Information Infrastructure in Sustainable System Development

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Abstract
In relation to sustainability, information technology is often seen as an enabler in ventures with an aim to have a positive impact on sustainability. These can be, e.g., economical, ecological and social. In order to achieve these goals there is a need to describe the information infrastructure. The base for such an infrastructure is the capability to store and manage information, and the technology that supports the flow of information. We apply this view on a project directed towards the development of a new information infrastructure within the municipality of Uppsala, concerning transport logistics in relation to sustainability goals. We explored our concept of information infrastructure to model the change in information pathways, between the old system and the new one. Experience from this work is our foundation for an information model usable when developing sustainable systems.

Keywords: information infrastructure, sustainable system development, information modelling, enabler for sustainable work, transport logistics

1. Introduction
Information technology is often viewed as an enabler for sustainability. There is a number of services that has an impact on sustainability; the reduction of travels by the use of conference systems, learning support as e-learning, logistics in the transport of goods, use of email instead of physical mail, and governmental e-services etc.

The purpose of this paper is to show that a concept of information infrastructure is a useful abstraction level when modelling systems. Our intention is to present a holistic view based on the management of information. In our case, the concept information infrastructure is used for the development of a socio-technical system to aid the sustainability progress within a municipality.

A prerequisite for information technologies to serve as an enabler is a working infrastructure. The organization of the infrastructure will in turn influence the effectiveness of the services that uses the infrastructure. The services, on the other hand, will induce changes of the infrastructure (Hanseth et al, 1996). The foundation for such an infrastructure is its capabilities to store information, the management of information, and the information technology supporting the flow of information. These three layers are the building blocks in an information infrastructure, according to our view.

In this paper the focus will be on information infrastructure as an enabler in sustainable systems and its services. Unfortunately, these services are often isolated from each other due to the inability to share information (see e.g. Tsalgatidou and Pilioura 2002, Scholl 2005), unless an effort is made to build specialized software with the sole purpose of information transformation and transfer. There is a lot of potential gain from a better supporting information infrastructure. The most obvious gain would be a shift from specialized to more generalized solutions for information transformation and transfer. Furthermore, information management relies on the supply and quality of information. To a large extent, the possibility to manage information is the foundation for services. Services are, in turn, often seen as enablers in sustainability work.
The information infrastructure plays an important role in the organizational structure of e-service systems. Services are often credited to have sustainability impact. According to our view these can broadly be divided into three groups; decision, learning and communication support. (1) Decision support, relies on the available information and the system’s reasoning capacity, thus the quality of the information infrastructure. Services in this category are for example logistics planning, human resources handling and customer support. (2) Learning benefits from an information infrastructure since information management is a vital part of learning support systems. Distance learning, collaborative learning and computer assisted learning are examples of services that belong to group two. (3) Communication is comprised of services that enable people and systems to share information, such as e-mail, instant messaging, Twitter, conference systems and information retrieval agents.

Infrastructure as a term is used in many different contexts. Often, as in this paper, the term is preceded by another concept to clarify the intended meaning. Infrastructure by itself is defined as “the basic physical and organizational structures (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise” according to Online Compact Oxford English Dictionary (AskOxford Infrastructure 2009). In the context of information science research the basic definition has extended to include non-physical as well as physical structures such as in IT systems. The focus has shifted towards the organizational structure as the phenomena to be described, physical or non physical in nature.

Steinmuller (1995) argues that knowledge is an important part as a base for the new developing view of what an infrastructure consists of. This view is predominately sprung from a growing awareness of the importance of knowledge within organizations. In the same context the focus of infrastructure is the systems that are used in knowledge management, such as systems for capturing knowledge and storing information (Baskerville and Dulipovici 2006).

This paper starts with an overview of the term information infrastructure and how the term has been used in relation to information science. Our view is described at the end of the overview. The following three sections describe a project within the municipality of Uppsala regarding transport logistics in relation to sustainability goals. The paper ends with discussion, conclusion and further work.

