2011

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June 12 - 15, 2011; Bled, Slovenia

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A Framework

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Abstract

The Internet-of-Things (IoT) concept has been gradually developing, but it is unclear how extensive this concept is adopted within the supply chain domain. We derive an architectural framework to investigate four layers of ICT deployment. This framework enables practitioners and scientist to specify a status quo on different architectural levels and to identify possibilities for further improvement. Four extensive cases are investigated with this framework. One of the important conclusions is that "IoT" like technology and applications are pioneered in research programs, but operational logistic systems in diverse organizations primarily rely on less advanced technology, organizational structures- and work forms. This work can help in identifying gaps where IoT can strengthen future applications.

Keywords: Internet-of-Things (IoT), Maturity Model, Supply Chain, Enterprise System, Logistics

1 Introduction

It is 2011, and in our current networked society we increasingly speak about the Internet-of-Things (IoT) (Ngai *et al.*, 2008; Buyya, 2009; Atzori *et al.*, 2010; Chui, 2010). In this paper we focus on how this IoT concept is adopted within the supply chain domain. IoT is not merely a new technology, but requires a complete different mindset and process orchestration between partners in supply networks. The prior concepts in SCM have been built to a large extend on the premise that collaborative

planning and information exchange with partners is positioned as the instrument to cope with uncertainty and to improve the overall supply chain (Lee, 1997) (Lambert and Cooper, 2000), and its robustness (Chen, 1999). The extensive literature review by Giunipero *et al.* (2008) concludes that organizations tends to concentrate more on an individual firm's operations rather than the wider supply chain function.

We recognize a "Status Quo" on the adoption of IoT in the supply chain domain. On the one hand RFID, event-based and sensor like technologies have been implemented in this domain, but on the other hand the entire adoption of the networked way of thinking -and working seems to hold back.

The contribution and objective of this paper is twofold:

First, we present an architectural framework to investigate four layers of ICT deployment. This framework enables practitioners and scientist to specify a status quo on different abstraction levels and also to identify possibilities for further improvement.

Second, we apply the framework on a total of four case examples. The framework's legitimacy is illustrated by mapping the past (before the case-intervention), the current (after the case intervention), and the potential for future improvements. The cases are non-exhaustive, but provide nevertheless a representative sample of IT in supply chain industry cases from the last decade.

2 Explanation of our framework

2.1 Research approach

Our framework is derived on taxonomical foundations (Parr & Shanks, 2000; Baily, 1994; Christopher *et al.* 2006). We started with the ambition to take a retrospective view into our extensive case material and investigate patterns between these cases. Our case material goes back to the beginning of this century and includes multiple cases of IS deployment in the supply chain. In this time period we have been observing various developments in business process reengineering, the implementation of packaged software and ES, towards the more recent first footsteps of agent based supply chain software. In this paper we discuss four cases. In each of the cases two or more of the authors mainly have been involved using action research, participant observation, interviews and design science. Three of the cases stem from longitudinal PhD studies (Douma, 2008; Katsma, 2008; Moonen, 2009).

To position and investigate our various cases we decided to take a wide angled research lens and use the domain of enterprise architecture (Lankhorst, 2005). In this domain various methods and models are available. For our research objective the architectural TOGAF model (The Open Group, 2009) is applicable as it depicts enterprise architecture in an open format of four layers; Business (1), Application (2), Information (3) and Technical infrastructure (4).

Figure 1 shows our framework that includes four (maturity) levels from left to right. We label them by the main technological driver; from ERP towards the Internet-of-Things. The four levels have not been selected arbitrarily, but depict four distinguishable advancements of ICT in the logistic -and supply domain. The ERP concept on the left stems from the beginning of the nineties in the last century. But its technology and the

accompanying other characteristics in our framework are still relevant and valid in many case situations. For each of the four levels in our framework we identify the accompanying attributes on each TOGAF layer. We start the explanation of the framework at the business level.

Level	*ERP*	*ERP 2.0*	*SOA/SAAS*	*Internet-of-Things*
Business	Singular Process optimization (focus within the business functions)	Optimization of the entire processes, with sub-optimization in the nodes (functions)	Dynamic optimization of entire supply chains	Agile & Networked optimization
Application	Integration of functional information systems	Extension of original ERP concept with bolt-ons (SCM, CRM and advanced planning)	Dynamic Integration between the various services & systems (MDA, BPEL).	Integration and application functionality is event driven and orchestrated by agents
Information	Emphasis on Transaction based data, efficiency and cost in data use	Integration and semantics between process nodes	Full Interoperability between various systems or services	Semantic web
Technical infrastructure	All IS internally (COTS)	Externally hosted systems (ASP)	Externally hosted services (SOA enabled SAAS)	Cloud Services & Mash-Ups, SAN

Figure 1: Framework based on the TOGAF model

2.2 Business Layer

The TOGAF model for this layer specifies the organizational structure; business process deployment, business strategy, organization, and key business processes of the organization. Before the rise of ERP and Enterprise Systems in the nineties, most organizations used isolated information systems that supported distinctive business functions. Organizations started reengineering initiatives to align processes and organizational units. Our first level in this business layer is specified by optimization of processes within the organizational entities. Organizations have been confronted with significant difficulties to transfer their organizational structure, competences and work force to really adopt working in end-to-end processes.

