Lappeenranta University of Technology
School of Engineering Science
Software Engineering
Master's Programme in Software Engineering and Digital Transformation

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Adding Value to Hazardous Analysis and Critical Control Points Process by Cloud-to-ERP Data Synchronization

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TIIVISTELMÄ

Lappeenrannan teknillinen yliopisto
School of Engineering Science
Tietotekniikan koulutusohjelma
Master's Programme in Software Engineering and Digital Transformation

Mikael Sommarberg

Arvon lisääminen elintarvikkeiden omavalvontaprosessiin pilvipalvelun ja toiminnanohjausjärjestelmän välisellä tiedonsiirrolla

Diplomityö
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Keywords: HACCP, digitalization, enterprise resource planning, integration

Elintarvikkeiden omavalvonta on oleellinen osa monien eri alojen, esimerkkinä ruoan käsittely alan, arkipäiväisissä toiminnoissa. Monesti tähän prosessiin käytetään edelleen kynää ja paperia, mutta osa prosessia suorittavista toimijoista on siirtynyt digitaalisiin ratkaisuihin. Tämän diplomityön päätarkoitus on lisätä arvoa omavalvontaprosessiin synkronoimalla prosessin suorituksesta kerätyt tiedot (esimerkiksi mittausdata) prosessin suorittaja yrityksen toiminnanohjausjärjestelmään. Tuloksena luotiin ohjelmistointegraatio tapausyrityksen sovelluksen sekä asiakkaan toiminnanohjausjärjestelmän välillä sekä kartoitettiin sen, ja omavalvonnan digitalisoinnin hyötyjä. Laadullisessa tutkimuksessa havaitut hyödyt korreloivat osittain tyypillisten digitalisaatiosta saatavien hyötyjen kanssa.

ABSTRACT

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77 pages, 15 figures, 1 table, 3 appendixes

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The Hazardous Analysis and Critical Control Points (HACCP) process is an essential process in many fields, such as, the food processing field. In this process, a pen and paper have generally been used for documentation but some of the operators in this field have started using a digital solution for it. The main purpose of this master's thesis is to add value to the HACCP process by integrating the documented data from the case company's application to a client's ERP system. As the results of this research, a software integration was developed for this data synchronization and the potential benefits of it and the digitalization of HACCP were researched. In the qualitative research, it was found out that the benefits of the digitalization of HACCP process correlate quite well with the typical benefits of process digitalization.

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During the five years in Lappeenranta, I have had the privilege of meeting hundreds of new people whom of many have become a friend of mine, some of which have become close ones. The people and the spirit created by them is really something to appreciate. Hopefully, these people can have their opinions heard in guiding the Lappeenranta University of Technology (or LUT University or whatever it may be when this master's thesis is being read) in the correct direction.

The support at home for working on this master's thesis project has been a crucial factor in succeeding and I guess having someone who has pushed through a similar project has its advantages. Luckily our paths crossed, and I think the sky is the limit what we can reach together.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABAP	Advanced Business Application Programming
BOR	Business Object Repository
CDS	Core Data Services
CRUD	Create, Read, Update and Delete
DDIC	Data Dictionary
EAIF	Enterprise Architecture Integration Framework
ERP	Enterprise Resource Planning
ER	Entity Relationship (Model)
FQDN	Fully Qualified Domain Name
HACCP	Hazard Analysis and Critical Control Points
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
II	Industrial Internet
IF	Interface
IPC	InterProcess Communications
IoT	Internet of Things
IP	Internet Protocol
JSON	JavaScript Object Notation
MM	Materials management
MVC	Model View Controller
OData	Open Data (protocol)
PO	Purchase Order
QM	Quality Management
REST	Representational State Transfer
SME	Small and Medium-sized Enterprise
SOA	Service Oriented Architecture
UPC	Universal Product Code
URI	Unique Resource Identifier
URL	Unique Resource Locator

URN	Unique Resource Name
VPN	Virtual Private Network
XML	Extensible Markup Language

1 INTRODUCTION

This master's thesis project attempts to find solutions by researching and developing ways to add value to Hazard Analysis and Critical Control Points (HACCP) process by using inter-system data synchronization to provide real-time information to all peers involved in the process. HACCP process is a seven-step systematic process which attempts to prevent biological, chemical and physical hazards by avoiding the potential identified hazards. For example, in the food industry on a very simple case, this means having an identified safe storage temperature for easily perishable materials and making sure the materials are kept in the temperature range by periodical measurements. In the context of this master's thesis, food products and industry are used as the basic example and concepts focus around it, but could also be applied in other fields, such as agriculture or biology. Data synchronization as a term, in this context, means having up-to-date information available on all ends in a near real-time timeframe. This research project is a case study for a Finnish software and hardware company. The case company is classified in the small and medium-sized enterprises (when categorizing enterprises in size) and the company's field of expertise is in the Internet of Things (IoT). The project attempts to solve issues for real client problems and attempts to solve problems to provide added business value to both client and provider companies. In this master's thesis project, a demo application is made for Android which demonstrates an integration between HACCP process and an Enterprise Resource Planning (ERP) software system. The application will consider a typical situation of an incoming inspection, which is done when a product is received from transportation in the food industry. The reason for conducting this kind of research is the fact based on multiple companies still using pen and paper in their HACCP process tasks. Most of the everyday actions of enterprises go through ERP software, but there are still many companies, who do their HACCP processes with pen and paper.

The topic and the research questions have been defined with the case company to solve a real-life business case. The problems described in this thesis are common and on a general level and are considering problems in the food industry, such as central kitchens and professional food services, i.e. restaurants. Depending on the similarity of the issue, the

reader can apply the solutions suggested in this thesis and the expected outcome should be close to this thesis' results. In other words, even though this thesis attempts to solve a specific problem for a specific company and a field of business, the proposed solution and technologies used to achieve the goals are common and widely available for everyone.

1.1 Background

The HACCP process has been an arising approach in many fields in the past two centuries. The first written articles mentioning the HACCP as a process are from the 1970s and in the 2010s it has reached its peaks in the number of articles written about it. When looking at the number of articles written around the subject in figure 1, which shows the number of articles annually regarding the HACCP process, it can be seen that in the last 10 years, the subject has kept its interest. The total number of articles is still relatively low (6328 results as of 11th of February 2019) but it can be seen that the interest and research among the subject are slightly increasing. Generally speaking, many of the most referenced articles are published in publications related to food and agricultural sciences or biology. The process itself is a systematic approach to identify and prevent hazards that could cause issues in the manufacturing of, for example, food products. The HACCP process has seven principles that build safety and quality in manufacturing to prevent chemical, physical or biological hazards. (Riswadkar, A. V., 2000)

