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A Multi-Usable Cloud Service Platform: A Case Study on Improved Development Pace and Efficiency

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Abstract: The case study, spanning three contexts, concerns a multi-usable cloud service platform for big data collection and analytics and how the development pace and efficiency of it has been improved by 50–75% by using the Arrowhead framework and changing development processes/practices. Furthermore, additional results captured during the case study are related to technology, competencies and skills, organization, management, infrastructure, and service and support. A conclusion is that when offering a complex offer such as an Industrial Product-Service System, comprising sensors, hardware, communications, software, cloud service platform, etc., it is necessary that the technology, business model, business setup, and organization all go hand in hand during the development and later operation, as all 'components' are required for a successful result.

Keywords: big data; case study; circular economy; data collection and analytics; development; efficiency; improvement; multi-usable cloud service platform; pace

1. Introduction

This paper addresses a micro small and medium-sized enterprise (SME), Adage AB (hereafter the company), in Sweden and its journey of developing and operating a multi-usable cloud service platform for big data collection and analytics. The company is a spin-off from BnearIT AB, an IT-consulting company, and was founded in order to commercialize and productize technology and ideas from BnearIT AB's participation in European research and development projects, customer interactions, and requests. The journey is described as a case study spanning three contexts: construction and prefabrication (monitoring of hardening process for concrete molds), real estate (monitoring of humidity inside of exterior walls), and recycling management (monitoring and optimization of recycling of glass, paper, metals, plastics, etc.). The latter context will be given the most emphasis, as it is the most interesting and developed one.

Many companies have a need to monitor, predict problems or maintenance need, and simulate and optimize production equipment or processes. The equipment, such as vehicles or machines, and buildings and real estate, as well as infrastructure like railways or tunnels, is subject to optimization of time, effort and money spent regarding development, operation, and maintenance. At the same time, more value is expected to be delivered as the surrounding society and technology continuously develop, become more sophisticated, and learn more about what can be expected or demanded. This is a challenge and this paper provides some insight into how a multi-usable cloud service platform, based on the industrial internet and internet-of-things (IoT) paradigms, can efficiently meet this challenge.

The research question in the paper is "how much improvement has been made and how has Adage AB managed to maintain a high development pace and efficiency throughout the development and simultaneous operation of the cloud service platform?" Further, the problem addressed in the paper is how the company has managed to develop applications for three contexts in an efficient and scalable manner. Besides the technical issues, a number of related matters that the company has overcome are also analyzed and discussed.

2. Related Work

The paper spans a number of research areas and the related work below were selected due to that the cloud service platforms are the most central entity and have a large impact on the research question. Further, brought up are also important issues such as security, trust, privacy and legal matters, which all are business critical and support the cloud service platforms. Traditional security may not be possible to reuse in a legacy manner and needed are new security, trust and privacy mechanisms as well as security frameworks. In addition, some benchmarking examples, regarding improvement in development pace and efficiency, are summarized.

2.1. Multi-Usable Cloud Service Platforms for Big Data Collection/Analysis and IoT

As the amount of data that various actors want to process increases, traditional data and analytics are beginning to meet their limits; an emerging solution for large-scale data collection and analytics is cloud analytics. Demirkan and Delen [1] demonstrate a conceptual architecture of service oriented decision-support, which includes data warehouses, online analytic processing, operational systems and end-user components. This is something that many other actors pursue as well, and three main cloud service offerings are distinguishable: Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS) [2]. However, there are quite a few more specialized offerings emerging as well, such as Security-as-a-Service and Identity-as-a-Service, complementing the three main ones. Further, Derhamy et al. [3] categorize a number of different cloud service platforms for IoT as: global cloud, peer-to-peer and local cloud. In addition, often "fog" or hybrids of global and internal clouds are positioned in between the global and local cloud paradigms. Regarding the **global cloud**, for instance, some of the largest and most used cloud service/computing platforms, briefly described below, are: Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform and IBM Bluemix—which are:

- AWS, a subsidiary of Amazon.com, offers a suite of cloud computing services that make up an on-demand computing platform. AWS has more than 70 services, spanning a wide range, including computing, storage, networking, database, analytics, application services, deployment, management, mobile, developer tools and tools for the IoT [4].
- Microsoft Azure is a cloud computing service created by Microsoft for building, deploying, and managing applications and services through a global network of Microsoft-managed data centers. It provides SaaS, PaaS and IaaS, and supports many different programming languages, tools and frameworks, including both Microsoft-specific and third-party software and systems. The offering includes: data analysis, network, storage, databases, IoT, enterprise-integration, development and monitoring [5].
- The Google Cloud Platform is part of a suite of enterprise services from Google Cloud and provides a set of modular cloud-based services with a host of development tools. Their product portfolio includes: computing, storage and databases, networking, big data, machine learning, management tools, developer tools, and identity and security [6].
- IBM Bluemix is a PaaS that supports several services and programming languages including Java, Node.js, Go, PHP, Swift, Python, Ruby Sinatra and Ruby on Rails and can be extended to support other languages such as Scala. It also includes offers such as infrastructure computation, storage, network, mobile, Watson, data analytics and IoT [7].

