

Infectious diseases and ICT
Rapid interaction by intertwining technology and institutions

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Abstract

Infectious diseases can spread rapidly and can have a strong disruptive effect on society. Therefore an appropriate and swift reaction is crucial. In the Netherlands the present approach to fight infectious diseases mainly consists of protocols and scripts. Important institutional arrangements between relevant actors are not well defined. Especially the related technological architecture is outdated and has many drawbacks.

This contribution summarises the analysis of the current systems and arrangements to cope with infectious diseases and the design of artefacts to solve these deficiencies. This analysis and design was part of an educational project supervised by René. This type of crisis management was one of René's primary points of interest since it has complex interactions between technology and the related institutional arrangements.

Based on the shortcomings in the present situation we specify requirements of an artefact and related institutions to improve the present crisis management. We designed two combinations of information systems and institutions that satisfy these requirements. The first artefact, the Disease Notification System (DNS), focuses on the lack of efficiency and standardisation between the general practitioner and the system they use to record their disease reports. The second, the Decision Facilitation and Empowerment System (D-FES), aims to improve the present suboptimal decision making in times of crisis. This system filters the information input from different sources. The implementation of these artefacts is expected to enable a more rapid and appropriate reaction on infectious diseases, and thereby prevents the potential disruption of the Dutch society.

Bios

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1 Introduction

In our modern, open society, with people having direct and indirect physical contacts with a large number of other people, often in many places and over a great distance, we are vulnerable to infectious diseases. The diffusion of these diseases can be very rapid. Moreover, these diseases are not only spread by natural causes, but there is also a risk of terrorist attacks or scientific mistakes that may lead to an outbreak. The success of treatment and prevention of further spreading of the infectious disease depends largely on the speed of detecting the infections, the institutional arrangements on information collection and response and on the information of the network, the disease and the disease spreading characteristics.

As this contribution will show, the current system to fight an infectious disease, comprised of both actors and technology, mainly consists of protocols and scripts, but important institutional arrangements are lacking and relationships between relevant actors in times of crisis are not well defined. In addition, the existing technological architecture is outdated and has a lot of drawbacks. The reporting process between general practitioners and public organisations suffers from the absence of unambiguous human communication protocols, which causes delays in time and inconsistency. In case of an outbreak of an infectious disease, it is of great importance that responsible authorities react adequately and proactively and set up a clear mitigation strategy to control the outbreak.

The many drawbacks of the institutional and technological system in place can have major consequences when an outbreak of infectious disease occurs and poses a problem for the problem owners, the respective Ministries of the Interior and Kingdom Relations and Health, Welfare and Sports. These systems will not be used much, because infectious disease outbreaks rarely occur. However, it is of great importance to have systems in place that care for the lives of the citizens of the Netherlands. Controlling an outbreak is also important since disease spreading impacts on sectors like communication, energy and transportation, urging policy makers to be more concerned with in an outbreak scenario.

The objective of this chapter is to derive the requirements of the technological and institutional system needed to prevent and react to an infectious disease outbreak and consequently use these requirements in the design of the actual artefact. In order to derive the requirements we start with an analysis of the status quo (January 2007), based on desk research and interviews with a heterogeneous group of experts. Consequently, we will determine the solution space in which we delineate the possibilities for satisfying these requirements. The requirements and the solution space provide the starting point for the design of two artefacts which are to decrease the problems currently associated with infectious disease mitigation.

The research underlying this chapter has been based on a study project supervised by René Wagenaar. The topic of the problem analysis and the designs closely relates to René's own interests in the fields of crisis management and IT and design. The theme of crisis management is a very clear example of the way in which ICT can have added value for society. The starting point is a real and technology-independent social problem: how can we guarantee a maximum of risk control and consequently safeguard health and safety for citizens? Many reports, among which was the influential report of the Adviescommissie Coördinatie ICT Rampenbestrijding (2005), pointed at communication as one of the crucial - and often malfunctioning - links in crisis management. Where communication is a problem, ICT is likely to deliver solutions, however, never only by means of digging a cable and sending bits over it. Communication for decision-making is a human process, where

technology can be facilitating. Although the technology itself may play a modest role, its existence can force institutions to change. As our case will show, the major improvement probably is not in the set-up of a new information system, but in the reallocation of responsibilities. At the same time, demands for changed institutions may lead to the introduction of new technology. Think of a centralisation of information, which is impossible without technology supporting the collection, aggregation and adequate representation. The mutual interaction between technology and institutions was at the heart of René's curiosity, and so it was the heart of the project.

