single discipline or they can cover several organisations. CoP assumes close co-operation among members of a community to achieve common aims and to exchange knowledge, especially tacit knowledge.

There are many examples of how CoP can be used in enterprises and how it positively influences organisational performance [42, 64, 65, 66]. However, there are few publications on CoPs in OSH [63, 67].

Since CoPs should be wholly voluntary, it is more appropriate to talk about the cultivation of CoPs than about their implementation. Nonetheless, it is necessary for the management to be involved and to initiate activities that would cause CoPs to achieve a level of sustainability and bring advantages. To build CoPs managers can, e.g., use Wenger's seven principles of cultivating CoPs [42] or consider McDermott's critical factors [68].

5.2. Tacit Knowledge, BBS and OSH Management

In general, safety knowledge can improve the level of safety in an enterprise because it reduces employees' unsafe behaviours. On the other hand, relying only on formal training and workers' professionalism may lower this level because it can increase the number of unsafe behaviours [61]. This means that there is potential in using BBS-related tacit knowledge in OSH MS (see section 4.2). The relationship between knowledge use and BBS programmes is two-directional. On the one hand, tacit knowledge transferred and disseminated among workers may influence the modification of identified critical safety behaviours. On the other, BBS programmes are an efficient mechanism that supports organisational learning within the scope of safety management. These programmes encourage learning via observations, coaching and mentoring. Studies on safety behaviours within reactor plants carried out in the UK confirmed this [57]. They showed that BBS approaches increased possibilities of organisational learning through communication and exchange of knowledge among employees.

5.3. Practical Techniques and Tools Supporting the Use of Tacit Knowledge

The discussion on the various aspects of tacit knowledge in OSH management indicates that the use of tacit knowledge has good prospects and can benefit an enterprise, particularly if rules of people-focused NGKM (see section 2.4) are used. However, dissemination of this concept will depend on managerial knowledge and availability of relevant methods and tools that support the use of tacit knowledge in OSH management. Literature on KM shows that there are solutions in this area, but so far their dissemination has been minimal and they have not been verified in practice yet. Sections 5.3.1., 5.3.2. and 5.3.3. bring examples of easy-to-adapt solutions.

5.3.1. Narratives

As mentioned before, narratives (storytelling) are a successful way of transferring tacit knowledge in OSH. If this method is used well, it has many advantages, more than standard communication techniques. However, implementing this informal method into routine procedures of OSH management is a problem, as is guaranteeing a good and sustainable flow of information and the use of tacit knowledge. OSH-related stories can be recorded and disseminated with various media: verbally, in writing, as films or pictures. For example, in Shell International Exploration and Production there was a formalised programme of gathering and popularising implemented narratives [69]. It consisted in employees submitting voluntarily via the intranet stories of various length and complexity on aspects of their work. However, according to other studies this kind of simple recording and archiving in databases is not effective because it loses "recipient design", a valuable feature of oral stories [70]. Recipient design means that storytellers adjust to their listeners and to their relations with them. A partial solution to this problem would be to use a computer-based

learning system that selected and supplied stories (also visual) most suitable to the listeners' needs. Better results can be also achieved through creating various social interactions and events with their natural conditions for storytelling (e.g., anniversaries, campfires and retirement parties) [71].

5.3.2. Thematic seminars and interviews

Thematic seminars or workshops and interviews are a slightly more formal method of acquiring and transferring tacit knowledge. The former can be especially useful in experts passing their knowledge to young or new workers. For example, there can be two- or three-day seminars on selected KM-related topics [71]. Their participants should have an opportunity to mingle with experts from various departments to see who knows what and who they want to learn from. It would also be useful to pass on practical behaviour rules, especially golden rules that often have the form of a metaphor. During such seminars case studies connected with respective narratives could be discussed, too.

Interviewing is a good method of acquiring valuable tacit knowledge from competent retiring employees. It is advisable that the interviewers know interview techniques and have an area of expertise similar to the interviewee. Interviews should have a certain fixed structure and should be similarly documented, but half-standardised interviews are a good approach, too [71]. The latter consist of several fixed questions with other ones asked freely depending on the context. Interviewing then may resemble storytelling and help to acquire tacit knowledge of greater value. Shell's Retention Of Critical Knowledge programme is an example of using interviews to acquire tacit knowledge from employees leaving an enterprise or retiring; interviews are carried out to identify so-called knowledge nuggets that should remain in the enterprise [72].

5.3.3. Wiki-type corporate encyclopaedia

A corporate encyclopaedia is based on the wiki concept, i.e., a special knowledge-sharing software tool with which users upload information to the Internet or intranet and edit materials uploaded by others. Wikipedia[2] is the most famous example of this concept, whereas Shell wiki, Shell's corporate internet encyclopaedia, is an example of how wiki can be used in KM and organisational learning. Shell wiki focuses on a voluntary exchange of knowledge by all employees. Its most popular features are easy updates, and filling the content of documents and direct links to other documents that provide, e.g., terminology of additional explanations [73]. The development of this platform and employee co-operation is promoted by company management and experts from various disciplines who, anonymously or not, take part in this process by creating a unique KM community focused on exchanging knowledge and personal experience.