Thus, there are quite a few multi-usable cloud service platforms. However, many of these do not have an effective and cost-efficient way to integrate and later operate many IoT-devices from a variety of manufacturers on a long-term basis.

Concerning **peer-to-peer**, Derhamy et al. [3] outline, for instance, the platforms and frameworks, etc. from IPSO, Thread, ThingSquare, IzoT, SEP 2.0, AllJoyn and IoTivity, which have approached IoT application development from a device level and support a high level of peer-to-peer operation, a functional solution for home automation as well as device management.

Currently, the **local cloud** is targeted mainly by the Arrowhead Framework [8], which addresses many challenges related to IoT-based automation, and is unique in its support for integration of applications between secure localized clouds. The approach is that IoT devices are abstracted as services in order to enable interoperability between almost all IoT devices. A local cloud based on the Arrowhead Framework provides improvements, compared to global clouds, regarding: realtime data, data and system security, automation system engineering and scalability of automation systems [8]. Thus, the Arrowhead Framework adds a "glue" to various IoT devices, etc. during the development/integration phase and later operation.

Further, with the emergence of service-oriented business processes, Dyche [9] concludes that architecture and infrastructure which include standardized processes for accessing data, the actual platform on which data resides does not matter. By applying a standard set of transformations to the various sources of data and enabling applications to access the data via open standards (e.g., SQL and XML) service requests can access data regardless of system manufacturer. However, regarding the data sources, many data sources such as IoT devices do not conform to standards and require a means to efficiently be integrated.

2.2. Important Issues Necessary to Manage: Security, Trust, Privacy and Legal Matters

Cloud computing presents many promising technological and economic opportunities. Many customers, however, remain reluctant to move their business IT infrastructure completely to the cloud. Birk and Waegner [10] state that one of the main concerns is cloud security and the threat of the unknown. Cloud service providers encourage this perception by not letting their customers see what is behind their virtual curtain. This continues to fuel insecurity on the sides of both providers and customers. Further, Jensen et al. [11] assert that although the economic benefits of moving to a cloud-based platform are clear, since it can reduce capital expenditure (CapEx) and operational expenditure (OpEx), it is still not clear how the technical security issues and the social trust issues should be resolved. Related to, and part of, security and trust is privacy, and access control and trust need to be aware of this [12] to not cause problems as well as how anonymization of data can be used for this [13]. Further, of interest may be also to be able to quantify the level of trust. The issues above need to be sorted out, together with, for instance, the legal requirements imposed by the EU (General Data Protection Regulation, GDPR) and USA, by any organization or company that approaches cloud services with any sensitive information stored, processed or communicated.

2.3. Development Pace and Efficiency—Benchmarking Examples

In response to the need for faster development pace, Fylaktopoulos et al. [14] describe a modular integrated development environment (including a run-time environment) for cloud-based applications which is a platform built to support model-driven development and team collaboration. The platform facilitates rapid development of advanced applications in the cloud and offers a solution for both rapid business development based on predefined components and application development, providing a layered distributed architecture. The result indicates that inexperienced developers are able to create business applications from scratch directly in the cloud and in a significantly smaller timeframe. Further, since there are no binary files, the installation of updates is an easy process with zero downtime. As the platform is also the runtime environment, the deployment of the developed applications is asserted to be instant.

The open source Arrowhead Framework provides architectural definitions of software systems providing the necessary services that enable the implementation of a self-contained local automation cloud. Delsing et al. [15] conclude, based on three cases, that time savings are in the order of approximately 70–80% when using the Arrowhead Framework, compared to legacy technology-based implementations, during the development/integration phase with IoT devices from different vendors.

Potential alternatives to using the Arrowhead Framework and the modular integrated development environment would be to use an existing IoT-platform together with a cloud service platform. However, that will likely not arrive at the same abstraction to services and integration between the IoT and cloud as well as interoperability in between additional local clouds, which may be needed.

3. Research Approach

The research approach was based on a case-study methodology proposed by Yin [16] with "a linear but iterative process" (p1) comprising: planning, design, preparation, data collection, data analysis and sharing of results. Alternative methodologies, such as action research or participatory design, would have also been possible to use, but might have required more time, effort and action from the researchers. The research question is "how much improvement has been made and how has the company managed to maintain a high development pace and efficiency throughout the development and simultaneous operation of the cloud service platform?", and the "how" indicates that a case-study methodology is appropriate to use. In addition, a case-study methodology was suitable as the researchers did not directly participate in the work that led to multiple contexts and customer cases.

The case-study company, Adage AB, is a high-tech micro SME located in northern Sweden and is very active on the northern European market. The company was founded in 2005 and has recently had an annual turnover of approximately 60 k€ and 110 k€ in 2016 and 2017, and expected in 2018 is 220 k€. Further, the company has one employee (the company currently uses development resources from its mother company BnearIT AB). The company provides services and products and participates in small and large research and development projects. Further, the company also provides cloud services and Industrial Product-Service Systems (IPS^2) [17].

