
Information Systems and Digital Technology

In this chapter, we will introduce the concept of information systems (IS), including a brief history of the domain. We will then define the concept of “digital” technology, and consider the role of IS and digital technology in a business context.

1.1. The concept of information systems

The concept of information systems (IS) includes two main aspects: first, the concrete organization which develops, innovates, communicates and records information, and second, the digital information system (DIS), an artificial, man-made object which makes use of the possibilities offered by information and communication technology (ICT) to acquire, process, store, transmit and render information in order to fulfill its role within the organization.

The key role of the DIS is thus to supply relevant information to each decision center, at all levels of the company hierarchy, for the purposes of monitoring, decision-making and innovation. In this way, the DIS is a crucial element in the decision-making process and in company operating and production processes; the DIS itself also interacts with these processes. The DIS is also a coordination tool. It plays an important role both at individual level, supplying information, i.e. representations used to solve problems in a decision-making process, and at collective level, transmitting shared representations throughout the organization.

According to Ermes-Groupe ESCP [ERM 94], “the information system of a company is the sub-system which contains all components of the company which interact through the provision of information. Its role is to provide information used to assist and monitor the operation of the business to all levels of the organization”. The IS defined in this way is not an exclusively computerized system, as a distinction is made between the organizational IS, covering activity associated with the operation of the IS, and the DIS, which only concerns computerized content [NAN 92]. For Le Moigne [LEM 90], “information systems serve to represent, memorize and allow access to representations (in symbolic form) of the operating system for the decision system”.

Definitions of some of the concepts used in this book will be given below. Systems science, also known as systemics, originated in the late 1970s. “Systemics is defined by a project rather than an object. Its roots lie mainly in systems theory, control theory and cybernetics” [NAN 92]. According to Le Moigne [LEM 77], the aim of systemics is “the modeling of complex perceived or conceived phenomena: the modeling of possible intentional interventions and their interconnected consequences for planning and forecasting purposes”. IS have their origins in the systemic modeling of organizations, of which they form one of the three components. Further details may be found in publications by Le Moigne [LEM 74, LEM 77, LEM 90], Nanci *et al.* [NAN 92] and Mélése [MÉL 79], among others.

According to Le Moigne [LEM 74], an IS is the system linking the operating and control systems. The operating system is the system in which physical or intellectual transformation takes place, and the control system is that in which decisions are made, in terms of aims and available resources. The IS enables decision makers and operators to access the information they need for, respectively, the purposes of control and action.

For Reix [REI 90], “the information system of an organization is made up of a set of methods and procedures for seeking, inserting, classifying, memorizing, processing and diffusing information. Its purpose is to supply this information in a directly useable form to different members of the company at the right moment, in order to facilitate correct operation and decision-making at various levels”. Note that the processed information should provide assistance in decision-making, and sometimes in coordinating actions. The system needs to respond to requirements in terms of response time, relevance, accessibility, precision, cost and reliability of

the information it provides. Information exchange occurs at different levels of command structures, and coordination issues may arise. Two types of coordination exist: “Vertical coordination, to avoid incoherency and conflict, and horizontal coordination, enabling users to work toward a shared objective, despite the division of labor. This coordination can either be carried out by mutual adjustment (direct information exchange) or by direct supervision” [REI 90].

For the purposes of this book, the following definition will be used, adapted from a definition given by the French *Commission Centrale des Marchés* (Central Contracts Commission, CCM [COM 90]):

An information system is a set of human, material and software resources, used by a user to carry out an activity within a given environment, which must be taken into account.

An IS, as described above, is not necessarily computerized. The computerization of IS within organizations has led to a distinction being made between the organizational and technical aspects of these systems; the latter is referred to as the DIS. The difficulties encountered when designing a DIS lie in the separation of the two systems. The DIS forms part of the IS as a whole, and strong interactions exist between the two aspects. Churchman [CHU 71] established nine conditions used to define a system, which will be discussed below in the context of IS:

1) *An information system always has an aim*, that of providing necessary information to all levels in the management structure. How is this objective to be defined? How can necessary information be supplied to all levels? What is necessary information? These points are rarely specified in an IS, as analysts tend to focus on the solution to the problem rather than on the problem itself. In this book, we will attempt to follow the advice of Morin [MOR 77]), cited by Le Moigne [LEM 91], who stated that “we need to consider the system as a problem, rather than the system as a solution”.

