

A Complex Adaptive System Perspective of Enterprise Architecture in Electronic Government

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Abstract

Within the public sector, the deployment of enterprise architecture is often an attempt to address the decentralization/centralization relationships to improve the links between the central and the local governments. The underlying aim is to provide a better structure to manage the diverse, independent and local IT-related projects and development activities.

In this paper we propose a novel approach to analyzing and understanding the requirements and limitations for enterprise architectures in government. We use the perspective of a complex adaptive system as a metaphor to examine 11 e-government projects with each involved the development of enterprise architecture in the Netherlands (1980s - 2004). Through analyzing the key interaction points between the central and the local governments, we identify architectural design principles that will increase inter-organizational jointness and IT implementation success.

1. Introduction

It is often stated that the implementation of enterprise architecture offers a way forward in integrating independent IT silos across inter-organizational agencies (e.g. [7],[20]). Within the public sector, the joining-up remains at the top of e-government agenda of most of the Western countries. As part of the modernization plan, governments seek to offer their citizens a seamless service delivery by linking various independently developed systems and applications. Yet the development and implementation of enterprise-wide technologies is a massive and complex undertaking [17].

One of the key obstacles is the legal issues may constrain the extent of business transformation and IT-

related development work that can be undertaken for enterprise integration [23]. For example, at the local level, governmental agencies have the autonomy to design their own information architecture so long as they adhere to the existing laws and financial regulations. This autonomy can lead to massive local differences as the centrally advocated architectural design principles and standards may not be adopted [16].

Due to the local diversity in terms of IT-based architectures and the number of vendors involved in the design and development of IT-based systems, increasingly central administrators and managers are finding it difficult to manage and effect the needed transformation and modernization [33]. Specifically, they are struggling in dealing with the complexity and problems associated with independently developed and managed projects at the local level. As local governmental agencies have a large degree of autonomy, they are often outside the central purview and control. Inevitably, systems developed and decisions taken in local governments are often out of sync with the central government. Also the ways in which the central government interacts with the central governments can increase the final complexity that enterprise architecture has to deal with. Simon [31] (p. 486) asserted that a complex system is one “made up a large number of parts that interact in a nonsimple way.” Hence, a key objective for using architectural concepts is to manage the complexity and contain the increasing rate of change [5].

As targets are increasingly difficult to formulate and the path to a long-term strategy can change as the target shifts [1], enterprise architecture needs to adapt to the change-on-change element that characterizes the surrounding environments. The large number of actors involved both at the central and local levels, and the dynamic and nonsimple interactions can hamper the

decentralization and improvement of links between the central and local government. In this regard, public organizations not only have to stay adaptive to the constant change but also manage complexity attributed to the interactions between the central and the local governments.

To understand the underlying interactions, we use the perspective of a complex adaptive system (CAS) as our empirical lens to examine the interactions between the central and the local governments. The essence of CAS is the study of systems built of individual agent that are capable of adapting as they interact with each other and with an environment, and especially the attempt to understand how the individual affect the system-level responses [2]. Most work in CAS has been conduct in highly abstract and artificial systems, like cellular automata and genetic computer algorithms, and in the fields of economics, sociology, microbiology and medicine [26]. In recent years, CAS has attracted much interest in management and organizational related literature (e.g. [9],[10]). It has been successfully applied to explain the adaptive behavior of biological systems, optimization tasks and inductive learning [10].

We use the general definition of CAS as a system that emerges over time into a coherent form, and adapts and organizes itself without any singular entity deliberately managing or controlling it [18]. Through the CAS lens, we examine the types of interaction points afforded by the development and implementation of enterprise architecture. Our intention is that by conceptualizing enterprise architecture as CAS, public administrators and managers can acquire a better understanding of interactions, and implement design principles that increase inter-organizational jointness and IT implementation success. As such we use CAS as a metaphor to analyzing the key interaction points between the central and the local governments, and to identify architectural design principles.

This paper analyzes 11 e-government initiatives with each involved the development towards enterprise architecture in the Netherlands between 1980s and 2004. The rest of the paper is structured as follows. In section 2, we review the literature about the relationship between enterprise architecture and the complex adaptive system theory. In section 3, we discuss our research approach. In section 4, we introduce and describe the developments and key interaction points within enterprise architecture for the public administration in the Netherlands. In section 5, we derive architectural design principles and guidelines based on the logic of CAS. In section 6, we discuss our findings. Lastly, we discuss future research directions in section seven.