The planning of the case study was crafted at the very start when the provider did the initial projects related to the construction and real estate contexts during 2010 and recycling management the year following. The focus on these three areas is due to that they all have similar technology problems and were developed on the same initial platform thinking (and later adapted to and re-built on the Arrowhead Framework) and that they were the starting points with interesting commercial outlooks. The planning was further updated during 2014 as a new business model was applied (IPS^2) to the recycling management context and the business volume increased rapidly. The intent was to follow the contexts on a regular basis and conclude the complete case study by 2017. The design of the case study included: formulating the study question, stating the study proposition: how has the company needed to change in terms of, e.g., the below, in order to improve and keep a high development pace and efficiency:

- Technology
- Development processes/practices
- Competencies and skills
- Organization
- Management
- Infrastructure
- Service and support

Most of these areas were initially predefined, except for management and infrastructure that were added later, based on practical experience from innovation and change management in companies. Further, the unit of analysis was the organizational level at the company. In addition, explanation building will be used to link the data to the propositions. It was decided that the criteria for interpreting the case study's findings would be made via rival explanations based on Patton's [18] approach, balanced defensively and offensively. The researchers wish to investigate how the company's set-up and organization has been affected when changing the development strategy and business model towards an IPS^2. The generalizability of the (multi-usable) cloud service platform is of great interest as well.

In order to prepare for the case study, a number of presentations, architectural/technical specifications, technical plans and marketing documents were analyzed. Further, a number of questions were presented to the company and ideas for changes and additional customer pain points were fed back to them as well. The initial data collection was done through semi-structured interviews [19,20] combined with workshops [21]. Further, intermediary data collection was conducted through multiple interviews and workshops, and the final data collection was accomplished via a workshop. Semi-structured interviews were used, with open-ended questions [19] allowing the respondents to give detailed answers and the possibility to add extra information where deemed necessary [20]. The duration of the interviews was between one and two hours, and the duration of the workshops was approximately two hours. In order to strengthen the validity of the study, the collected data were displayed using a projector during the interviews and workshops, allowing the respondents/participants to immediately read and accept the collected data. Subsequently, the collected data were displayed and analyzed using matrices (cf. [22]). The analyzed data were finally summarized into a matrix, and the findings categorized according to the areas of concern, i.e., development pace and efficiency gains, development process/practices, technology, competences and skills, organization, management, infrastructure, and service and support. Finally, the results were shared with the provider and some of their customers (as well as with a broader audience through this paper). During the case study the part of the research process (i.e., design/preparation/data collection) was iterated, since it was realized that more could be explored.

4. A Multi-Usable Cloud Service Platform and the Case Study's Three Contexts

This section will firstly outline the technical aspects of the cloud service platform architecture used, followed by the three contexts covered by the case study. The last context, i.e., recycling management, will be thoroughly described, as it is the most developed one.

4.1. Multi-Usable Cloud Service Platform—Architecture

The multi-usable cloud service platform from the company was initially developed using legacy technology and techniques. This was not deemed as efficient and scalable, and as the Arrowhead Framework and its components were made available during the Arrowhead project's progression (2014–2017)—the company re-engineered the complete solution and based it upon the Arrowhead Framework components as well as its proposed development processes and other related frameworks.

In brief, the Arrowhead Framework comprises the following main systems, sub-systems, procedures and methods [8,23]:

- **Mandatory core systems**—service registry, authorization, orchestration
- **Automation support systems**—plant description, configuration, system registry, device registry, event handler, quality of service manager, historian, gatekeeper, historian to historian secure data path, translation
- **Application systems**—application services
- **Deployment procedure**—secure bootstrapping of devices and systems into a local cloud, creation of Arrowhead Framework compliant systems, interfacing legacy systems, verification of compliance

Figure 1 outlines the new architecture, based on the Arrowhead Framework [23], for the company's cloud service platform. The architecture comprises the mandatory core systems and services, including an authorization system (for users and services, etc.), a service registry (where services can be registered and looked up), and an orchestration system (in order to maintain system connections), and an application systems and services part. The latter contains the actual business logic and provisioning, which differ for each context. The SOA principle is based on the foundation of the three 'L's, Lookup (discover/set presence), Loosely coupled (autonomy's and distributed components) and Late binding (dynamic system of system compositions) together with strictly defined service contracts and architectural methods.

