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# A Structural Framework for Analyzing Information Technology

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## A Structural Framework for Analyzing Information Technology

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### **Abstract**

*With the rise of technological advance, organizations require methods and tools to analyze technologies regarding their fit to the needs of an institution. Research on the evaluation and selection of technologies has mainly adopted a process perspective so far. We argue that it is crucial to consider the inner structure of technologies as well and describe its elements and connections. Hence, in this paper we propose a framework for analyzing information technology by reconstructing its inner structure. We transfer concepts of philosophical Structuralism to technologies by analyzing the striking proximity in the assembly of theories and technologies as conceptual networks. By describing technologies in such a way, we are able to formulate a set of questions which allows for analyzing and evaluating the suitability of technologies for specific requirements. In order to demonstrate the utility of such theoretized technologies we apply our approach to the technology .NET.*

**Keywords:** Technology, Technology Management, Theory Nets, Structuralism, IT Artifact

### **1. The Challenge of Selecting Technologies**

Although managing technology is an active research issue in both IS research and other disciplines (Burgelman et al. 1996; Orlikowski 1992), the concept of technology is not fully understood yet (Orlikowski and Iacono 2001). For IS practitioners it is an ongoing issue how to find the most appropriate technology to solve a certain problem in an organization. Therefore, the first two questions we address in the course of this paper are: *What is the current state of research regarding the concept of technology?* We will find that research on management of technology mainly focuses on the *process* of evaluating and selecting technologies. We argue, however, that the *structure* of a technology significantly influences its appropriateness for a specific problem. The relations between technologies unfold a complex conceptual network which requires an analysis of the inner structure of its building blocks. We argue that there is a striking proximity between theories and technologies because both of them serve as elements of a conceptual

network (Balzer et al., 1987; Tondl 1974). Therefore, we apply some ideas of philosophical Structuralism in order to reveal the inner structure of technologies. Thus, the second question of this paper is: *What structure is required to support the analysis and selection of technologies?*

The remainder of this paper is organized as follows: we present a framework that organizes related research. In the following we argue transfer the network property of theories to technologies. By including IT artifacts we develop a model of the inner structure of technologies. Then we reconstruct the .NET technology in order to demonstrate our approach. The paper concludes with a summary and an outlook on future research.

## 2. Related Research

Evaluating technologies has to consider both innovative and existing technologies to estimate possible contributions to the companies' ability to achieve its business goals (Krcmar 2004). In the following, we summarize existing research on technologies in a conceptual framework spanning two dimensions.

The *first dimension* addresses technologies as phenomena. On the one hand, research efforts may focus on the *internal perspective* (T1) of a technology – on the technology itself. Research objectives may be the assembly of a technology, its relationships, and the processes of evaluating and choosing technologies. On the other hand, from an *external view* (T2) technologies can be seen as elements of a complex system. Here, research is focusing on the role of technology and its impact on the overall system (see Table 1). The *second dimension* focuses on the scope of research. Following systems theory, systems can be analyzed according to their *structure* (R1) as well as their *behavior* (R2) or processes, respectively (Ropohl, 1999). Therefore, research efforts could focus on the *structure* of artifacts, i.e. the elements of technologies, their interdependencies and mutual relationships with their environment. Furthermore, *processes* of artifact construction, choosing, using, and evaluating technologies may be of interest. Results of such efforts would be methods or tools for artifact evaluation and selection (see Table 1).

	Internal perspective on technology (T1)	External perspective on technology (T2)
Structure of technology (R1)	→ focus of this paper	Structurational model of technology (Orlikowski 1992), Technology frames (Orlikowski and Gash 1994)
Process of technology usage (R2)	Technology Intelligence (Bright 1980), Innovation Management (Rogers 1995), Technology Management (Burgelman et al. 1996)	Technology assessment (Jantsch 1967), Piloting socio-technical innovations (Schwabe and Krcmar 2000), Use / usefulness of technology (Cooper and Zmud 1990)

**Table 1.** Framework of research on structure and behavior of information technology.

In section R1/T2 research results describe and prescribe the structure of socio-technical systems. For instance, Orlikowski (1992) develops a structurational model for describing relationships and interactions between technologies and organizations. Technologies have impact on organizations, their behavior and structure. In turn, organizations and humans influence the use, the meaning, and further advances of technologies. Hence, technologies are just one relevant part in a complex social system (Orlikowski 1992).