The increase in standardization in the last decade lead to inter-organizational collaborations and optimization in entire supply chains, e.g. in the automotive sector (Lee, 2004). This marks the second "maturity" level on the business layer. Increasing globalization caused the need for agility in these supply chains. Besides organizations also adjusted to their core competences while releasing supporting business functions or outsourcing them. This marks level three in our business process layer and marks the transfer of more service oriented organizational structures.

The recent developments in the ICT industry enable and force organizations to adjust their business models even more swiftly than before (Friedman, 2005). This is expected to make organizations change their structures in networked or community-based forms. Present formal structures still sometimes prohibit these organizational forms, but it is expected that cell based or community based organizations will develop in the near future. This specifies level four in our model. Expertise cells or service centres based on

their specific competences or excellent efficient performance deploy will specific services or parts in the supply chain. These agile organizational nodes are shaped in various forms and are able to create ad-hoc collaborations that are not necessarily chain oriented.

2.3 Applications Layer

This layer describes the individual information systems deployed in the organization. It specifies the interactions between the information systems and their relationships to the core business processes of the organization with the frameworks for services to be exposed as business functions for integration. The development of applications partly is described in the prior business layer. But more specific we see the following distinctive developments on the applications layer.

According to Davenport and Brooks (2004) early ERP was not primarily focused on the supply chain. But organizations that were able to attach SCM solutions to their ERP structure were able to gain benefits. This elegantly describes the first level in our framework. The second level describes the evolvement by package vendors in their adjustments of their ERP systems towards ES. The latter included the complete information functionality for entire organizations and incorporated advance logistic planning engines over entire supply chains.

Level three marks the adoption of the service based architectures. Organizations have been adopting integrated information systems since the beginning of the nineties. Real integrated implementations mostly have been accomplished after several reimplementation efforts. This era is followed by the adoption and transfer of a service based application functionality. This level of application maturity has not been finished as the real transfer from enterprise packages to service based applications currently is in full swing.

Recent developments in research shows agents based applications are the next trend. The rise of interoperable web-standards, API's and services offer agents or distributed negotiation protocols the possibility to fully or semi automatically support parts or entire business processes. Integration and application functionality is orchestrated by agents themselves depending on various business situations, as can be seen in the travel domain in the last three years. This functionality also is arriving in the logistic ICT arena.

2.4 Information Layer

The information and data layer describes the structure of an organization's logical and physical data assets and the associated data management resources. It also describes how organizations deploy the management of information with for example business intelligence, knowledge management, etc. In this paper we put a specific focus on interoperability and standardization, but especially how data is entered and transformed in logistical planning operations.

Information in the upper left first level mostly is entered manually and the ERP facilitates hard coded, but integrated core data in one central database. Semantic differences between partners in the supply chain often are problematic in this level. This level is extended by an increase in data interoperability by EAI on level two, where

OCR and barcode techniques support the data entry process. This level also realizes semantic integration between partners in the supply chain.

Level three offers complete data interoperability in entire supply chains. RFID technology is used in this level as data entry method. The last level, on the right in the framework concerns the IoT concept for the information layer. Self-sensing networks create and transfer data, where interoperability is realized on a semantic level by the semantic web concept.

2.5 Technical infrastructure Level

This layer describes the hardware, software and network infrastructure needed to support the deployment of core, mission-critical applications.

This last technical layer is the essential driving force behind most innovations and changes on the prior explained layers. Our first level in this layer includes the first dedicated ERP systems like Baan and SAP in the beginning of the nineties. These IS are hosted within the organizations themselves and are based on the first client server architectures and departed from the old host based solutions in the 70' and 80's. In this first level on the far left column of our framework the data entry in the business processes is executed by hand.

Level two includes the further development of Enterprise Systems, sometimes described as ERP 2.0 (Møller, 2005). Classical bolt-ons like CRM, SRM and SCM now are built in the ES and often these systems are hosted via ASP or three tier architectures.

Level three characterizes the transfer from entire configurable packaged software towards Enterprise Systems based or supported on webservices and SOA based architectures. This level marks the entrance of architectures where data, application and service architectures physically are separated by the use of internet standards.

Level four is the extension of SOA and SAAS towards individual cloud based services and mashups. Packaged software is exchanged by smaller web components from various vendors. Data storage is cloud based (e.g. amazon's EC2, SAN storage). This level exemplifies the technology necessary for the Internet-of-Things. Currently the technology is able to support this vision, but a broad adoption is expected in the forthcoming decade.

