Information Systems – From a systematic literature review to a modern vision of a resilient system

Roberto PAIANO
University of Salento, Dept. of Engineering for Innovation, Lecce, Italy; roberto.paiano@unisalento.it
Luca MAINETTI
University of Salento, Dept. of Engineering for Innovation, Lecce, Italy; luca.mainetti@unisalento.it
Anna Lisa GUIDO
University of Salento, Dept. of Science, Lecce, Italy; annalisa.guido@unisalento.it

Abstract

An information system is highly critical for a company's long-term viability. The concept of information is used in several contexts and to understand several concepts: from a small software system, to a complex system that manages a company's information. This confuses people who need to thoroughly understand the concept of information systems (researchers, businesspeople, students, manager etc.).

To help resolve matters, this article presents a comprehensive, well-informed examination of the definition and classification of the term information system. The paper highlights the previous research, challenges, current status, and future directions of three key concepts:

1. the concept of data, information, and knowledge very useful for the definition of information system;

2. the concept of information system and all the considerations related to the distinction between the information system and information technology;

3. the classification of the various types of information systems.

This review highlights three issues: i) very few authors consider "knowledge" in the definition of information system; ii) there is a great confusion between information system and information technology; ii) there is a no integrated vision that proposes a general classification of information systems.

These issues are addressed in the paper presenting a new direction for a modern definition and for an effective design of information system.

Keywords: Information systems; data information knowledge; information system classification; Digital Ecosystem

Introduction.

Nowadays, the use of Information Systems (IS) is highly critical for a company's long-term viability.

It is important to understand what exactly is meant by the term Information System and this is useful both for companies, in order to allow an effective and efficient use aimed at achieving their business goals, and in the learning context (higher education) where students need to understand the Information System concept and its implications.

On analyzing the literature in this research area, there is much confusion about what is meant by an Information System. Typing in the keyword "Information Systems" on the main search engines (Scopus, ACM, IEEE) it is possible to obtain

several occurrences in many scientific papers but each one with a different interpretation of the Information System concept.

Some papers speak about Information Systems related to a specific application domain: “Geographic Information Systems”, “Health Care Information Systems”, “Security Information Systems” and so on.

Many times, the term Information System is used to refer to a simple application that manages a part of the overall Information System. This confusion is assessed by Lee (2010) “Whenever IS researchers and professionals have used the term ‘Information System,’ one could substitute the term ‘Information Technology,’ ‘computer system,’ or simply, ‘the computer’ where the substitution would often make little or no difference. In retrospect, it is no exaggeration to state that most IS researchers have used the term ‘system’ or ‘systems’ to refer to anything that involves electronic information technology”.

In the first decade of the third millennium, Paiano, Guido and Pandurino (2009) introduced the terms Web Information System focusing on web software systems (and this add more confusion to the panorama). Since the introduction of Web Information System, other new technologies have been created, for example the introduction of mobile technologies that open up a new research field in the Information System by Mainetti, Paiano, Pandurino and Bolchini (2012).

If we refer to mobile Information Systems, for example, it is possible to understand a difference between traditional (desktop) Information Systems and mobile Information Systems. Pernici (2006) highlights that “Mobile Information Systems may also vary depending on the context of system usage, and user requirements can change dynamically which means that the mobile systems have to adapt themselves to satisfy new requirements” Shakhovska et al. (2019) consider the current problem of mobile investigation applications and development of mobile systems for medical recommendations.

The dynamicity concept of Information System is not related only to mobile systems, but it is a characteristic of Information Systems independent from technology. Caione et al. (2016), manage the complexity of Information Systems using their knowledge base, but they do not refer to the mobile aspects.

The time has come for clarification within the Information System scientific panorama and to provide the scientific community and professionals with a starting point for their studies when new technologies/concepts (big data, mobile application etc.) make the general scientific panorama even more complex and confusing.

In this paper we analyze papers from the scientific community using two main research questions:

- What is an Information System?
- How can we classify systems?

To search for these research questions, we use these keywords:

- Information System definition
- Information System classification
- Framework for Information System classification
- Types of Information Systems

This systematic review was carried out between 2017 and 2021.

