# Supporting decision making on the information infrastructure with a formal specification tool

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***Abstract***
*Problems with information planning methods are summarized and an alternative way of strategic information management, focusing on the information-infrastructure, is presented. It is explained how formal specification languages can contribute to the strategic decision making about information-infrastructures.*

*key words: strategic information management, information planning, information-infrastructure, formal specifications*

## 1. Introduction

In literature a large number of mostly only slightly different terms can be found for the still unclarified act of connecting strategy and information technology.
This article's contribution to this lack of uniformity is *strategic information management* with the following definition:
*a set of management activities with the purpose of coordinating information system (IS) development in the organization (or cluster of organizations), by transforming the overall organizational goals and objectives into more specific guidance for the IS function.*
The main purpose of presenting this definition is to clarify the nature of the decision making under consideration in the research discussed here.
Strategic information management is a fairly arbitrary alternative for the most common label applied to the activities mentioned in the definition. In methods for management of system development projects especially they are usually distinguished as the initial project phase and denoted *information planning (IP)* (Pandata 1989). There IP is interpreted as a process.

Our deviation from the terminological mainstream stems from the fact that IP can be interpreted in a second way, namely as a methodology, i.e. a structure of ideas underlying methods. IP as a methodology forms the basis for methods to support the activities in the first phase of the system development life cycle (i.e IP as a process). Examples of such methods are BSP, ISP, SSP and IE.
It is crucial to realize that the IP-methodology is not the only one that can be applied to the IP-process. In fact we hope to make clear below that in many circumstances it does not make sense to apply methods that are based on it.
To avoid confusion information planning as a process will be denoted as strategic information management in the remainder of this document. The term information planning will be applied to the methodology only.

The next section contains a brief description of the essential characteristics of the IP-methodology. In section 3 the problems with the methodology will be summarized. An alternative way of strategic information management concentrating on the information infrastructure will be presented in section 4. As an example section 5 deals with the GBA-system, a large information system in the Dutch public sector with an infrastructural nature.
The specific character of decision making on information infrastructures and the role executable specification tools can play in its support are discussed in section 6 and 7 respectively. Section 8 forms the conclusion.

## 2. Essential characteristics of the Information Planning methodology

The numerous publications describing IP reflect the following essential characteristics of the methodology.

*Objective is "ideal" information environment*
In the information planning methodology the organization's information strategy is designed essentially at one point in time in a comprehensive process which has to result in a design of an **ideal** information environment that will support current and future business needs.
All characteristics of this environment are articulated in **one** integrated process.

*Top down, analytical approach*
The methodology presents **detailed analysis** of (future) constraints and requirements as the means to achieve that goal.
Senior managers provide information about the current and future business objectives to ensure alignment of IS strategy with business strategy.
Within the organization business functions are identified and these are further divided into business processes. For each of those the future information requirements are established, normally via interviews. An affinity analysis is performed to identify clusters of closely associated requirements. This way major system areas can be identified. Simultaneously the current situation is investigated.

*Architectures to guide implementation*
The analytical efforts have to result in a set of plans or architectures.
They provide the direction for the migration from the current to the ideal situation. Normally the required development effort exceeds the available development resources and consequently a long-term development plan has to be drawn up. The indications in the architectures enable defining specific information system projects, their ranking and generating a development schedule.

## 3. Experience with IP-methods

The IP-methodology has a strong relation with the basic Western conceptions about "good management" (Venkatraman 1985; Goodhue 1992; Premkumar & King 1994). This significantly contributed to its success, especially in academia. But evidence indicates that application of the IP-methods is quite problematic. Before the summary of this evidence its main sources will be discussed briefly.