2. Theoretical Background

2.1. Enterprise architecture

Enterprise architecture lacks a universally accepted definition [30]. It is a kind of city plans that detail policies and standards for the design of infrastructure technologies, databases, and applications [14]. Architecture aims at creating some kind of structure in a chaotic environment using systematic approaches [1]. The term “enterprise” refers to the scope of the architecture, dealing with the organization as a whole or multiple agencies rather than with a certain organizational part or individual components and/or projects [8]. The architecture is based on statements of how an enterprise wants to use IT, not on what and how information has to be made available. The strategic aspects of IT systems provide the contexts for the architectural design choices and decisions. Enterprise architecture models provide ways to deal with the complexity including work (who, where), function (how), information (what) and infrastructure (how to) [5]. The enterprise framework formula, in general terms, specifies how information technology is related to the overall business processes and outcomes of organizations, describing relationships among technical, organizational, and institutional components of the enterprise [12] [29].

The idea of enterprise architecture is that it can be used to guide design decisions and limits the solution space by setting constraints. *Architectural principles* are textual statements that describe the constraints imposed upon the organization, and/or the decisions taken in support of realizing the business strategies. Principles restrict architectures and set the direction for the future. Architectural descriptions can form the basis for the implementation and transformation of existing structure into the desired architecture.

2.2. Complex Adaptive System Theory

Desai [10] introduces the term adaptive complex enterprise (ACE) to differentiate from Holland’s [18] complex adaptive systems. This new term depicts that many human-designed systems and processes are not complex and the focus should be on the complexity of non-designed processes, interactions and relationships in addition to systems. They argue that a key managerial task is to design adaptive systems or processes that bring back or push forward conditions that are far from equilibrium into state of equilibrium.

According to Lewin and Regine [22], the best-run organizations function much like a flock of birds, in which individuals follow simple rules, interact with

others to form a cohesive and dynamic whole. They further assert that complex adaptive systems emerge as a result of the interactions among members. A CAS has the following emergent characteristics [13]:

1. *Emergence*: Agents in the system interact in apparently random ways. From all these interactions, patterns emerge, and inform the behavior of the agents within the system and the behavior of the system itself.
2. *Co-evolution*: All systems exist within their own environment, and they are also part of that environment. As their environment changes, they need to change to ensure best fit. But because they are part of their environment, when they change, they change their environment, and so it goes on as a constant process.
3. *Sub optimal*: A complex adaptive system does not have to be perfect in order for it to thrive within its environment. Once a complex adaptive system reaches the state of being good enough, it will trade off efficiency with greater effectiveness.
4. *Requisite Variety*: The greater the variety within the system, the stronger it is. Complex adapt systems rely on ambiguity, paradox and contradictions to create new possibilities.
5. *Connectivity*: The ways in which the agents in a system connect and relate to one another is critical to the survival of the system, because it is from these connections that the patterns are formed and the feedback disseminated. The relationships among the agents are generally more important than the agents themselves.
6. *Simple Rules*: Complex adaptive systems are not complicated. The emerging patterns may have a rich variety, but like a kaleidoscope the rules governing the function of the system are quite simple.
7. *Iteration*: Small changes in the initial conditions of the system can have significant impacts after they have passed through the emergence of feedback loops.
8. *Self-organizing*: There is no hierarchy of command and control in a complex adaptive system. There is no planning or managing, but there is a constant re-organizing to find the best fit with the environment. The ability of the agencies to intervene in the course of events is a key characteristic of CAS [9].
9. *Edge of Chaos*: Complexity theory is not the same as chaos theory, which is derived from mathematics. But chaos does have a place in complexity theory in that systems exist on a spectrum ranging from equilibrium to chaos. The most productive state to be in is at the edge of chaos where there is maximum variety and creativity, leading to new possibilities. Controls, such as rules and regulations or institutional and budgetary restrictions, ensure that an agent's behaviors is limited, in this way changing the

aggregate behavior and helping the CAS to behave in a predictable way [9].