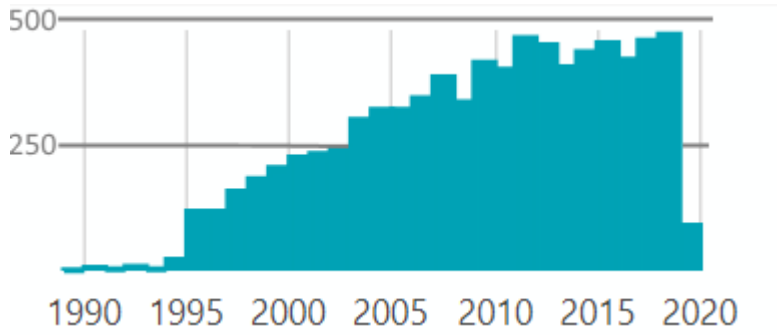

Figure 1 The relative number of peer-reviewed articles published annually with keyword "HACCP" or "Hazardous Analysis and Critical Control Points"

In the modern age of technology, there are continuously new opportunities to improve the already good and working processes towards better efficiency, more time-savings and eventually bigger profits. Internet of Things or the Industrial Internet (II) are the technologies which this research project considers to be the technologies in providing added value to both the client company which uses HACCP process in their business and the provider (the case company) who creates and sells the tools and services to do HACCP tasks digitally. IoT as a technology requires multiple other technologies to work properly and reliably such as cloud computing, different wireless technologies, and massive storage systems. (Lee, I., Lee, K. 2015)

The added value that this project attempts to achieve comes from the reduced amount of manual work required in HACCP tasks. By reducing the manual work that is repeated either on a daily basis or multiple times a day, the employees in the company can use their time in something else which could provide better value, either financially or quality wise, to the employer company. Also, enterprises nowadays collect all possible data for further use. By digitalizing the HACCP process, the process related data is already in an easier format to analyze for future usage.

Arik Ragowsky and Toni M. Somers in their article from 2002 describe that ERP systems can have a significant benefit when properly selected and implemented for an enterprise. On average, the enterprises who have implemented an ERP system had their raw material costs reduced by about 15 percent and inventory costs reduced by 25 to 30 percent in the long term. On the other hand, many of the ERP software projects fail due to too high expectations or not completely understanding what the ultimate goal is with ERP systems. The writers on this article, however, remind the reader that not all companies will gain the same benefit and all ERP systems are not the same. It is also said, that an important role of ERP systems is to provide a platform for other applications. (Ragowsky, A., Somers, T., M, 2002)

In this master's thesis, it is important to consider the ERP software as a part of the solution and problem. As stated in the previous chapter, most of the large enterprises rely on ERP software in their everyday business processes. By linking the HACCP tasks to efficient

application to enterprise resource planning software, the correct information will be available to all peers necessary. There is also a potential for added value to the enterprise in the HACCP report data: in the long term, the task data can be analyzed to improve the efficiency of these processes. It is also possible to use machine learning to find patterns in the report data and notify the peers involved in the process before anything has happened. In the context of this master's thesis, it should be noted that generally speaking, ERP software projects are time-consuming and difficult integration projects due to the critical nature of the systems and heavy restrictions and constraints. Analyst company Gartner has estimated that 55-75% of ERP software project, whether they are new implementations or upgrades, fail to meet their targets. (Deloitte, 2018)

1.2 Goals and delimitations

This thesis project attempts to find ways to provide additional value to both the client and the provider. The value is added to the HACCP process by transferring data from the HACCP application (the provider) to ERP (the client) and vice versa. The ultimate goal is to have both systems up to date at all times and eliminate the manual work currently needed in the management of HACCP application. The typical workflow is, that the task definitions and quality parameters are fetched from the ERP system to the HACCP application and the measurements and actual quality data are then pushed back to the ERP system from the HACCP application. On the other hand, when the results of tasks done in the HACCP application are reported back to ERP software, certain actions can be triggered to reduce the manual management work in expected scenarios. In the long term, the report data can be exported in a data warehouse for analysis and other purposes, such as machine learning. The hypothesis of this study is that it is possible to add value to the HACCP process by integrating software together to provide up-to-date data available both in the HACCP application and ERP software. The hypothesis is based on an educated guess that digitalizing parts of a rather manual process provide added value to companies using the HACCP process and on the other hand willing to pay from this kind of service. To support the hypothesis, it is also assumed that it is possible to transfer process related data to and from ERP software.

The research attempts to answer the research questions for this thesis:

RQ1: What are the feasible technologies that can be used to transfer information between a cloud application and ERP software?

RQ2: What benefits can be achieved by synchronizing the data in HACCP application and ERP software?

RQ2a: What are the benefits for HACCP application service provider?

RQ2b: What are the benefits for the industry that are required to perform HACCP?

RQ3: What kind of added value the companies can achieve by digitalizing the HACCP process?

The research viewpoint in this thesis is from the HACCP application provider but it also attempts to look at the problems from the viewpoint of the application consumer. The ERP software to be studied for this software integration project is SAP S/4HANA due to the need of the case company and it is a requirement provided by the case company. An assumption regarding the ERP systems features is made to support this limitation: even though the different ERP systems have different strengths and weaknesses, it is possible to move data using different interfaces (Application Programmable Interfaces (APIs), software views or manual migrations) even though the technology underlying could be different. An assumption is made that the process of synchronizing data for the HACCP process to an ERP system is similar to synchronizing data for any processes.

1.3 Research methodology

The theoretical part of this thesis is a literature review of the selected related technologies and the HACCP process. The purpose of doing a literature review of the technologies, processes and other aspects is to get a wider insight and understanding to support the

empirical and qualitative parts of this thesis. The theoretical part attempts to examine the technical and practical issues and goals of this project on a general level without focusing too heavily on the HACCP process. The theory and the general concepts behind the HACCP process are examined and described in the theoretical part.

Qualitative research is done by interviewing clients of the case company. In this interview process, the clients are asked questions to find out what kind of value can be added by digitalizing the HACCP process and synchronizing the data between the HACCP application provider and the company's ERP software systems. The interviews are done face-to-face if possible, but an option to have remote meetings, for example, on Skype, is given to the interviewees. A hypothesis of benefits gained from digitalizing the HACCP process and the synchronization with ERP software are as follows: it saves time in the long term, documents are stored more reliably and it generally improves quality and safety aspects related to the HACCP process, such as food safety in professional kitchens. Convenience sampling with elite interviewing is used as the sampling procedure for these interviews to make sure that the interviewees know, at least roughly, what they are talking about. As a hypothesis for the results of the qualitative research is that the benefits are similar to the general digitalization benefits. Digitalization is a key in improving internal efficiency in organizations or for providing new opportunities by offering new services and products to a company's customers (Parviainen P., et. al, 2017). Based on this statement, it is expected that digitalizing the HACCP process improves the efficiency of the persons exercising the process (employees can save time by using digital tools), and by saving time, an employee can do other tasks, indirectly providing more value to the employer.