Hoffer's publication is based on 12 case studies of IP-exercises, primarily within AT&T (Hoffer et al. 1989).
Lederer and Mendelow organized three nominal group technique sessions for IS practitioners from different levels of management (Lederer & Medelow 1986) to classify problems with IP-methods.
In a survey of 80 organizations Lederer and Sethi examined the problems faced by IS managers trying to implement IP-methods (Lederer & Sethi 1988; Lederer & Sethi 1991). As part of a broader analysis on data resource management Goodhue et al. studied the strategic data planning initiatives of five firms and identified the major problems (Goodhue et al. 1988). Four other more detailed case studies focused specifically at reconstruction of the history of a number of SDP-efforts (Goodhue et al. 1992). Adriaans and Hoogakker (1989) describe an IP-initiative at Netherlands Gas. Lederer and Mendelow (1993) held 20 structured interviews among top IS executives to focus on the problems of priority changes in information plans.

*Articulation of strategy*

Strategic direction forms an important input in the IP-process, often presented as one preceding the others. It is advocated that the strategic direction is communicated via organizational plans describing structure, strategy *et cetera.*

Understandably, the information planning methods do not give much attention to the formation of an articulate strategic plan. They simply assume it is there. The usefullness of a strategic plan is however under severe attack (Mintzberg 1994). The crisism on general strategic plans to a large extent applies to information plans as well. In fact much of what follows in the next section is a specific case of problems related to strategic plans.

But even if this were not the case, the fact that it is almost impossible to obtain a valid strategic plan in itself already creates a major problem in IP-planning exercises.

In practice it is a major problem to acquire clear and extensive top management objectives (Lederer & Mendelow 1986). The large dependence on this type of input becomes clear in the criticism on the methods for requiring too much top management involvement (Lederer & Sethi 1991). Still key pieces of information are often not known or unavailable (Hoffer 1989) and methods are at the same time blamed for not eliciting organizational goals and strategies (Lederer & Sethi 1991). The lack of clarity from top management is in accordance with the school of thought of "logical incrementalism", which claims that good managers do not make plans and instead "muddle through". (Wrapp 1967; Quinn 1978). Yet, in the absence of a business plan it is not uncommon for IS employees to try to do the planning themselves. Most of the time top management interprets this as IS challenging their competence, leading to territorial disputes. Delegation of IS planning to planning professionals, a far from rare phenomenon, may increase the likelihood that the plan contains a long term perspective but it also makes it more probable that it is an inadequate one. The detached specialist easily gets out of touch with what is going on in the organization, when not intensively updated by top executives. Consequently many plans contain inappropriate assumptions, e.g. about future organization size (Hoffer 1989; Lederer & Sethi 1991).

Related are the difficulties in securing top management commitment (Lederer & Sethi 1988; 1991). Not seldom a *champion* (Beath 1991) does not step forward to push the plan (Lederer & Mendelow 1986; Hoffer 1989). It is not uncommon for top management to consistently act in conflict with the plan (Hoffer 1989).

*Articulation of requirements*

The analysis of requirements tends to be very extensive (Bowman et al. 1983; Lederer & Sethi 1988; Hoffer 1989; Lederer & Sethi 1991). The 5 case studies described in (Goodhue et al. 1992) all deal with SDP-initiatives taking more than 26 weeks. .

Especially the matching of entities and functions as a first step of the creation of an architecture requires significant computer support to guarantee completion in reasonable time. Complaints about insufficient computer support occur frequently especially for the less widespread methods (Lederer & Sethi 1988; Hoffer 1989). The consequences in terms of computer support development forms an important reason for many organizations to buy in a method instead of developing a custom made one (Lederer & Sethi 1988).

The extensive analysis is very time-consuming and requires a high commitment (Goodhue 1988). Interruptions due to current problems occur frequently, key personnel cannot be kept on the project all the time or is not available at all (Hoffer 1989).

Because of the time required it is likely the businesses and its information requirements change while the plan is developed (Goodhue 1988). More flexibility is required than the planning cycle provides (Lederer & Mendelow 1986). Adjustment of the plan to organizational changes is very costly.

The plan ignores implementation issues and few tools are available to support the transformation to concrete project objectives. With their rigid top-down approach, concentrating on the "ideal", the methods are blamed for not taking into account the current information system application portfolio and actually developing the information architecture from scratch. As a result full implementation of the proposal tends to be extremely costly (Goodhue 1988; Hoffer 1989; Lederer & Sethi 1991). Implementing only a subset of the plan is problematic as well, when proposed and existing systems interface along different boundaries. When application packages are used to fulfil the requirements this problem only increases (Goodhue 1988).