In the next section, we will briefly outline our methodology, including theories used. After that, we will explore the problem (section three) and formulate design challenges (section four). This results in two artefacts for two distinguished but somewhat interrelated problems: the Disease Notification System (section five) and the Decision Facilitation and Empowerment System (section six). We conclude with a discussion and reflection.

2 Methodology

This paper is an extract of our report for the SEPAM Design Project (Bun, de Koning, Monasso, Veldhoven, & Verheij, 2006), one of the key courses in the largest master programme at the faculty of Technology, Policy and Management at TU Delft. For the design project, a typical TPM approach is used. Information systems cannot be designed without simultaneously taking institutions into account. The technological perspective describes the hardware, software and communication chains, whereas the institutional design concerns the way responsibilities are distributed across actors. The mutual interaction of technologies and institutions are well described by structuration theory and actor-network theory. For an overview of these theories, see Hanseth & Monteiro (1998).

New technologies, or adaptations in current systems, cannot go without thinking through the institutional consequences (Groenewegen, 2005; Hanseth & Monteiro, 1998). In a less passive way, changing institutions could help the functioning of technology. We consider technology and institutions as equally important in this report; however, institutional changes are often related to the technological system. An institutional design will deal with issues like the arrangements between actors, the way their relationships are regulated, the allocation of tasks and responsibilities, as well as costs, benefits and risks.

In this paper, we will use the definition of institutions that institutions are a “system of rules that structure the course of actions that a set of actors may choose” (Scharpf, 1997). This definition has a good fit with our focus on a socio-technical system, in which the primary focus is on actor interactions around and with technology. It is also broad enough so it does not restrict creativity in the process of exploring the solution space too much.

We will focus on structuration theory here, because it has regularly been applied to the analysis of IT systems. Although it does not provide much prescriptive guidance (I. J. Cohen, 1989), it points at the necessity of an integrated design and delivers the analytical tools to investigate and think about the interactions at a general level. We will use a framework (Groenewegen, 2005), originating from the field of institutional (heterodox) economics, to check the coherence of technology and institutions. This model is an extension of Williamson's classic model (2000) on institutional change that integrates technology. The model is shown in *Figure 1*. As his model consists of many relations, we will focus on the ones that may be most insightful for our design: technology and formal institutions, technology and actors, technology and institutional arrangements and, finally, formal institutions and institutional arrangements. These relations are displayed in bold. We have chosen these relations, because for the problem owners – the central government – it is easiest

to steer on technology, formal institutions and institutional arrangements within a reasonable time scope.

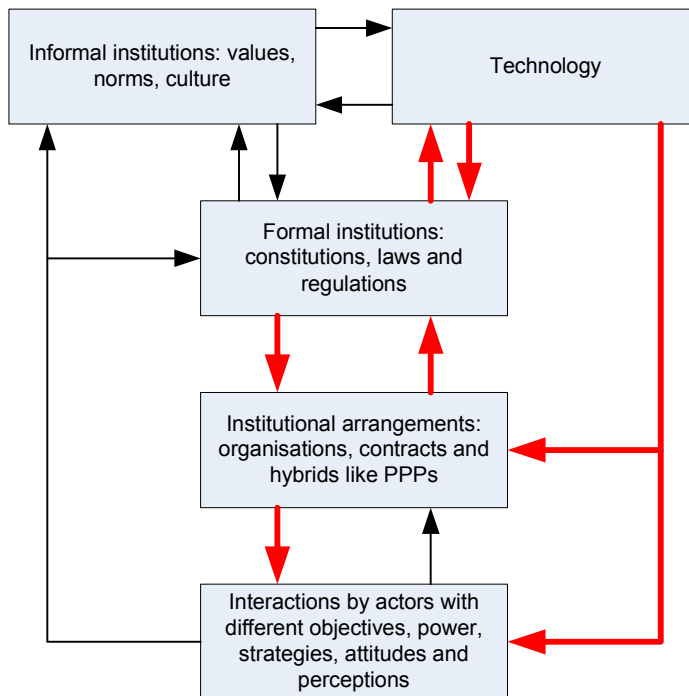


Figure 1 Model for institutional analysis (Groenewegen, 2005). The bold arrows indicate the relations used in this institutional analysis.

