

2 Literature Review: ICT, SDPs and System Design for User Needs

Chapter 2 provides a literature review, together with theoretical topics pertaining to Information System Theory, Information and Communication Technologies (ICT), Service Delivery Platforms and System Design for User needs, and relates current literature to all of these topics within this investigation.

Section 2.1 introduces the study and its context. Related research to Information and Communication Technologies and the Information Systems Theory is introduced in the second part of this Section. Service Delivery Platforms (SDPs), as one possible application of general web-based platforms are introduced, and their possible fields of applications are presented using the example of SPICE - Service Platform for Innovative Communication Environments, within the third Section (2.3) of this thesis. Different approaches in terms of user needs, for designing a system, together with system design aspects when designing ICT systems, is introduced in Section 2.4 of this Chapter. This Chapter then puts this PhD thesis into context with other research studies, and lists publications done by the author.

Finally, Section 2.5 summarises a conceptual framework for developing web-based platforms, with the example of an SDP in terms of ICT environments for the future, being introduced. The concepts of human-computing interaction and the conceptual framework from Trick and Weber (2009) were briefly introduced. The research gap is presented and a handful of research questions are presented and formulated to illuminate the research problem outline in Chapter 1. All literature research is distributed within Chapter 2 systematically. All relevant background information to the essential related technology and the complexity of these are presented in Appendix A - Sections 8.1 to 8.3.

2.1 Introduction

This Section provides a literature review of the relevant topic areas, providing explanations about the related research, and further defining and introducing important terms and definitions.

Ubiquitous Computing, also described as ubiquity of computers, was initially formulated in the article "The Computer for the 21st Century" by Marc Weiser (1991), who, at the time, was head of the Computer Science Laboratory at Xerox PARC. Computers should unobtrusively support a person in their daily tasks, whereby they should remain seemingly invisible, in the background, yet

should be available, always and everywhere. This idea has fundamentally revolutionised the way we think about, and work with, computers. The computer disappears as the focus, and in its place steps the human being surrounded by computers, which have to support him on a daily basis, and take over many of his day-to-day tasks (Wohltorf, 2004: p. 91).

To be able to achieve this target, downscaling quantity of machines and more efficient use of energy, or the development of new sources of energy, is necessary. Above all however, the computer should actively sense its environment, and should be able to adjust to any situation that arises. This requires the vast use of sensors that can deliver the necessary information over the available environment, and therefore instruct the computer, by using these indicators, which actions it must take. The term Sentient Computing was created for this special form of ubiquitous computing (Wohltorf, 2004: p. 91).

Pervasive Computing (lat. pervadere = interfuse) can be understood as a synonym of Ubiquitous Computing. It describes the fusion of everyday life with connected, intelligent objects, able to communicate with one another. Pervasive Computing, is therefore, frequently regarded as a form of the industry-named variation of Ubiquitous Computing. This technology supports people with personalised services and is universally accessible and obtrusive (Burkhardt *et al.*, 2001: p. 24-25).

Wearable computers are miniature electronic devices that are either worn under, with or on top of, clothing of the bearer. This class of wearable technology has been developed for general, or special, purpose information technologies and media development. These types of computers are particularly useful for applications that require more complex computational support, than just hardware coded logics. One of their main features is that one does not need to turn it on or off, as it is always active.

Another feature is its ability to multi-task. There is no need to stop what you are doing in order to use the device. These devices can be incorporated by the user to act like a prosthetic. It could be an extension of the user's mind and/or body (Starner *et al.*, 1995).

Cloud computing has been defined as being the practice of using a network of remote servers hosted on the Internet and stores. It manages and processes data as opposed to a local server. It relies on sharing of resources to achieve coherence and economies of scale, similar to a utility, over a network. Three types of cloud computing can be defined (Armbrust *et al.*, 2010; Voorsluys *et al.*, 2011):