Convenience sampling is a commonly used sampling procedure and one of its main benefits is the convenience of the researcher. Typically, the interviewees selected by convenience sampling are the most suitable ones and easiest to get an interview from but has also multiple other advantages and disadvantages. It is said, that using convenience sampling can lead to research results being hard to generalize, research results being biased and having a high level of sampling errors which all lead to credibility issues. As for benefits, it is relatively simple, can provide helpful insight for pilot studies, it is relatively quick to set up and apply,

and it is also cheap when thinking the costs of acquiring interviewees in another matter. (Research-methodology.net, 2018)

Elite interviewing is a technique where a person to be chosen as an interviewee is selected by their position or another attribute for a particular reason, rather than randomly or anonymously. It is said, that elite interviewing has similar downsides to convenience sampling which are the issue of having a biased option as the common result in the research. By having a small sample size and biased opinions it is important to note that the results may seem generalized due to an illusion caused by the selected interviewees. In an article, there were three suggestions to make elite interviewing work best: 1) Use as many interviewees as possible to get more opinions, 2) Ask the interviewees to critique their own subjects and 3) If a bias show through too heavily or noticeably, move on to next questions where there may not be too much bias involved. (Berry, J. M., 2002)

It is important to understand the convenience sampling and elite interviewing techniques in the context of this master's thesis, at least on the basic level, due to them being used in the interviews. The expected results are most likely biased due to all interviewees being in the same country having to comply with similar regulations in the food industry. The compliance of regulations is validated by inspectors. The convenience sampling fits well to research where the case company is giving the possible interview targets to the research. Elite interviewing suits well in cases where the interviewed persons are experts or "elites" in the subject of the interview, which is the case in this master's thesis. In the qualitative part, the interviewed persons are working in a high-level position on a municipality or a company performing HACCP process during their operations.

The empirical part consists of a solution based on the technologies studied in the theoretical part of this thesis. A prototype of the integration solution is developed. Prototyping is considered as a convincing method for conducting empirical research, but are considered to be slow, expensive to develop (especially if a complicated system is needed) and not so flexible as doing a simulation. (Mämmelä, A., 2006) The empirical part takes into consideration the wishes of the case company and other aspects related to software

engineering. These aspects include the reasons for software maintenance and the technologies used in the company, as well as the technologies suggested by the developer guides of the software systems involved. The empirical part takes the viewpoint of the provider of the HACCP application and tries to add the maximum value possible for both the customer and the provider. The integration challenges that are attempted to be solved are from the clients of the case company. It is assumed, that companies can solve their problems in a similar manner to the ones described in this thesis. Depending on the resources available, laboratory tests can be used to determine the best option available when needing to choose a direction in the empirical part.

1.4 Structure of the thesis

This first chapter of the thesis gives an overview of the project. It explains to the reader what the backgrounds and the reasons to start this project are. The goals and delimitations of this project are told to the reader with the reasons for leaving out certain parts of this integration challenge. The methodology used for this thesis is described after the goals and delimitations. In the methodology chapter, the hypothesis of qualitative research is also described and introduced to the reader. Finally, the structure of this thesis is introduced to the reader.

The second chapter of this master's thesis introduces the reader to the theoretical background of this project. It attempts to tell what kind of technologies, processes, and other aspects need to be considered when attempting to synchronize the data between a cloud-based application and an ERP system. The topics for this part are selected by the problem definition and by facing issues when doing the empirical work. For example, before implementing a way to communicate with a system it is important to find out how software systems communicate. At the end of each subtitle, it is explained why each topic is important in the context of this master's thesis project.

The third chapter tells the reader about the case company's customers and the customer interviews done in this master's thesis. It also tells the users the principles of the interviews,

the theories, and reasoning why it is done. In this chapter, the added value to the case company's customers is analyzed.

The fourth chapter of this thesis explains the empirical and practical part of this thesis. In this part, the components of the technical implementation are explained to the reader. The technical choices are explained and reasoned to the reader. The fifth section describes the implementation steps and software in more detail. It analyses the used software development choices and reasons the selected choices if multiple ones are available.

The sixth chapter describes the results and discusses how successful the project was overall. It describes the faced issues and potential problems for future research. The conclusions chapter contains the reasoning for conclusions and summarizes the conclusions. After this, the references and appendixes are listed.

2 THEORETICAL BACKGROUND

This chapter is a literature review of the underlying technologies and other aspects related to this master's thesis. It explains what the HACCP process is about and why it is important that the process advances with the available technology. It attempts to give an overview and the basic understanding for the reader of the technologies to be used. The first subchapter is explaining what is the process which is being integrated into ERP software systems and the second subchapter tells what kind of technologies are used in the integration.

2.1 Hazard Analysis and Critical Control Points System

Hazard Analysis and Critical Control Points (HACCP) is a process to identify and prevent hazards that could cause issues. For example, in the food industry, HACCP process attempts to prevent biological, chemical and physical hazards. The Finnish Food Safety Authority (Evira) describes HACCP as a management system for the food industry that can guarantee safety for the prementioned hazards by managing the production, distribution, and sales. HACCP process is a part of the food processing facility's self-control and self-monitoring system. In Finland, there is a law requiring all food processor companies to have a self-control and self-monitoring system. The self-control and self-monitoring system contains the support systems for self-monitoring, HACCP system, and employee hygiene and self-monitoring training. (Finnish Food Safety Authority, 2008) The first mentions of the HACCP process are from the 1960s when it was developed for a space program. The first official HACCP protocol included seven principles for preventing hazards. (Riswadkar, A. V., 2000)

1. Conduct hazard analysis and risk assessment
2. Identify and define critical control points
3. Establish critical limits for each critical control point
4. Establish procedures for monitoring the critical control points
5. Establish corrective action protocol for each critical control point

6. Establish procedures for valid recordkeeping
7. Establish procedures for an effective verification

In the context of this master's thesis, the steps from 3 to 7 are the focus points of the case company. Step 3 is improved by fetching the material critical limits for products from the ERP software, which are typically related to temperature and humidity but can also be inspected visually. Step 4 is improved by mapping IoT based sensors from already existing storage locations to collect the critical control point data. Step 5 is improved by providing automatic alerts and notifications based on the IoT sensors' data. Also, corrective action tasks can be fetched from the ERP software. Step 6 is improved by storing HACCP records to the clients' ERP software for permanent record keeping. Finally, step 7 is improved by providing automatic ruling and policies for continuous auditing and verification based on ERP data. The first two steps are something that the companies performing HACCP tasks need to consider themselves based on the materials being handled. In some cases, a health inspector or a consultant is used in determining a risk analysis and figuring out the critical control points.

2.1.1 Conduct hazard analysis and risk assessment

According to Finnish Food Safety Authority, a hazard is a biological, physical or chemical actor or state of a food product that can cause a health issue therefore assessing risks is limited to food safety aspects, not quality. If assessment and analysis are not thorough enough, some risks and hazards can be unidentified. In the process of assessing risks and analyzing hazards, the workgroup analyzes all product production materials and additives, packaging materials, production processes, storage and distribution related to biological, chemical and physical hazards. When doing the assessment, the users of the product and product potential usage needs to be taken into consideration. Also, the severity and probability of hazards need to be considered. (Finnish Food Safety Authority, 2008)

2.1.2 Identifying and defining the critical control points

The second principle in the HACCP process is identifying and defining the critical control points based on the hazard analysis and risk assessment. A critical control point can be, for example, a phase in the production process in which it is possible to set a limit of acceptance. In a critical control point, it should be possible to do corrective operations which remove, prevent or reduce the hazard to a level that makes the food product safe to use. It is important to select such a critical control point that is not covered with supportive actions, such as hygiene working principles. A critical control point should produce a measurable result, for example, a temperature (in food processing, the phase of heating material can be a critical control point) or moisture (in food processing, the phase of changing the texture of the product can be a control point). (Finnish Food Safety Authority, 2008)