A second theoretical strand to be used is Transaction Cost Economics. TCE makes a fundamental distinction between governance structures like firms on the one hand and contracts on the other. The purpose is to explain governance structures that match specific types of transactions in a way transactions can be coordinated at minimal costs. Cost, in the case of disease spreading, directly relates to money, time and effort it takes to mitigate the spread. The two extremes of governance structures are market and hierarchy (Williamson, 1998). Factors that determine the cost, which determine the price on this continuum, are asset specificity, frequency of contact and uncertainty, which are in fact determined by the following key characteristics; bounded rationality, opportunistic behaviour, a-symmetric information and environmental complexity and uncertainty (Groenewegen, 1995). Asset specificity is the most important explanatory variable: “Transaction cost economics maintains that the principal factor that is responsible for transaction cost differences among transactions is variations in asset specificity.” (Riordan, 1985)

3 Problem description

We will describe two problems identified. First, the collection of information on individual infections will be analysed, and later on, be taken up in a design for an improved IT system. Secondly, the decision making process at the managerial and political level and the inherent quest for information will be examined and a new IT system design will be proposed.

Collection of information on individual infections

In the Netherlands many organisations are involved in combating the outbreak of an infectious disease. To this end, many IT systems are in place to support information sharing and decision making. The current technical architecture of these systems reveals a complex

infrastructure with a mix of many different, rather scattered IT systems (Bökkerink, 2006; Van Dijk, 2006). These systems can – in theory – perform much better when they are coupled, aligned and supported by non-ambiguous IT governance. In the current situation, the general practitioner is the first actor who actively collects data about infectious diseases. If an infectious disease has been identified, the general practitioner places a report in OSIRIS, an IT system. Accordingly, a GGD (municipal health service) worker constructs a report on this information and sends it to the National Health Inspection and the National Institute for Public Health and the Environment (RIVM). They could approve the report thereafter, or send their recommendations back to the GGD. In case the report is approved, it will be marked as official and handed to the decision makers involved. All these transactions are electronically handled by OSIRIS.

OSIRIS stores quite detailed information about the incident, but there are some drawbacks. General practitioners can use OSIRIS to report incident, but in practice the most used communication media are still the telephone and the snake mail (Jacobi, 2006). Obviously, these archaic communication means lack consistency, meta-data, speed and are more vulnerable to human interpretation mistakes. Another problem is the depth of the information provided. More information about the situation of the patient and the symptoms could be very useful in determining the exact type of disease and for fundamental research on diseases. The third problem of these systems is that they are not directly connected to international databases. There are contacts with the European Center for Disease Prevention and Control (ECDC) and the World Health Organisation (WHO), however connecting to the databases of these organisations is difficult and initiatives are focused on specific types of diseases (Jacobi, 2006).

Crisis decision making

The escalation procedure is used to describe the essence of the system of handing over command during crises (Ministry of the Interior and Kingdom Relations, 2004). As long as a problem does not supersede the local or regional level, the command is in the ultimate hands of mayors. Of course, in an operational sense, the command is being exercised by police and medical officers. If the problem cannot be handled at the regional level and has national implications, departmental crisis centres get involved. They reside under the various ministries that have to do with safety. The departmental centres are physical locations with coordination facilities, where teams of civil servants are responsible for coordination, with the ultimate command in the hands of the respective minister. If the problem exceeds the policy area of a single ministry, the national crisis control centre (NCC) is the new crisis control headquarters. Ultimate command is in the hands of a team of ministers, with at least the minister of the Interior and – in the case of terrorist involvement – also the minister of Justice taking part. For the combat of infectious diseases, a slightly different structure is being used. The institutional structure described above does not contribute to the speed of the process when an outbreak occurs. In addition, the lack of consistency within the reports of general practitioners decreases the speed even more.

In situations where the institutional setting, the interactions and the informational requirements all have a high risk of changing and where the future developments are highly uncertain, the process of mediating the disease spreading is very ambiguous. In times of crisis, there is a need for clarity, unambiguity and logging for the purposes of accountability, goals which are not yet satisfied.

4 The challenge

Based on our analysis of the different phases in disease spreading, we concluded that the two phases (information collection on individual diseases and crisis decision-making) have different requirements with respect to the required information, the actors that need to be involved and the technology which is most appropriate for combating the disease in that specific case. Furthermore, each phase, from recognition to controlling the disease, should be taken into account when designing a decision support IT system. Below we will discuss the main shortcomings in the current technical, institutional and process arrangements and thereby derive the high level requirements of the artefact under design.

Collecting information

In order to identify appropriate and efficient measures to prevent an outbreak of an infectious disease, information is a crucial aspect in the first spreading phases. Information about the disease characteristics, such as the incubation period and the infection threshold are derived from GGD disease reports and lab results. Although this first step is crucial for determining the scope of the disease and possible intervention measures, the current system has many shortcomings (Jacobi, 2006). First, when general practitioners recognise certain symptoms with their patients, they are obliged to inform the GGD. Transfer of this information happens by means of ordinary mail, or by fax, which causes a substantial delay. The same holds for communication between the Ministry of Internal Affairs and the local governments (Bökkerink, 2006). On the other hand, when samples from these parties have been examined in the lab, these results are transferred to the GGD. As there is currently no coupling between the lab data, the GGD reports and the information management system (OSIRIS) it takes a long time to find the required information and derive conclusions from this data.