10. *Nested Systems*: Most systems are nested within other systems and many systems are systems of smaller systems.

If the organizations want to harness the benefits of a complex adaptive system, then the design of enterprise architecture has to balance between excessive and no controls, and allow flexibility and adaptability such that systems are not frozen because they are tightly constrained or disintegrate due to little order [10]. Often the behavior of complex adaptive systems can be predicted using a few simple rules [9]. In this respect, using simple rules, enterprise architectures should constrain the actions that can be taken and give guidance for taking the right direction, in such a way that it is still possible to adopt and evolve as the environment changes.

3. Research approach

To explore the nature and background of enterprise architecture in the public administration of the Netherlands, we conducted comparative case studies. We gathered data primarily through semi-structured interviews. Following the recommendation of Eisenhardt [11], we used a theoretical sampling approach to guide our case selection and to refine our research questions. With an emphasis on cross-case diversity, we selected 11 e-government projects with each involved in the development of enterprise architecture.

Each case involved a retrospective, in-depth examination of at least 2 key informants' account of the contexts and rationales of how the enterprise architecture was developed. Many interviews were directly involved or experienced the results of multiple projects. In total, we interviewed 25 informants, and each interview lasted between 1 and 3.5 hours. Especially the interviews involving multiple projects lasted for more than one and a half hour. The interview transcripts were then analyzed to identify the contexts underpinning the key interaction and contact points between the central and the local governments, the key actors involved in the development, and the business and technical logics behind the design choices and solutions. To validate any claims and factual information, we also collected data from multiple sources including follow-up phone interviews, internal memos, website research, publicly available information and other relevant consultancy reports.

4. Case study: development of an enterprise architecture

Figure 1 displays the networks of agencies: the national agencies at the top and the municipalities at the bottom. The focus of the present study was on the key interactions between the Ministry of Interior and the municipalities.

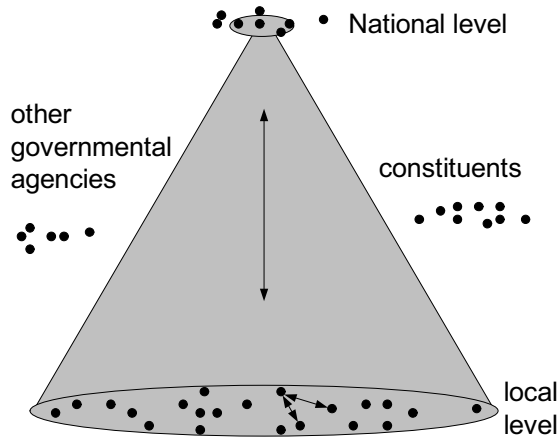


Figure 1. The network of agencies

4.1. Background

Within the existing laws and financial regulations of the Netherlands, the local governments enjoy a high degree of autonomy in making their own decisions. They have their own budgetary control and can make independent IT investment decisions. The local governments are hierarchically organized with varying degrees of coupling and autonomous coordination.

Despite all the good intentions and efforts, the existing efforts to direct IT investment and developments are often ineffective. This has resulted in a highly fragmented and heterogeneous architecture within the organization with disparate business processes, applications and operating systems. The systems in place have different capabilities, data formats, content, and user-interfaces. There is no uniformity and interoperability is limited.

System development projects can be characterized by the silos-like behavior including redundancy and duplication of efforts, and the lack of reuse and information sharing. The silos can be attributed to the autonomy that individual municipalities have in exaggerating their unique business requirements and therefore demanding for unique systems. And the systems got out of hand as there exists no structure in

place to monitor and govern the development at the municipality level.

Although the central government tries to guide this process by setting national targets, the top-down approach is often criticized for not taking the local realities into consideration; and the unrealistic timescales for the realizing those targets often result in a rushing mentality, which in turn has led to poor quality and substandard implementation. With the advent of e-government, the Ministry of Interior has decided that they want to have more grip on the system architecture of local municipalities. Against this backdrop, the Ministry has started since 1980s to develop enterprise architecture as a means of directing and constraining the architectures among the Dutch municipalities.

