Sustainable Development in the Watershed: Roposal for a Knowledge Management System

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Abstract

Sustainability has become a recurring theme discussed by all members of society. The discussions revolve around the economic, social and environmental dimensions of this subject. Of particular interest is water, perhaps one of the most critical resources for human survival. Herein we used exploratory research, with a qualitative nature, to develop a conceptual model that adopts a prescriptive approach to identify ways of assessing, integrating and complementing concepts related to the sustainable management of watersheds. We considered the actors, the amount of information and the complex management process and propose utilising an Information and Communications Technologies-based knowledge management system to assist in the management of water resources. When utilised cyclically, our systematic four-step model will create knowledge that can help guide and manage the decision-making processes in this area.

Keywords: Sustainability; Watershed; Hydric Security; Knowledge Management Systems; Information Technologies.

1. Introduction

Currently, sustainability is a recurring theme that is the subject of conversations by people and the focus of both public and private institutions. This focus and concern are primarily because this topic significantly impacts the economic, environmental and social dimensions, and the balance among these dimensions must occur to guarantee sustainable development. Gadotti (2008) states that sustainability goes beyond the preservation of natural resources and the feasibility of development without harming the environment; it is a balance among humans, the planet and even the universe. In this sense, the use of natural resources can continue to occur as long as nature manages to recover without degrading itself. However, people and organisations must support social justice issues and contemplate their productive activities.

They must obtain financial and economic resources to continue acting and surviving in an increasingly competitive environment for public or private institutions. In this sense, while economic sustainability is crucial, seeking environmental and social sustainability is also essential, Since these are factors that improve the projected image of an organisation and consequently influence economic sustainability, a sustainable organisation must simultaneously respect the environment, be economically efficient, and deal adequately with social justice (Barbiere and Simantob, 2007).

When contemplating sustainable development, undoubtedly, one of the most critical factors for the survival of humanity is the existence of water, which brings to the discussion the theme, the sustainable management of water resources. Due to the scarcity and finite quantities of water, the preservation of the watershed ensures that water is appropriately used and returned to the environment with proper treatment.

Watersheds are systemic entities in which there is a delicate balance between the incoming and outgoing water. However, since all urban, industrial, agricultural activities occur in or around these bodies of water, these activities can significantly impact these water sources (Porto and Porto, 2008). According to Porto and Porto (2008), hydrographic basin sustainability requires a database of socially accessible information, a clear definition of use rights, control over impacts on water systems, and decision-making.

Additionally, Magalhães and Barp (2014) make a compelling statement when they state that integrated water management relies primarily on public and private organisations' decisions and strategies to achieve pre-determined goals. Since these decisions impact a relatively large group of actors who depend on and share this resource and territory, the organisations' decisions need to be materialised into action strategies and presented in the form of plans (Magalhães and Barp, 2014). Thus, there is a need for a strategic plan for efficient management of water resources, which must be based on collected information and newly created knowledge to support its elaboration and decision-making process. In this sense, through the strategic plan, the vision and mission of an institution are defined, and the objectives, goals, strategies, and financial, material and human resources are established (Thompson et al., 2008).

This line of thought follows Porter (2003), who states that every institution has strategies to operate in its market, and a planning process is necessary for formulating these strategies. Indeed, planning is a stage in the management process that leads to establishing a coordinated set of actions, intending to achieve the objectives. Notably, Falsarella and Jannuzzi (2017) point out that the planning process is related to the decision-making process within organisations.

The development of a strategic plan in the context of hydrographic basin sustainability is complicated because there are many people and organisations involved, as well as a variety of economic, social and environmental factors related to the management of water resources. For example, urban populations and rural areas need water for consumption and private companies that consume this good in their production activities. Also, public companies must collect and treat the used water with a high level of basic sanitation techniques before the treated sewage and waste return to the environment.

In addition to the various actors and factors involved in managing water resources in the watershed, the strategic plan must also consider the need for constant monitoring and analysis for determining if the objectives and goals are being met. Due to the enormous amount of potential information, these steps add another layer of complexity that needs to be effectively handled. A rational approach for dealing with situations that generate large amounts of information that need to be rapidly analysed is to utilise Information and Communication Technologies (ICTs).