2.6 Framework deployment

Our framework can be used to assess an organization by specifying the case situation on all four architectural layers. Figure 2 shows the graphical representation the framework, with its four architectural layers; B, A, I and TI. By positioning two colour codes in the four different levels (I, II, III and IV) it is possible to distinguish before and after situations. This firstly specifies the status quo of the case situation. Secondly it also is possible to depict the vertical alignment between the four architectural layers. This gives an indication on how well the organization in this specific case is aligned. Thirdly the graph also specifies potential improvements for the future.
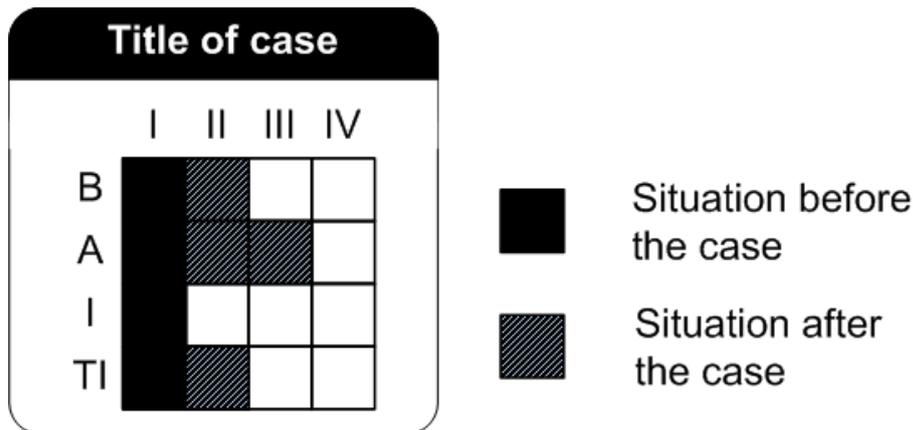
Figure 2: Deployment of the Framework

It is important though to be aware that our framework can be used to inspect different abstraction levels. It can be deployed to investigate an entire organization, but also focus on parts or an entire business process. In the latter situation the various quadrants can be assessed for different processes and a combined map then covers the situation for the entire organization. Not all business processes in a company are equal. Some are highly operational transactional processes, such as order fulfilment, whereas other processes have way more a one-off character and have a more strategic character, such as partner selection. Goldkuhl names this the Business Action Theory, a frequently cited division in six different phases, originally tracing back to his (Goldkuhl, 1998) paper:

1. Business identification phase
2. Exposure and contact search phase
3. Contact establishment and negotiation phase
4. Contractual phase
5. Fulfilment phase
6. Completion phase

In this paper we focus on phase 5. In other words, the involved organizations show a mature and stable cycle of planning, ordering, shipping and receiving materials. The information system solutions in the four cases all cover the major planning support in this cycle. But the four cases show a large variance in how they operate this fulfilment phase on the levels of our framework. We selected four cases to illustrate our framework based on the involved actors in the respective planning horizon of the case.

3   Cases

3.1   Introduction of the four different cases

We selected a total of four cases we have been involved in over the last five years. All projects deal about the logistical planning function, although all include a slight different scope and objective. We selected these cases based on the amount of inter-

organizational complexity. Figure 3 displays the four cases and shows that they span from a single organization towards a completely inter-organizational network.

Case #1 deals about the materials management, logistic planning and supply information system of a western European army and its ministry. This is a mono organizational case, as it deals in essence about the internal logistics of the defense organization. Nevertheless in its complexity this case is interesting as it covers the merge of four force units into one with an extensive number of SKU's and exotic materials and supply planning. Case #2 describes a case in which wireless sensor networks are utilized to redesign construction plant processes, from the perspective of a manufacturer of concrete. Case #3 describes the design of a new planning system for the real-time control of truck-to-order assignments, and is a case in which information from other organizations (namely the customers and suppliers of the focal firm) are important, however, these organizations are not directly participating in the system other than that their information is brought in. Case #4 describes the work on an inter-organizational system for the Port of Rotterdam in which barge operators and container terminals are helped with a system which helps in smoothing the operations of all parties involved by resulting in better coordinated barge rotation schedules. Hence, it exemplifies an inter-organizational structure, however, lacking ownership currently withholds real implementation.

Planning horizon	Single organization	← →		Inter organizational network
Case	#1	#2	#3	#4

Figure 3: organizational complexity of the four cases

3.2 Case #1: ERP implementation at a Ministry of Defense
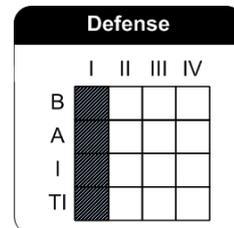
3.2.1 Case description

A large western European ministry of defense is confronted with outdated legacy systems and budget cuts at the beginning of the millennium. Both problems are addressed by joining its four forces into a new organizational structure combined with the implementation of one SAP solution. This solution covers the logistic, financial and operations management processes, but excludes the already implemented HRM COTS solution. One of the authors participated in this case over a period of two years and investigated the business blueprinting stage. In this case an action research approach was used to investigate how the redesign process was organised and deployed. It includes in depth field studies of the project teams that redesigned and integrated finance and budgeting, planning operations and materials management processes. But also the redesign and formation of the new created integrated service unit from the four independent forces (Katsma, 2008). The research focus was on the change process

itself, acceptance in the organization, quality of the business process redesigns, information integration, and the functional deployment in the SAP system.