2) *The performance of an information system can be measured*. What is system performance, and how is this performance to be measured?

3) *An information system always needs to respond to the preferences of a user*. How are user preferences to be defined? What do these preferences mean? Which user is being considered? When identifying actors involved in an IS, the term “stakeholders” is generally used instead of considering individual users.

4) *An information system contains components which have their own objectives.* The objectives of information subsystems (components) are no easier to define than those of the IS itself.

5) *An information system operates in an environment.* The environment is rarely mentioned, and not often taken into account. Organizational aspects should be taken into account during system design.

6) *A digital information system must be paid for.* The buyers are rarely considered as stakeholders in the DIS design process, unless they also play a part in this process. It is important to give due consideration to the available resources when considering the functions to be fulfilled by a DIS.

7) *A Digital Information System has a designer.* The stakeholders involved in designing a DIS generally include an analyst (the designer) and a programmer. The way in which these parties relate to the final users of the system is rarely specified.

8) *The aim in designing a Digital Information System is to achieve user satisfaction.* How is user satisfaction to be evaluated?

9) *A Digital Information System provides a way of verifying the feasibility of the designer's intentions.* How are the intentions of the DIS designer to be verified, and at what stage in the design process does verification occur? What verification procedures are to be used?

A certain number of key questions need to be answered: Who are the stakeholders? How do they interact with each other? What is being done (i.e. what problem is being tackled)? How is this to be carried out (how is the problem to be solved)? Where (in what organization)? What influence will this place or context have on the system? What part does this context play in the user/machine relationship?

In all the cases, decisions are made based on the information. "The true role of the information system is in providing the simplest and most appropriate form of support to users when reconsidering raw data, redefining useful and relevant information, and rebuilding decision models in order to make them more effective" [COU 93]. Information is as important in diagnosing problems as in choosing appropriate solutions. All information is intimately linked to the subject of study, and is contextual. "An object should always be designed with an eye on the larger context: a chair in a room, a room in a house, a house in a neighborhood, and a neighborhood in

a town plan” (Eero Saarinen, cited in [INM 93]). Information treated in this way needs to be represented. In designing a DIS, the representation of all relevant information is one of the main issues at play. A solid structure is, therefore, needed for the DIS design process, including defined stages, from information acquisition to transformation, representation, treatment and interpretation.

The rapid changes which have taken place in ICT in recent times have led to reconsideration of the way in which DIS are designed. This evolution can be described through four major steps, from the appearance of the first computers in the 1950s up to the explosion of ICT at the start of the new millennium.

1.2. History of the concept of information systems

Following a brief summary of the role and functions of a DIS, we will consider the main turning points in DIS design, triggered by technological developments.

1.2.1. The centralized processing stage (1950s–1960s)

This stage was characterized by constant, relatively stable linear development. The information technology (IT) developed during this period enabled tools to be designed to improve productivity in scientific and administrative tasks. Applications were implemented by large calculation centers. This method, known as batch treatment, was functional, specific and non-real time. The period was characterized by the use of mainframes, centralized architectures and work stations. DIS were centralized, and corresponded to “process-oriented” design methods, such as the Warnier method and the structured programming method. These methods were influenced by the technological resources available at the time, which were based on the use of files. They took a functional approach to organization and used a top-down methodology, consisting of a hierarchical breakdown of problems into subproblems, mirroring the image of the organization. The development cycle for systems of this type followed a strictly sequential cascade model.

1.2.2. The data decentralization stage (1970s–1990s)

This stage was characterized by a less deterministic, less predictable and increasingly complex evolution, marked by rapid change and increased competition. This is the period which saw the emergence of the microcomputer. The possibility of devolving some of the processing capacity allowed designers to establish non-real time handling processes for centralized data and/or real-time processes for decentralized data. Thus, DIS were called upon to handle large quantities of data, with key functions including memorization and calculation. These systems essentially handled “stable”, structured data of types specified by the analyst and designer of the DIS [PRA 97]. The period was characterized by the use of databases and database management systems. The design methods corresponding to the appearance and expansion of databases included Merise and Axial, particularly in France. The development cycle for systems of this type continued to follow a cascade model, remaining essentially sequential, while establishing correlations with the results obtained at each stage of the development cycle (V and W cycles).