However, collecting and processing significant amounts of information only makes sense if it is possible to generate value, which refers to knowledge that can be used to assist the management in the decision-making process. Thus, the following question is established: How can ICTs be utilised to effectively manage and systematise the information arising from the environmental, social and economic dimensions and generate knowledge for improving water resource management? To answer this question, this research aims to develop and propose a conceptual Knowledge Management System (KMS) model that assists in making decisions related to sustainable water resource management.

Considering that there are few references to applying the concept of knowledge management (KM) and KMSs in the management of water resources, the present study is characterised as exploratory research (Gil, 2008). The collected data of qualitative character were obtained through bibliographic research. This type of research searches for the solutions to problems through published theoretical references (Pizzani et al., 2012) and pursues explanations of a result that contributes to an area of science or activity (Garcia, 2016), which in the present study involved themes such as sustainability, water resource management, strategic planning, knowledge management and knowledge management systems as they pertain to the watershed. Furthermore, the data analysis for the construction of the conceptual model adopts a prescriptive approach since it seeks to observe different ways of assessing how the concepts involved are integrated and related and how they complement each other.

2. Knowledge management systems

The influence of information and knowledge today is undoubtedly significant and has drawn the attention of scholars on the subject (Jannuzzi et al., 2016). According to Strauhs et al. (2012), knowledge is an essential resource of companies that want to improve efficiency. Primarily, knowledge results from lessons learned (i.e., the successes and failures of individuals or teams) and is stimulated by interactions between/among people, as well as multidisciplinary teams within, as well as from partners, suppliers, customers and even competitors outside the organisation (Strauhs et al., 2012).

Historically, implicit knowledge has always been managed, and organisations are continually trying to determine the optimal ways to carry out their management effectively and efficiently to gain a new dimension in the discourse of current society (Grey, 1996). Consequently, the development of many studies related to this theme has been performed. Indeed, it is possible to find numerous concepts of knowledge management (KM) in the literature. However, when examining these works on the concept, it becomes evident that there is a lack of consensus among them. In general, KM is the act of transforming information into actionable knowledge that can be easily made available and applied in an organisation or company (Dalkir, 2017).

When discussing knowledge, it is necessary to address a variety of different aspects. For the most part, data and information management, process management, methods/techniques, and tools are concepts that receive a great deal of attention; however, the skills, competencies, ideas and motivations of the people who participate in the construction of knowledge are of equal importance (NISSEN et al., 2000; Rubenstein-Montano et al., 2001). Thus, it is necessary to consider the developments each of these elements can offer to understand the term. For example, among the tools, the construction of automated information systems, such as Decision Support Systems, Specialist Systems, Business Intelligence Systems and Knowledge Management Systems are notable examples, with each being specifically designed to share and integrate the knowledge of organisations (Nissen et al., 2000; Rubenstein-Montano et al., 2001).

The plurality of elements that make up KM gives it a complexity that can only be translated by systemic thinking, which has led to the understanding that the inherent properties of a given system disappear when they are treated separately (Rubenstein-Montano et al., 2001). This understanding is perhaps best illustrated by Franco and Barbeira (2009), who state that KM should be seen as a set of processes that guide the creation, dissemination and use of knowledge to enable organisations to achieve their objectives. In other words, it is a process that brings together information, technology and management, for creating an organisation's strategy, culture and information systems (Franco and Barbeira, 2009).

According to Alavi and Leidner (1999), Information and Communication Technologies (ICTs) can be utilised for systematising, facilitating and streamlining the transmission of knowledge throughout a company. Indeed, such systems are employed in management activities to create, collect, organise and disseminate the knowledge. It should be pointed out that cultural and organisational issues are also commonly incorporated into these processes in addition to the technology.