Unfortunately many plans do not even reach the point where their implementation is seriously considered. No matter the pretensions of rationalization and decomposition, a strategic direction is never inherent to the methods (Sullivan 1985).

In spite of the extensive analytical efforts the plan does only very rarely reflect the synthesis that is supposed to be the result. It fails to determine an overall organizational data architecture, does not provide priorities for database development and lacks organizational plans for hardware and data communication. It does not provide a statement of objectives for the IS department and significant further analysis is required for project initiation and implementation of a data architecture.

Consequently information planning frequently is not the first step in a long-term management process; the plan is regarded as not very useful (Lederer & Sethi 1991) and simply shelved after completion (Goodhue 1992)[1].

*Rationalization and decomposition*

Due to the rationalization the methods are often very elaborate, making it hard to learn them (Goodhue et al. 1988). As a result most participants in an IP-exercise are insufficiently trained (Hoffer 1989).

Methods do not provide enough flexibility and significantly inhibit creativity. On the other hand the high level of rationalization cannot prevent that biases of analysts sneak in. Recent events have a disproportionally large influence on the plan's content.

The success of an information planning exercise depends to a large extent on factors in the political sphere, not addressed in the method. The methods seem to assume implementation via edict and do not pay attention to a careful intervention process (Hoffer 1989). They do not address resistance to change. Many of the ignored implementation issues in fact belong to this category. A team leader who is aware of this lacuna in a method and has the ability to work around it is therefore crucial to the success of an exercise (Lederer & Sethi 1988; Hoffer 1989). Yet many claim it is difficult to find a team leader with the right characteristics, partly because the method does not prescribe what they are.

The high level of abstraction of the plan hinders communication about it e.g. regarding the benefits of the proposed implementation. The plan document only seldom contributes to the goal of having people change their perceptual boundaries and see "their" system in a wider perspective. It is difficult to keep all relevant stakeholders informed during the various planning stages (Hoffer 1989). Given the necessary resources serious effort has to be put in communicating the exact purpose of the IP-exercise, to the various stakeholders, but especially top management. A significant portion of the disappointment with the ultimate result stems from misunderstandings about the objectives of the planning initiative (Goodhue 1992).

## 4. An alternative to information planning: information infrastructure management

An alternative methodology for strategic information management, centred around the concept of an information-infrastructure will be presented here.

The problems described in the previous section suggest that a totally integrated articulation of the implementation strategy is not the best way to coordinate system development initiatives.

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[1]Premkumar & King (1994) did find a strong correlation between information planning and implementation, but it is not exactly clear how they defined the two. Since they limited their survey to organizations which were regarded "sophisticated planners" it is questionable how representative their results are for the average organization.

In the shadow of publications about IP, authors have suggested to limit integration efforts to certain parts of the information system. (Goodhue 1992b, Allen & Boyton 1991). None of them did work out this concept in detail however.
Along their line of thought a methodology centred around an *information infrastructure* will be presented here, with the basic purpose to
*provide a set of common IT-provisions which enable the subsequent development of information systems serving the needs of individual organizational units.*
The concept of an information infrastructure is not entirely new, but up till now it has been given quite different meanings (Weill 1993). Traditionally the term has a technological connotation and is associated with the centralized hardware environment. Most publications focusing on information-infrastructures still originate in the domain of telecommunication, but as a concept in the field of information management its prominence is growing (Niederman 1991).
The idea expressed here is related to the view of Maes et al. (1990) and Bemelmans (1991), who present management of the information-infrastructure as a means to confirm system integration while at the same time leaving as much flexibility as possible to system development at the local level.
However, to present the information-infrastructure as a true instrument for management it should be considered more as a conceptual entity than is done in even those publications.
Thinking of the information-infrastructure as primarily a real entity suggests that the distinction between infrastructural and non-infrastructural (local) information technology can be made based on the material characteristics of artefacts. The consequence of that position is the complete denial of any real room for management influence on the development of the information-infrastructure.
But management sovereignty is respected in the interpretation of the information-infrastructure as a primarily conceptual construct. In that view almost any element of the information system can be **made** part of the information-infrastructure, by convention.
The question "what is an information-infrastructure" is stripped of management complexity; the answer to that question can be very clear. The crucial management problem becomes: "Given this definition, what part of the information system should be information-infrastructure?". This is completely subject to the strategic management process.