Standardisation poses another issue, since the labs, the GGD and OSIRIS all use different data standards and formats (Jacobi 2006). Although many involved organisations, such as hospitals, have standardised their internal documentation, these standards remain proprietary. When information is exchanged, the format of the information is not designed for the purpose of mitigating the spread of the disease, therefore finding the relevant information can be difficult as these documents tend to grow very large. Although many types of information are gathered and stored, finding the right information can be very difficult, due to the different formats and the lack of a database which filters the information. Filtering of information is also very desirable for the different phases of disease spreading. Based on previous experiences, what type of information is required can be defined beforehand, but currently the information is not being filtered with respect to relevancy for each specific stage. Nevertheless, when an outbreak is detected, one hardly makes use of standardised protocols, because the real crisis situation always differs from scenarios constructed.

If we map the current situation to the list of success factors for management information systems identified in a large meta-literature study by DeLone & McLean (1992), we observe that most success factors cannot be recognised in our case, among which are clarity, format, appearance, accuracy, precision, completeness, currency and timeliness all contributing to information quality. On the level of the database, the redundant databases, the system reliability and human factors may pose problems.

Decision-making

When an outbreak is detected, the characteristics of the network in combination with the disease characteristics described above, to a large extent determine the effectiveness of intervention measures. The effect of the measure will depend on the correctness and completeness of information presented. Since decisions are taken based on the available information, often in the early phases where such information is lacking, these decisions are

based on existing protocols and hypotheses about future scenario's (Bökkerink, 2006). A paradox exists with respect to timeliness of information and the verification of information. A tension exists between the information that is verified and updated information about the situation, which is highly relevant but not yet verified (Van der Brugge & Kemp, 2006). More specifically, as information often comes from parties at a decentral level, once this information reaches the coordination structures on a national level, it could already be outdated. Another drawback of the decentralised system is that during interpretation and analysis of data, at different levels these data are interpreted according to individual perceptions and experiences. This could result in a situation where different local authorities execute different strategies for mitigating the disease. Because local governments have – to a large extent - the authority to execute their own policy, it is difficult to impose one coherent national policy (Van der Brugge & Kemp, 2006).

Other current shortcomings in decision making is that information from various parties cannot be used appropriately in the OMT (Outbreak Management Team), IBT (Interdepartmental Policy Team) or IMT (Interdepartmental Management Team), due to the fact that the information is too technical, information is delivered too late and too many formats exist (Bökkerink, 2006). This is caused by the fact that in many cases it is unclear which party has what information at his disposal. Although currently, many parties can deliver the same types of information, a centralised aggregation and filtering of information is highly desired (Van der Brugge & Kemp, 2006).

Although many protocols, white papers and guidelines exist with respect to crisis situations (Jacobi, 2006; Ministry of the Interior and Kingdom Relations, 2002, 2004), an unequivocal system, which integrates both information and agreements regarding sharing and authorisation of information, is not yet accomplished. On the other hand, in the current National Handbook on Decision Making during Crisis the national government has no absolute authority in the decision-making process (Ministry of the Interior and Kingdom Relations, 2002). In many cases the fact that a consensus has to be reached before action could be taken, dramatically decreases the speed of the process (Bökkerink, 2006). Besides, decision-making on a global and local scale are interdependent. Strategic choices are influenced by choices made at a local level and vice versa, therefore there is an increased need for coordination, especially in case of time pressure. After a crisis, the evaluation takes place according to a specified protocol, the Evaluation Guideline. Nevertheless, these experiences are weakly documented and communicated on both a national and international scale to the responsible persons. International information sharing takes place but has a focus on evaluating the mitigation strategies (Jacobi, 2006). Especially the status position of certain persons, such as a mayor, makes effective feedback difficult. Therefore the learning effect of a crisis is limited.

Although our analysis encompasses the entire disease spreading cycle (from recognition to control) and every step necessary from information gathering to data evaluation, a system supporting every activity would pose severe implementation and managing difficulties. Therefore we will focus on the critical aspects in the disease spreading cycle, where currently the main problems reside and no initiatives are undertaken to improve the technical systems. From the interviews we held with several experts within the RIVM and the Ministries of Internal Affairs (Bökkerink, 2006; Jacobi, 2006; Van der Brugge & Kemp, 2006) it became clear, that the critical aspects were perceived to occur in the early stages of disease spreading. Furthermore, they perceived that data collection and data exchange activities are the basis of good analysis and decision making. Following DeLone & McLean again (1992), we observe that almost none of the success factors for a management information system are satisfied.