When explicitly discussing KMSs, Laudon and Laudon (2010) state they should enable organisations to capture and apply knowledge and expertise, allowing them to manage their processes better. Moreover, O'Brien and Marakas (2013) add that KMSs support the creation, organisation and dissemination of business knowledge within an organisation. For Alavi and Leidner (2001), the KMS is an IT-based system developed to support and improve organisational processes for creating, storing, retrieving and transferring knowledge. Furthermore, Iskandar et al. (2017) state that the objective of a KMS is to use information systems that can transform tacit knowledge into explicit knowledge. Importantly, it is this transformation that makes it possible to structure and store knowledge.

It has been proposed that KM consists of three essential and complementary pillars: people, technology and processes and that these elements must be considered when developing a KMS (Iskandar et al., 2017). For example, the internal information collected from employees, operation records, company decisions, previous results, and other sources (people) need to be structured. In this way, the knowledge can be extracted (technology) and transferred and utilised (processes) throughout all levels of the organisation (O'Brien and Marakas, 2013).

However, it is important to point out that in addition to internal information, external information should also be included in the KMS. Franco and Barbeira (2009) claim that inter-organisational networks create and develop new knowledge. However, the authors emphasise that a KMS must be implemented to incorporate this type of knowledge. In this sense, KM is understood as a collective and interactive process that assembles information and attitudes obtained during the various stages of knowledge development (Franco and Barbeira, 2009). Consequently, the KMS-facilitated creation and dissemination of organised and structured knowledge, arising from information collected from different organisations, serves as a mechanism of efficiency, productivity and organisational excellence for all members of an inter-organisational network (Franco and Barbeira, 2009).

In addition to inter-organisational networks, where all its members have the same purpose, structured and unstructured information from different sources such as social networks, mobile cellular devices, scientific activities, simulations and experiments, environmental sensors, and others can contribute to the creation of new knowledge. In the past, it was not feasible to handle such large amounts of data. However, with the advent of currently available ICTs, such as Big Data and the Internet of Things (IoT), the ability to capture, process/analyse, structure, and transform this information into knowledge is now a reality that organisations can exploit. Moreover, after creating this new knowledge, it can be stored and disseminated through a KMS. Falsarella et al. (2017) affirm that Big Data is an ICT concept that can handle vast volumes of structured or unstructured information in real-time. Moreover, Big Data can also analyse this information and extract reliable information while at the same time discarding unreliable information to generate value, which can be understood as knowledge. Concerning IoT, Tan (2016) states that it is a system of devices, in the form of sensors, connected to the internet that captures and transmits information, thus instilling a digital capacity to objects that can function as a source of information and potential knowledge.

At this point, it becomes clear that many variables can be used to create a KMS. In the following sections, we will discuss how certain elements and capabilities can be utilised and applied to sustainable water resource management.

3. Sustainability and water resource management

As mentioned previously, sustainability is a recurring and current theme and a concern among people and public and private institutions. The relevance of this topic spans across the economic, social and environmental dimensions and in this sense, a balance among them must be met to guarantee sustainable development.

According to Boff (2012), the most accepted definition of sustainability is the Brundtland Commission, which views it as a transformation process involving resources, investments, technological development and institutional change to meet human needs and aspirations (WCED, 1987, p.49). As mentioned above, sustainability revolves around three dimensions, economic, social and environmental. Munck and Souza (2009) mention that economic sustainability focuses on the market, seeking a competitive advantage and quality improvement. Social sustainability is concerned with social responsibility, supporting community growth, developing human resources and promoting and participating in socially related projects. Furthermore, environmental sustainability involves using clean technologies, recycling, sustainably using natural resources, complying with legislation, and treating effluents and waste. It is important to emphasise that the objective of the environmental dimension is to offer ecologically correct products without or with minimal environmental impact.

Notably, these dimensions of sustainability are directly applicable to the area of water resource management. For example, in the economic context, water quality is essential for the development of rural and urban areas and activities and socially, water quality is essential to meet the needs of human beings. In the environmental context, which is perhaps the most important, is water, or in other words, the water that can be collected from a watershed in quantity and quality to meet the needs of the other two dimensions.