In section R2/T2 research results provide methods for managing technology. Technology assessment methods provide decision-support on future impacts and second order effects of new technologies (Jantsch 1967). Furthermore, within IS a large research stream is focusing on the introduction of innovations in organizations (e.g. Schwabe and Krcmar 2000) as well as assessing the use and usefulness of technology (e.g. Cooper and Zmud 1990).

In section R2/T1 research focuses on exploiting technology advances. For instance, technology intelligence methods allow evaluating technologies in their earliest stages regarding strategic advantages (e.g. Bright, 1980). Technologies in the actual technology lifecycle are evaluated and (de-)selected according to their current and future benefit to business success (e.g. Burgelman et al. 1996). Another main area of research is managing the introduction of innovative technologies in organizations (Rogers 1995).

While, Table 1 reflects only a small portion of all available research results, it shows that researchers have mainly focused on the external view and the process of managing technologies. We are not aware of any results describing the internal elements of technologies and their structure (R1/T1). Hence, we will describe a structural framework of technologies.

### 3. A Structural Framework of Technologies

Following Bunge (1974), technology can be defined as a specific form of knowledge that facilitates the human manipulation of the natural environment for a specific purpose. Consequently, the concept information technology (IT) refers to knowledge of processing and distribution of information by constructing and using IT artifacts. Tondl (1974) argues that there are no structural difference between natural and technological sciences, as they are merely differing in their goals (“possibility of finding a solution” and “implementing the solution”). Hence, we argue, no structural differences should be found in the results: theories and technologies. In the same way as theories, technologies can rarely be analyzed or applied without being affected by other technologies. Hence, relationships between technologies that constitute certain forms of influence are important characteristics of technologies (Balzer et al. 1987; Tondl 1974).

Our reconstruction of technologies in form of a structural framework is based on two theoretical foundations: IT artifacts and philosophical Structuralism.

*IT artifact perspective.* Technologies comprise IT artifacts and bundle them to cope with real world complexity. An isolated IT artifact is often not able to provide a solution which fits the granularity of the problem. The programming language C# for example requires the .NET programming framework to realize its advantages over languages like C++. Therefore, it is crucial to analyze the role of IT artifacts within technologies to be able to define the internal structure of technologies. One can differentiate four type of IT artifacts (March and Smith 1995): *constructs* provide the language concepts in which the problem is described and the solution is communicated. *Methods* explicate the processes of how to solve a problem and offer guidance how to search the solution space. *Models* utilize the constructs to represent an application domain and express the problem and solution space. Models are the result of applying a method. Finally, *instantiations* constitute the realization of constructs, models and methods in a working system. These four types of artifacts and arbitrary combinations of them are important building blocks of technologies. For instance, models can express the relations between other IT artifacts,

for example between constructs and instantiations at a conceptual level and thus ease the acquisition and the spread of a technology.

*Structuralism perspective.* As theories, technologies do not appear as isolated entities but form a conceptual network (Balzer et al. 1987). Therefore, we introduce the concept of *linked technologies* as part of their internal structure. It is plausible to assume that relations like *specialization*, *theoretization*, *equivalence* and *reduction* which hold for theories are also useful in the context of technologies. A *specialization* between theory elements is the result of a more restrictive fundamental law within one theory element. This result can be transferred to technologies. A less general technology can be identified because it employs more specific IT artifacts. This results in a more restricted set of intended applications of this particular technology. An example for a *specialized technology* is the operating systems Linux and its more focused versions for embedded systems. *Theoretization* provides the fundamental vocabulary of one theory element to another theory element. Thus, theoretization aims at extending the expressiveness of a theory by utilizing another. This relationship can be found within technologies as well. It is often the case that the application of a technology entails another technology, a so called *prerequisite technology*. For example the internet technology requires the availability of technology to transfer data over a physical medium. *Equivalence* describes a relationship between theory elements with the same or very similar intended applications. Also *competing technologies* share a comparable set of intended applications. They solve the same problem by applying different technical solutions, i. e. different IT artifacts. Examples of competing technologies are Microsoft's .NET and Sun's Java technology. A *reduction* relation can be observed between historically related theory elements which are concerned with similar applications. A technology which stands in such connection can be called *substituting technology*. Substitution is a strong form of the competing relationship, because a substituting technology supersedes another one by being more efficient or effective. An example for a substituting technology is Microsoft .NET. It replaces Microsoft's COM+ and DCOM technology. From the four sorts of inter-theoretical links also four kinds of *linked technologies* can be derived: *specialized technology*, *prerequisite technology*, *competing technology* and *substituting technology*. These relationships map very well to research results, e.g. Pfeiffer et al. (1989), which are based on an analysis of the relations between technologies.