Based on literature and interviews we found that the bottlenecks and shortcomings in the two phases identified are most problematic and solutions are not under development yet. Therefore, two alternatives will be proposed to tackle the process-oriented data collection and data exchange problem of general practitioners and the more technical-oriented problem of the lack of intelligence within the system.

5 Disease Notification System

The first alternative, which we will call the Disease Notification System (DNS), solves the efficiency and standardisation problem between the general practitioner and OSIRIS. General practitioners and lab workers use the DNS through Web Services which is an extension of the Electronic Patient File (EPD). When they fill-in the provided application form with the symptoms of an individual patient, this information is analysed by the Disease Classification System (which is a part of the DNS) which determines the level of importance in relation to a possible disease outbreak, and notifies the general practitioner or lab worker accordingly. This way, all relevant data is immediately online available to all relevant parties and the GGD worker can directly process it in OSIRIS, instead of manually organising and storing all incoming data. To use these Web Services a Service-Oriented Architecture (SOA) has to be implemented in order to manage the interfaces for ensuring interoperability of the EPD with legacy systems. Using the DNS, the crucial time it takes to determine if a possible disease outbreak is bound to occur is decreased significantly and information is stored in a standardised and efficient way.

For the institutional design of DNS the elements of technology, formal institutions and institutional arrangements have been used. The main role of technology will lie in enforcement of certain procedures within a given period of time. Compliance with these procedures can be monitored in detail. Regarding formal institutions, one norm is of particular importance for distributing and storing patient data, namely the NEN 7510 norms about information security in the health care sector. Another formal aspect that has to be accounted for is the allocation of responsibilities. The institutional arrangements focus on the relation between the general practitioner and the system on three variables: frequency, uncertainty and asset specificity. The frequency between a general practitioner and the system, as well as uncertainty is low, while the asset specificity is high. With the scores on the variables, Williamson's framework suggests a hierarchy. Changing the relationships themselves in order to achieve a hierarchical configuration would prove difficult since many independent organisations are involved. Therefore, we suggest an intermediate form which leaves more room for diversity, but still counters the risk of exploitative behaviour. Relational contracting, a combination of semi-market contracts and the development of enduring trust relationships, can be used for this purpose (Williamson, 2002).

The relationship between the actor and technology level in Groenewegen's model is particularly interesting and problematic here. General practitioners' primary goal is supposed to be the caring for individual patients, which is derived from the oath of Hippocrates. Their contribution to the early warning system for infectious diseases does not directly contribute to that goal. That means that this type of informational obligation is regularly seen as an unwanted administrative task, which consumes time from the primary process (point raised in a discussion with René). A somewhat related worry at the side of the doctors is that confidential information about their patients will be shared with other doctors, or even worse, non-medical staff. Confidence in technical solutions or fundamental choices (such as the anonymisation of patient data) aimed at the prevention of this exchange is far from obvious.

In our design, we try to mitigate these barriers of resistance by using an information infrastructure already under development, the EPD. Although its implementation is problematic as well, practitioners (representatives) are heavily involved in its design and implementation. Another measure might be the legal enforcement of the obligation to inform. However, without very invasive measures, it is hard to check for compliance. Therefore, a culture change – increasing awareness by explaining the importance of this system – might be more appropriate. An attractive way of doing this is to give some feedback on the information collected. Doctors may want to know which of their colleagues have similar patients. This information could be exchanged without revealing any sensitive data.

The DNS primarily consists of server-side software modules that are accessed through a secure channel by lab workers and general practitioners. The advantage of a centralised architecture is that the practitioner’s IT systems, which are mutually very different, hard to manage and secure, do need only slight adaptations. Physical security and a secure configuration can better be guaranteed and updates can be installed much quicker. The finance structures can also be simpler, as a limited number of organisations need to be paid in order to implement the system.

This secure channel already exists and only a small proportion of server side hardware must be placed to run our software modules on. As this system will be linked to the existing EPD, no additional software is required on the client side. On the client side, practitioners and lab workers will only have a small additional module in which relevant data is submitted which replaces the traditional paper-based communication. Authentication and authorisation (not shown in the figure) can be based on the existing infrastructures as well. *Figure 2* presents an overview of the DNS. As the required data and its format and layout will be consistent with the traditional communication, lab workers and general practitioners will not require training other than a general and well-written briefing. Nevertheless, support must be provided in case of technically or semantically related problems with the system.