- *Infrastructure as a Service (IaaS)*: This is a cloud service model whereby cloud providers offer computers as physical or virtual machines. A hypervisor runs these virtual machines as guests. The management, of pools of hypervisors by the cloud operational support system, precipitates the ability to

scale a large number of virtual machines. Other resources in IaaS clouds include images in a virtual machine image library, raw (block) and file-based storage, firewalls, load balancers, IP addresses, Virtual Local Area Networks (VLANs), and software bundles. These resources are maintained in large pools found in data centres, and can be supplied on demand by IaaS cloud providers (Voorsluys *et al.*, 2011). To deploy their applications, cloud users then install operating system images on the machines along with their application software. According to this model, it is the cloud user who is responsible for patching and maintaining the operating systems and application software. IaaS does not refer to a machine that does all the work, but rather to a facility provided to businesses, which offers users the advantage of extra storage space in servers and data centres (Voorsluys *et al.*, 2011).

- *Platform as a Service (PaaS)*: The PaaS model allows cloud providers to deliver a computing platform that typically includes an operating system, programming language execution environment, database, and web server. Application developers are able to develop and run their software solutions on a cloud platform without bearing the costs and complexity of buying and managing the underlying hardware and software layers. Some PaaS offer functions in such a way, that the cloud user does not have to allocate resources manually, by scaling the underlying computer and storage resources automatically in order to match application demand (Voorsluys *et al.*, 2011).
- *Software as a Service (SaaS)*: According to this model, cloud providers install and operate applications in the cloud, and cloud users access the software from cloud clients. It is not the task of cloud users to manage the platform and infrastructure on which the application is running. Due to this there is no need to install and run the application on the cloud user's personal computers. This saves maintenance and support time. A cloud application is elastic, and this renders it different from other applications. This elasticity is brought about by cloning tasks onto multiple virtual machines at run-time, in order to keep up with changing work demands. Load balancers distribute the work over the set of virtual machines. This process is inconspicuous to the cloud user, who only sees a single access point. To accommodate a large number of cloud users, cloud applications can be multi-tenant, which means that any machine is able to serve more than one cloud user organisation. Specific types of cloud-based applications are often referred to, as software with a similar naming convention: desktop as a service, business process as a service, test environment as a service, communication as a service (Voorsluys *et al.*, 2011).

Being able to develop and implement applications and services in the current century, extremely flexible architecture is needed, in order to support the concepts of ubiquitous computing and others described above. One possibility is to use a Service Oriented Architecture (SOA).

Service Oriented Architecture is an architectural paradigm that can be used to build and facilitate infrastructures, in line with consumer's needs, and with provider's capabilities to interact via services, across different domains of technology. Services act as main facilitators of data interchange, but in order to function, additional mechanisms are required. Several new trends within the computer industry rely on SOA as an enabling foundation. The automation of Business Process Management is included together with composite applications (applications that aggregate multiple services to function), various new architecture and design patterns generally referred to as Web 2.0 (Valipour *et al.*, 2009; Voorsluys *et al.*, 2011).

Service orientation demands, services with operating systems, to be loosely coupled with other technologies that support applications. SOA defines functions as distinct units, referred to as services which developers make accessible over a network. This is done to allow users to combine services and then reuse them in the production of applications. In fact, SDPs are based on Service Oriented Architecture concepts. SOA is a set of principles and methodologies for the design and development of software services. These services are defined business functionalities that are constructed as pieces of software codes or data structures that can be used for different purposes. The design principles of SOA are used in developing and integrating systems (Bieberstein *et al.*, 2005).

SOA increases awareness of the available SOA-based services, defines various ways of integrating contrasting applications for Web-based environments, and uses multiple implementation platforms. SOA defines the interface in terms of protocols and functionality. These services, and their respective consumers, communicate with one another by passing data in a well-defined, shared format, or by coordinating an activity between two or more services (Valipour *et al.*, 2009). Service Delivery Platforms (see Section 2.3) are designed and implemented on the concepts of SOA. The next Section introduces the reviewed literature regarding Information Communication Technology (ICT) it describes important terms and discusses what other researchers did, in this field of study.

2.2 The Connection of Information and Communication Technology (ICT) to SDPs

The following Sections describe the different technological areas, Information Systems Theory and Information Communication Technology, with appropriate definitions, and present an analysis of the up-to-date academic literature based on the current state of the art. This related topic focused on technical research, with an emphasis on the technical perspective. Related research from the user's point of view does not exist, except with another application on work of the author himself, focusing on Service Delivery Platforms to improve Railway Telematics Systems. This study was also done from the perspective of the user and investigated the use of Railway Telematics. Details of this related research application and the context for this PhD study, will be explained in Section 2.4.5.3 – Thesis in Context.