2.1.3 Establishing critical limits for critical control points

Every critical control point needs to have a critical limit in the measure attribute. For example, when setting a temperature as a critical control point, the upper temperature for frozen products can be -16℃ and a lower limit can be -26℃. The limits should be readily arguable, measurable and be based on, for example, legislation, authority recommendations, literature, food product test results or professional opinion. Typically, when using numeral measurements, alert limits are used to warn the measurement being close to critical limits. These alerts can be used to prevent damage to the product before critical limits are reached. (Finnish Food Safety Authority, 2008)

2.1.4 Establishing procedures to monitor the critical control points

For every critical control point, there need to be procedures set in place for monitoring. The reason for monitoring is to determine if the critical control point is in control and in specified critical limits. In the monitoring, it is also possible to identify changes within the control points, for example, a closing measurement to critical limits to create alarms to create corrective operations before going over limits. In the procedure definitions, it should be

described what is being monitored, how it is monitored, how often it is monitored, who is monitoring it and who is being notified when critical limits are crossed. (Finnish Food Safety Authority, 2008)

2.1.5 Establishing a corrective action protocol for each critical control point

The corrective operations related to the HACCP process, are the actions taken when the person doing the monitoring identifies an anomaly in the measurement data. These corrective operations can be depending on the criticality of the measurement, for example, continuing the heating or freezing, classifying the batch status as dangerous or unhealthy, classifying the batch status as pending or reprocessing the product. In addition to handling the product, the control point should be returned to a controlled state (within the limits). Also, the cause of losing control needs to be figured out and removed. Additionally, the cause should be prevented for the future. The corrective operations are usually documented in a separate document to the normal HACCP process. (Finnish Food Safety Authority, 2008)

2.1.6 Establishing procedures for valid recordkeeping

In the process of determining procedures for effective recordkeeping, it should be set how records are created, what kind of documents are created, where the created documents are stored and who is responsible for storing them. Typically, if manual paper-based documents are used, all documents must be signed and if digital documents are created automatically, the person responsible for it must validate the documents frequently. It should be noted, that if validation of the documents is poor, the HACCP process loses its reliability, and in some cases, the benefits of it. (Finnish Food Safety Authority, 2008)

2.1.7 Establishing procedures for HACCP process verification and validation

The verification and validation of the HACCP process are done to ensure that the process is defined properly. The verification and validation are also done to check if the HACCP process has been used as planned and if it is sufficient to ensure product safety. In addition,

the validation process determines if the process should be changed in one way or another. The frequency of validation and the methods of validating need to be determined. Typically, an outsourced validator is used to ensure a non-biased view of the process. Before starting to use a HACCP in a production environment, a start validation should be done, and revalidation should be done periodically. (Finnish Food Safety Authority, 2008)

The HACCP process is in the core of this master's thesis project. It is therefore important to understand the basic concepts of it. As stated at the beginning of this chapter, this research project focuses on principles three through seven. Principles one and two are something that the company performing food business need to consider themselves and the two steps are very difficult to solve with software without a major amount of historical data available. In the future, at least principle number two could be solved or improved by machine learning algorithms on historical material handling data or other meaningful data.

2.2 Application programming interface

"An Application Programming Interface (API) is a description of the way one piece of software asks another program to perform a service." (Orenstein, D., 2000) Instead of manually transferring data from an application to another one, the developers of software can create APIs to communicate with other software. To put it bluntly, these APIs provide a way to access, read, write, and delete data without human interaction. In some cases, APIs can be used to trigger functions, for example, a call to an API could label a task as started and send an informing email to all stakeholders who are interested in the task. When considering the master's thesis context, it is important to move data through the application's business logic rather than importing directly to the database due to the fact of data consistency being a critical aspect among enterprise software systems and especially.

One way to classify APIs is IBM's three different categories: Internal, External, and Partner. Internal APIs are usually consumed within an organization, External APIs are externally available to consumers and Partner APIs are specifically designed for partners to, for

example, synchronize data between services. (IBM Developer documentation, 2014). In the context of this master's thesis, it is important to understand the basics and principles of application programming interfaces due to the assumption of being able to move the required information with APIs. The API category to be used in this context are external or partner APIs.

2.2.1 Representational state transfer

Representational State Transfer (REST) is an architectural framework for building web services between computer systems. In the formal description of REST architecture, there are six constraints: client-server style communication, stateless communication, caching labeling constraints, a uniform interface between components, layered systems constraint, and code-on-demand style. Client-server style communication is most known architectural style for network-based applications. In this setup, the server offers a service and client consumes the offered service with requests and the server responses accordingly. In this context, stateless means that every request must contain all the information necessary for the server to process the sent request. The cache labeling constraint requires the response data to be labeled implicitly or explicitly as cacheable or non-cacheable. The uniform interface constraint requires REST interfaces to transfer data in a standardized form, such as JavaScript Object Notation (JSON). The layered system constraint means that services should be built in hierarchical layers in a way that system components can only see the immediate layer. These layers can be used to encapsulate and decouple services. Finally, the code-on-demand constraint allows the client to extend the service by uploading and executing code to be run on the service. This code-on-demand is optional constrain for REST due to reducing the visibility of service. (Fielding, 2000)

There are 6 data elements in the REST architectural style: resource, resource identifier, representation, representation metadata, resource metadata and control data. The resource means a conceptualized package of data, for example, an image or a document of some sorts. The resource identifier can be a URL (Uniform Resource Locator) or URN (Uniform Resource Name) identifier to map resources to a path, for example, "image.jpeg" or

“document.pdf”. The representation means the format in which the resource is represented. The example “image.jpeg” can be represented, for example, as an image file or Base64 string. The representation metadata can contain things like media type and timestamps. The resource metadata contain related information to the resource, such as alternatives or source references. Lastly, the control data contains, for example, caching instructions for the client. (Fielding, 2000)

In comparison to older web service standards, such as SOAP, RESTful web services generally yield higher performance due to light-weight nature. The light-weightiness is achieved by avoiding unnecessary XML markups and extra encapsulation for API input or output. (Zhao, H, Doshi, P, 2009) When analyzing the benefits of RESTful web services against, for example, SOAP web services, it is important to acknowledge that the comparison is according to some authors meaningless, since the technologies have different objectives and benefits can be significant for both technologies based on the context to be used (Garriga, M., 2016).