From the above mentioned ideas the following slightly more formal structure of definitions was developed.
The **information system** (I) is the *formal system for collecting, structuring, storing and providing information in the organization* (O). I forms an aspect system of O.
Ideally, **I** is completely reflected in a set of specification **S**. In so far a specification of some part of **I** does not exist that part is regarded as specified only *virtually*. After all, an implementation in **I** fixes itself. Via initiatives like reversed engineering the virtual specification can be transformed in a *real* one.

O can be split up in departments.
A **department** is a *relatively autonomous unit of O with some decision authority regarding I.* In turn a department can contain other departments. But given the requirement of authority regarding I, splitting up the organization in smaller and smaller departments is a finite process. Departments that cannot be split up further are elementary departments. An analysis of O at the level of the elementary departments is an analysis at aggregate-level 0.
An analysis with one level less detail is an analysis at aggregate level 1 etc.[2]

[2] How the departments are aggregated and how many aggregate levels are distinguished in an analysis is highly arbitrary

**In an analysis of O at aggregate level n the specificand (in I) of an element s from S is regarded part of the information-infrastructure for a department d if and only in so far s sets restrictions on the authority of d[3], due to standardization.**

the interpretation of **standardization** is:
*in an analysis of O at aggregate level n outside d at least one other department can be found which is limited in its authority by the specification.*
Note that it is possible that d imposed the restrictions on itself, as the result of a lateral decision with other departments.

**Information infrastructure management** is *the concious development of those standardizing specifications to productively manage the information system.*
The concept will be illustrated with an example in the next section.

**5. Example: the GBA-system**

GBA is the Dutch abbreviation for the Municipal Base Administration for the Register of Population. The GBA-system was developed to improve the exchange of data from the population registrations between the more than 650 municipalities in the Netherlands (e.g. when someone moves to another town) and the more than 600 primarily federal institutions which rely on the data (e.g. the Department of Defense and the Tax Agency). Currently it is generally accepted that the system should act as a "point of crystallisation" and a basis for a new style of public enterprise with a stronger reliance on information technology. Total development costs of the GBA are budgeted on 250 million Dutch guilders.
When development of the system started in 1984, the discussion about automation of the municipal register of population already had a history of more than two decades.
Automation of the municipal population registrations started in the 1950s. In 1965 already 30 percent of the municipalities had an automated register of population. But an 1887 law still obliged all municipalities to keep a manual registration. The municipal initiatives stimulated the desire for adjustment of the law regarding population registration and nation-wide coordination of its automation.
In 1963 the Secretary of the Interior installed a committee to investigate "how efficient use of one or more computers can be stimulated by mutual attuning of the administrations of the information supplying and receiving institutions". In the next years a number of other committees were installed with related tasks.
In their investigations the emphasis lay on benefits for the central government. The various committees advised that, for reasons of efficiency among other things, one central organization should be created with the responsibility for collecting data from the municipalities and providing them to the federal and private institutions. Based on this advice the Ministry of the Interior presented the proposal *Central Population Administration* in 1976. In spite of severe criticism on its practical consequences, in particular the lack of guarantees regarding the protection of privacy, the Ministry of the Interior held to the CPA-approach. In 1982 the CPA-bill was rejected in the House of Representatives for similar reasons.
Then both the central government and the representing body of the municipalities (VNG) started working on proposals for more decentralized alternatives incorporating networks. This eventually lead to the proposal for the GBA-system.