1.2.3. The interoperability and standardization stage (1990s)

During this period, organizations were focused on seeking new markets, creating a demand for new, powerful tools in order to establish communications between heterogeneous systems. Client-server technologies, object-based methods and reusable components led to the creation of conceptual tools and new, better techniques. DIS evolved from a focus on carrying out bulky calculations in non-real time to a focus on data storage, and then to an object-centered approach and finally onto enterprise resource planning (ERP).

Thus, over 70 object-based methods, or variants thereof, existed by the early 1990s. In 1997, the object management group (OMG) adopted unified modeling language (UML) as a standard [KET 98]. UML was the result of a broad consensus, taking account of the latest advances in modeling and software development techniques, based on the work carried out by experts in the field of object modeling. In order to standardize the DIS design process, the unified process (UP) standard was also submitted to the OMG. The development cycle described by this standard was iterative and incremental. At the same time, integrated management software packages

began to appear, and were adopted by a number of businesses from 1996 onward. These packages aimed to offer a library of standard trade processes, adaptable using specific parameters, in order to automate the management of key activities. The packages provided a transversal view of businesses, unifying their DIS using a single format for management applications. Treating companies as a whole, using a tool to simplify the cycles involved in bringing products and services to market as far as possible, the “integrated packages” approach was seen as a reformulation of company applications, producing a more standardized form of DIS [LEQ 99]. Unfortunately, most of the companies did not apply the necessary organizational changes and trade processes when using these packages; this is a very real and widespread issue.

1.2.4. The universality and globalization stage (2000 onward)

A new form of “information economy” emerged in the early 2000s, based around the Internet and the increasingly global use of digital technology, creating the so-called “information highway”. The universality of standards and the capacity for connection reduced blockages in information flows, enabling the acceleration of search, modification and transaction activities. The most striking visible results of these changes included the emergence of online shopping and the online marketplace.

Design methods have evolved over the years as new technologies have appeared, highlighting organizational dimensions: the connection between an organization and its DIS appears to be increasingly strong, and organizations are now “irrigated” by their DIS. The first stage in this process was marked by the predominance of computerized services. During the second and third stages, the roles and missions of those involved designing DIS evolved, and new actors became involved, in the form of project managers, representing the company in negotiations with contractors. This development required a shift toward collaborative working in order for application projects to succeed. The presence of project managers in the DIS design process highlighted the increasing influence of organizations on the design of their IT systems. Moreover, instead of simply managing, processing, recording and diffusing information, IT systems took on a role as “facilitators” in communication, explanation, coordination and cooperation activities. Moreover, the need for knowledge capitalization within organizations led to the development, proliferation and integration of certain

technologies, partly as a result of research in the field of knowledge engineering. This created new capabilities in terms of knowledge management within organizations. The combination of these factors meant that a new approach to DIS design was required.

Based on these evolutions, the DIS development cycle came to be considered as an iterative, incremental and constructivist approach.

Stages	Development methods	Technologies	Development cycles	Actors in the development process	Design focus
<i>1950–1970 Centralization of data</i>	Warnier and structured methods	Mainframe and files	Cascade sequential	Computer scientists	Processing
<i>1970–1990 Decentralization</i>	Merise Axial	PC, SGBD and client/server	Cascade, V cycle, W cycle	Clients and computer scientists	Data
<i>1990–2000 Interoperability and standardization</i>	Object-based approaches: OMT, OOSE and UML UP	ERP and Internet	Incremental and iterative cycle	Contractors, clients, users, specialists and computer scientists	Organization data processing
<i>2000 – present Universality and globalization</i>	UML, RUP, MKSM, KADS, participative approaches and agile approaches	ERP, Internet and ICT Web 2.0	Incremental and iterative cycle, constructivist approach, agile method and rapid analysis design (RAD)	Contractors, clients, users, specialists, computer scientists, cognitics engineers, architects and urban developers	Organization collaborative working, knowledge management shared, diffusion information, sources of knowledge and workstations

Table 1.1. *The four stages of the development of digital information systems (DIS)*

The ubiquity of digital technology within businesses and its impact on the complexity of IS has resulted in a tendency to consider the digital aspect of these systems alone, i.e. a tendency to focus on the DIS. This reductive view of the IS is false. IT company specialists often make presumptions concerning the requirements of service employees, without taking account of certain specific trade factors. We will now consider the “digital” aspect of DIS.