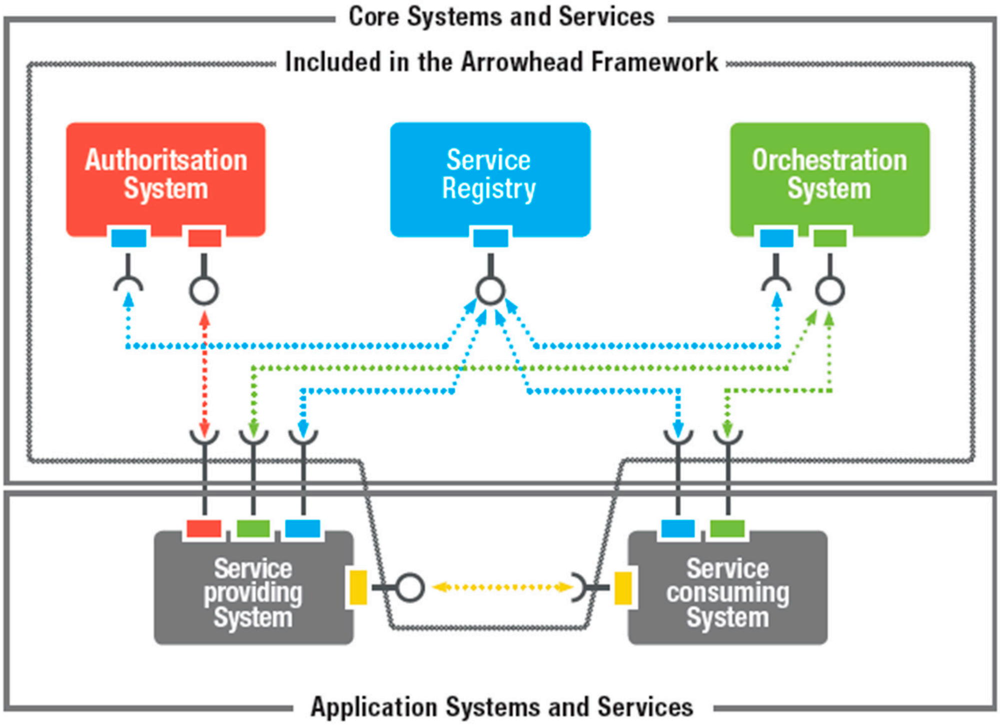

Figure 1. Outline of general architecture of Adage AB's multi-usable cloud service platform.

In further detail, the function calls and parameters used in Figure 1 are briefly outlined (for additional details see [8,23]). Input parameters are in normal text and output parameters in bold text:

- Authorisation (Service Discovery, **Authorisation Management, Authorisation Control**)—provides authorization and fine grained access rules to specific resources as well as configuration of access tickets in combination with use of authentication mechanisms such as, for instance, certificates and certificates handling
- Service Registry (**Service Discovery**)—provides service registry functionality based on DNS and DNS-SD standards. The architecture and solution handle self-registering services, which state their availability within the network. Consumers of specific information knows where they can find and use it. Producers notify their awareness. This handles the SOA-principles called lookup and late binding
- Orchestration (_ahfc-servprod types, Authorisation Control, Service Discovery, Orchestration Push, **Orchestration Store, Orchestration Capability, Orchestration Management**)—provides service consuming systems with consumption patterns as well as end-point information of the produced services that are to be consumed. The function provides the possibility to combine a system-of-system collaboration that fulfill the current need for a specific situation. Further, this handles the SOA-principles called late binding and loosely coupled.

4.2. Construction and Pre-Fabrication Context

Concrete pre-fabrication production is a very traditional craft which extensively builds on the hands-on experience of the producer. The same goes for builders that make concrete platforms for building houses or other structures. Common approaches for analogue sensing when the concrete pre-fabs or platforms are hardened and ready for use are to use the fingers to sense, using nails to estimate the hardness, or use other rules-of-thumb regarding what temperature or time has elapsed since the concrete moulds were filled, or which sand quality that was used in the concrete. This analogue setting is not optimal for development and also makes knowledge transfer time-consuming, e.g., when an adept is to take over from an experienced pre-fab maker or builder. In order to overcame this analogue setting and make it digital, the company has developed a sensor-bridge-cloud system with sensors embedded into the wet concrete. The sensor information is used as input to an algorithm which will let the pre-fab or builder management know the temperature and the humidity in the mould. The algorithm further calculates the hardening process of the concrete based on the time, humidity, temperature, type of concrete as well as additional parameters. With this information, the pre-fab maker or builder gets vital information if the ambient settings are optimal—and the algorithm can suggest optimizations by adjustments of time, temperature and humidity settings. This new capability both enables the pre-fab maker and builder to validate the quality of the set concrete and to know when to remove the mould(s). Thus, using collected data and the algorithm allows use of facts rather than estimations or rules-of-thumb to reduce/optimize the production time—which directly affects revenue.

4.3. Real Estate Context

Long-term owners of real estate, and in particular of larger commercial and multi-tenant apartment buildings, need to maintain the buildings in order to avoid deterioration (i.e., asset value is lost), uphold the customer value (be able to collect rent) as well as to keep the buildings healthy and comply to the societal requirements of energy efficiency and environmental consciousness/certifications. The company has for the real estate context developed an offer which measures, for instance, the moisture level in the exterior walls. This is needed for early detection of excessive moisture levels and thus a need to take action in order to avoid a complete renovation of the wall. A complete renovation of a wall far exceeds the cost of taking preventative measures at an early stage. The company's offer collects the data using sensors, and then the data is collected and analyzed in a central cloud service platform. This can be compared to commercial solutions with passive RFID tags that require a person to walk around and use a scanner. The benefit with this solution is that the batteries in the passive RFID tags will last for a long time. However, it is not a really scalable and cost-efficient solution if the real estate portfolio comprises several hundreds or thousands of buildings scattered over several cities or countries.