In the decision making process after the installation of the GBA-project bureau the following prominent issues can be distinguished:

[3]Note that it depends on the perspective (department level in the organization) whether something is part of the information-infrastructure (for that department).

*level of centralization*
A high level of uniformity in the automated municipal registrations, and thus an extensive set of specifications, was desirable for external institutions relying on it.
But the municipalities, who wanted to defend their autonomy, were against specifications beyond what was absolutely necessary. Although officially without authority within the project bureau, the VNG worked out proposals and designs to "prevent that all kinds of data sneak in which are not an essential part of a register of population".
*order of task design and automation*
To protect the equality of rights of the Dutch citizens implementation of the GBA-system required that a law would be developed dealing with the various procedures for using the system. In the project group lawyers and system developers had to cooperate intensively.
*nature of implementation*
The base document in the development of the components of the GBA-system was the Logical Design. It contains the minimum requirements for systems to be connected to the GBA-network. Based on these most municipalities developed their own registration applications. A survey and testing (S&T) team within the project bureau checked every application before it allowed a municipality to participate in the GBA-system.
*responsibility for costs*
Budgeting of the development costs proved to be a significant problem and this was even more so for the distribution of the costs between central government and the municipalities. This discussion was a major cause of the delay in the project (about 2 years).

The eventual content of the Logical Design is schematically represented in figure 1.
DCI stands for a data communication infrastructure. It is not specific for the GBA-system, but the protocols for exchange of data are.
The S&T-requirements and the procedures (moving, death etc.) have been discussed above. The institutions only have to be able to send and receive data via the network, but automation of their administration is not a necessity. The data dictionary specifications only apply to the municipalities, since the institutions are only users of the data. From within the project bureau a smaller organization for management of the GBA-network was developed.
Note that the municipalities were not differentiated (no aggregation). The specifications apply to all of them and no additions are made for certain subgroups (e.g. big cities).

| | Municipalities | Network | Institutions |
|---|---|---|---|
| Hardware | -------- | DCI | ------- |
| Applications | S&T-requirements | Protocols | S&T-requirements |
| Data | Data Dictionary | ----------- | ------------- |
| Organization | Procedures | Management | Procedures |

Figure 1: the components of the GBA-infrastructure

## 6. Decision making regarding the information infrastructure

Although a majority of the publications deal with strategic information management as a primarily objective and therefore rather sterile process even the brief description given above makes clear that such a description is highly inaccurate in the case of the GBA. Given the nature of the confrontation between the various parties (eg. central government vs. the VNG) it would be more accurate to describe the process as negotiation. In this respect the project is by no means an exception. Various publications have criticized the rationalistic approach of

system development (Lynne Markus 1983; Grover et al. 1988) and emphasized its often highly political nature, resulting from the leverage information technology can provide to shift the distribution of power.
Decision making on information-infrastructures is extra vulnerable to these political influences.

- by definition information-infrastructures affect relatively independent groups, with different orientations. In some cases (interorganizational systems) these groups do not even share a "higher authority" .
- of all investments in information technology, the benefits of the infrastructural ones are the most difficult to establish. The benefits of a set of base provisions is largely determined by the local systems that (will) depend on it. The long life time of an infrastructural element only intensifies the problem of finding the total expected benefits.

Here the assumption that an **optimal** solution can be found in a completely objective way is explicitly rejected. Instead of analytical rationality, consensus building is assumed to be the key to specification of the information-infrastructure.
We thus abstain from trying to find rules to ensure that regardless of time and place the outcome of the selection process will be the same. For this reason the definitions of the information-infrastructure in section 4 did not include a rule to establish what **should** be part of the information-infrastructure and what should not.
Given the objective of consensus building, communication between the various parties involved in the decision process becomes vital.
An assumption in this research is that improvement of the communication can therefore significantly enhance the quality of the decision process as a whole.
It will be investigated to what extent *formal specification languages* can contribute to the communication related to decision making about information-infrastructures. In the next section formal specification languages and one executable specification language in particular will be introduced.