2.2.2 Open Data Protocol

The Open Data (OData) protocol is a communication protocol to perform create, read, update and delete (CRUD) operations and additional custom behavior using HTTP (Hypertext transfer protocol) requests. OData protocol is based on RESTful design principles. The OData protocol provides uniform ways to describe the data model and the representations of data which increases the interoperability between software systems. OData requests allow the request maker to provide a response type, although this does not mean that the service must obey the request if it is unsupported by the service. In addition to having benefits of uniformity, the OData protocol also supports performing protocol level operations, such as searching, filtering and counting, for example. (OASIS, 2014)

The most important advantage of the OData protocol is flexibility. The possibility of not restricting the data of predefined aggregations can be a huge benefit when designing long-term enterprise architectures (Rafal Cupek, Lukasz Huczala, 2015). Also, the possibility of

selecting the format of communication can have a significant effect on energy consumption, response times and predictability of both. In the experiment made by Thoma M. et al., there were significant differences between formats. In the worst-case scenario, the response time and energy used in milliampere-seconds were 7 times higher in extensible markup language (XML) than in JSON format. (Thoma M. et. al, 2014)

The understanding of RESTful web services and the basics of REST architectural style is important in the context of this master's thesis due to the requirement of the case company. The SAP S4/HANA system exposes data services via REST web services. The benefits and knowledge of OData protocol are important for this master's thesis project because the SAP data services typically expose the data through this kind of protocol.

2.3 Cloud-to-cloud communication

When two software systems are running in the cloud and communicating with each other, it is called cloud-to-cloud communication. Cloud computing is a distributed computing paradigm which means accessing shared pools of computing resources being treated as services. The benefits of cloud computing are the scalability and rapid provisioning and releasing in most cases over the Internet. One of the key issues in the cloud computing paradigm are the security issues often related to the administration of the data centers, including the management of network communications, hardware and access of users to them. (S. Dowell, A. Barreto, J. B. Michael and M. Shing, 2011)

The computation hardware found in the cloud data centers is usually close to the typical non-cloud data centers and widely available. The virtualized servers in the cloud have slightly reduced performance due to the virtualization overhead from hypervisor processing and therefore cloud virtualized server can have slightly (0-10 %) lower raw performance with the same hardware. The overhead that is caused by the hypervisor systems varies, but it is important to remember that hypervisors are the entities in the cloud computing paradigm that makes it possible to provide high availability on virtual machines. The hypervisors in

addition to computing virtualization, also manage network connections, storage solutions and other operations related to cloud computing. (P. Vijaya Vardhan Reddy, Lakshmi Rajamani, 2014). The networking capabilities of cloud computing can be considered one of its benefits, but it also is a challenge. As stated in the definition of the cloud computing paradigm, it is a massive scale of shared computing resources which also applies to network. (Raouf Boutaba, et. al, 2015).

The security aspects of cloud computing are usually considered a major issue to the potential customers of cloud computing services. These issues include uncertainty of, for example, data security, network security, authorization, and authentication. When considering the security aspects, the benefit of making resources available through the Internet can be considered a risk if the configuration and all aspects are not taken care of properly. (Subashini S., Kavitha V., 2011)

The importance of understanding the cloud-to-cloud communication challenges and benefits is based on the fact of running all parts of the software in the cloud. The case company is running the backend services in a public cloud. The ERP software nowadays and in the future are moving towards the cloud computing paradigm. In 2015, Ruivo P. et. al. conducted exploratory research to find the direction where companies are moving terms of ERP computing. In 2015, less than half of the surveyed companies were using an on-premise solution. 41 of the 53 surveyed companies answered, that most likely during the next 10 years, they will move or have moved to at least a hybrid solution, which has both, on-premise and in the cloud computing. (Ruivo, P., et. al., 2015) The test and development system for the empirical part are running in the cloud.

2.4 Client-Server computing paradigm

The Client-Server computing paradigm has its roots in the 1980s when the LAN based software first was reaching the larger public. In the Client-Server computing paradigm, typically one or more servers are hosting services available to one or more clients. Servers,

with the supporting technologies from operating systems and interprocess communication (IPC) systems, such as networking, form a composite system to serve a client. In the client-server paradigm, the client always initiates the communications. An ideal server is such that hides the entire composite system prementioned from the client and the client should be completely unaware of the server's platform components, as well as the communication technologies. (Sinha, Alok, 1992)

In 2011, there was an article published in the Journal of Business & Economics Research by Carl S. Guynes and John Windsor discussing whether or not client-server computing paradigm is still relevant. It is said, that client-server computing plays an important role in decentralizing applications to smaller distributed systems. The decentralization provides an added value to the paradigm by providing reliability and performance through replication. A major benefit of the client-server paradigm is the well-defined data security and assurance standards, which are still being improved to provide defense in layers to both data and computing resources. On the other hand, the security aspects are also one of the main issues regarding the client-server paradigm, especially the current cloud computing move in the corporate world. Providing open access to a server from anywhere in the world increases the requirements of security for the servers. Failure to apply strong enough security procedures will virtually guarantee the failure of the system security. To conclude, the client-server paradigm holds its place in the computation field and provide a solid way of communication. It should be noted, that the benefits and concerns for the paradigm should be considered when making decisions for selecting client-server over another type of communication. (Guynes, C.S. & Windsor, J. 2011)

In the context of this master's thesis project, it is important to understand the basic principles and benefits of the client-server computation paradigm. This is due to the fact that API communication over the Internet is typically implemented with client-server communications. In this project, all three components involved, are acting both as both, servers and clients depending on the communication direction. Additionally, the users interacting with the backend services, either through a mobile application or another interface, are considered as clients.

2.5 Service-oriented architecture

Nowadays, there are no simple way to describe what Service-oriented architecture (SOA) is. There are many definitions and many research groups that are dedicated to studying this technological innovation. One definition of SOA defines the technology to be based on reusable services that are well documented with public interfaces. These services are supplied by a supplier and consumed by the service consumer. Typically, a service consists of four abstract layers: the service business logic and data, a service contract, restrictions, and an interface. (Dinarle Ortega, et. al, 2009). Services are functional components which are in this context business components that are designed to be accessed by a service consumer. Typically, a service represents a business function in this context, such as get product information. (Cheng Hsu, 2007, pp 87-90)

2.5.1 Web Services

Web services are becoming the typical implementation of SOA. Web services are pieces of software that are built to support system-to-system interaction over a network connection. There are two major classes to web services: REST-compliant web services and arbitrary web services. Both of these classes use web protocols to communicate and URIs to identify resources. As an example, a web service can use HTTP as a communication protocol and XML as a data format. Typically, useful web services have four characteristics. First, they are discoverable, which means that the service consumers need to be able to access them. Second, they need to be communicable, which usually means that the messaging needs to be asynchronous and service consumer initiated. Third, the communication between a service consumer and a web service need to be conversational. This means sending and receiving information without losing context. Lastly, all communication and data need to be secured, manageable and fault tolerant. (W3C Working Group, 2004)

Enterprise architecture integration framework (EAIF) is an architectural framework which attempts to help software integration projects to be better organized and give a more unified view of the main aspects and elements in an enterprise environment. In a case study by Dinarle Ortega et. al, where the research group extended EAIF architecture with SOA principles, the researchers achieved good results and propose that enterprise integrations should use the new technological trends. (Dinarle Ortega, et. al, 2009)

Many enterprises, whether they are large or small, use IT systems and computing technologies to remove distance, time reactivity or interoperability barriers. Enterprise engineering (EE) is the process of improving efficiency and effectiveness of business processes by analyzing, restructuring, designing and optimizing parts of business process entities. In this context, a supply chain can be considered an example business process entity. (Cheng Hsu, et. al, 2007, pp 77-87)

It is important to understand the SOA principles in this master's thesis context due to the empirical part being done in a service-oriented architectural style. The implementation and design follow the principles of a REST-based web service with enterprise architecture kept in mind. The web service to be created for data transferring purposes will have usability, security, reliability, and speed as the primary attributes for performance measurements.