Looking for these keywords, other important issues arise and will be addressed in this paper:

1. very few authors consider “knowledge” in the information system definition, for this reason we clarify the concept of data, information and knowledge in order to introduce the concept of “knowledge” in the information system definition;

2. there is great confusion between information system and information technology, for this reason in this paper we provide a clearer explanation of the difference between these two concepts;

3. there is a lack of an integrated perception that proposes a general classification of information systems, for this reason we provide a new vision of an information system as a Digital Ecosystem.

The rest of this paper is organized as follows.

In Section 2 we provide the concepts of Data, information and knowledge already defined in scientific works but very interesting for the definition of Information System.

In Section 3 we present a literature review regarding the concept of Information System and in Section 4 we provide a more harmonized perception of Information System. In Section 5 we present a new classification more aligned with the integrated perception of what an Information System is. In Section 6 we present our conclusion and future works

Data, information and knowledge

The Information System concept cannot be contemplated without the concepts of Data, Information and Knowledge. The production of Information is the core of the Information System. Right from the design phase, it is very important to identify the user's information needs and to go back in order to understand the production process of information. The company's Information System has the main goal of bringing together information in order to manage data using technologies. Information must be available for decision-making and control processes. It is very important to provide the concept of data, information and knowledge and to understand the relationship between them.

Several authors focus on the research about data, information and knowledge and a new research area, named knowledge management, a new research area born in the late 80's and early 90's thanks to three authors, namely Wiig (1993) and Nonaka & Takeuchi (1995). Freitas et al. (2016) explain well the difference between information engineering (from data to information) and knowledge engineering (from information to knowledge), briefly represented in figure 1. Knowledge Engineering provides a methodology to understand processes, tools, and strategies to support decision making processes in the organization.

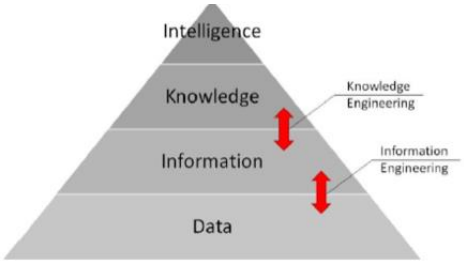


Figure 1: difference between information engineering and knowledge engineeringIn the paper of Freitas et al. we find a detailed survey to describe the concept of data, information and knowledge. An interesting table coming from Souza (2015) simply and clearly explains the concept of data, information and knowledge. Stenmark (2002) provides for other definitions useful for our work.

From our point of view, the concepts most related with the Information System definition are from Davenport & Prusak, Nonaka & Takeuchi and Quigley & Debons. The essence of the Davenport definition is that data is objective about events: data does not provide a sense to what happens in the organization but simply describes what happen. As Quigley and Debons say, data does not answer a particular problem. Very interesting are the "5Cs" (Contextualized, Categorized, Calculated, Corrected, Condensed) that describe information as starting from data and providing a meaning to the data. In the thinking of Quigley & Debons, information answers the who, when, what and where question. Finally, the concept of "fluid mix" from Davenport & Prusak is useful to explain that information is able to create new experience and information is knowledge. From Nonaka & Takeuchi the concept of flow is interesting as data (and information) are not static but are dynamic, as is the company.

Starting from the definition of data, information and knowledge, it is useful to understand the relationship between these three concepts. Stenmark (2002) publishes a diagram about these three concepts.

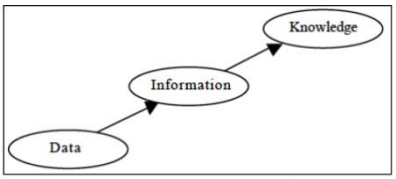


Figure 2 represents the linear relationship between data, information and knowledge.

In the image, the distance between data and information is the same as between Information and Knowledge and this means that the effort to go from data to information is the same as that required to go from information to knowledge. Figure shows that the relationship is asymmetric: from data it is possible to obtain information and knowledge but from knowledge it is not possible to go back to data.