3.2.2   Case intervention – business layer

During this implementation the organizational structure is transformed from 4 separate organizations that mostly are functionally organized into one organizational service centre that adopts integrated planning and materials management. The planning process especially is important as joined operations increasingly are required and the reorganization offers a savings of 1080 FTE and annual savings of 80M€. Speaking in terms of the levels in the framework, this is a step up from non-existing (Level 0) to the first level in the framework.

3.2.3   Case intervention – application layer

Prior to the implementation the four force units each deployed their own materials management and planning systems (level 0 in the framework). The merged planning, organization uses defense specific maintenance and planning functionality covered by three SAP modules. The amount of customization is low as best practices have been chosen as standard.

3.2.4   Case intervention – information layer

This implementation includes an extensive data cleansing effort. Data integration is realized within the package but also extensive time and effort is put into realizing unanimous data semantics between the several organizational units. Data entry in this process is mainly supported by terminals and bar code scanners (also reaching level 1).

3.2.5   Case intervention – technical infrastructure layer

The legacy systems were hosted by one defense wide service organization. This same organization now hosts the ES. Several legacy applications in the four force units are turned off during this implementation, but indispensible weapon specific systems are tied to the SAP package. The implementation is a classic three-tier client server architecture. A negligible amount of SOA is used. Mostly to connect to the indispensible weapon specific systems.

3.2.6   Potential for further improvements

The ES implementation in the historical perspective seems outdated as large SAP packages have been implemented for over 20 years. On the other hand this case is exemplified by its magnitude. This organization made a giant attempt to reorganize its organizational structure and business processes. Strong improvements have been achieved, but the envisioned integrated logistic concept still is not realized completely and therefore on the business and application level there is substantial potential. Besides on the information and technical infrastructure layer other forces have shown what is possible. The US defense forces for example have been deploying RFID technology in the last 5 years successfully.

3.3 Case #2: MASSCO, agents & sensors to replenish construction sites
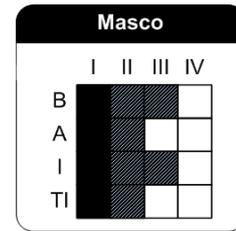
3.3.1 Case description

Construction sites are heavily dependent on transportation of resources and materials, as space on construction sites is relative scarce and limited. The MASSCO project focused on the realization of a new planning system aiming at a reduction of the (total) transport mileage, while decreasing the amount of delay due to stock outs. Topic of study was the (re)placement process of dry mortar.Mortar is one of the ingredients for producing concrete, by mixing it (on site) with water and sand.

In this project we chose to combine a multi-agent system (MAS) with real-time sensor technology to empower a more intelligent delivery process. The sensors helped to get real-time insights in consumption patterns of all silos installed, the MAS helped in assigning proper fulfilment routes. As a result, delivery is not necessarily driven by stock-outs, as is largely the case in the existing offline scenario, but can also be triggered by the fact that a neighbouring site is to be replenished and the delivery truck has spare capacity.

In the project we did research a design for such a system extensively through simulations, with interesting results. Also the sensor system was tested in real practice, with good results. Near future will show real implementation, as also a mortar company was involved, and a company active in software systems for construction site planning. Potential does go, of course, beyond the scope of solely mortar related activities.

3.3.2 Case intervention – business layer

Although only focusing on one particular process, this system introduces a chain wide optimization approach (level three), leaving possible ground for extension into other construction site related delivery activities. Before the processes of mortar supplier and construction site were largely disconnected (level one),.

3.3.3 Case intervention – application layer

Prior to the implementation the mortar supplier and the construction sites had no integration other than contracts and telephone/fax communication. This design makes integration of construction site data into the advanced planning system explicit by linking up. As such from level one to two in terms of the framework.

3.3.4 Case intervention – information layer

Data collection importantly changes in this design, and is fully automated utilizing self-organizing wireless sensor networks. We see a step up from one to three.

3.3.5 Case intervention – technical infrastructure layer

The technical infrastructure in the design includes webservices, sensor systems, GPS data, et cetera. Although mash up functionality is used we basically deal about an ASP type of infrastructure (growing from level 1 to 2), as the mortar company itself is the initiator in this system. The construction sites have web-access to their system for manual adjustments and looking up statuses; the wireless sensors connect autonomously.

3.3.6 Potential for further improvements

Further improvements can be made especially at the application layer, making this a basis for other construction site related delivery-coordination. Hence however, that the initiator of this system is solely active in mortar supply, and might not be interested in that.