2.6 Event-driven programming

Event-driven programming is a programming paradigm that describes the behavior of the program. Typically, event-driven programming can be characterized by performing actions, functions or other behavior triggered by an event rather than in a pre-determined order as in procedural programming. The basis of functional programming is the functional decomposition of the software. To put it bluntly, this means that functions are built in a modular matter and large functionalities are built from smaller functions which solve a piece of the problem or produce the desired functionality. Modular software also improves the reusability, manageability, and maintainability of the software code. Object-oriented programming can be used to support event-driven software, which is the programming

paradigm used in this master's thesis project due to the strict constraint from the case company for using Java as the primary programming language for any software that is made. (Philip, G. C, 1998)

Typically, event-driven web software is built using event producers, event consumers, and event-processing software. Messaging systems are used to pass messages in a channel, which is the transportation method to pass the message. (IBM Developer documentation, 2011) In the context of this thesis, event producers are the case company's backend software and the ERP software. The same entities are also the event consumers of events generated by the opposing system. This master's thesis project attempts to build a solution that works as event-processing software between the event producers and consumers. The messaging system used is HTTPS (Hypertext transfer protocol secure) and the transportation channel used is over the Internet (or using a secured network between all peers, such as a VPN (virtual private network).

2.7 Model-View-Controller (MVC) architectural pattern

Typically, when building an application, the modularity of software components has a great benefit when considering the understandability and maintainability. Model-View-Controller (MVC) architectural pattern is a three-way factored paradigm, which consists of operations related to the application domain (the model), the displaying of the application's current state (the view) and the interaction logic handler of users' actions (the controller). Typically, the interaction cycle consists of the system taking an input from a user, which is then passed to the related controller as notification to change the model accordingly. The model then executes the operations in the notification and the results are then broadcasted back to dependents: the views and controllers. (Krasner, G. E., & Pope, S. T., 1988)

Often MVC is used in conceptual development and it is also a case in this project. The main benefit from the usage of the MVC architectural pattern is modularity and reusability. (Krasner, G. E., & Pope, S. T., 1988). The components built for the purpose of this project

can be very easily integrated into other projects due to very lose coupling made possible by the MVC architecture. In the context of this master's thesis project, loose coupling and relatively easy integration to other software components are desired features. It should be also noted, that even though MVC architecture was selected and required for this software project, it is not the only one that can be used to reach similar results and functionality.

3 QUALITATIVE RESEARCH

The aim for the customer interviews in the context of this master's thesis was to find opinions and potential answers to the third research question: what kind of benefits the digitalization of the HACCP process makes possible. It was also used to generate insights, viewpoints, concepts and to expand the understanding that is not already taken into consideration in this project. Ultimately, it was used to confirm or decline the hypothesis described in the introductory chapter about the benefits of digitalizing the HACCP process and the integration to ERP systems. The interviews were done in a qualitative way: the questions are prepared and delivered to the interviewees in advance, the interview results were analyzed later and reported in the results section of this master's thesis. The interviewees were selected from interested customers of the case company and therefore was chosen to be interviewed. The questions related to these interviews were created for the sake of this study and do not take part in a larger survey. The interviews were done face to face, remotely via a telephone call or Skype. If the interviewees allowed, the interviews were recorded for better documentation.

3.1 Interview questions

The questions for these interviews were formed specifically for this master's thesis with the opinions and guidance from a representative from the case company to get the most accurate results possible. The interview consists of 3 major subjects: 1) how the company feels about the ERP software, 2) how the company performs the HACCP process and 3) what are the opinion of the company in using an application to perform HACCP tasks and importing HACCP reports into ERP software. Each subject will be discussed in the interview on an own section. The section will consist of two or three questions with a possibility of additional questions made from the answers.

The questions in the interview are:

1. How would you describe the company's relationship to ERP software?
2. Would you say that ERP is the root of your company's business? Please explain how it shows day to day.
3. What would you say that the strengths and the weaknesses of your current ERP system are?
4. How is the company currently performing the HACCP process related tasks?
5. What kind of tools are you currently utilizing in the process? Note that the tools can be either digital or "mechanical" (such as paper-based documentation).
6. Do you think that your approach is the most modern? Please explain your viewpoint.
7. Do you think that digitalizing the HACCP process and tasks is beneficial? Please explain your viewpoint.
8. Do you think that syncing the HACCP process into an ERP system would provide an added value to the company in a short or long term?

Next, the reasoning behind every question and what kind of answers the interviewer is expecting are described. The first question, how would you describe the company's relationship to ERP software, is to find out how the interviewee feels about ERP systems, what is the general opinion and the feelings related to ERP software and what kind of ERP are they currently using. The second question, would you say that ERP is the root of your company's business, is to figure out how the interviewee's company uses the ERP system in their everyday operation. The third question, what would you say that the strengths and the weaknesses of your current ERP system are, attempts to find what kind of improvements could be made to the current everyday processes of the interviewee's company. These first three questions attempt to find out answers about the general feelings and thoughts of the company's representative regarding the ERP systems.

The second group of questions tries to find out information about the company's HACCP process and how they are performing it. The fourth question, how is the company currently performing the HACCP process related tasks, attempts to get an overview of the current state. The fifth question, what kind of tools are you currently utilizing in the process, attempts to improve the picture created in the fourth question by asking what kind of tools they are using to do these HACCP tasks. It is also used to figure out whether or not the interviewee's company has digitalized these tasks and if they are, the completeness of digital solution is attempted to find out. The sixth question, do you think that your approach is the most modern, attempts to find out if the company is happy with the current approach, or if there are obvious downsides to the current approach. Also, the willingness to modernize the approach is mapped.

The third group of questions tries to get opinions on the project of digitalizing the HACCP process. The seventh question, do you think that digitalizing the HACCP process and tasks are beneficial, is used in this interview to gather opinions on what the digitalization benefits of HACCP could be for the interviewee's company. Also, ideas to further improve the project and things that we may have overlooked are gathered with this question. The final question regarding ERP integration tries to map the benefits of this master's thesis project for the interviewee's company.

3.2 Interviewed companies

The interviewed companies were selected with the convenience sampling method as the primary selection methodology. The companies which have a friendly relationship with the case company were asked whether or not they would like to join this master's thesis research as an interviewed company. All of the companies are located in Finland. The companies are either privately owned businesses aiming for profit or companies providing services for the cities and towns in a municipality, such as a central kitchen, both using HACCP processes in their daily tasks. The persons that were targeted in the selected companies or other organizations were selected with the elite interviewing methodology in mind to get the most

accurate and descriptive opinions. In elite interviewing, the persons who are responsible and are professionals in the discussed matter are usually selected and preferred over a random choice from a group of potential interviewees.