5.3.4. Virtual reality

Virtual reality (VR) technologies provide promising results as support tools in acquisition and transfer of tacit knowledge. Current VR systems can generate virtual environments (VEs) that effectively simulate various conditions of work and life and, at the same time, successfully support learning processes. The more senses are involved in the learning process and the greater the brain activity, the better the processed information will be stored and remembered. Therefore, VR applications enhance human abilities and motivation to absorb new knowledge and to modify inefficient and false working procedures [71].

According to a European study, VR applications can have a potentially large impact on learning processes and KM [73]. Hendrix and Johannsen described possible VR applications of those processes that proved the unique usefulness of VEs in transferring tacit knowledge. They also said that "in many cases, therefore, VEs could be a valuable substitute for real experiences,

2 http://en.wikipedia.org

providing first-person experiences and allowing people to acquire tacit knowledge that otherwise could not be transferred through traditional methods" (p. 328).

VR could also be successfully used in transferring tacit knowledge through narratives, particularly in OSH management [71]. It is easy to picture narratives being used to create scenarios of real-life stories, case studies, work processes or rescue missions that could be precisely simulated in a VE. Vaught et al.'s study (section 3.1), in which narratives were used to train miners, rescuers and people responsible for emergency management in mines [37], is a good example.

6. CONCLUSIONS

The literature review on KM in OSH management, followed by a desk analysis, identified sections of OSH MS in which acquiring, creating, processing and transferring tacit knowledge was important and could substantially contribute to the core objectives of the system, i.e., preventing or reducing occupational injuries, incidents, diseases and ill health. Those sections (according to the structure of system specifications in ILO-OSH 2001 [44]) are

- competency and training;
- communication;
- hazard and risk prevention (including prevention and control measures, management of change, emergency prevention, preparedness and response, procurement and contracting);
- performance measurement and evaluation;
- investigation of work-related accidents, diseases and incidents.

Tacit knowledge is also important in three other sections of OSH MS. They are not directly linked with identifying, assessing and preventing hazards and risks; however, they concern managerial activities aimed at proper functioning and improvement of OSH MS. They are

- worker participation;
- preventive and corrective action;
- continuous improvement.

Tacit knowledge contributes to building workers' and managers' awareness of hazards and risks in the workplace. It is also important for disseminating efficiently OSH knowledge and shaping safety culture within the enterprise. Tacit knowledge can also improve hazard identification and risk assessment at workstations, and improve selection and application of preventive and protective measures (including those associated with emergency prevention, preparedness and response). Thus, elimination, prevention and reduction of occupational hazards and risks can be reduced.

Workers' tacit knowledge on hazards and risks at their workstations is essential in providing input to measuring and evaluating OSH in an enterprise, particularly in proactive and reactive OSH monitoring. Improvement plans and any corrective and preventive actions, which will be based on this knowledge, will reflect workers' real concerns and needs more successfully and better address irregularities within OSH MS. Workers' tacit knowledge is also embedded in ideas or other inputs into OSH matters that are submitted under the general concept of worker participation. However, both the managers and the whole enterprise will appreciate the usefulness of that knowledge if workers are motivated to be involved actively in OSH management activities, and if all their suggestions for OSH-related improvements are suitably received, considered and responded to.

In the section on preventive and corrective action, tacit knowledge may play an important role in identifying root causes of any inconsistencies or nonconformities within OSH MS, which will then lead to a better reaction and more efficient correction of those failures. Finally, tacit knowledge in continuous improvement activities should also be highlighted, because it relies on its valuable potential to shape habits and skills of routine application of continuous improvement techniques by all members of the enterprise.

The review of literature carried out to identify and analyse KM applications (section 3) showed that they are fragmentary and selective. The summary of this review indicates that to date

there has not been any conceptual model that would describe and explain holistically the role of KM processes within OSH MS, in particular those related to creating, converting and transferring tacit knowledge. Such a model is necessary since it would allow better understanding and use of the potential of KM and tacit knowledge concepts. It would also allow better promotion among enterprises and their stakeholders of the idea of incorporating KM into OSH MS.

This is why it is necessary to undertake studies on conceptualising and building such a model, which would be followed by testing and validation. The model should be based on theoretical concepts rooted more in social sciences and psychology than in business management sciences. Particular stress in the model should be placed on explaining mechanisms of acquisition and creation of OSH tacit knowledge, as well as on conversion, transfer and use of this knowledge, taking into consideration that it is deeply hidden in and distributed across the minds of individual people. In this context, studies on the potential role and implementation of CoP, storytelling and social networking in improving OSH management could be especially interesting. As there is a strong focus on human aspects in these concepts, they could be studied from the perspective of NGKM (section 2.4). Studies are also necessary to analyse and emphasise the role of tacit knowledge in BBS programmes, and to integrate of those approaches into formal OSH MS.

Furthermore, to achieve significant progress in using KM principles in OSH management it is necessary to develop and disseminate practical methods and tools that would help enterprises to explore and transfer knowledge within OSH MS. This article has presented several examples of such methods and tools (section 5); however, this is not an exhaustive list of potential solutions. Currently we do not know, either, if the end-users would find them efficient and acceptable. Thus, further studies are needed to develop new methods and tools, and to validate and adapt existing ones.

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