3.4 Case #3: Real-time container truck planning
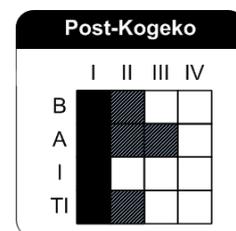
3.4.1 Case description

This case refers to a research project in which a prototype system has been developed for planning road-container transport at Post-Kogeko, a Logistics Service Provider in The Netherlands. Although logistics is often referred to as a potential candidate for the application of multi-agent systems (MAS), this research was to our best knowledge one of the first experiments with MAS in the real practice of logistics. The created prototype let us evaluate a series of aspects important in applying MAS in transportation (Moonen, 2009) (Moonen and Van Hillegersberg, 2011).

The multi-agent system (MAS) designed is a real-time planning (support) system to support truck planning processes. In Goldkuhl's (1998) terms, this is the fulfillment phase. The MAS consists of different types of software agents monitoring their environments. This includes TruckAgents monitoring truck movements, traffic jams, and keeping track of their expected time of arrival (ETA), and OrderAgents monitoring container availability and customer preferences. Truck(Agent)s negotiate in real-time with Order(Agent)s about assignments, and utilize a mechanism that considers the order details (minimizing lateness of orders), the movements of the fleet, reduction of empty miles, and potential delays due to traffic jams. As such, a central assignment mechanism is absent.

The prototype has been evaluated and validated applying four different methods, including an in-company field test – see the UI developed and utilized in Figure 4. The combination of different methods, with different balances between rigor, relevance and control was useful in getting a balanced insight in the potential of MAS for transportation (Moonen, 2009).
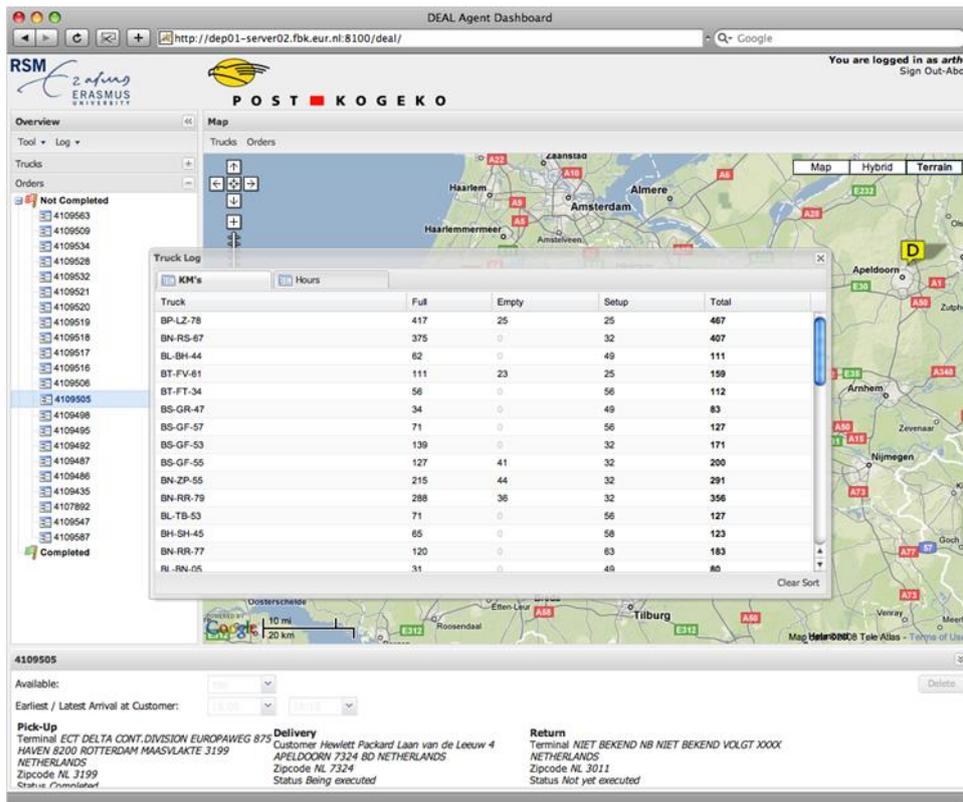
Figure 4: The prototype user interface, showing the log dialog panel

3.4.2   Case intervention – business layer

During the design and implementation of the prototype the organizational structure is transformed from an internally focused organization into an organization that connects more explicit with partners' up- and downstream systems. This is an important step, as improvement of the basic process of transportation (of containers) requires stringent coordination with suppliers and customers. In terms of the framework, a step was made from level one to two.

3.4.3   Case intervention – application layer

Prior to the implementation the container planning's systems were little integrated with up- and downstream parties (level one in the framework). The novel design leans on a combination of model driven application integration with software agents monitoring changes in status, linkages to existing databases and an existing GPS based tracking and tracing system. Before, the human planner was the integrator of information sources, in a process in which the phone and fax played an important role. As the deployed software agents are limited in scope, and aspects such as automatic discovery are no integral part of the prototype, we plot the application layer at level three.

3.4.4   Case intervention – information layer

Data integration is little changed in the design and implementation of the prototype. The system leans on the same data and same input sources as were present before. The level therefore remains where it was: level one.