The second step after discussing the companies to be interviewed with the case company, the companies were reached out by calling the representatives. It was discussed, that the best way to reach the persons, who potentially have knowledge on the matter, was by dialing them directly. Unfortunately, it was found out during the initial phone calls that most of the persons were quite busy during business hours and were difficult to reach. It was decided that the best way to get as many responses and interviews as possible, would be to send a cover letter regarding the missed call and the subject of it. The companies providing services for cities and towns in municipalities were generally fast to respond back after the sent email and negotiating a schedule for the interviews. It was agreed by both peers regarding the interview, that the interview questions will be delivered one or two weeks before the actual interview to get the best results. The interviews were scheduled for roughly one to two months in advance.

3.3 Interview execution

The interviews were executed remotely due to companies being around the country. The basic setup for the remote dials was setting up a conference call in either Skype or via telephone. Whichever was used, were then set up for recording when the approval from all peers was confirmed. The interviews done with Skype were recorded with the built-in recorder and the telephone calls were recorded using an application made for call recording.

The interviews started by introducing everyone in the call. Typically, there was the interviewer, a case company representative and at least one person from the interviewee organization. The role of the interviewer was to ask questions and initiate additional discussion based on the answers given to the pre-shared questions. The case company representative's main role during the interviews was listening through the conversations

taking part in the discussion if there are conceptual mistakes, customer problems that require answers, or when there was explaining why certain design decisions have been made. Additionally, the case company representative attempted to find and identify potential use-case stories for marketing and other materials. The interviewees' role was to answer questions regarding the research and share their thoughts on how they felt about things that came up.

There were only minor issues during the interviews, such as agreed schedules not holding (the issues were caused by the interviewees having a more urgent situation and needing to prioritize), misunderstanding what an ERP system is and not understanding the question properly. These issues were solved by explaining what the interviewer was looking for in each question, explaining what an ERP is and giving examples. The scheduling issues were solved by either rescheduling interviews or just simply starting the interviews late.

After an interview was held, the recording was played through and processed while taking notes from the interesting parts of the discussion. The lengths of the recordings varied between 15 and 45 minutes, some containing quite a lot of off-topic matters. The variable interview length also reflects the fact that some interviewees were more prepared and had thought about the questions more than the others. The shorter interviews were the ones having more answers and thoughts ready, which meant that there was no need to initiate in digging more thoughts.

3.4 Interview results

In this subchapter, the results of the interviews are analyzed and concluded. The interview results are analyzed question by question, while summarizing the answers given by the different interviewees. The three larger interview sections are summarized after all the questions regarding the section is analyzed. Total of eight companies or municipalities were interviewed.

3.4.1 Thoughts regarding ERP systems

The first section in the interview mapped how the interviewee's company used ERP systems, what their role in the everyday business is and what the general feelings about them are. Of the eight companies, six were using ERP system of some sorts. Every company using an ERP in their business mentioned that it is either important, very important or crucial for their everyday actions. In figure 2, the features that the interviewees considered important for their business are graphed. It can be seen from the result, that most companies consider the billing features as an important feature found in the ERP systems. It is quite logical due to the importance of having a stable system for handling billing to ensure successful money traffic. Another important feature was the management of both, sales and procurement orders. This was in all three cases mentioned side by side, which would suggest that in case of handling orders through ERP, both inbound and outbound is being handled within the same system. The interviewed persons were all related to a professional kitchen in one way or another, which makes the products and recipes management being the third and fourth most commonly mentioned features, with storage management being shared in the fourth position. As a surprise to the interviewer, it was found out that logistic operations, such as receiving and sending articles and items were mentioned only once.

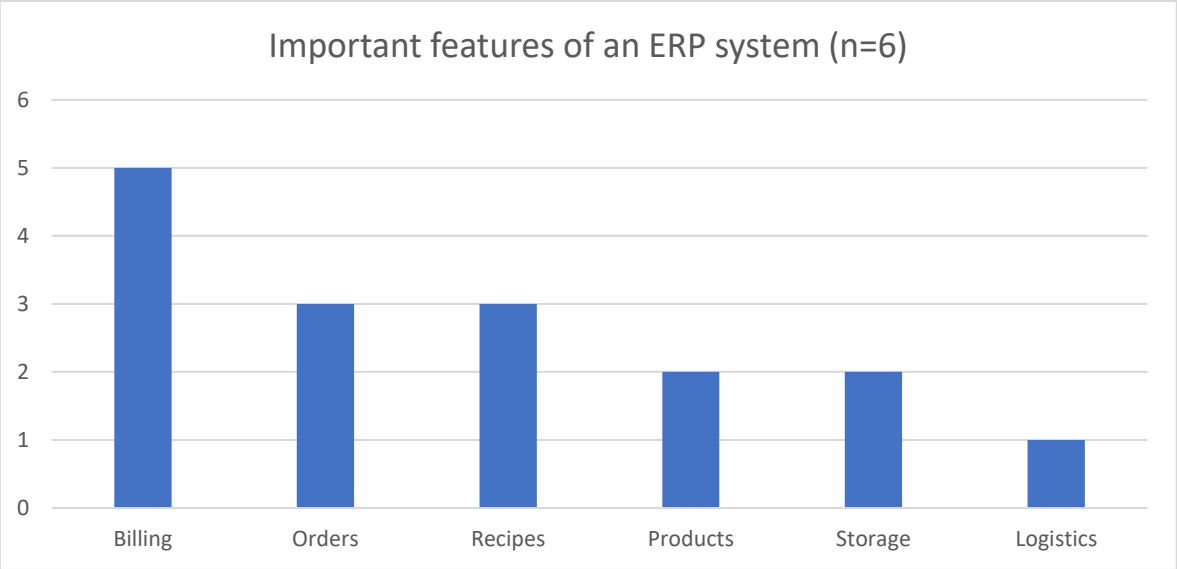

Figure 2 ERP features mentioned as being important

The second question attempted to find out how the employees of the interviewee's company see the usage of ERP systems. The answers were classified into three categories by the benefits that were mentioned by the interviewees: 1) Workflow automation, 2) Time saving and 3) Data documentation. In figure 3, these categorical answers are drawn in a bar chart. From the results, it can be seen that the companies mostly use the ERP systems for automating the everyday work they do, which is simultaneously saving time. While doing so, as an added benefit the data of who is doing what and when is being documented and stored digitally. The general attitude towards ERP systems was quite good and positive, although some comments were made towards the ERP systems being generally very difficult to use and do not offer a complete solution: additional systems are needed around the company for everything to run well. The few companies that were interviewed but did not have an ERP system in place were a slightly different type of kitchens: they were a restaurant rather than a central kitchen. It is quite logical, that when there are a lot of repetitive tasks to be done such as in the central kitchen, the workflow can be automated to save time.