The company's offer can be extended with sensors; e.g., for water/leakage/flooding in basements or laundry rooms, status of doors (open/shut/number of passages), temperature (to detect open outer doors or fires), etc. Thus, actions that trigger the sensors can invoke immediate/planned inspections, alarms or event logging.

4.4. Recycling Management Context

The company provides a recycling IPS[2] to municipalities and companies who are responsible for managing recycling containers. The containers are mainly for households and are used to deposit glass, plastics, paper, packaging materials and metals. The main idea is to optimize the emptying of these containers as they are almost filled up (but not over-filled) to avoid people putting what is returned outside of the containers (i.e., littering) when they are over-filled. Further, the waste management company wishes to avoid emptying containers that do not need to be emptied. Thus, the waste management company wants to empty the containers on-demand and to minimize unnecessary transports with trucks in areas with high traffic loads as well as in rural areas (long distances). Figure 2 outlines a general overview of the IPS^2, of which the aim is to provide decision-making information to the customers with high availability.

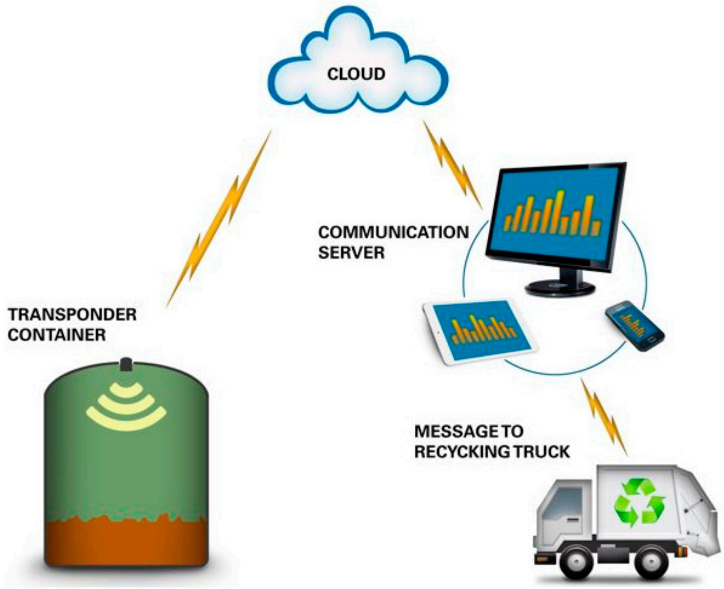

Figure 2. General outline of the Industrial Product-Service Systems (IPS^2) for optimizing recycling management.

Further, Figure 3 shows how the architecture is used/adapted for the recycling management context. On the service-providing system side, the containers and their sensors are connected to the cloud service platform and on the service-consuming system side, the output from the cloud service (i.e., decision-making information) can be consumed/accessed through the browser in a mobile phone, notepad or lap-top, etc. or be further processed in other information systems on the customer side.

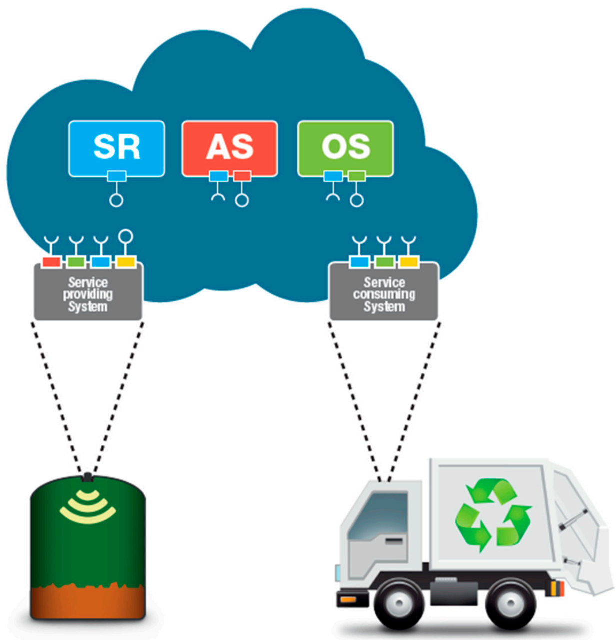

Figure 3. Architecture used/adapted for a recycling management context.

The adaption of the architecture for the construction and pre-fabrication as well as real estate contexts are made in the same manner, re-using/sharing all the business functionality from the recycling management context and its implementation.

The IPS^2 is built on the industrial internet and IoT paradigms. The IPS^2 uses sensors to measure the filling level within containers, vibrations (to indicate emptying), as well as temperature (to adjust filling-level measurements and indicate/detect possible fires) and other wanted parameters. Further, the IPS^2 pre-processes data to minimize data flows, uses wireless communications (mainly mobile networks or WLANs), provides a cloud service for data collection and analysis of big data, and performs additional wanted data mining and visualization of results (such as which containers should be emptied). The IPS^2-components attached to the grid are powered by green electricity (hydropower) and the cloud service is run in green data centers (powered by green electricity and cooled by the low-temperature air in northern Sweden).