1.3. What is “digital” technology?

The term “digital” was initially used, as an adjective, as the opposite of “analog”. The *Concise Oxford English Dictionary* (2004) defines “digital” as “relating to or using signals or information represented as digits using discrete values of a physical quantity [...] involving or relating to the use of computer technology”. The difference between analog and digital methods can be illustrated using the example of sound. Using an analog method, a vinyl disk creates vibrations in a diamond in order to generate an electrical signal, which is amplified to create a sound. Using digital means, compact disks (CDs) operate using a digitized sound signal, rendered discrete and reproduced in the form of numbers. This representation must then be decoded in order to generate a sound. In physics, an analog signal may include an infinite number of values between two points, unlike a digital signal.

Digitization is a basic process used in electronic technologies, involving the treatment of discrete numbers. Computers, for example, use base 2: series of 0 and 1. However, man was able to process numbers well before the appearance of computers in the second half of the 20th Century. Note that a computer is “an electronic device which is capable of receiving information (data) and performing a sequence of logical operations in accordance with a predetermined but variable set of procedural instructions (program) to produce a result in the form of information or signals”, according to the *Concise Oxford English Dictionary* (2004). Thus, a slide rule, which is a machine for digital information processing, cannot be considered to be a computer as it is not electronic, unlike a calculator (see Figure 1.1).

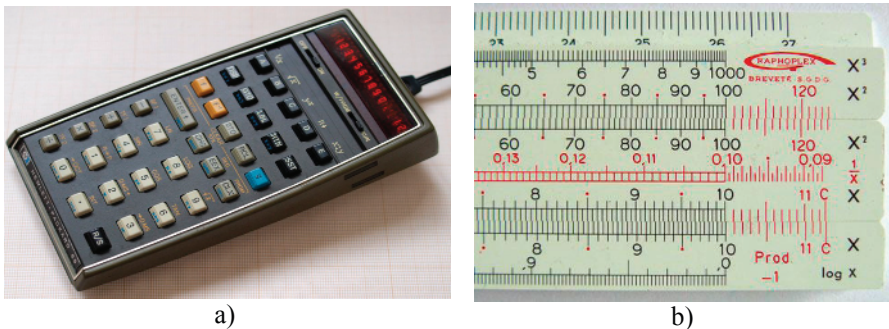


Figure 1.1. A calculator a) is a computer, an electronic machine for the digital processing of information, unlike the slide rule b), which is not electronic

In an organizational context, we consider that:

Digital technology is the set of artifacts which represent information in binary form, and which use Information and Communication Technology.

Digital technology has become increasingly mobile and ubiquitous. In organizations, digital technology is used at a range of levels, from the DIS used by employees to distribute information and share knowledge, to the smartphones used by individual members of staff, often key to their personal social lives. Digital technology can also be used by human resources to record clocking in and clocking out, for example, or for health purposes: the use of smartwatches means that health itself can be digitized, i.e. represented through a series of characters.

For certain Chief Information Officers (CIOs), digital technology is seen as being more for client-related, external purposes, whereas the IS is intended for internal management. However, digital technology does not always provide the type of automatic information processing desired. For example, certain organizations bring in external agencies to digitize their paper documents; once digitized, these documents become digital images which can be processed, stored and diffused using a DIS. This information can thus be processed automatically. Without optical character recognition (OCR), however, the processed information is not the content of the images, i.e. the text included in the paper documents, but rather the digital coding of the images alone. Computer science relates to the automatic processing of digitized information, independently of whether or not this information has meaning for those who receive it.

As we have seen, digital technology, via the evolution of ICT, has fundamentally altered individual habits, with a knock-on effect on organizational activities and processes, research and innovation, management, communication, client relations, logistics, skill sets and career management. Digital technology has also transformed the relationship between CIOs and the stakeholders in the IS. The term “digital business” is sometimes used, due to the ubiquity of digital technology within companies. In the context of this book, the term “digital business” will be extended to apply to all types of “digital organization”. Ménard (cited in [ROH 14]) defines a digital business as “a company with a digital vision and a digital plan for all aspects of its business model”. For Menard, this is “a global

approach for the company, which wishes to create value via digital means, i.e. through personal and professional use of information technology”. It is important to consider how the visions of IS, as presented above, and digital technology are to be integrated into company strategy.