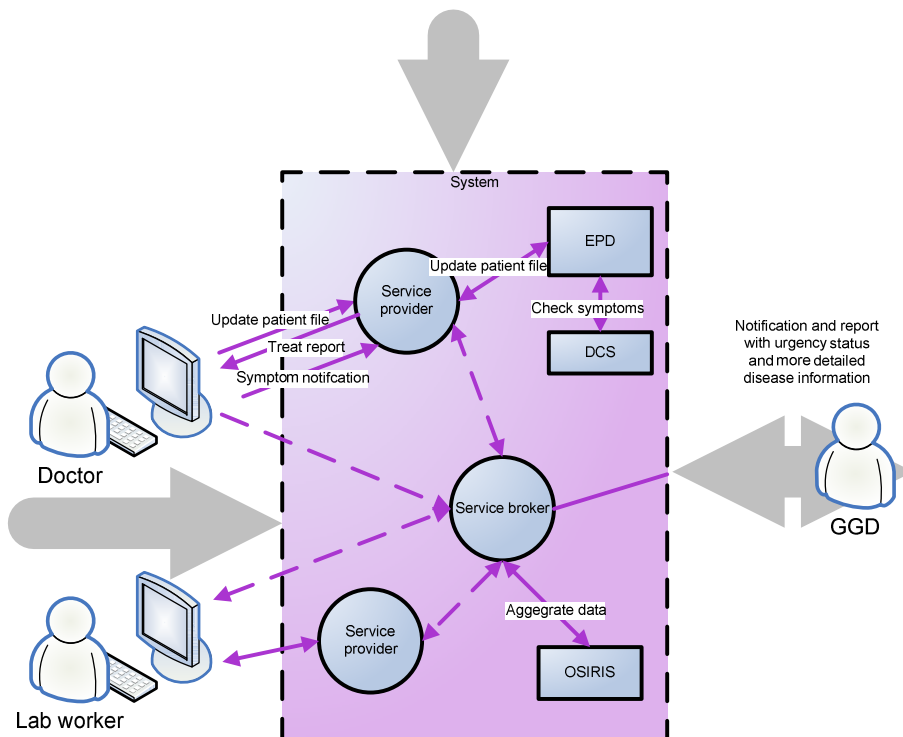


Figure 2 Overview of the DNS

6 Decision Facilitation and Empowerment System

To solve the second problem, namely suboptimal decision making in times of crisis, we propose a second alternative, named the Decision Facilitation and Empowerment System (D-FES). This system filters the information input from different organisations and adds meta-data to it. This meta-data is used to relate different information types to each other and aggregate a packet of related information to each other. Furthermore, the meta-data is used to determine which information is relevant for which decision body, i.e. operational or strategic. Hence, information is not only standardised, it is also filtered based on its relevancy. On the other hand, the D-FES creates a clear responsibility structure and protocol while at the same time facilitating organisational learning. XML is the standard format in which information and meta-data is stored, as this is (becoming) the industry standard and is most flexible towards future changes. It can also deal quite well with many different source systems, as XML messages can easily be transformed into a different template. D-FES generates PowerPoint slides as output, which can be used to structure a meeting between decision-makers. This software tool is used as it is concise and enforces some structure, but not too much. To integrate the different information streams we have used a Service Oriented Architecture in this alternative. Again, this provides most flexibility for re-using the information in different settings and adapting the system when needed. *Figure 3* shows an overview of D-FES.