Stenmark (2002) highlights their disagreement with the linear and one-sided relationship (from data to knowledge without being able to go back): often knowledge is used to derive information and information is used to create data. According to the authors, "data and information are only two opposite ends on a continuum". The effort to go from data to information and from information to knowledge is not the same: to go from information to knowledge is a very complex task as it needs to take in consideration not only internal aspects of the company but also external ones.

Focusing on the concept of information, we can state that in a company, information is a resource: the main difference between information and other resources is that information is the most frequently exchanged and processed resource from coordination and control management activities.

Bracchi et al. (2000) affirm that Information is an intangible resource and forms the basis of all other intangible resources such as experience and knowledge. Information:

- is not easily divisible or appropriable
- is not destroyed through use
- may become obsolete
- increases its value with use in the sense that it is self-regenerates.

The identification of knowledge often generates the request for the production for further knowledge.

However, these characteristics are only potential and depend on how information is used in management processes.

In summary: In the company, there are raw data. Data are objective with respect to the events that take place in the company, but data describe these events. There is a flow that adds value to the data creating the information. Information, an important resource for the company, is the basis for all immaterial resources and makes sense of the data by adding the 5C (Contextualized, Categorized, Calculated, Corrected, Condensed). When the information generates new experience and new information it is knowledge. It is very important, within an organization, not only to generate knowledge but also to share it among employees as Alshamsi et al. (2017) affirm. It is also important to capture and reconcile formal and informal knowledge and enable collective intelligence. Lemoisson et al.(2018) affirm that reconciling the two forms of knowledge is a big challenge.

It must be possible at any time to pass from information to knowledge and it must be possible to obtain the data from which the knowledge was generated.

Information Systems definition in literature

To have a clear definition of the terms Information System, it is important to establish a common ground for understanding and researching.

Our work analyzes the most relevant available definition of the Information System to provide a clear definition of the Information System concept.

Laudon (2012) states that Information Systems are more complex [than Information technology] and can be understood by looking at them from both a technology and a business perspective. “Information technology” consists of all the hardware and software that a company needs to use in order to achieve its business goals. This includes not only computer machines, storage devices, and handheld mobile devices, but also software, such as the Windows or Linux operating systems, the Microsoft Office desktop productivity suite, and the many thousands of computer programs that can be found in a typical large firm.”

Authors define Information Systems as a set of interrelated components that collect (or retrieve), process, store, and distribute information to support decision-making and control within an organization. In addition to supporting decision-making, coordination, and control, Information Systems may also help managers and workers to analyze problems, visualize complex subjects, and create new products.

Stairs & Reynolds (2010) affirm that an Information System is a set of interrelated components that collect, manipulate, store, and disseminate data and information and provide a feedback mechanism to meet a specific

goal. It is the feedback mechanism that helps organizations to achieve their goals, such as increasing profits or improving customer service. Businesses can use Information Systems to increase revenues and reduce costs.

Boell & Cecez-Kecmanovic (2015) provide for a very interesting survey about Information System definition is, making a critical reflection on how Information System are currently defined in literature. In this survey it is clearly manifested that providing a definition for Information System has been identified as one of the main challenges for the Information System field. The paper refers to an editorial by the European Journal of Information Systems by Paul (2007) where it is explained that: "It could be a surprise that what an IS is is not established. On the other hand, since many people are studying IS from a variety of perspectives, maybe it should be no surprise that there are a variety of definitions. But then, how would Society know what IS is and what it can do if there is no clear understanding?".

The survey classifies Information System in four different views: Technology view, Social view, Socio-technical view, and Process view.

- Technology view: Symons (1991) states that "The system utilizes computer hardware and software; manual procedures; models for analysis, planning, control and decision making; and a database. The emphasis is on information technology (IT) embedded in organizations".
- Social view: Land (1985) affirms that "an Information System is a social system, which is embedded in IT information technology. The extent to which information technology plays a part is increasing rapidly. But this does not prevent the overall [information] system from being a social system, and it is not possible to design a robust, effective Information System, incorporating significant amounts of technology without treating it as a social system".
- Socio-technical view: Lee (2001) states that "the Information Systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomena that emerge when the two interact".
- Process view: Alter (2008) affirms that "An Information System is a work system whose process and activities are devoted to processing information, that is, capturing, transmitting, storing, retrieving, manipulating, and displaying information".