Watersheds represent an important aspect of water resources and are an essential component of environmental sustainability. It is an area of land drained by a river and its tributaries. At the highest point of the terrain, considering the geographical limit, the slopes or topographical dividers guide the flow of water towards the main estuary or river. However, if the water produced by natural hydrological cycles is geographically contained within the watershed, its use is also contained in other spheres, involving economic, social, political and cultural practices built by the human element (Tomaz, 2006).

To assess whether the relationship between production and consumption of water resources is sustainable for a given location, Tucci (2017) estimated sustainability by adding two components. The first component considers the value that nature would need to use to dilute the untreated effluent that returns to the rivers after being used by the population. To obtain the real value of the demand for urban flow, the value of this first component needs to be added to the consumptive use of the population. The second component is called the water sustainability index, and it estimates the relationship between the demand for water and its availability in a given location. Therefore, water sustainability would result from governance mechanisms that favour the search for a balance between the availability of obtaining water resources and the demands generated by human and animal consumption, domestic use and agricultural and industrial use, in general. In this sense, water collection, transportation and consumption need to be managed using rational processes that avoid waste, going beyond the mere commodification and pricing of this finite natural resource (Gleick and Iceland, 2018).

Along these lines, in 2015, the concept of hydric security was established through the Water Resources Thesaurus of the National Water Agency. This concept is defined as a reliable availability of an acceptable quantity and quality of water for consumption and ecosystem preservation, and other uses, together with an acceptable level of water-related risks to people, economies and the environment (ANA, 2015).

This concept is often brought up when discussing economic activities that guarantee the conservation of aquatic ecosystems, even if accompanied by an acceptable level of risk droughts and floods (Gleick and Iceland, 2018).

Climatic and geological cycles continue to interfere with the stability of societies; however, when the majority of the world population is concentrated in cities, other dangers and threats arise among man, society and the environment (Moraci and Fazia, 2013). For example, agro-industrial activities, demographic concentration, the indiscriminate use of non-renewable resources for transportation and energy, combined with the uncontrolled disposal of contaminated materials and contaminants into the environment, could potentially lead to the depletion of natural resources in general, water stress or even water scarcity. For this reason, there is an intense global movement attempting to reduce the risks associated with this precious resource.

It is worth stressing that water emerges as the primary resource among the typical goods at risk of becoming endangered. Indeed, this commodity is surrounded by uncertainties regarding its sustainability. The fundamental issue is not linked to its availability or the technological capacity for treating it, but to the complexity, effectiveness and applicability of water resource management and governance instruments (Chaffin et al., 2016).In addition to climatic and environmental factors, such instruments must address the water life cycle, which includes generating this resource through natural hydrological cycles, retention and storage, capture, treatment, distribution, consumption and treatment, and return for reuse. In this sense, new approaches need to be implemented for monitoring and evaluating each step.

For Soares et al. (2011), when problems are converted into indicators, the definition of policies and action strategies precedes diagnoses, facilitating their understanding and the decision-making process. An indicator is any measurement or value that summarises or predicts a particular phenomenon in its simplest definition. However, the element being measured is far more significant than the value associated with it (Malheiros et al., 2012). According to these authors, data becomes an indicator when its understanding exceeds the value, and it provides meaning through the interpretation of the information (Malheiros et al., 2012).

In this sense, sustainability indicators are helpful instruments for measuring complex phenomena such as sustainable development. Concerning the management of water resources, such indicators facilitate the monitoring of the economic, social and environmental components and identify the relationships between/among the parties and barriers (Maynard et al., 2017). If implemented correctly, it can assist in the decision-making process. Furthermore, Pires et al. (2016) present four groups of water resource sustainability indicators that include: (1)indicators that measure water consumption linked to the agricultural, industrial and domestic sectors,(2) indicators related to environmental issues such as conservation and preservation of water and other natural resources and the treatment of waste, (3) indicators related to hydrological parameters such as precipitation, evaporation, and soil moisture and (4)indicators related to non-extractive practices, such as recreation, transportation, energy generation, pollution, and other social activities.