1.4. Information systems and digital technology for business

The aim of an organization is to produce goods and services; a strategy and specific sets of skills are used in pursuit of these goals. Strategies are created using activities based around trade processes. These processes require information input. Consequently, from a systemic perspective, the “information system” is of the same nature as the organization in itself, and will always exist in some form. The DIS acts as a support for the IS. This is also true for family units, for example, which have an IS involving communications between members, with or without the use of ICT. Michel Serres draws an analogy with communication techniques used by American Indians, based on smoke signals. The fact that the IS and the organization are consubstantial is crucial; the IS itself is not visible, but is the way in which individuals communicate, whether face-to-face or using technological means.

DIS appear to have taken over, leading to a widespread belief that the IS is exclusively digital. Whatever the organization involved, ICT now forms a part of all processes. Technology has an impact on production processes, and these processes have an influence on technology: the two are interdependent. Over the course of their evolution, DIS have modified the way in which individuals communicate, as well as production processes, with a knock-on effect on business strategy. This strategy, used to determine the activities which take place, may both affect and benefit from ICT via the IS. These dimensions are all, therefore, interdependent, and the DIS is at the heart of their interactions.

An IS is made up of individuals, who communicate with each other directly and via the DIS. The IS supplies services to support activities and assist in decision-making. All entities and objects within an organization are now able to communicate, due to ICT, meaning that individuals can be considered as both components and users of the IS.

IS, therefore, involve a human and social dimension, characterized by the individuals involved, who contribute to the final processes used by the organization, and communicate between themselves. They also involve a technical aspect, in the form of the DIS, an artificial, man-made object.

IT offers features which can lead to uses different to those for which they were initially intended, leading to modifications at the organizational level, with changes to existing processes. A loop exists between use, design and technology. Discussions with CIOs have shown that technological evolutions precede reflection. Social networks are used constantly by individuals, leading to reflection within companies as to whether or not this should be authorized. Questions surrounding the way in which DIS are designed have not yet been fully answered, as no method yet exists to respond to the problem of organizational complexity. One emerging problem in the domain of IS, more precisely in terms of access to the DIS, relates to the critical issue of security. An IS supported by a DIS is integrated into a socio-technical environment, which itself acts as a support for all decision-making processes within an organization. These DIS offer new functions, leading to new usages and new behaviors, as we have seen with the emergence of smartphones, from both social and organizational perspectives. Processes are modified, creating new problems and new requirements. In this context, artificial intelligence, knowledge-based systems (KBS) and research carried out in relation to the decision process can offer solutions, although a single solution to all of these problems does not currently exist. The interactions between the possibilities offered by IS, technologies and organizations need to be reconsidered on a continuous basis by all those involved, in both private and professional contexts.

IS are transversal and apply to all services and disciplines, from financial management to human resources via accounting. The DIS supporting these systems are also transversal. A multi-disciplinary approach to teaching and research in the field of IS is, therefore, needed, and organizations need to recruit candidates with suitable training in this area. Clearly, technicians are required, but expertise in this area is also vital in other domains, including management, human resources, finance, etc., in order to fully understand the complexity of organizations and the way in which IS need to react. DIS are directly connected to users, who play a central role in the system, as well as to those who design, maintain and sell these systems. DIS are designed by human operators, for human operators: these final users may use the DIS in a way different from that envisaged by the designers.

The human dimension of IS can be obscured by the presence of digital technology. All participants in an organization are affected by the IS: management, the CIO, those responsible for DIS design, suppliers and, especially, the final users of the DIS. However, behind every DIS there is always a designer, and in front of every DIS there is always a user: these elements must always be taken into account, unless a fully automated robotic system is to be envisaged. This human dimension is essential, and user expectations need to be taken into account in the technological design process. It is also important to be aware that users may use the DIS in a different way than we might expect, as mentioned above.