Figure 4 shows how some of the decision-making information is visualized for managers at the customers. Consequently, the customers need to change their processes and management to be able to fully benefit from the decision-support provided—in order to achieve good optimization.

Using the information provided in Figure 4, the managers concerned with managing the recycling get information about which containers need to be emptied (or will soon need to be emptied). Further, the managers are supported when planning optimal routes and dispatching an optimal number of trucks. Figure 5 provides graphs about the filling details when the managers click on the containers in Figure 4.

In addition, to make it simple, another status indicator is possible to add in the decision-making information as well. Figure 6 is commonly configured so that the green container is less than 50% filled up, the yellow between 50–80% and the red at +80% (thus indicating that emptying is needed soon). A prognosis for which containers will reach +80% within 4–5 days can be calculated based on the filling patterns.

Further, a graphic or numeric filling report can be issued or retrieved for each customer's containers and filling-levels. In addition, commonly the filling-levels green/yellow/red can be customized at wanted thresholds for each customer.

Customers get improved (realtime) information with high availability regarding the filling-level of containers, and are thus able to better plan emptying schedules and dispatch an optimal number of trucks (and avoid over-filled containers). The latter is important, as the customers are responsible for cleaning up any litter or recyclables that are left outside of the over-filled containers. This takes time, and sometimes a lot of time, when the emptying trucks should instead be on the move, performing their actual task. Realtime monitoring of the filling-levels provides input for planning emptying, and using historic data and analytics a prognosis can also be made for when the containers will reach +80% filling-level. According to one major customer concerned with the glass containers, they have made large improvements compared to in the past when containers where emptied at an average 55% filling-level and every 12th container was over-filled. Thus, the customers can use an optimal number of trucks (which has a large impact on profitability), take other suitable contracts that can be combined when they are better able to plan the recycling business, drive less in areas with high traffic loads, and drive less in rural areas with large distances in between containers.

Thus, the total outcome, enabled by the IPS^2, supports the circular economy in an environmentally friendly manner.

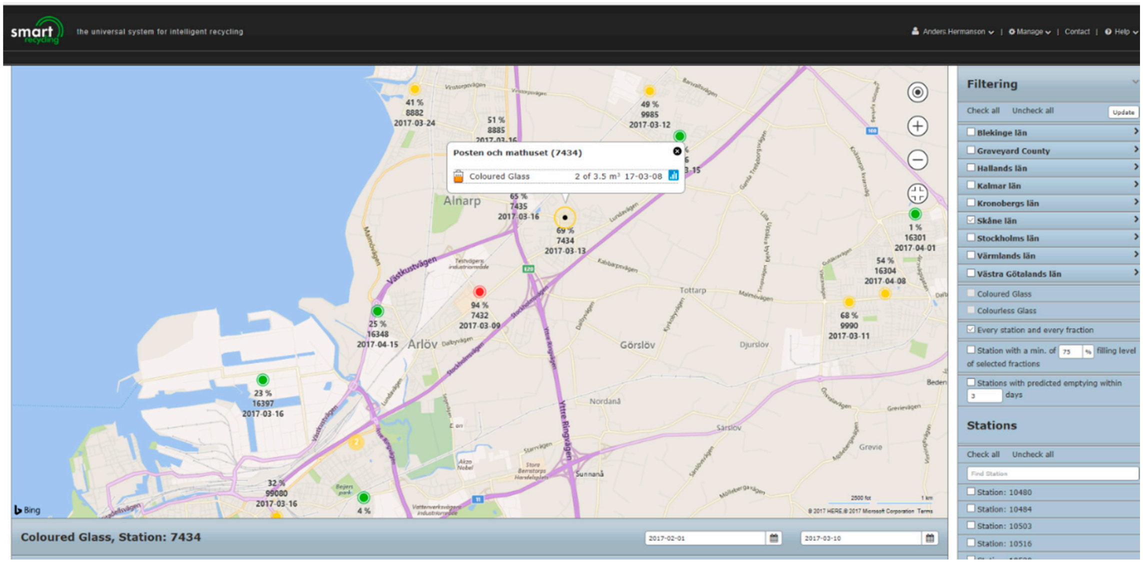

Figure 4. Visualization of a management view—high-level decision-making.