4.2. Overview of developments

Starting from the eighties, the emphasis was on automating the citizens' records by enabling municipalities to process and authenticate information in relation to applications for passports and social security. The most important initiative in this regard was the creation of standards for the GBA (in Dutch: Gemeentelijk Basis Administratie). The GBA is the Dutch vital record registration of data about all residents living in a particular city or village.

Also due to mergers and consolidation of the software market, two software vendors became the dominant suppliers and had effectively created a duopoly for the municipality market. The technical dependency and the contractual *lock-in* had made switching to another vendor very costly. One of the architectural aims was to reduce this duopoly by opening up the technical lock-in through the use of modular components and standardizing interfaces among the components.

In the mid-nineties, public managers became aware of the need for directing developments towards e-government. This has resulted in a number of plans and revised plans of the ministry of interior and kingdom relationships (e.g. [5][6][15][25]). Table 1 provides an overview of the projects initiated at the national level and the municipalities' responses. This table is limited to the main projects at the national level, as the number of projects is far greater considering that the number of local agencies is almost 500 and the number of municipality departments is even higher.

Table 1. Overview of national initiatives and local-level responses

Year	National level initiated project	Local government response	IT implementation Outcome/Performance
1980s	Standardization by founding a citizenry authentication registry. This registry defined the data to be stored in the registry but not the system modules and functionalities.	Municipalities developed and started operating the citizenry registry. Overtime the development and maintenance was shifted to commercial software vendors and all kinds of extensions were developed to provide services based on data. The software market for municipalities is characterized by the duopoly lock-in.	Upside: Clear data ownership resulting in higher data quality, improved interoperability and additional functionalities. Downside: An increase in the level of technical and strategic lock-in, and the number of systems in place.
1995-2000	OL2000: development of a standardized product and service catalogue to enable the creation of one-stop shop by municipalities	Local customization and deviation among agencies of the use standardized product and service catalogues. Some organizations extended this catalogue, as it did not contain policy-making or law-enforcement related product and services	Upside: Standardized products and services catalogues. Downside: Customization deviated from the standards.
1998	The parliament set the target that 30% of the content and services should be available online by 2001.	Local governments start developing websites on a one-to-one basis. A number of software vendors developed web information systems for use by government agencies. The number and variety of systems increased to meet this target.	Upside: Clear targets. Downside: Duplication of development projects; creating of interoperability problems, no fostering of reuse; and no sharing of experience
2000-	Re-development of business registry that previously operated by over 500 municipalities. The aim was to connect all the municipalities by 2004 and to enable to access all basic information at a national level.	Municipalities were involved in the development of the business registry, yet currently there is still no consensus how the interface should look like. The tendency seems to be to define the building blocks and interfaces, and let multiple software vendors build a registry.	Upside: Clear data ownership resulting in higher data quality and additional functionalities. Downside: An increase in lock-in and the number of systems in place.
2001-	Selecting and support of 'super pilots'. A limited number of large municipalities were given a large amount of money to develop certain components of the architecture (e.g. authentication, back-office integration, etc.)	The evaluation of these pilots was very disastrous. The developed components were not suitable to reuse, the reports describing the experiences remained too vague and the "super pilots" were lagging behind on other municipalities who did not get any funding.	Upside: Fostering local development. Downside: limited reuse for other municipalities, not dealing with interoperability problem.
2004-	The parliament set the target that 55% of the transaction service should be available in 2005, and 65% of the services should be available online by 2007.	As with the target set discussed in the row above, this resulted in an increase in the variety of systems in place.	Upside: Clear targets. Downside: Duplication of development projects, creating of interoperability problems, and no reuse and/or learning transfer.
2002-	Founding the ICTU, an over-coupling architecture program office running all the nation-wide programs including: open source and standards, and infrastructure component developments.	Municipalities find it difficult to adopt the reports, systems and concepts provided by the ICTU. They have a lack of knowledge to interpret the reports and translate them to their own situation.	Upside: Clear focal point for e-government enterprise architectures. Downside: For municipalities it is not clear how the results and reports of the ICTU can be used
2004	Data cannot be easily exchanged as various definitions are used and could be of low quality. Founding	Municipalities will be forced to obtain business data from the business registry, which will be operated by the chambers of	Improved interoperability, clear data ownership resulting in higher data quality.