2.2.1 Basic concepts

Information Technology (IT) is a branch of engineering that deals with the use of computers to store, retrieve, and transmit information. The acquiring, processing, storing and dissemination of vocal, pictorial, textual and numerical information by a microelectronics-based combination of computing and telecommunications are its main fields. Modern and new fields of IT include next generation web technologies, bioinformatics, cloud computing, global information systems, large scale knowledge bases, to name a few. Progress is mainly driven in the field of computer science, built on an evolving electronics' infrastructure, promulgated by Engineering, Physics/Mathematics, Defense (military) expenditures, public/private R&D, and the consumer product marketplace (Melody *et al.*, 1991).

System Theory (ST) is the foundation of a generic understanding of the world. The concept 'system' is a universal analogy used for anything, regardless of its particular properties, origin or substance. It therefore provides a synergistic force to counter the fragmentation, or analytical aspects, of science and empirical knowledge. It can also be used to translate and unify ideas throughout fragmented, and somewhat estranged, fields of knowledge (Bailey, 1994).

System theory postulates that everything is a system, signifying that the concept system is applicable to everything in a meaningful and practical sense. Everything is a system that is composed of sub systems, which interact to create that system. Thus, ultimately, there is only a field of primitive systems, and the information that mediates their interactions. Through their permutations and combinations, they build up the successive levels of systems. Every system is a sub-system within larger systems, and interacts with other systems passing information, coordinating, organising, cooperating, competing, etc., thus forming a

higher-level super-system, and so on, up to the universe as a whole, which is a single, unified, and coherent system (Weinberg, 1975).

Information Systems (IS), is the study of the complementary networks of hardware and software that people and organisations use to collect, filter, operate, create, and distribute data (Lee, 1991). The study links business and computer science, using a theoretical basis of information and computation so as to study various business models and related algorithmic processes within a computer science discipline. Computer Information System(s) (CIS), is the field of study of computers and algorithmic processes, including their principles, software and hardware designs, applications, and their impact on society (Benbasat and Zmud, 2003).

The history of information systems coincides with the history of computer science that began long before the modern discipline of computer science emerged in the twentieth century. With respect to circulation of information and ideas, numerous legacy information systems remain today and are continuously updated so as to advocate ethnographic approaches, ensure data integrity, and improve the social effectiveness and efficiency of the whole process. Generally, information systems focus on processing information within organisations, particularly within business organisations, and the benefits are shared with modern day society (Agarwal, 2005).

Silver *et al.* (1995) provided two perspectives on Information Systems (IS). The IS-centred viewpoint includes software, hardware, data, people, and procedures. Another managerial outlook includes people, business processes and Information Systems. There are different types of IS, for example: transaction-processing systems, office systems, decision-support systems, knowledge-management systems, database-management systems and office-information systems. Users criticise many information systems that are typically designed to allow humans to perform tasks for which the human brain is not well suited to. These tasks cover areas like dealing with large amounts of information, performing complex calculations and controlling many simultaneous processes.

Silver *et al.* (1995) defined Information Systems as systems, implemented within an organisation for the purpose of improving the effectiveness and efficiency of that organisation. The capabilities of the IS and the characteristics of the organisation, its work flow, human resources, and its development and implementation methodologies together define the extent to which that goal is achieved (Benbasat and Zmud, 2003). Several IS scholars have debated the nature and basis of Information Systems, which have their roots in other reference disciplines such as Computer Science, Engineering, Mathematics, Management Science, Cybernetics, and so forth.

Information systems research is primarily interdisciplinary, focused on studying the effects of information systems on the behaviour of individuals, groups and organisations. Hevner *et al.* (2004), categorised research in IS into two scientific paradigms comprising of behavioural science and design science. The purpose of the former is to develop and verify theories that explain or predict human or organisational behaviour. The latter stretches the boundaries both of human and organisational abilities by creating new and innovative history.