*Intended Applications.* An important part in the structure of theories is the element of intended applications. Also technologies are developed with certain intended applications in mind. A definition of the set of *intended applications* helps to foster the selection of the technology which fits the problem at hand best. This requires promoters of technologies to explicitly state the conditions by which a technology can be applied as well as under which circumstances the usage of a technology is not appropriate.

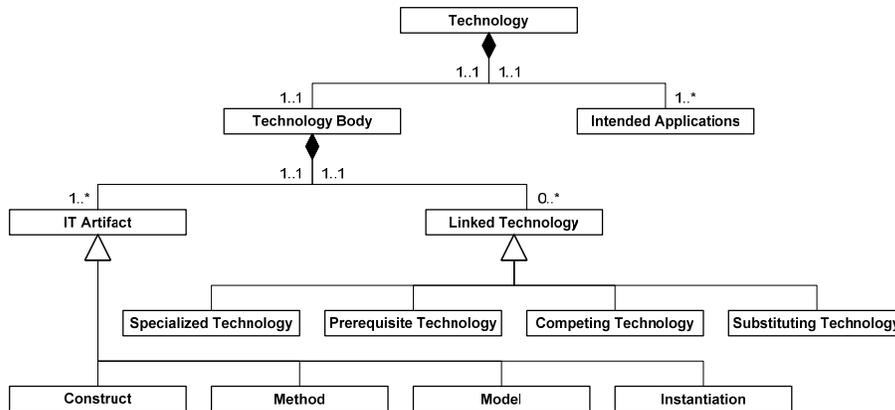


Figure 4. A structural framework of technologies.

The *technology body* comprises a set of IT artifacts as well as a set of connections to linked technologies. A technology consists of a technology body and the intended applications. Figure 4 describes the internal structure of a technology. In the following we will reconstruct the .NET technology based on our structural framework discussed in this section.

#### 4. Application of the Framework to the .NET Technology

The .NET technology is an application programming framework developed by Microsoft and has been recently released as version 2.0 (Microsoft Corporation 2005). However, we will focus on .NET version 1.1 as it is most widely used yet. According to Microsoft, .NET consists of four parts: the actual .NET framework for developing applications, development tools, servers for running applications, and client software, such as the Microsoft operating system Windows (Microsoft Corporation, 2005).

Based on the structural framework of technologies we have introduced above, the technology analysis process can be guided by the questions displayed in Table 2. Questions 1-3 are necessary conditions in order to successfully apply a technology in an organization. Question 4-6 assure that also specialized, substituting and competing technological approaches are considered during the selection process.

As Table 2 shows, by following the structural framework, we gain a concise analysis of the .NET technology. By supporting different relationships between technologies, we are able to identify possible interesting technological advancements: Besides programming languages the .NET technology does not provide any modeling language. Therefore, Microsoft is adding domain specific languages to its visual development tools (Havenstein 2004). Based on such a domain specific languages (DSL) it is possible to incorporate domain specific reference models into .NET, which allows specializing .NET for industry-specific requirements (Havenstein 2004). As Microsoft is developing DSLs as an integral part of Microsoft's developing tools, it eventually will become a prerequisite technology (Havenstein 2004). Such developments may have huge impact on the perceived appropriateness of the .NET technology.