Authors affirm that Information Systems are complex phenomena and each approach is only a different point of view. It is important to highlight that in the technology view, Information System and Information technology are the same.

Galandere-Zile & Vinogradova (2004) wrote a paper where the Information System is defined with the goal of understanding the difference between Information System and knowledge management system. Authors highlight that information processing can be carried out using manual instructions, so they consider only computerized Information Systems. The definition used is: "[Information System] is a group of components working together. These components include equipment (or hardware), instructions (or software), data stored in the system, the people to operate the system, and procedures for the people to follow. Peppard (2016) affirms "an Information System supports one or more work systems using information technology to capture, transmit, store, retrieve, manipulate or display information". Relevant, in this work are two aspects: the first is that they affirm that Information System can be carried out manually (although definition focuses on computerized Information Systems); the second is that authors consider the business process as a first-class concept in the Information System research. They affirm "A work system is a system in which human participants perform business processes using information, technology, and other resources to produce products for internal or external customers. The core of the work system (and thus the Information System) is a business process". The simplest Information System supports only one business function, but the Information System can support a number of business functions. An Information System has two benefits: better information, that is producing information starting from data and increasing productivity, that is making work more productive in a shorter period of time.

Peppard (2016) provide for a a clear definition of Information System compared with the definition of Information Technology. Authors clarify one key concept: Information Systems existed in organizations long before the advent of information technology (IT). Authors define Information Systems as the means by which people and organizations, increasingly utilizing technology, gather, process, store, use and disseminate information. The domain of interest for Information Systems researchers includes the study of theories and practices relating to the social and technological phenomena that determine the development, use and effects of Information Systems in organizations and society. It is thus concerned with the purposeful utilization of information technology, not the technology per se. Only some Information Systems are totally automated by IT, but most Information Systems are not totally covered by IT. People can find it difficult to distinguish between Information Systems and IT because the technology (the T in IT) seems to overwhelm their thinking, obscuring the business Information System that the technology is intended to support or enable.

Pighin (2011) and Bracchi et al. (2000) point out that Information Systems existed before the introduction of information technology and therefore it can be said that the Information System exists independently from the information technology: information technology only has the task to add automation to daily operations.

Holtzer et al. (2019) affirm that "IT often refers to systems of linked hardware devices. Starling (2002) suggests that IT consists of more than isolated devices, but rather a system of linked technologies. In contrast, IS involve the integrated technologies and the human resources required to effectively manage information (O'Leary & Williams, 1989)."

Rtal & Hanoune (2021) affirm that "Information systems are a group of programs that are used to archive, manage and organize data, and process them with specific procedures established according to the workflow mechanism in the organization, in order to obtain the final outputs. It is noteworthy that information systems are completely different from information technology, as information systems use information technology techniques which were created to serve its based business."

They in paper talk specifically of artificial intelligence however; it is interesting to note that yet in 2021 the researchers ask themselves the same questions that are addressed in the paper with the aim of providing a modern, complete and effective vision of the concept of the Information System.

A new integrated perception of Information Systems concepts.

From a previous definition, several aspects guide us towards a new definition of Information System.

First of all, Laudon (2012) and Stairs & Reynolds (2010), define an Information System as a set of interrelated components with the main goal of managing information.

Boell & Cecez-Kecmanovic (2015) affirm that the concept of Information System can be analyzed from several points of view (oriented towards processes, technological point of view) while Nickerson (1998) highlights the definition of Information System as a system that uses IT to manage information of the company. Pighin (2011), Bracchi et al. (2000) and Peppard (2016) highlight the difference between Information System and Information Technology.

One the one hand, the Information System manages information and on the other makes information management more efficient. The distinction between Information Technology and Information System is not clear in literature: often these two concepts are presented as overlapping (totally or partially).

In order to define a boundary line between Information System and Information Technology, it is useful to analyze what drives the Information System and what drives the technical system.

The Information System manages information, and this is useful for decision makers to ensure achievement of business goals and to compete on the global market. This is true regardless of the tool used to do so. The company, as an open system as stated by Psarouthakis (2017), is strongly driven, in the pursuit of its goals, both from what happens internally (production, sales, logistics, etc.) and from what happens externally (market, politics, etc.).