2. Information infrastructure from an information science view

The term information infrastructure (II) has been used in information science related research for several decades. The use and intended meaning has shifted over time, however, this is not to say that one use of information infrastructure has been replaced by a new one. Early on II was seen as an important concept to describe how to organize and structure the information in an emerging digital world. The focus was on libraries, archives and other centres for information storage and how these could be connected. Important stakeholders in this view of II were education and publishing that would rely on communication services as an important component of the infrastructure (see e.g. Salem 1986, Collins and Straub 1991, Al Laham 1992).

The concept of II is also used to describe the organization of business systems and the communication between different information systems in a commercial setting (see e.g. Turnbull 1991, Thissen and Stam Wim 1992, Zack 1992, Monk 1993). Exchangeable, the term corporate information infrastructure (CII) has been used to describe this (Hanseth and Braa 2001). Arguably, the term CII is more suited to describe the II in an organizational context to avoid the confusion caused by using two different abstraction levels to describe the same concept.

During the early 1990’s the use of the term shifted to describe the organizational structure of the internet. In this context the II was usually referred to as national information infrastructure (NII). This view on II is more focused on the physical challenges of building and expanding the national digital network, the Internet (Kettinger 1994, Chismar 1996, Garfield and Watson 1997).
In later years there are examples of a transition towards using II to describe what is in reality NII (Ani 2005, Datta and Mbarika 2006). Hanseth et. al. (1996) explicitly stated that since there was no unanimous abbreviation for information infrastructure they would follow the example of the Clinton/Gore plan, “National Information Infrastructure”.

Information infrastructure is also mentioned as an important part of social equity and prosperity (Thajchayapong and Reinermann, et al. 1997). Another social factor that has been mentioned is the importance of a gender perspective regarding II (Shade 1998). The role and importance of II regarding information poverty has also been discussed (Britz 2004). Business and economics are frequently studied subjects where the use and importance of an II is often mentioned (Tan and Uijttenbroek 1997, Renkema 1998, Blanning 1999, Strader and Lin, et al. 1999). The term II is also used to describe more technical phenomena such as wireless networks (Durgin and Rappaport et al. 1998) and digital video encoding (Fan and Kan 1998).

As the Internet is established as an existing infrastructure for digital communication, II has gotten a better defined role to describe non physical infrastructural aspects. However this is not to say that II by itself is well defined. It has been used to describe more or less similar concepts in different contexts where the common denominators are the ability to store and manage information, and to support the flow of information.

Our view of an information infrastructure is, as mentioned, that it shall support the storage of information, the management of information, and the technology supporting the flow of information. This can be viewed upon from different perspectives dependent on where in the development life cycle the current project is. In this paper we have focused on information infrastructure as an abstraction when modelling the desired system. The perspective on the information infrastructure becomes more technological as the project develops, the abstract notion of functions described on an abstract level will be realized as the different concepts goes from model to implementation. Each part of the abstract model corresponds to a real world solution that builds up the technical manifestation of the information infrastructure.

3. Reason for sustainability work in the municipality of Uppsala

The European Union has put forward strategies in order to strengthen the progress in sustainability work among its member states. As a consequence the Swedish government has legislated laws regarding sustainability in Sweden. This has put pressure on the municipalities, among other organizations, to revise their strategies regarding sustainability impact.

In the municipality of Uppsala several projects have been conducted to investigate how to be more efficient. One example is transportation of goods and ordering routines within local government activities. Another area that is under investigation is the travels between customers/patients and time spent with customers/patients by home-help service personnel. Both of these areas are heavily dependant on information infrastructure to increase efficiency. The later of these two studies is an ongoing project; the first one is finished and will therefore be used as an example.

In the study “Utredning Effektiv Handel – Logistik: Rapport från förstudie Hållbara Varutransporter” (2008) the aim was to reduce the number of transports needed to deliver goods for different functions within the municipality and to build an information infrastructure for sustainability reporting. The variables that were examined were economical, ecological and social. This project was mainly limited to include day nurseries, schools, libraries, and geriatric care situated in the southern parts of Uppsala.