The term Information System Theory (IST) was used to describe theoretical computer science, where a computer was a system that processed information. Here, information is far more general than simply the contents of computer files or data structures. Each system comprises of information and additionally processes information, regardless of the form, that information takes, regardless if its medium is a computer file, light rays, particles of matter, etc. (Lee, 1991).

The term Information and Communication Technology (ICT) refers to the convergence of audio-visual and telephone networks, with computer networks through a single cabling or link system. Significant economic incentives are in place, based on minimising costs by eliminating telephone networks and merging of audio-visual, building management and telephone networks with computer network systems, by using a single unified system of cabling, signal distribution and management. This has initiated the increase of organisations using the term ICT in their company names, to draw attention to their specialisation in the process of merging the different network systems (Melody *et al.*, 1991).

The Internet is a global system of interconnected computer networks that use the standard Internet protocol to serve billions of users worldwide. It is a network of networks, consisting of millions of private, public, academic, business, and government networks, on a local and global scope, that are linked by a broad array of electronic, wireless and optical networking technologies. It consists of an extensive range of information resources and services, such as the WWW's interlinked hypertext documents, and an infrastructure that supports different services i.e. email, chat, and TV. ICT standards are very important to enable technological systems to interoperate with each other. This is especially relevant as the main idea behind ICT, is that information storage devices can communicate with communication networks and computing systems in a media-frictionless manner (Melody *et al.*, 1991).

ICT systems and environments are an extension of Information Technology (IT), and they have broadened the term IT via the integration of telecommunications and focussing strongly on unified communications. Telecommunications focus on telephone technology and systems operating, both with wired and wireless signals. The scope of IT is wide, beginning with the integration of computers and crucial organisational software, middleware, storage systems and including audio-visual systems. This allows users to create access, store, transmit, and

manipulate information and data. Basically, ICT consists of IT in addition to telecommunications, broadcast media, all types of audio and video processing and transmission, as well as network-based control and monitoring functions (Melody *et al.*, 1991).

March and Smith (1995) suggested a guideline for the research of different aspects of Information Technology, including output of the research (research output) and activities to carry out the research (research activities). They identified research output as follows:

- Constructs as concepts forming the vocabulary of a domain and that include a conceptualisation utilised in describing problems within the domain and specifying their respective solutions.
- A model consisting of proposals or statements expressing relationships between constructs.
- A sequential method made up of a set of steps (an algorithm or guideline) utilised in performing a task. Methods are based on a set of underlying constructs and a model of the solution space.
- An instantiation is the realisation of an artefact in its environment.

Other research activities include:

- Constructing an artefact to perform a specific task.
- Assessing the artefact to determine if any progress was made.
- In terms of an assessed artefact importance on determining reasons the artefact worked, or conversely did not, within its environment allows for theorising and justifying theories about IT artefacts.

Although Information Systems, as a discipline, have evolved over the past 30 years, the focus of IS research continues to be subjected amongst scholars. Two main viewpoints surrounding this debate are: a narrow perspective that focuses on the IT artefact as the central subject matter of IS research and a broad perspective focusing on the interplay between the social and technical aspects of IT that are embedded into a dynamic evolving context (Agarwal, 2005). Given that information systems fall under the auspices of an applied field, they are expected, by industry practitioners, to generate findings that are immediately applicable in practice. However, this is not always possible, as information systems researchers frequently explore behavioural issues in more depth than practitioners would expect them to. This may render information systems research results difficult to understand, and in turn face criticism (Ron, 2002).

2.2.2 *Convergence and ICT4D*

Telecommunications convergence, network convergence, or simply convergence are terms, generally used to describe newly formed telecommunications technologies and network architectures used to move many communications services into one network. This particularly entails converging previously distinct media, such as telephony and data communications, into common interfaces on single devices. Rajendra and Siddhartha (2010), define convergence, in their Policy Initiative Dilemmas on Media Convergence: A Cross National Perspective, as integration and digitalisation.

Integration, in this case, is defined as "a process of transformation measure by the degree to which diverse media such as phone, data broadcast and information technology infrastructures are combined into a single seamless all-purpose network architecture platform". Digitalisation is not solely determined by its physical infrastructure, but by the content or the medium.