	<p>of six authentic registries for citizens, business, addresses, building, land and maps. The business registry should be adopted in 2007.</p> <p>All government organization must reuse the information stored in the six authentic registries by 2007.</p>	<p>commerce. Businesses provide changes in data only to the chamber of commerce. This is similar like citizens only have to provide changes to the municipality they are living in, operating the citizen's registry.</p>	<p>Downside: no additional functionalities and interfaces are included which might result in a large variety of systems having different granularity</p>
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The control of the enterprise architecture was traditionally scattered around national agencies. One interviewee remarked that “we have not only one control body; we have at least 10”. Consequently, the Ministry of Interior sought to create a Program Office that would oversee, approve, and coordinate the many independent and uncoordinated efforts of the IS department, and hence the founding of the ICTU. Its first mission was to concentrate all development activities and other related efforts under one program office. The next step was to ensure that there is a systematic and coherent relationship among the various programs. This was done by defining basic infrastructure building blocks, which included:

- 1) DigiD: A national authentication service for citizens and business combining on a number of existing authentication projects initiated by various agencies.
- 2) Public key infrastructure: creating an infrastructure for facilitating transaction between governmental agencies.
- 3) Citizens service number: Defining a unique number for each citizen to gain access to it's personal data by all governmental agencies.

- 4) Authentic registration: the Founding of six authentic registries for citizens, businesses, buildings, land, addresses and maps.
- 5) E-form generator: defining a generic form generator for generating standard as well as customized forms

Besides the development of these basic building blocks there are several other programs to help municipalities (i.e. <http://www.ictu.nl/activiteiten.html>), such as open source and standard (OSS) program and transaction port. OSS is aimed at stimulating the use of open source software by providing knowledge about open source concepts and the stimulation of the development of standards. The transaction port is functioning as a channel for exchange information between businesses and governmental agencies.

Over time it was recognized that it was important that initiatives should be started at the local level. Table 2 shows the initiatives emerging at the local level and which were adopted at the national level. The uptake of emerging initiatives is inline with CAS theory.

Table 2. Overview of local level initiatives and responses at national level

Year	Local level initiatives	National level response	IT implementation Outcome/Performance
2001	One municipality developed a web-intake system what was regarded as a best practice. To recoup the investment costs, they started marketing and selling their system to other agencies. Based on this idea EGEM was founded.	Founding the EGEM by the information managers of the Dutch municipalities to collect and disseminate best practices. The EGEM was a project within the ICTU. The EGEM was assimilated by the ICTU and is now a separate program.	Upside: Close to organizational realities at the local level. Downside: Agencies can still select other systems.
2000	In the early years of this century, some municipalities started merging their ICT-departments. They found their ICT-budget too limited to meet the targets set by the national government.	The national level reacted to the emerging of ICT-departments and sharing of services at a local level, by looking at opportunities to develop infrastructural building blocks that can be shared by local agencies.	Upside: Concentration of efforts, lowering costs, access to more expertise. Downside: Remaining at a local level and sharing is limited
2002	Each municipality had to develop their own authentication service to provide access for citizens. This could range from a login using name and zipcode to the use of identity cards.	Within the ICTU a new program was started to build an authentication service. Bundling of various authentication efforts into a basic infrastructure building block for creating a nation-wide authentication service.	Upside: Reuse of functionality, concentrating development.

Current developments seem to have the tendency to centralize critical activities after they emerged at the local level, but nevertheless still giving enough freedom to the decentralized level. Which is conforming the ideas of CAS theory. For this purpose interaction points between agencies need to be fostered, but interactions should also be directed by concentrating them. Without concentration the initiatives might not be aware of each other and create much more diversity than is needed and manageable. We also found that breeding diversity is important as this results in better outcomes, however, too much diversity results in large interoperability problems.

5. Architecture design principles

In a CAS, agents interact in an unpredictable and unplanned way. CAS predicts that the agent can never optimize as the space of possibilities is too vast and there exists no practical way of finding the optimum. However, from those interactions, regularities emerged and form a pattern [18]. Choi et al. [9] state that collective influence of schema in a CAS follow a pareto principle, i.e. a few dominant principles dictate the vast majority of behavior. Thus, the generative mechanism organizing a CAS is often referred to as “a few simple rules.”