IS involve communication, listening, personal implication, elements of psychology, mutual understanding and thorough comprehension of each other's requirements. A third dimension may, therefore, be added to IS model, in addition to organizational and technological aspects: this aspect concerns social and public responsibility, or ethics. The introduction of a new tool into an organization can have far-reaching consequences, something which may be referred to as digital ethics.

Given the ubiquity of digital technology and its impact on the complexity of IS, for each new project, the DIS design process needs to take account of the nature of information and the roles of individuals acting as components and users of the system. This consideration, combined with the results of research in knowledge management, has led to the creation of a tripartite classification of information types [GRU 01, GRU 03]:

- *main-stream information* concerns the flow of information concerning the state of production and operating systems in a company, notably those which are structured and recorded using databases, decision systems or ERP;

- *shared information* includes information processed by technological means which fulfill the following criteria:

- allowing instant transfer of digital multimedia documents including text, images, video and sound, and offering the possibility of asynchronous information exchange, changing our relation to time and space,

- enabling electronic conferencing, allowing users to effectively be in several places at the same time,

- leading to a transformation of working behaviors;

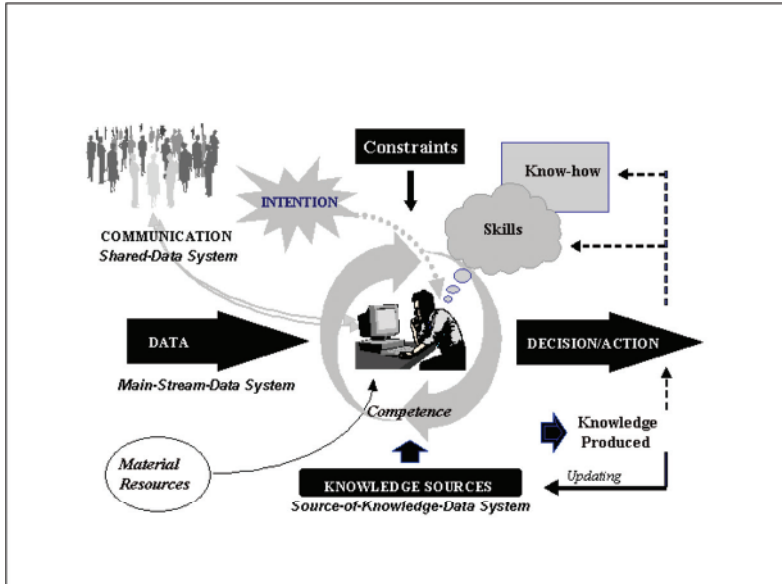


Figure 1.2. Three types of information [GRU 03]

These technologies mark a clear shift from earlier methods, due to the changing relationship of users to space and time, to the capacity for ubiquity which allows us to pass from the physical to the virtual world and from the manipulation of concrete objects to the manipulation of abstract objects. They generate real-time information exchange processes and knowledge sharing in a way not possible using older technology;

– *information as a source of knowledge* is notably the result of a knowledge engineering approach (KBS or expert systems (ES), analogy-based reasoning, etc.) which provides techniques and tools enabling us to acquire and represent knowledge. Knowledge is encapsulated in programs presenting this knowledge in the form of information which can be directly understood, accessed and handled by users. The data which a person receives, requested in relation to a specific context, are transformed by interactions with their own knowledge and skills: these data are activated in order to produce knowledge which is useful in understanding and solving problems, making decisions and acting.

The distinction between the three types of information is based on a definition of the term “knowledge” which does not dissociate the individual

from the professional processes in which he/she is involved, the decisions he/she makes and the relationships he/she has with the surrounding system (individuals and artifacts).

It is, therefore, important to find the best possible means, in both technological and organizational terms, of designing a DIS in order to allow an actor at a workstation, carrying out attributed tasks, to share tacit knowledge and to access the information (used as a source of knowledge) required to understand and solve problems, make decisions, accomplish tasks and capitalize on the knowledge produced during these activities. Thus, designers must consider users as components of the system. They must also take account of the information which an individual, acting as a decision maker, needs to be able to access.

Knowledge management will be presented in Chapter 2.

1.5. Key points

The key ideas to remember from this chapter are:

- an IS is a set of human, material and software resources, used by a user to carry out an activity within a given environment, which must be taken into account;
- digital technology is the set of artifacts which represent information in binary form, and which use ICT.