When contemplating a water resource management process and considering the number of actors involved and the amount of information and knowledge generated, other indicators such as the management styles of the actors in each area should be factored into the decision-making process. However, it is important to point out that using indicators is only meaningful in the decision-making process once the goals, objectives and actions are defined and incorporated into a strategic plan.

4. Conceptual model of knowledge management

The proposed KMS, represented by a conceptual model, was developed to assist in the decision-making processes associated with water resources management. In this section, we outline and describe the four steps of this model. These steps include obtaining information, transforming information into knowledge, disseminating the knowledge and integrating the knowledge into a strategic plan (Figure 1). This model is systematic, and the results obtained are re-evaluated continuously to identify new knowledge. Such an approach allows the researchers to assess whether or not the goals are being achieved. In the following paragraphs, each step will be described in more detail.

The first step is to obtain information that originates from both internal and external sources and can be structured or unstructured. Sources of information include various computerised information systems, and the actors are those involved in the water life cycle of the watershed. The water life cycle includes water generation through natural hydrological cycles, retention and storage, collection, treatment, distribution for consumption, consumption and the treatment and returns to nature for reuse. For this purpose, ICTs, such as IoT sensors, can monitor and collect data at specific locations within the hydrographic basin without human resources.

The second step involves transforming the collected information into knowledge as well as its storage for later retrieval. In this case, ICTs, such as Big Data, can process and analyse enormous amounts of information, whether structured or unstructured and in real-time. This stage also manages the veracity of the data by extracting the reliable and discarding the unreliable information.

Notably, once the information is analysed and the tacit knowledge is transformed into explicit knowledge, value is generated. This new knowledge can then be stored in a database or KMS for later retrieval and analysis.

It is worth mentioning that knowledge can also be created when information is quantified and transformed into indicators. These indicators can be grouped into their respective dimensions of sustainability, such as economic, social and environmental. In this form, the data can assist in the decision-making process and facilitate strategic actions in this area. Provided that there are means to foster inter-organisational networks, this type of relationship can also contribute to creating new knowledge, allowing the creation of knowledge to be collective, interactive and participatory.

The third step is the dissemination of knowledge to the actors responsible for the management of water resources. This delivered knowledge can be qualitative or quantitative and should be organised in the economic, social and environmental dimensions to facilitate the analysis of water sustainability and hydric security.

In addition to analysing the knowledge that originated from the main actors involved and the inter-organisational networks, it is also necessary to evaluate the leading indicators and their evolution (positive or negative) and the positive and negative impacts on sustainability hydric security.

An acritical point in the dissemination of knowledge stage is the form in which the data is presented. For example, a dashboard offers easy-to-view graphical interfaces, often displaying the leading indicators and relevant information. In this form, the evolution and future projections can be predicted by mathematical models. By continually monitoring and recording data over time, this type of interface greatly facilitates analysing the data and the decision-making process.

Following the analytical phase of the model, the fourth step integrates these results into a strategic plan. In this stage, the knowledge generated provides the management with new strategies and actions to contribute to the decision-making process. The overall goal is to improve the management process in this area. Significantly, since new information is continually being collected, transformed into knowledge, disseminated and analysed, this process should be cyclical and continuously repeated over time.

5. Final considerations

Due to the plurality of its constituent elements, a KMS presents itself as something extremely complex. Moreover, it gains significant relevance by transforming information into actionable, accessible and applicable knowledge in organisations by converging areas involved in strategy, culture, decision-making, information systems and KM.

Along these lines, when discussing sustainability or, more specifically, the sustainable management of water resources, the KMS becomes an exciting part of the discussion and a potentially valuable part of the management process itself primarily because the management of water resources in watershed relies on identifying attribute-based information, which is essential for establishing a balance between water resources and societal demands.

A common problem faced by organisations is how to transform information into knowledge, consequently generating value. Indeed, this drives the actions of individuals, managers and users, allowing them to recognise the capacity to act or react in response to this new knowledge.

In this sense, the proposed model for managing water resources is supported by information and knowledge, collected and processed using ICTs, and depends on principles oriented around structuring and elaborating a KMS. Herein we suggest a solution from the user and usability point of view, where the human being is at the centre of the technological environment.