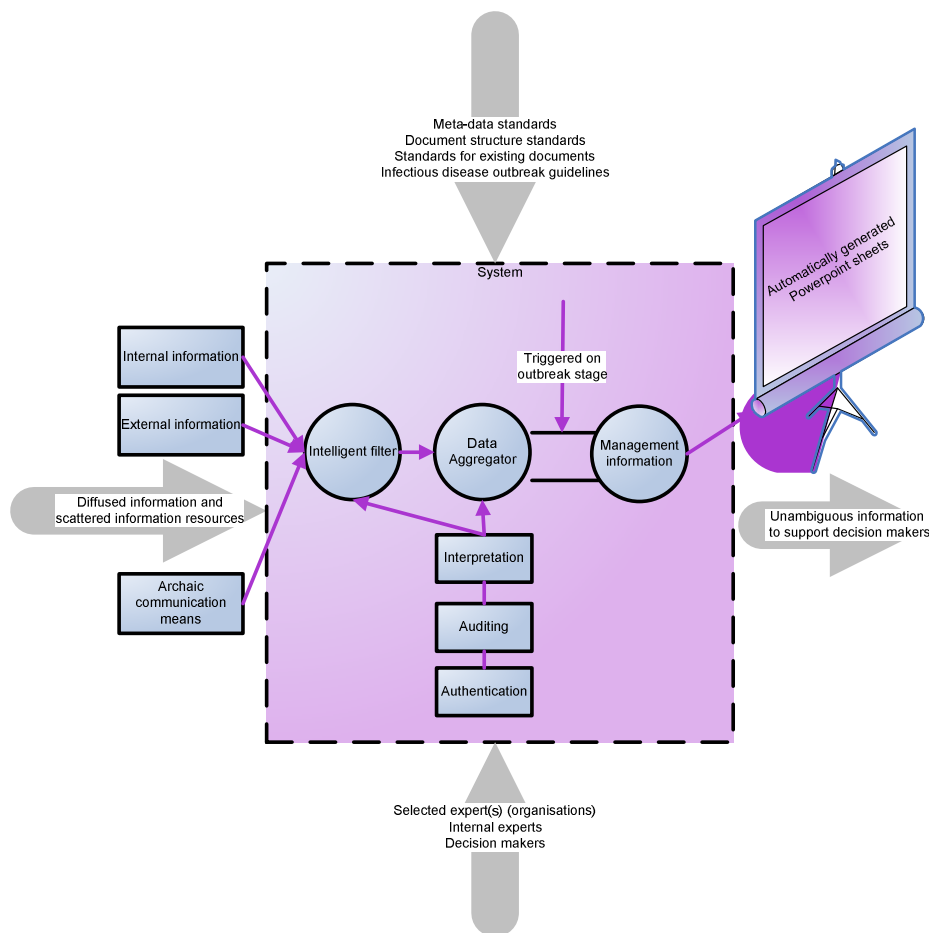


Figure 3 Overview of D-FES

For the institutional design we looked again at frequency, uncertainty and asset specificity to match these characteristics with a governance mechanism, but from two different positions; from an administrative and from an operational position. For the administration of D-FES, the frequency and asset specificity are low, while uncertainty is high, which matches with trilateral governance, since this suits best the diversity in actors and systems using D-FES. For the operation of D-FES, the frequency is very low, with very high asset specificity and uncertainty can be neglected. Williamson's framework clearly suggests a hierarchy here, due to the fact that decisions may need to be enforced. We propose a decoupling of the organisational and the information structure to make it possible to bypass regular bureaucratic structures for exchanging information. Therefore a Crisis Information Officer (CIO) will be installed which directly reports to the decision making bodies. *Figure 4* shows the relation between important actors and the CIO.

Structuration theory reminds us of an important design awareness. Whereas we try to influence organisational structures (micro-social environments) by technology, it might also work the other way around and, in the same causal direction, have unwanted consequences. Following Giddens (F. Cohen, 1997) and Orlikowski (1991), the mutual relationship can be described from three perspectives (*modalities*): interpretive schemes, resources and norms. Staying in their terminology, interpretive schemes formalise and encode the existing stock of knowledge. Resources reinforce themselves through the positive feedback loop of controlling organisational focus. Finally, norms, especially when coded in technology, ensure that people act in conventional ways and determine priorities, criteria and other policies. In other words, an IT system can create a reality of its own as it shapes structures, and simultaneously is shaped by them. In our case, we have to be very cautious in applying an IT system as the only way of working. It is desirable that the system converges semantics, individuals' perceptions and ways of working, as a lack of these are exactly the core of the problem under scrutiny. However, if the system does flatten creativity, responsibility and flexibility, new problems may be reduced. As now crisis is completely predictable, neither can its information structures be preformatted. A continuous reassessment of the way the system functions and interacts with the organisational structures is necessary. Our appointment of information liaison officers which can communicate through a variety of media, and the choice for a human explanation of the data by the chief information officer (the decision-making expert) is also a measure that counters too rigid structures.

Bouwman et al. (2005) discuss media richness theory as an analytical tool in assessing the use of ICT in organisations. This theory suggests that not all media are equally suited to handle all communication tasks. When there is a need for information equivocality (similar understanding and perceptions) and not only for a large quantity of facts, rich media are more suitable than others. Rich media have, to some extent, the characteristics of providing instant feedback, multiple cues, the ability to express natural language and to keep personal focus. The fact-based system we suggest is a very thin medium in this sense. That suggests its use should be only supportive and not replace richer media channels like face-to-face communication.