## 7. Formal specification languages and ExSpect

Formal specification languages form a subclass of formal methods (Gibbins 1988). The discipline of computing science has performed research on the latter for more than 25 years with the objective to provide better support to the cycle *specification - construction - verification* in system development (Hall 1990). Although some researchers still ignore the use of formal specification languages without a direct connection to verification or even maintain that it is useless, more and more individuals claim that given the current level of maturity of formal specification its potential to increase the productivity of system development is especially utilized when it is used independently.

A definition of formal specification languages can be found in (Wing 1990) and a more qualitative one in (Bergstra 1989).
A formal specification language L is a collection of possible expressions in a formal syntax.

- it contains primitive language constructs, mostly derived from mathematical logic
- it is precisely defined: it can be established if an expression is a legal one in L (decidable type checking)
- to every legal expression in T a mathematical construction can be assigned as its meaning.

The connection with mathematics guarantees an objective meaning of expressions in T[4].

The biggest advantages of using formal specification languages are related to their objective meaning. Currently their relative obscurity create the biggest problems.

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[4]Bergstra also requires that a formal specification language contains concepts which allow the description of digital systems. Although this is an absolute necessity in case the languages have to be used for the purpose mentioned above it is not a typical characteristic of formal languages.

The majority of proponents of formal specifications are computing scientists. Some of them have also strongly advocated a wider use of formal languages in the first phases of the system development life cycle, but the benefits they claimed were mostly related to the development phases.
In management information systems the dominant attitude towards formal specifications is scepticism, based on the conviction that - contrary to the suggestions from the realm of computing science - the emotional elements in expressions (de Swart 1989), which cannot be included in a formal specification, are not a perversion of a degenerated profession but play an essential role in the first phases. This is not rejected in this research.
Still it is assumed that with formal specifications the various alternatives which are discussed in the strategic decisions about the information-infrastructure can be presented more clearly. In addition it is presumed that this clearness will lead to a more open discussion, reducing the inefficiency that stems from lack of understanding and related political games.
The research centres around one particular tool, namely ExSpect (Executable Specification tool). It was developed at Eindhoven University of Technology. The first version was introduced in 1988. Theoretical foundations of ExSpect are described in (Hee 1989)[5].
The ExSpect specifications are executable: a prototype of the system can be run to enable the clients/users to validate the system specification. The disadvantage of low accessibility of formal specifications for non-experts can be overcome this way. The combination of prototyping and formal specification has got increased attention (see e.g. Siddiqi 1993). Although ExSpect was developed primarily for information system specification it has been used for modelling and simulating other types of systems as well, e.g. the Dutch Railway Organization uses ExSpect to support the decisions on adjustment of their infrastructure.
With ExSpect it is possible to build functional models of the alternatives that pop up in the consensus building process, animate their behaviour and clarify their characteristics after simulation and analysis[6]. In the later phases the initial specification can be subsequently refined.

## 8. Conclusions

In spite of the (for Westerners) appealing conceptual foundation of the IP-methodology, its practical application is not without problems. It becomes clear that totally integrated articulation of future system development initiatives is not the most desireable approach of strategic information management.
As an alternative information-infrastructure management is gaining prominence. Reflection on its nature makes clear that consensus building and thus communication between the stakeholders is vital in this process.
In the field of management information systems formal specification languages deserve much more attention for their potential as a communication tool in the initial phases of the system development life cycle.
In the research project discussed above it is investigated how a particular formal specification tool, ExSpect, can support the strategic decision making on information-infrastructures.
In its continuation it will be analyzed in more detail to what extent the results of ExSpect-simulations can be linked to the specific arguments used in the assesment of infrastructural investments.

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[5]ExSpect uses coloured Petrinets for specification of processes and their inputs and outputs (Jensen 1981). To specify the active components in these processes it uses a typed functional language, similar to Z (Woodcock 1992).

[6]A rudimentary model of the eventual GBA-system was built in the beginning of this research. For obvious reasons it could not be used for the support of the strategic decision making anymore

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