3.4.5 Case intervention – technical infrastructure layer

The software agent based integration platform which also offers a user interface which utilizes mashup components is externally hosted on a (university) server. The users access the system through a browser based interface, and are able to control most of the underlying systems from there. In the technical infrastructure of the existing systems nothing was changed. In terms of the framework we can thus speak of a move from level one to two.

3.4.6 Potential for further improvements

As this case describes a large research project which did not yet result in a concrete implementation potential for improvements can be found at different levels. First is real implementation itself; looking at the different elements in scope in the existing solution we furthermore see especially a gap in the architecture at the information layer, which was largely untouched in this project, whereas smarter data entry and discovery of patterns in the data might be of great value to the case.

3.5   Case #4: Barge rotation planning in a sea port
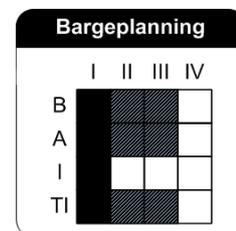
3.5.1   Case description

The Port of Rotterdam is a key container transshipment hub for Europe. Since the early 1980s, the river Rhine has increasingly been recognized as a 'natural' connection with the German hinterland. Currently commanding a 40% market share, inland container shipping with barges has in recent decades developed into a vital hinterland connection.

However, supply chain inefficiencies do exist. The pre-planning of terminal visits is recognized as one of the key problems – it is a process asking for a synchronization of activities between the barge operators and the container terminals. Currently, this planning is performed manually – which results in local-optimizations. When a barge visits the port, it has to call on several terminals to load and unload containers. To guarantee short sojourn times in the port, the barge operator (BO) schedules convenient arrival times at the concerning terminals. The terminal operators (TO) on the other hand want to operate efficiently and have to decide when a barge can be processed, taking into account all kinds of restrictions, e.g. specific times at which containers need to be at the terminal.

A new agent based planning approach, topic of research in a series of projects for about a decade now, shows substantial increases in fuel and time efficiency. But also enormous challenges from an implementation and adoption perspective due to its inter-organizational nature. See for example the research results by (Moonen *et al.*, 2007), (Douma, 2008), (Moonen, 2009), and (Eckartz *et al.* 2010). All three authors participated in this extensive project. During a period of approximately three years we deployed an action design research (ADR) (Hevner *et al.* 2004) approach. Our work started with a review of a first system design (Moonen *et al.*, 2007), followed by the

logistic agent concept described in Douma (2008). In hindsight we helped the network of involved actors on the four layers to come up with a viably and implementable solution. During the process we co created solutions with a stable set of stakeholders from the various participating organizations. Our ADR work includes a mature specification of the necessary technological architecture and functional agent system definition. First initiatives are deployed on creating an inter-organizational business case that specifies the value and cost for each of the stakeholders.

3.5.2 Case intervention – business layer

All research, simulations and designs made for the barge rotation coordination system have been focusing on establishing a real inter-organizational coordination system. Instead of little information exchange between parties, this system relies on extensive exchange of information between parties. Plotting this in the framework we see a move from level one to three.

3.5.3 Case intervention – application layer

Prior to the implementation the barge operators were little integrated with the container terminals and vice versa (level one in the framework). The novel design leans on a combination of integration with software agents and connecting BPEL processes - hence the main application foundations come closest to level three in the framework, but agent technology is also used.

3.5.4 Case intervention – information layer

Data collection is only slightly changed in the design and implementation of the prototype. The system leans on the same input sources as were present before. In this case the level remains where it was: level one.

3.5.5 Case intervention – technical infrastructure layer

The technical infrastructure in the (future) implementation leans heavily on externally hosted services, to run functionality and to deliver connectivity (level three). Before, all parties in this inter-organizational landscape had their own internal systems - often as limited as Excel based planning sheets. Now these point solutions are connected and unleashed in the larger inter-organizational coordination system.

3.5.6 Potential for further improvements

This case is also an example of a project, which has not yet resulted in an implemented fully working system, although important steps have been set over the past years (Eckartz *et al.* 2010). Utilizing the framework we see a discrepancy in the design of the information layer, where the level remains as it were – which can partly be explained by the operational focus of the design utilizing existing data. This might be an interesting starting point for future work. Speaking in terms of functionality, we see potential for further inter-organizational functionality, such as swapping/exchanging orders between barges – which can only be achieved with such as system in place.

4 Cross case analysis and Discussion

4.1 Cross case analysis

Our cross case analysis in Figure 5 shows that three cases start entirely at level I. Case #1 took extensive decision time to decide on implementing an ES and leaps from level 0 (outside the framework) towards level I.

The cases, #2, #3 and #4 show a high ambition level. These cases all are part of subsidised scientific research programs, exploring future applications. Case #1 is a pragmatic commercial implementation that apparently aims at achieving level I at all architectural levels. Two cases (#2 and #4) adopt agent technology.

All cases, except for the second case, do not realise great advancements on the information layer. Logistic planning processes require quick and reliable operational data, but apparently in these four cases little business intelligence, data-mining or meta-data analysis was deployed, let alone entirely more ontology driven semantic data formats.