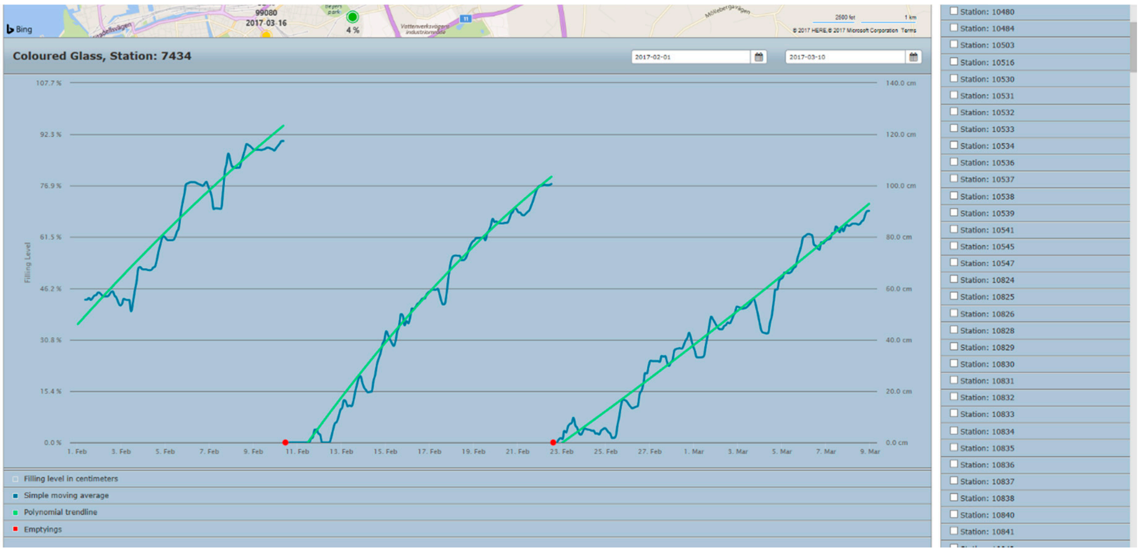

Figure 5. Decision-making graphs—drill-down on container filling levels.

Figure 6. Simple decision-making—visualization of container filling-levels (green/yellow/red).

5. Results

Regarding the degree of improvement and how the company has managed to keep a high development pace and efficiency throughout the development and simultaneous operation of the cloud service platform, the results are listed in Table 1. The findings are the outcome of the workshops and interviews conducted during the case study. The findings are attributed to: development pace and efficiency gains (PEG), development process/practices (DPP), technology (T), competencies and skills (CS), organization (O), management (M), infrastructure (I), and service and support (S).

Table 1. Improvement and how a high development pace and efficiency has been accomplished at Adage AB.

#	Area	How Much and How
1	PEG	From start when using traditional/legacy development processes/methods/tools, etc. until later stages—a 50–75% improvement regarding pace and efficiency. Thus, a significant saving of effort, time and costs.
2	DPP	Usage of the Arrowhead Framework [7,21] and its requirement engineering and development process, as well as usage of strict Service-Oriented Architecture (SOA) principles, has enabled streamlined development and cooperation.
3	T	Usage of the Arrowhead Framework to abstract IoT devices and sensors as services saves a lot of time and effort. Further, re-use and refinement of the data collection and analytic platform, together with re-use of analytic tools and frameworks, has further hastened development and improved efficiency. The addition of secure remote configuration and updating of the cloud software and sensor software has been key to scalable technical management and operational efficiency.
4	CS	Firstly, whole new businesses (and customer segments) unfamiliar to us had to be learnt. We were also used to mainly providing products and services, and had to learn more about complex business models. Secondly, we needed to learn more about: cloud services, SOA, Arrowhead Framework, sensors, robust data and mobile communications, industrial internet/IoT, big data, data modeling and data analytics, and IT/information/cyber-security. In particular, the business parts, data modeling, data analytics and security have been challenging. Thus, this has been very challenging—but on the other hand developed the company considerably.
5	O	It was necessary to change to a new business model i.e., IPS^2, from a product with a services model. When changing the business model, with subscriptions based on 36–60 month contracts and the pricing depending on the volume, the business took off and the volumes rapidly started to grow. Further, we have started to set up partner networks in order to scale up the business and sales/marketing efforts. In addition, we had to win the trust of the customers by firstly knowing their business, and then having an offer that they found attractive.
6	M	Internally, we have had to add missing competencies to the board of directors, and use long-term financial planning and strict cash-flow to not impede the fast pace of customer installations.
7	I	We moved from an own operated cloud service to a green-powered cloud platform service provider, which has allowed us to focus more on technical- and business development instead of operations. Further, this is much more stable and we do not have to have the same number of people concerned with operations.
8	S	We have learnt a lot by doing service and support, set up a service desk and support organization, contracted service partners, and have consequently developed e.g., health indices for sensors (i.e., battery level and function) and other equipment in order to reveal maintenance need for physical installation and ensure high availability of the decision-making information to the customers.

The company estimates that it has saved between 50–75% development time, for each of the three contexts, by using the Arrowhead Framework combined with strict SOA-principles instead of using "more traditional/legacy" development processes, methods, practices, and tools, etc. By following the principles and processes in the Arrowhead Framework, it has been easy and straightforward for requirement engineering and development activities and further resulted in fewer misunderstandings. Further, there is improvement for each iteration as additional experience and re-use of components, analytical tools and frameworks etc., provide effect over time. The savings estimation is based on comparisons of development plans and efforts spent. The savings estimations for 6 larger projects are: 50%, 55%, 60%, 60%, 70 and 75%—i.e., in between 50–75%. To corroborate this saving, previous research conducted by Delsing et al. [15] shows that the use of the Arrowhead framework saves development time/efforts, related to industrial IoT and cloud services, in the range of approximately 70–80%. Thus, this ought to be of interest also for other companies and organizations involved in development activities related to the industrial internet and IoT.