Hereafter, we derive some simple rules grounded in CAS theory, based on the analyses of the 11 projects. We label them as architectural design principles or guidelines, as they are textual statements that describe the constraints imposed upon the organization, and/or the decisions taken in support of realizing the business strategies and can be used to guide future projects. The principles are based on the primarily findings that solely breeding of diversity is not sufficient, there is a need to have a focal point to concentrate activities and efforts and an increase in the number of interactions result in new and better initiatives.

5.1. Solely breeding diversity is not sufficient

CAS states that the greater the variety within the system the stronger it is to use contradictions to create new possibilities to co-evolve with their environment.

1) *Stimulate diversity/ breed diversity*

The first six projects show that solely breeding diversity is not sufficient for an effective governance of enterprise architecture. The stimulating of diversity resulted in a large number of heterogeneous information systems and numerous interoperability problems. The concentration on a few projects can

breed variety, however, might not result in the desired outcomes as shown by the fifth super-pilots project Budget was allocated, however, the conditions to spend it were not provided. The results obtained from the super-pilots projects were not reusable by other agencies.

Variety is important, but should be created with care. The conditions, such as reusability and the justification for spending the money, should be defined without disputing the autonomy of the initiatives.

2) *Set no targets without providing constraints*

The targets set by the parliament and the Ministry of Interior strongly encouraged the municipalities to adopt. They developed systems, made their content available online and started developing transactional services. As such, the informants found it as a very powerful mean to direct initiatives. The setting of targets without providing any constraint resulted in a variety of heterogeneous systems and accompanying interoperability problems. From an architectural point of view, this can be considered as undesirable. Each city council allocated different amounts of budgets to its ICT-department to accomplish this target, however, all at the same time were duplicating efforts. Each department had to reinvent the wheel and there was no coordination among efforts. A more fruitful direction seems to be to constrain the number of directions that can be taken.

5.2. Concentration of activities

A key characteristic of CAS is that there is no hierarchy of command and control in a complex adaptive system. The best initiatives might be disseminated better by concentrating efforts and creating awareness of this concentration point. This is clearly support by ICTU, which concentrates all e-government related programs within one organizational entity.

3) *Stimulate growth of successful projects*

The basic idea behind this principle is to breed initiatives that might become successful and result in best practices. This also means that projects targeting similar areas and not likely resulting in success should not be supported and discouraged. The current policy is to have several overlapping projects. By using a successful municipality as a reference point for other municipalities, the resources can be concentrated and leading to better results and generate more enthusiasms among the municipalities.

4) *Develop standard infrastructure components*

Information systems are built on top of a complex layer of computer and software infrastructure to communicate with other systems and making easy access to the readily available infrastructure service. Over time a number of basic infrastructure components evolved that were likely to be used by every agency and had limited variety. The reuse of readily available and proven infrastructure components can help to develop new systems quicker.

5) *Develop modular architectures*

Whenever heterogeneous types of systems were developed, there were inevitable giving rise to interoperability problems. Instead of being involved in the design of complex systems architectures, the idea of this principle is to define the basic component functionality and interfaces to invoke the components. This should constrain the variety of systems and ensure that the systems can interoperate with each other.

5.3. Increase cross-boundary and level interactions

CAS is based on the concept that the ways in which the agents in a system connect and relate to one another is critical to the survival of the system and is more important than the agents themselves. As such, enterprise architecture should provide interaction points that foster the building of relationships among agencies.

6) *Stimulate sharing*

The municipalities are free to design their own systems and choose the means to accomplish this. Municipalities started looking for innovative ways to accomplish the targets set at the national level, and after budgets were cut, targets could not be met on their own. Sharing of ICT-departments, functionalities, services at a local level helps to reduce costs, also increase the available budgets in this way providing access to expertise and systems formerly out-of-reach.

7) *Develop competencies*

If people at the local level have not the competencies to fulfill a particular task, they are unable to adopt the results of national projects or meet targets. Knowledge and capabilities are necessary to use and integrate the infrastructure components and other results of the ICTU program. There should be mechanisms in place to develop those capabilities. Prior to starting something the necessary competencies should be identified by organizing seminars, starting courses and so on.

8) *Stimulate the formation of coalitions*

The agencies tend to do things on their own and resist the initiatives of the national levels. Coalitions having participants from multiple agencies at a national and local level might breed new ideas.