Vertically we see that developments occur at mostly more than two architectural layers. And that vertical alignment is relatively stable, with mostly one layer which lacks behind. Having only analysed four cases this is not enough proof to derive to generalization, but might be an aspect to search for in follow up work.
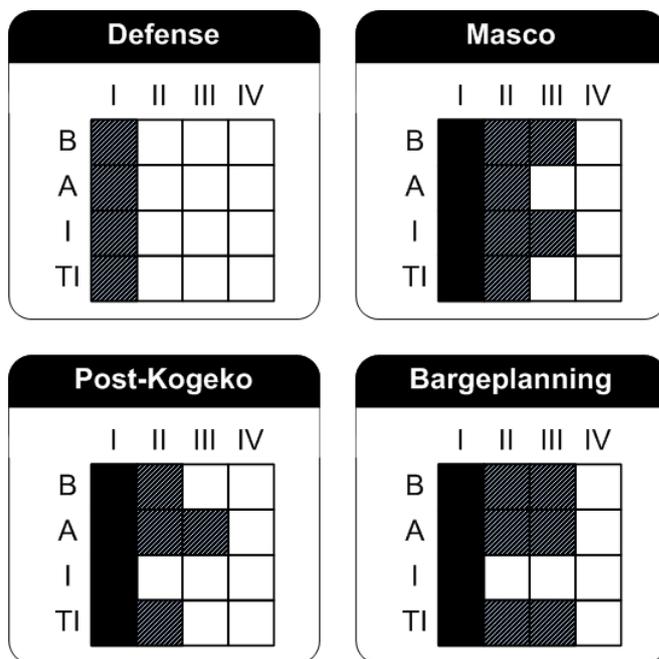

Figure 5: Comparison of the four cases

4.2 Discussion

In this paper we presented an architectural framework to specify architectural development aspects of information systems for logistical planning and investigate how the Internet-of-Things concept has arrived in this domain. We observe that three of the

four recent cases show adoption of IoT elements to some extent; the framework pinpoints these developments. One strong conclusion from our framework inspection is that three cases show mutual differences on specific developments towards IoT in the respective layers. Although these cases intend to adopt the IoT concept, they have their respective layers that do not fulfil the IoT level. In the three cases the business and application layer lead the way, but the entire adoption of the IoT concept is not yet complete, especially the information layer, but also the technical infrastructure layer, have received less attention within the described projects.

Despite the clear division in four architectural layers, each with four different maturity stages, we faced difficulties positioning the four cases within the framework. Analyzing the cases we had ample debates among ourselves where to exactly position cases. Plotting the cases into the framework depends on the attributes of the 16 different panes in combination with the available case material. Our framework originally is created based on the TOGAF template, but enriched and further specified with a logistical information systems mindset. Our available case material is extensive and rich in format. Nevertheless there is a severe difference between case #1 and the other cases. The first case is an extensive decade-long implementation project, with hundreds of people involved in design and implementation, which is now changing the entire organization. The three other research projects do follow a more proof-of-concept kind of approach, and with only a tiny fraction of the amount of people involved compared to case #1. Hence that the research cases (case #2, #3, #4) where limited in their exact scope, changing only part of the processes – often leaving existing elements at a lower maturity level – which in turn made it sometimes difficult to plot accurately.

This framework is tested in one specific domain; the domain of logistics information systems focussed on operational processes. Nevertheless we expect that the framework can be deployed across other domains or within the logistical domain for different processes due to its generic format. The framework is strong in enabling structured comparison between cases on abstraction levels and also in investigating alignment of aspects within a case; hence also to spot architectural domains for further improvement.

Considering cases we find in recent literature and our own involvement in other projects, we selected the four selected cases. Pragmatically we went for cases with our full involvement, as it is better not to compare solely papers or dissertations but to have access to full details of the case. Furthermore we selected cases related to developments in IoT that all carried their own unique aspects. The cases do importantly differ in the amount of inter-organizational complexity– see also Figure 3. Together these constitute a diverse set of cases, representative for the work currently going on within supply chains. An important next step is to test and evaluate the framework with other case material, and to investigate its efficacy concentrating on the question whether this is a useful instrument in identifying points of improvement for next generation enterprise applications driven by the IoT.

The first layer, the business layer, in the framework is supply chain specific. Considering the division made by Goldkuhl (1998) we foresee application of the framework as-is throughout all the different stages described. However, this business layer should be adapted in case of application within another domain. The other layers are more generic as these cover more enabling and supporting technologies.

Another possible improvement to our work might be to explore an increase of the framework's granularity; e.g. by creating more panes, or specifying more attributes within each pane. This would make the framework scientifically sound and increase its validity, but on the other hand would decrease its applicability. At the moment we tend towards an applicable and simple structure as it is, but we are open for discussion and alternative suggestions

References

Atzori, L; Iera, A; Morabito, G. (2010). "The Internet of Things – A Survey". Computer Networks, Volume 54, pp 2787–2805, 2010

Bailey, K. D. (1994). "Typologies and Taxonomies: An Introduction to Classification Techniques". Los Angeles, Sage Publications Inc.