The eight areas in Table 1 are all interconnected as they rely on, support or depend on each other. The areas #1, 2, 3, 4 and 6 are directly affecting the development pace and efficiency whereas areas #7 and 8 indirectly contribute. Finally, area #5 is driving the rest and at the same time supported by the rest.

6. Analysis

The pace and efficiency regarding the development of the multi-usable cloud service platform have been significantly improved compared to previous reliance on more traditional development methods and tools. In this regard, the Arrowhead framework has been the key enabler to the improvement—although a number of the areas in Table 1, increased experience and re-use of tools etc. have also contributed with approximately 20–25% of the **50–75% improvement** at the company. However, re-use of analytical tools and frameworks would, of course, have been possible anyway. In order to be successful with the customer offers, the company has experienced that the development of technology, business model, business set up and organization needed to be synchronized and go hand in hand. The development-, technical- and infrastructure-related matters were perceived as easier to overcome compared to the business model-, business set up, organizational (including acquisition of skills and competencies), management, and service and support-related ones. One explanation for this is that the company was a high-tech micro SME with mainly engineers employed initially—and thus more interested in the engineering-related areas. This can be an important lesson for others considering taking on a similar challenge.

To conclude the analysis, Chesbrough [24] posits that the choice of business model is key, as "a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model" (p. 355).

7. Discussion and Conclusions

The paper has contributed to literature with a case of a multi-usable cloud service platform, developed and used by a micro SME, outlining that the micro SME has improved its development pace and efficiency by 50–75%. This paper also describes how this process has been accomplished. Of particular interest is to notice the main changes i.e., use of the Arrowhead Framework as well as strict use of SOA-principles. Further, the areas in Table 1 have contributed to increased development experience and re-use as well as improved knowledge of customers, customer processes, and the overall system. The possibility to abstract IoT devices from various vendors as services provides a great advantage, both during the development/integration phase and later during the operations/maintenance phase.

Further, the paper has given input to practice by indicating that a number of changes are needed to improve the development pace and efficiency. In particular, re-use and refinement of the data collection and data analytic platform plus re-use of analytic tools and frameworks rendered a good result. However, this would have been possible in many other contexts as well without using the Arrowhead Framework. Regarding scalable technical management, remote configuration and updating of cloud service platform and sensor software are key for operational excellence.

In addition, the paper has provided lessons for management, as the micro SME also changed its business model to an IPS^2 from a product with services. The business model change, together with other necessary organizational-, managerial- and infrastructural changes, combined with adding missing competencies, invoking long-term financial management and strict cash-flow, setting up a service and support organization, was demanding and required a lot more effort and resources than initially anticipated. Thus, to be successful in the innovations, the technical aspects need preferably to go hand in hand with business and organizational aspects. This will create stronger customer value and, consequently, an attractive customer offer.

Regarding the case study's proposition, it is clear that the company has had to change in all aspects listed (and probably more that were not discovered during the case study). Making such a number of changes during a few years requires management support, funding (the company has received considerable additional funding from its owners during the duration of the case study), a technical vision, inclination for business development, and trying new business models to learn new markets and embrace change management. Making a lot of changes is hard, and requires a lot from an organization. However, compared to larger organizations, it is likely easier for a micro SME to make a lot of changes.

Concerning the rival explanations, in terms of technology and organization, the company looks completely different after the case study. The new business model used (IPS^2) has impacted the organizational setup and need to change the underlying technology to an efficient multi-usable cloud service platform. As a rival explanation—would it have been wise and better to keep using traditional/legacy development processes, methods, practices, tools, etc. compared to moving into the Arrowhead Framework and SOA-principles? For the case study in question—the answer is no.

The research question "how much improvement has been made and how has Adage AB managed to maintain a high development pace and efficiency throughout the development and simultaneous operation of the cloud service platform?" has been answered above. An improvement of 50–75% should be of great interest for other companies and organizations to investigate as well. Further, regarding generalizability, the company's use of the Arrowhead Framework is possible for others as well, since most of it is available as open-source [23]—and possible to download, test, and use. In addition, the managerial lessons i.e., that a lot of changes need to go hand in hand to successfully get new offers to the market and stay competitive, can also be of a general interest for other organizations planning for cloud service platforms.

In terms of sustainability, the paper indicates that considerable improved economic sustainability can be reached for the provider through higher efficiency in engineering and development efforts. Further, as the cloud service platform is used for instance in optimization of recycling management as well as monitoring in real estate, the cloud service platform also has an impact on environmental and social sustainability.

The company will, according to its management, continue to develop the multi-usable cloud service platform and the whole setup, and look to continue to develop their offers and business modeling. Another demanding business model of interest for the future is to provide a function or Functional Product [25–27].

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