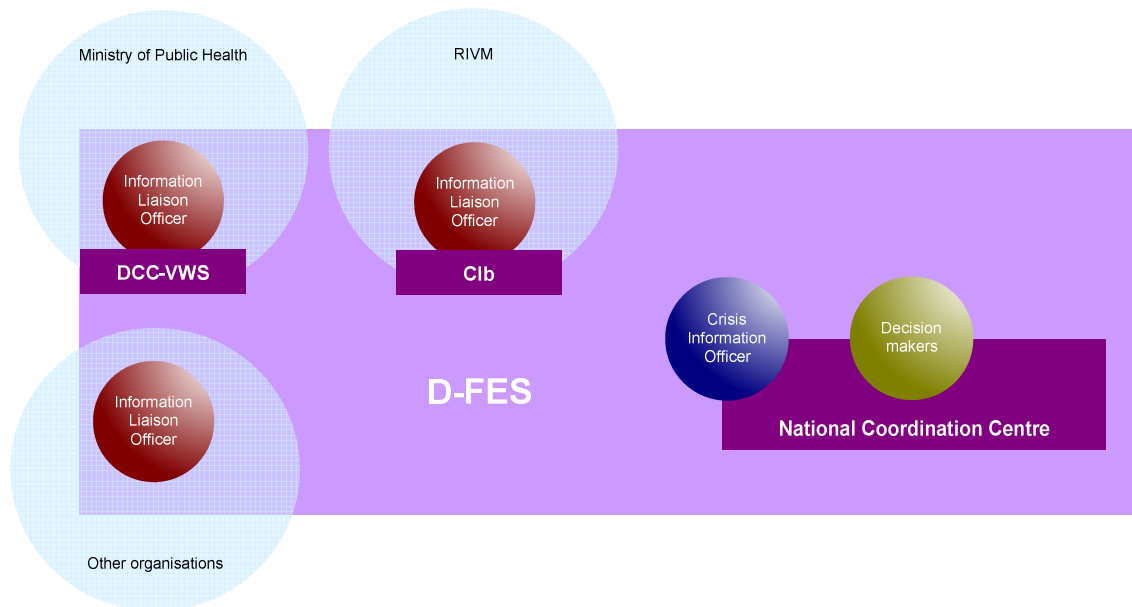


Figure 4 Position of the Crisis Information Officer

7 Discussion and reflection

The two IT systems presented can operate independently from each other. The power of their combination is that the information process needed for effective decision-making is improved across all phases of the spreading. Information from the DNS will not directly be used in crisis situations, but can prevent an escalation of the process. The many differences between architectural choices of both systems remind us of the fact that no standard approaches can be used in designing systems that are aligned with their organisational and problem context. In René's perception, the problem context in terms of its actors, systems and processes should be the starting point in designing an appropriate artefact to mitigate disease spreading. During the process René especially emphasized the importance of interviews with relevant stakeholders and explicitly required that the processes are designed in a way that they take into account possible resistance of e.g. general practitioners in adopting their daily operations to the proposed solutions.

An effective reaction on infectious diseases increasingly depends on the interactions between multiple parties using a broad spectrum of ICT solutions. In this paper we used an approach aligned with this insight for a more holistic design. This approach consists of a technological design laying down ICT solutions and a design of the institutional arrangements. The mutual interaction between technology and institutions was at the heart of René's curiosity. The fact that although technology itself may play a modest role, its existence can force institutions to change and reallocate existing responsibilities, thereby provides a window of opportunity for improving safety by means of ICT.

Groenewegen's framework indicated some relations that were in need of investigation, but in itself it did not provide any substantial analytical tools. There is a need to 'feed' the framework with other theories and to operationalise them further. Because the framework is so flexible, it provides little guidance in a design process. The detailing of all relationships may suffer from eclecticism, which is a strength and weakness and the same time. A strength, because it enables the researcher-designer to use an interdisciplinary perspective. Its weakness lies in the possibility to selectively shop from the theoretical assortment and not enforcing

enough focus to check for the coherence of all perspectives applied. We tried to reduce that danger by applying structuration theory which operates at the intersections of Groenewegen's elements. However, not all relationships are investigated with the same depth, which may introduce a bias in our recommendations and considerations towards the relationship of technology with the actor level. Our theoretical understanding of IT systems may benefit from a more rigid, validated and parsimonious adaptation of Groenewegen's framework. Nevertheless, the outcomes of our research are still of a rather abstract nature. A further specification of the design choices down to the level of requirements will provide more guidance for policy change. A continuous movement between abstract and more practical levels of analysis can feed our theoretical understanding as well. Regarding DFES, think about a careful analysis of a real or simulated crisis situation (which may already have been transcribed in the past) which feeds an improved version of our design, for instance by examining the exact types of information needed. The system can then be compared, in an experimental setting, with the 'traditional' way of information gathering, as a way of validating our arguments and assessing effectiveness. With regard to DNS, insights from the Electronic Patient File may be used to improve our design. The designs are highly context- and time-dependent, but the method of analysis can be repeated from time to time, building on already existing insights.

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