Bellifemine, F. L., G. Caire (2007). "Developing Multi-agent Systems with JADE", Wiley.

Buyyaa, R., C.S. Yeoa, S. Venugopala, J. Broberg, I. Brandic (2009), "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility", Future Generation Computer Systems 25 (2009) 599-616.

Chen, F. G. (1999). "Decentralized supply chains subject to information delays". Management Science 45(8): 1076-1090.

Chmiel, K., M. Gawinecki, P. Kacmarek, M. Szymczak, M. Paprzycki (2005). "Efficiency of JADE agent platform". Scientific Programming 13(2): 159-172.

Christopher M, Helen Peck, Denis Towill, (2006) "A taxonomy for selecting global supply chain strategies", International Journal of Logistics Management, The, Vol. 17 Iss: 2, pp.277 - 287

Chui, M; Löffler, M.; Roberts, R. (2010). "The Internet of Things". McKinsey Quarterly, Volume 2010, Number 2.

Davenport, T. H. and J. D. Brooks (2004). "Enterprise systems and the supply chain". Journal of Enterprise Information Management 17(1): 8.

Douma, A. M. (2008). "Aligning the Operations of Barges and Terminals through Distributed Planning". BETA Research School for Operations Management and Logistics. Enschede, University of Twente. PhD thesis.

Eckartz S., C. Katsma, M. Daneva, (2010), "The Inter-organizational Business Case in ES Implementations: Exploring the Impact of Coordination Structures and Their Properties". Communications in Computer and Information Science, 2010, Volume 110, Part 3, 188-197, DOI: 10.1007/978-3-642-16419-4_19

Friedman, T. L. (2005). "The world is flat". New York, Farrar, Straus and Giroux.

Goldkuhl, G. (1998). "The six Phases of Business Processes - Business Communication and the Exchange of Value", Proceedings of the Beyond convergence: The 12th Biennial ITS conference - ITS´98, Stockholm.

Giunipero, L.C, R.E. Hooker, S.Joseph-Matthews, T.E. Yoon, S. Brudvig (2008). "A decade of SCM literature: past, present and future implications". Journal of Supply Chain Management, Volume 44 (4): 66-86

Hevner, A.R., S.T. March, J Park, and S. Ram (2004), "Design science in information systems research". MIS Quarterly, 28, 75-105

Katsma, C.P. (2008) "An organizational change approach for ES implementations". PhD Thesis University of Twente, The Netherlands. ISBN 978-90-365-2680-7

Lambert, D.; Cooper, M.C. (2000): "Issues in supply chain management". In: Industrial Marketing Management, Vol. 29, pp. 65-83, 2000.

Lankhorst M. (2009), "Enterprise Architecture at Work: Modelling, Communication, and Analysis". Berlin, Springer, 2009.

Lee, H.L. (2004). "The Triple-A Supply Chain". Harvard Business Review (October 2004): 102-112.

Lee, H.L., V. Padmanabhan (1997). "Information distortion in a supply chain: The bullwhip effect". Management Science 43(4): 546.

Møller, C. (2005), "ERP II: a conceptual framework for next-generation enterprise systems?" Journal of Enterprise Information Management, Volume 18, Number 4, 2005 , pp. 483-497

Moonen, H. (2009), "Multi-Agent Systems for Transportation Planning and Coordination". Erasmus Research Institute in Management (ERIM), ERIM PhD Series, #177, Rotterdam

Moonen, H., J. van Hillegersberg (2011), "Real-Time Coordination in Container Trucking – Prototyping and Evaluating a Multi-Agent System for Real-Time Container Truck Planning at Post-Kogeko". Forthcoming as a bookchapter, edited by J.A.E.E. van Nunen and P. Rietveld, to appear at Springer Verlag, Berlin.

Moonen, J.M., B. Rakt, I. Miller, J.A.E.E. van Nunen, J. van Hillegersberg (2007), "Agent Technology supports Inter-Organizational Planning in the Port." Managing Supply Chains - Challenges and Opportunities. R. B. M. d. Koster and W. Delfmann (editors). Copenhagen, Copenhagen Business School Press.

Ngai, Y. (2008), "RFID research: An academic literature review (1995–2005) and future research directions". International Journal of Production Economics, Volume 112, pp 510–520 (2008)

Parr, A.N. and G. Shanks (2000), "A Taxonomy of ERP Implementation Approaches". In Proceedings of the 33rd Hawaii International Conference on System Sciences-Volume 7 - Volume 7 (HICSS '00), Vol. 7. IEEE Computer Society, Washington, DC, USA, 7018-.

The Open Group (2009), "TOGAF 9 - The Open Group Architecture Framework Version 9," The Open Group, USA, p. 744, 2009.

Zachman J.A. (1987), "A framework for information systems architecture," IBM Systems Journal, vol. 26, no. 3, pp. 276–292.