6. Discussion

6.1. Usability of CAS for enterprise architects

By conceptualizing enterprise architecture as a CAS, public managers can interpret enterprise architecture in a more complete manner and develop more effective interventions. From our case studies, it becomes clear that CAS offers an alternative, interpretative framework to conceptualize the behaviors among actors within the environment of enterprise architecture. Awareness of the architectural principles can help public administrators and managers to target resources for more effective interventions.

To most of the enterprise architects, the principles derived might not be come as a surprise. However, what should be noted is that despite the fact that these principles might be known and intuitively appealing, most of the initiatives of enterprise architecture have failed to implement these design principles. Our objective here is to pinpoint the CAS not only can be used to facilitate conceptualization and better understanding of the underlying dynamics but also can offer the design architects the theoretical underpinnings and explanation to support the selection of design choices and solutions. This can help avoid interventions, which may lead to undesired behavior.

6.2. Balancing central and decentral layers

The networks of public agencies exhibit local as well as global complexity. The decision making occurring at the local level is very different from that occurring at the global level and hence the complexities as well as its measures are different. At a local level other objectives are important than at the global level. The global level aims at balancing the overall interests of the many different local agencies.

The decisions about which functions should be performed at the centralized and decentralized level is a critical decision at a strategic level. Such a decision has a long-term impact can have significant complexity and risks. Peak and Azadmanesh's [24] research suggests that strategies oscillate unevenly between domination of centralization and decentralization, and that commercial computing has already experienced two centralization/decentralization

cycles. They observed that centralization emphasis shifts based on changes in technology. Therefore there is a need for constant re-assessment of centralization/decentralization options.

Designing central infrastructure developed only slowly as each organization is autonomous and controls its own technical architecture and decisions. What seems to work is to wait for the emergence of basic infrastructure components at the local level, generalize and scale them up. Despite this success, the translation of policy into implementations of the basic infrastructure components discussed in our case studies took in average five years.

The development of modular functionality and defining of interfaces to guide systems development seems to be suitable for managing the variety of systems and overcoming the interoperability problem. Determining the granularity of modules, ability to configure and interfaces is no sinecure and more easily stated than performed. In the past, they tried to define the functionality and relationships among them at the national level, which resulted in confusions and lack of adoption. Here, it also seems to be of importance that such system architectures emerge from the local level, instead of trying to define them at a national level.

7. Conclusions

In this paper we developed a broader understanding of use of enterprise architectures in the Dutch public administration by analyzing the key interaction points from a complex adaptive systems (CAS) perspective. A complex system consists of a network of highly interactive and interdependent entities. Rather than being planned or controlled the entities organize themselves into patterns to be adaptive to its environment. From a CAS perspective, a number of relatively simple principles can guide development and a key challenge is to create an enterprise architecture that merely sets the direction for the future, ensures uptake of emerging initiatives, and is ready to adapt and evolve as the environment changes. This ideas matches reality as tight control is not something you can have over a complex system of agencies and projects spanning multiple levels and jurisdictions.

We investigated 11 e-government projects and analyzed the interactions between agencies at a national and local level. We derived architectural design principles using complex adaptive systems theory that can be used by enterprise architects to direct further projects. They are based on the primarily findings that solely breeding of diversity is not sufficient, there is a need to have a focal point to concentrate activities and efforts and an increase in the number of interactions result in new and better

initiatives. We found that the CAS lens can help to facilitate conceptualization and better understanding of the underlying dynamics. Moreover, CAS theory offers enterprise architects the theoretical underpinnings and explanation to support the selection of design choices and solutions.

Although we derived the architectural design principles based on interviews using CAS as a metaphor. We did not validate the application of these principles in new projects nor did we develop a model of the complex adaptive system. Future work should focus on evaluating the implications of principles on complex-adaptive systems. A multi-agent simulation model might be used, as agents can be used to model the behavior of each individual entity and the aggregate behavior of individuals can show the dynamic and emergent behavior over time (e.g. [21], [26]). Once an agent-based model is created, various parameters can be manipulated and rules could be modified in order to study the emergent outcomes. In this way the implications of design principles can be evaluated and used to modify the design principles.

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