1 Investigation on Efficient Trade – Logistics: Report from a Preliminary Study on Sustainable Goods Transport
4. Background to the project
At the start of the project there were several different sources for acquiring the products needed to run each service, see figure 1. Some of these products could be ordered directly from the central municipal depot. Other products were delivered from external suppliers, often via a central warehouse that acts as a local hub for the supplier. Furthermore, many of the work places did some purchases from local stores, often done using a car intended for another use. As a result, many of the activities had goods delivered several times each week, not only causing a lot of emissions, but also having an adverse impact on the local environment due to the presence of motor vehicles in an urban milieu primarily made for people, such as schoolyards and cycle tracks.

![Figure 1: Goods transports and information flow before the project.](image)

The communications and information paths required for ordering and billing follow the same patterns as the arrows depicted in figure 1, the width of the arrows is loosely linked to the size of the delivery. However, it is important to remember that communication is bidirectional. The municipal responsibility in this project is primarily transports and information flows between work places and the municipal depot. The sustainability impact measured in the project is based on transports and the handling of invoices where the goods in question are passing through the municipal depot.

The functions within the municipality are supposed to order their goods from suppliers that have a framework agreement with the municipality. When this was not done, it caused additional transports since it could not be coordinated with transports arranged by the municipality. In rare cases employees themselves went to a local store and thereby exposed themselves to risk by handling cash. In both cases the billing process was affected and caused a loss of efficiency.

5. Project result
The solution tested, figure 2, in the project was to rearrange the information infrastructure; the sustainability goals were to have an impact on economical, ecological and social issues. Below, we will describe how the new information infrastructure supported the sustainability work.
Regarding the economical goals there were several factors involved. An infrastructure for order management, that encouraged utilizing a web based solution instead of other techniques such as fax, phone and email was emphasised. This decreases the usage of alternative ways of placing orders, which earlier complicated the invoice handling, both at the work places and at the central municipal financial department.

Furthermore a new rule was implemented which stated that all orders should be placed at the municipal depot. To accommodate this, the information infrastructure had to support a mediator function between the order manager at the work places and different suppliers. Logistically this reduces the amount of transports to and from the work places since all deliveries originated from the municipal depot that only needed to make a delivery run once a week. From an order management point of view this requires a higher degree of planning, but it also means a more efficient handling of arriving goods. Moreover, it reduces cash purchases that were often connected with a higher total cost when transportation and work hours where taken into account. The new information infrastructure also supports a decrease in production loss associated with logistics. Primarily, the reason is that the personnel at the municipal depot can build a strong knowledge base to support their work since all logistic issues are handled by them. An overview of the new system can be seen in figure 2. Early indications are a significant decrease in the number of transports as well as a decrease in time spent placing orders.

The ecological goals were closely linked to the reduction in transports needed to supply the different workplaces. There is also a decrease in the deliveries made by external suppliers since deliveries are only made to one work place within the municipality, the municipality depot, which can order in larger quantities and not as frequently as before. As depicted in figure 2, the central role of the municipal depot in the new information infrastructure had a large impact on the amount of transports needed. In fact the local transport between the municipal depot and the work places once a week replaced all the other transports shown in figure 1.

Social goals were achieved by the reduction of transports in the urban environment close to the work places. This makes it safer for the citizens as well as the employees. Moreover, it helps to improve the environment in the vicinity of the work place due to a reduction in pollution, noise-levels and vibrations. Furthermore, it also makes the area more passable for pedestrians and bicycles. Another result is a reduction in the employees’ cash purchases minimizing exposure to risk.
To reach these goals a new information infrastructure was implemented to accommodate the new rule set for order management, both at the different workplaces, as well as the municipality depot. These changes did not require a new IT system but a change in work practises. Secondly the information infrastructure had to secure the format of information to be used by the sustainability reporting IT system. The sustainability report system, in turn, has to deliver information in a useful format to ensure that it is possible to use, act upon and learn from. An overview of the new transport and information flow that is the result of the implementation of the new information infrastructure is seen in figure 2.