Question	Description	Example .NET
1. Does the set of intended	To find an appropriate technology it is necessary, to compare the intended	According to Microsoft, .NET is capable of being used in any software

applications of the technology map to the real world problem?	applications of the technology with the parameters of the current situation. Only if a matching between these properties can be established the technology is suitable.	development projects. Intended applications of .NET are web service based applications (Microsoft Corporation 2005).
2. Are all prerequisite technologies available in the application domain?	As technologies are dependent on each other, it is crucial to check whether the organization disposes of these prerequisite technologies. Do any technical, organizational, legal or managerial restrictions apply?	Prerequisite technologies for .NET are especially web technologies e.g. Web Services. Furthermore, the Microsoft operation system for server and client platform is needed (Microsoft Corporation 2005).
3. Do the intended applications of all IT-artifacts of the technology also fit to the real world problem and are all required IT-artifacts available?	As technologies refer to IT artifacts the same assessment which has been performed on the technology as a whole can be repeated for each of its components. It must be assured, that the intended applications of each IT-artifact fit to the real world problem. Furthermore, all IT-artifacts which are required by the technology must be available.	.NET consists of various artifacts, e.g.: Intermediate Language (IL) or C# as programming constructs; the MSDN Library contains various programming methods (yet no overall method is provided) as well as patterns as an example for models (yet no support for modeling); the most important instantiations within .NET are the Common Language Runtime (CLR) and Visual Studio as a development environment (Microsoft Corporation 2005)
4. Are there any specialized technologies which also fulfill the conditions of question 1-3?	If a more specialized technology can be identified which provides a solution for the problem at hand, than this technology is probably more adequate for the situation, because its application would most likely require less resources or a better output.	A more specialized technology of .NET would be the .NET Compact Framework for application development on mobile devices, such as PDA's (Barnes 2005).
5. Are there any substituting technology available? which also meet the conditions of the questions 1-3?	If a substitution technology can be found, than it is most likely that this technology can solve the problem more efficiently or more effectively than the predecessor technology.	.NET version 2.0 has recently been released by Microsoft as successor of .NET 1.1 (Microsoft Corporation 2005). .NET replaces technologies like COM+ and DCOM.
6. Are there any competing technologies available which also meet the conditions of the questions 1-3?	At the first glance in very few cases only one technology provides an adequate solution to a certain problem. More often there are competing technologies with similar intended applications which must be compared in order to find the technology which fits the problem best. Therefore, all of these technologies must be analyzed according to their answers on questions 1-3.	Java may be seen as the main competing technology to .NET. Both are covering the same intended application, for instance Java disposes of a more specialized technology for mobile devices as well (Sun Microsystems 2005).

**Table 2.** Analysis of the technology .NET.

## 5. Summary, Limitations, and Outlook

The high economic importance of the selection of appropriate information technology marked the starting point of this paper. We analyzed existing scientific results on

technology management and concluded that only little research has been performed on the structural properties of technologies so far. Based on philosophical Structuralism and by considering IT artifacts we were able to derive a structural framework of technologies. By reconstructing the .NET technology by means of this framework we could demonstrate its practical significance.

However, this structural framework still faces some limitations. As the framework is suitable to analyze the internal structure of technologies and their relationships, it does not yet connect this internal analysis with existing research on technology in organizations (DeSanctis and Poole 1994; Orlikowski 1992; Orlikowski and Iacono 2001). At this state the framework may be used to analyze the static structure of technologies. However, technologies are changing over time and usage, thus a dynamic perspective is missing.

Hence, further research will address the following issues:

- The analysis process in order to explicate the structural properties of technologies according to this framework requires guidance. How could this guidance be given?
- How can this structural framework and available technology selection processes be incorporated into one holistic approach?
- The framework developed in this paper has not yet been subject of an empirical validation. It is an important aim of further research to seek an empirical justification of the results presented in this paper.

Overall, reconstructing the internal structure of technologies based on the proposed framework allows analyzing technologies in a systematic way and may be seen as a first step towards closing the research gaps identified in this paper.

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