As companies are increasingly dynamic and open to a global market, Information Systems need to be able to adapt to changes, to new business models, and therefore to new markets as well, so the Information System of companies must be extremely dynamic.Information technology has the task of ensuring effectiveness and efficiency in the management of information.

Changes to the Information System must be translated into changes in the information technology of the company and this is the relationship between Information Technology and Information System. Information Technology must not restrain the dynamism of the company (remaining anchored in obsolete technologies) but must rather pursue it..

As previously discussed, speaking about the information concept in a company is reductive. Information is a fundamental resource in the company: it is generated from data and it creates knowledge. In the definition of Information System, it is important to consider the concept of data, information and knowledge.

Starting from these considerations, our definition of an Information System is:

"An Information System is a constellation of methods, tools and techniques aimed at the optimal use of a company's data, information and knowledge that must achieve its business objectives. The main goal of the

Information System is to provide the right information to the right user at the right time, in order to allow the worker and / or the decision maker to carry out their work effectively; the Information System cannot therefore disregard the organizational structure that is an integral part of it. Information Technology is a set of hardware and software tools that aim to make data, information and knowledge management within the company more effective and efficient".

From the previous definitions, it emerges that the Information System exists independently from the supporting information technology. The main purpose of the Information System is to facilitate the company in achieving its goals: it defines the requirements that will then be implemented by the Information Technology in order to make the achievement of that goal efficient.

Information System: a Digital Ecosystem

The definition of Information System defined in this paper provides a holistic (integrated) vision of Information Systems independent from technology.

Speaking about the “holistic vision” of Information Systems, we mean that it is a complex system with its own characteristics not associated with the sum of single characteristics that make up each part. This means that speaking about Information Systems is not the same as speaking about Data processing, Management Information Systems or strategic Information Systems separately. Speaking about Information Systems means consider all interrelation between components that allow data to be transformed into information and knowledge. Using this vision, we can manage an Information System correctly and efficiently.

Starting from this concept, the classification of Information Systems (see previous section) is, while correct, only a partial classification as it does not provide an overall vision and does not provide a methodological approach useful for understanding the real essence.

The survey about Information System classification refers to papers from several years ago (some papers are before 2000) and there are not, as we are aware, recent studies oriented towards Information System classification.

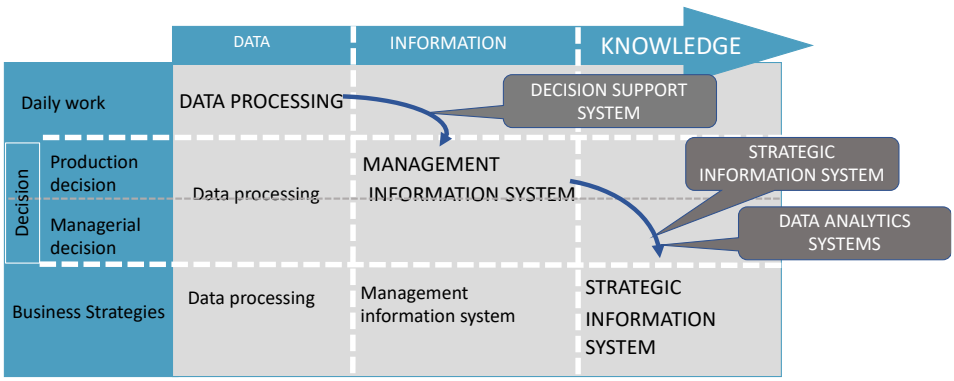
There are several papers about Decision Support Systems, but we found few papers about Strategic Information Systems.

The proposed classification refers to the relationship between data and information but does not relate to the relationship between information and knowledge. This lack may be because knowledge related to information is difficult to manage, to structure and to insert in an operative procedure.

The attention of managers and workers was, for years, focused on the operational aspect of the company, thinking about the automation of manual activities and, at best, through business process reengineering (before automation).