Convergence is defined by Blackman (1998), as a trend that exists in the evolution of technology services and industry structures, and then later further defined as the merging together of telecommunications, computing and broadcasting into, a single digital bit-stream. Mueller (1999) disagreed with the statement, that convergence is really a takeover of digital computers of all forms of media. There are different types and classes of computers, which are constantly developed providing the easiest and fastest way to handle different forms of media information. Convergence services including VoIP, IP-TV, Mobile TV, and so forth, will eventually replace old technologies and are posing a threat to current service providers. IP-based convergence is inevitable and will cause new services and demands on the market. Once old technology converges into common public, IP-based services become independent of access or less dependent on access. The old service is access-dependent (Bores *et al.*, 2001).

Information and Communication Technologies for Development (ICT4D) is a general term that refers to the application of Information and Communication Technologies (ICTs) within the fields of socioeconomic development, international development and human rights. The basic hypothesis behind this approach is that increasingly, more and enhanced information and communication, development of a society (either through improving income, education, health, security or other aspects of human development). Presently, the most tangible and effective ways to improve information and communication flows in a society is to adopt ICT, therefore ICT4D (Sutinen and Tedre, 2010).

The aim stated that ICT-for-development is to make use of this ongoing transformation by actively using the enabling technology to improve the living conditions of societies and segments of society. Historically, social transformations of this kind, such as the industrial revolution, the resulting dynamic are interplays between an enabling technology, normative guiding policies and

strategies, and the resulting social transformation. With ICT4D, this three-dimensional interplay is shown as a cube. Following the Schumpeterian School of thought (Michaelides and Milios, 2008), the first enabling factor for the associated socio-economic transformations is the present technological infrastructure: hardware infrastructure and generic software services. In addition the human requirements for making use of these technologies include capacity and knowledge of these foundations (horizontal green dimension in Figure 6). They are the basis for the digitalisation of information flows and communication mechanisms in different segments of society.

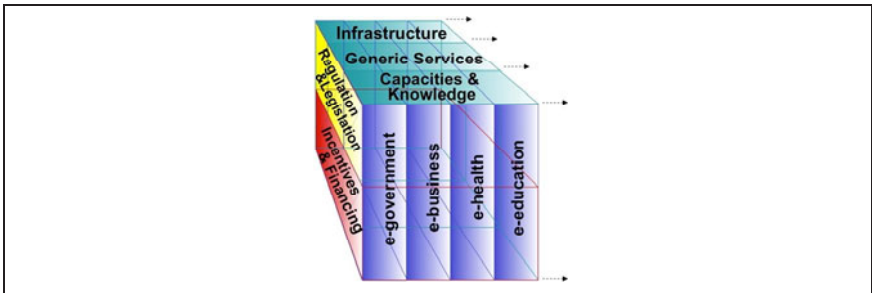


Figure 6: ICT4D cube: interplay between technology, society, and policy (Hilbert, 2011; source: <http://www.martinhilbert.net/HilbertCube.pdf>)

When part of the information flows, and communication processes in these sectors are carried out in electronic networks, the prefix "e-" is often added to the sector's name, resulting in e-government, e-business and e-commerce, e-health, and e-learning, etc. (vertical blue dimension in Figure 6). This process of transformation represents the basic requirements and building blocks; however, they are not enough for development. The mere existence of technology is not sufficient to achieve positive outcomes because there is no technological determinism. ICT for Development policies and projects is geared at promoting normatively desired results of this transformation, minimising negative effects, and removing probable bottlenecks.

There are basically two types of interventions: positive feedback (incentives, projects, financing, subsidies and so forth that accentuate existing opportunities) and negative feedback (regulation and legislation, etc.) that limits and tames negative development (diagonal yellow-red dimension in Figure 6) (Hilbert, 2011; Naismith *et al.*, 2004). Although ICT4D is primarily dependent on technology, one should heed that the concepts and applications of ICT4D also require a clear understanding of issues of community development, poverty, agriculture, healthcare, and basic education. The acronym ICT4D contains a divisive disciplinary discussion by Richard Heeks (2009). As atomised by

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