6. Conclusion and discussion

An information infrastructure should support the storage and management of information. To achieve this, a technology for supporting the flow of information is needed as a part of the infrastructure. Our view is influenced of the importance of knowledge as a part of the information infrastructure (Steinmuller 1995) as well as the development of the concept described in section 2.

In the project the concept of information infrastructure was used to model the change in information use needed to realise the new system. Furthermore, the concept information infrastructure is a useful metaphor in the discussions with project members that have non-technical background. An analysis of the proposed organizational changes was made in order to identify the information flow and supporting systems. This information is the base for the description of an initial model for developing sustainable systems, which is presented in figure 3.

When using our view of the concept of information infrastructure, the strength is the ability to model the flows and actions involving information in the proposed system. As depicted in figure 3, the management systems (A) play a central role. A consists of a distributed order management system, a logistic management system and a knowledge base management system. The latter one is comprised of the accumulated knowledge in computerized systems combined with the personal knowledge of the employees’ regarding the tasks involved in logistics and goods handling.

The systems in A are responsible for compiling and the delivery of information (a) to the sustainability reporting system (B). This information is, e.g., fuel consumption divided into different types of fuel per type of activity such as schools, day care centres and homes for the elderly. Information regarding transports, invoices etc. is broken down in a similar manner.

In B the information (a) is processed in order to compile a sustainability report, the result (b) is reported back to A for follow-up. The result comprises, e.g., emission data such as CO₂, NOₓ and SO₂, economical data and number of transport kilometres that each invoice has generated.

Information from b enhances the knowledge base in A, which is an important factor for developing improved management routines. These have a direct impact on sustainability via the effect (c) of A:s actions. Effects are, e.g., the number of orders placed and the amount of transport both to the municipal depot and the different work places.

Figure 3: Model of the proposed information infrastructure.

The systems in A are responsible for compiling and the delivery of information (a) to the sustainability reporting system (B). This information is, e.g., fuel consumption divided into different types of fuel per type of activity such as schools, day care centres and homes for the elderly. Information regarding transports, invoices etc. is broken down in a similar manner.

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Information from b enhances the knowledge base in A, which is an important factor for developing improved management routines. These have a direct impact on sustainability via the effect (c) of A:s actions. Effects are, e.g., the number of orders placed and the amount of transport both to the municipal depot and the different work places.
Sustainability improvement (C) can be measured and the changes (d) in sustainability impact are reported back to A. C denotes all factors measured regarding economical, ecological and social sustainability. This information is gathered as an initiative from A and the result is returned to A via d, e.g., as reduction in noise-levels, pollution and cash purchases.

In the introduction we broadly divided the types of e-services that support sustainability in three groups; decision, learning and communication support. The two first groups are implemented in A and B, where as the third, communication, is a prerequisite for a, b, c and d.

The notion of information infrastructure allows us to have a holistic view of the storage of information, the management of information and the flow of information. An information infrastructure is an abstract concept, enabling a system model that is not based on technology or human actors, but is based on information use. In the implementation phase the decision is made regarding roles of humans and IT-systems to realize the project goals. Our view of information infrastructure is more abstract than, e.g., national information infrastructure, corporate information infrastructure and the early view of information infrastructure as discussed in section 2. Thus our view of II could be used for modelling more specific types of information infrastructures.

7. Further work
An important task is to further develop the theoretical and methodological framework regarding information infrastructure. This includes how it can be a methodological support for enabling sustainability effects in the development of IT-systems. Our approach to information infrastructure will also be tested in ongoing and further projects. We believe that the described information infrastructure is a concept that can be further generalized as a modelling tool, and thus be an aid in the development of information systems.

References