Furthermore, the KMS presented in this study sought to identify the essential steps for generating, sharing and integrating knowledge into a strategic plan. In the scope of the discussion on water resources management, the proposition of this conceptual model gains relevance by contemplating the water life cycle in stage one (obtaining information), the characterisation of the dimensions and indicators of sustainability in stage two (transforming information) and the creation of a dashboard with indicators, water evolution and future projections, in stage three (knowledge dissemination).

This conceptual model can be adopted by any public or private organisation that operates managing water resources. It is based on a consistent confluence among information, knowledge, and decision-making inherent to management and can be well oriented to achieve the objective and goals of the strategic plan. It is plausible that if this model is applied to water resource management in the watershed, it could become another differential in the fight for sustainability.

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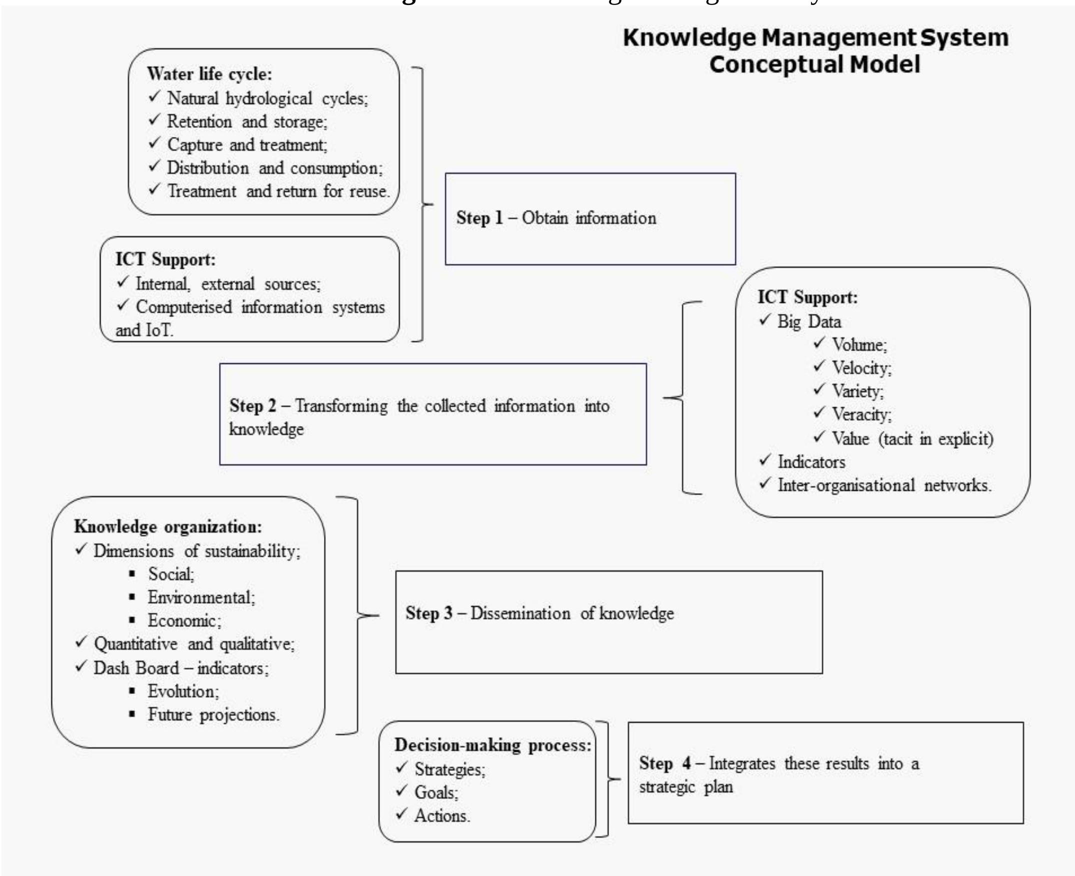
Figure 1 – Knowledge Management System



Source: authors