Starting from the systematic review of these concepts, we present in this paper a classification of Information Systems based on taxonomies retrieved in literature that allows us to have a clear and complete vision of the topic, and to derive the holistic definition we have provided in this article, while still talking about Information System risks being reductive, and would be more appropriate to talk about Knowledge Systems. Actually, at the end of the chapter we will introduce a clearer and more explanatory concept. This gives researchers a clear starting point to organize, compare, and discuss their works addressing shared open issues and research questions like those we propose at the end of this section.

The proposed classification is represented in figure 3.



The classification refers to two analysis dimensions:

- Organizational dimension: this dimension refers to the organizational classification proposed by Anthony and used by Laudon. In this dimension we have:
  - *Daily work*: the daily activities to produce goods or services.
  - *Decision:* activities related to operational decision important for the company to go on. Decisions can be related to the production (warehouse management, definition of production quantity and so on) or managerial decision and thus related to strategic goal.
  - *Business strategies*: activities useful to understand business strategies more suitable for company.
- Informational dimension:
  - Data: data management in the daily work.
  - Information: useful for decision maker
  - Knowledge: useful to define and refine strategies.

In our view, the classification is a wider framework that considers the characteristic of an Information System to transform data into information and knowledge.

In this two-dimensional matrix, the border between Information System categories are not well defined (represented by the dotted line in the picture). The dotted line represents the fact that in the real world, the border between data, information and knowledge is not well defined.

The “Data processing” defined and classified in our survey are the main systems in the data management during daily work (in the image they are in capital letters). Data processing is also used for the decisional and strategic layer: this layer should take account of the data management, although this is not a priority.

The “Management Information Systems” are used at decisional level and not in daily work: Management Information Systems are used also to define business strategies.

In this classification view we add other systems that are borderline between data and information and between information and knowledge.

We speak about Decision Support Systems, which have been covered comprehensively in this paper, but in a new interpretation: a Decision Support System has, here, the role to transform data into information useful for the decision maker.

We place the “Strategic Information System” and data analytics system in the transition from information to knowledge.

Strategic Information Systems are tools that support the decision maker in strategic decisions. In these systems, it is possible to use not only information coming from the company but also information coming from the ecosystem where the company does its business.

The “data analytics systems” refers to the examination of a large volume or fast-changing set of data that can be either structured (e.g., multiple spreadsheets and linked tables) or unstructured (e.g., text mining and click-streams), to extract useful information ,so that stakeholders can make informed decisions as stated by Chang et al. (2014).]. These systems rely heavily on software and specialized programs.

In the holistic vision presented here, there is no mention of the purely technological aspect of software systems and therefore no reference to the fruition channel (web, mobile etc.) or to the Data warehouse concept or the database etc. This is a well-defined choice of the authors in order to make the Information System concept clear without focusing on the technical aspects seen as “implementation detail”.

We defined the new vision of Information Systems with several terms: holistic, integrated, complete; however, we can consider the Information Systems as a Digital Ecosystem with a set of organisms (such as views, products, implementations or perceptions) interacting in a given context, thus constituting a resilient system.

Therefore, interactions, flows and exchanges take place within this, always in a dynamic equilibrium in continuous evolution.

This dynamic vision of an information system is therefore capable of adapting to various situations in a context characterized by high environmental uncertainty (as defined by Chen (2013)) and allows researchers and professionals to move within a defined and safe perimeter when making strategic decisions to improve the competitiveness of companies.

Conclusions and future works

The main goal of this paper is to clarify some concepts in the Information System research field. To achieve this goal, it was very important to understand the actual scientific panorama about three key concepts:

1. The concept of data, information and knowledge. very useful for the information system definition;

2. The concept of information system and all the considerations relating to the distinction between the Information System and Information Technology;

3. The classification of different types of information systems. For each aspect, a detailed literature review was presented, and some considerations were made in order to obtain a new definition of information system and a new view about information system classification.

In the final analysis, Information Systems, which until now considered only some aspects of the problem to the detriment of others, should be considered complex and resilient systems capable of dynamically adapting to the context of use and the level of information required.

The proposed definition and classification will be very useful for our next research question: how can we think about design in modern information systems? Are design techniques the same as 10 years ago or has there been is a change?

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