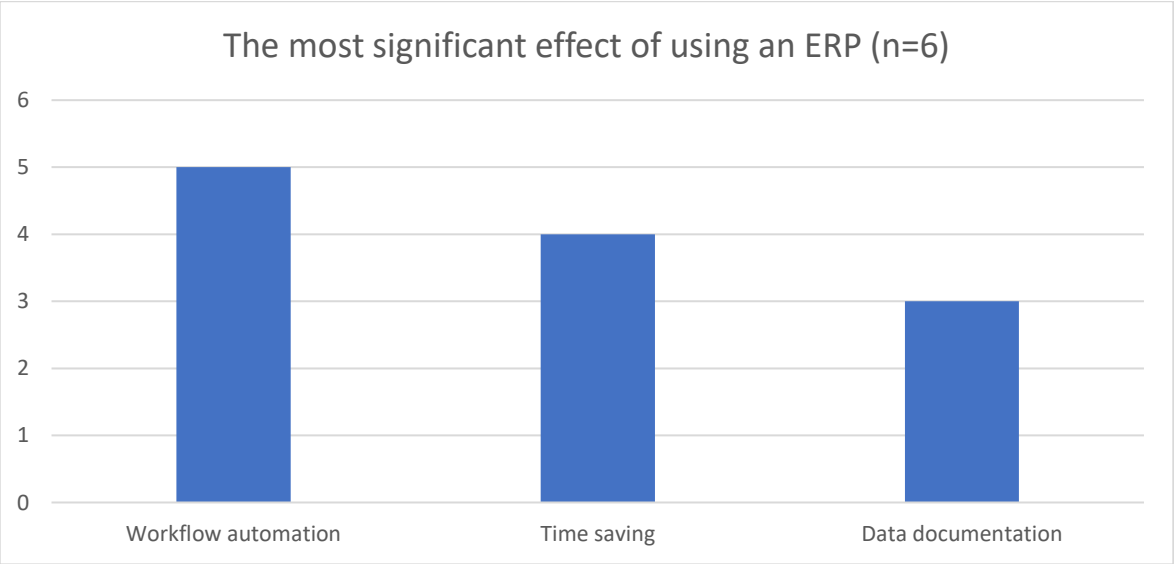

Figure 3 Daily benefits obtained by using an ERP system

The third question asked opinions of the current ERP system the companies or municipalities were using. The opinions were asked in a way that asked the interviewee about the strengths and benefits of the current ERP software system. Generally speaking (4 out of 6), the most

mentioned strength was that the used ERP system is suitable for the company or the municipality and offers just the feature sets they need. In some cases, it was said that a certain ERP system is made for humans (easy to understand) and in other cases flexible for sudden changes in the business. Strengths that were mentioned once or twice were price, easiness to use, flexibility and operational reliability. Weaknesses that were mentioned once or twice were difficult limitations, inflexibility, short usage lifespan and slow adaptability when the operational environment changes. Due to the reason of every company having a different ERP software system in use, a wider summary is not made since the second most mentioned strength and weakness were mentioned only twice.

A general thought for the first section after the first three questions was that the interviewed company and municipality representatives were generally quite happy on ERP systems and how they are used to optimize their everyday actions. In the context of this master's thesis project, the thoughts for ERP systems were mapped due to the interest in integrating a process into an ERP software system.

3.4.2 Attitude and feelings towards HACCP process

The second section of the interview focused on the HACCP process and the attitude and thoughts towards it. The interviewees were asked on how the company or municipality they work for perform the HACCP process (task-wise), what tools they are using and whether they are feeling happy on how they are performing it. The second section was answered by all eight interviewees.

The first question in the second section asked what kind of tasks are performed in the HACCP process. In figure 4, the tasks mentioned by interviewees are listed and graphed by the numbers mentioned. Every interviewed company and municipality were performing measurements from the food products that were served. This is most likely due to the Finnish regulations, as health inspectors demand that this kind of measurements are made. The second most common task were the logistics measurements, which means tasks like incoming inspection. Typically, in this kind of inspection at least temperatures are measured

on receiving of the products and visual inspection is made. Some of the companies have included cleaning tasks in their HACCP plan and are performing certain tasks daily, weekly, monthly and annually. As a surprise, not every interviewee mentioned the monitoring of storage temperatures, which is something that in the mind of the interviewer is an important aspect. It is also possible, that the persons being interviewed thought it is self-explanatory that storage temperatures of sensitive materials are monitored. Some companies also take quality samples from the foods they serve in their HACCP tasks.

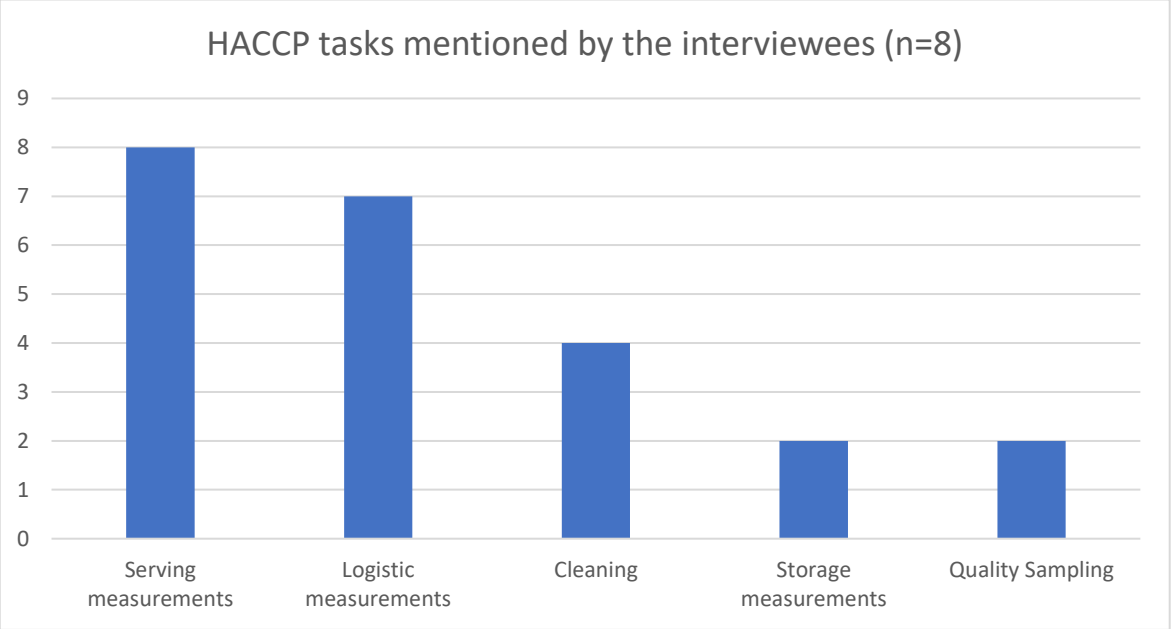

Figure 4 HACCP tasks performed in the companies

The second question in the second section attempts to map what kind of tools the companies and municipalities use in their HACCP process. All eight companies used at least partly digital solutions, but only one was fully digital. In the discussion, this meant that the process of digitalizing the HACCP tasks is either too expensive or the persons performing the tasks were reluctant in using digital tools and conservative against switching away from pen and paper. In figure 5, the number of interviewee's companies using digital tools and more traditional pen and paper approach is graphed. It should be noted that most of the interviewees had knowledge from multiple locations and not all were the same. In addition to digital tools and pen and paper, some companies had additional tools mentioned in their

HACCP plans, such as hygiene tests, regional premises monitoring and other process equipment (for example, milk processors).

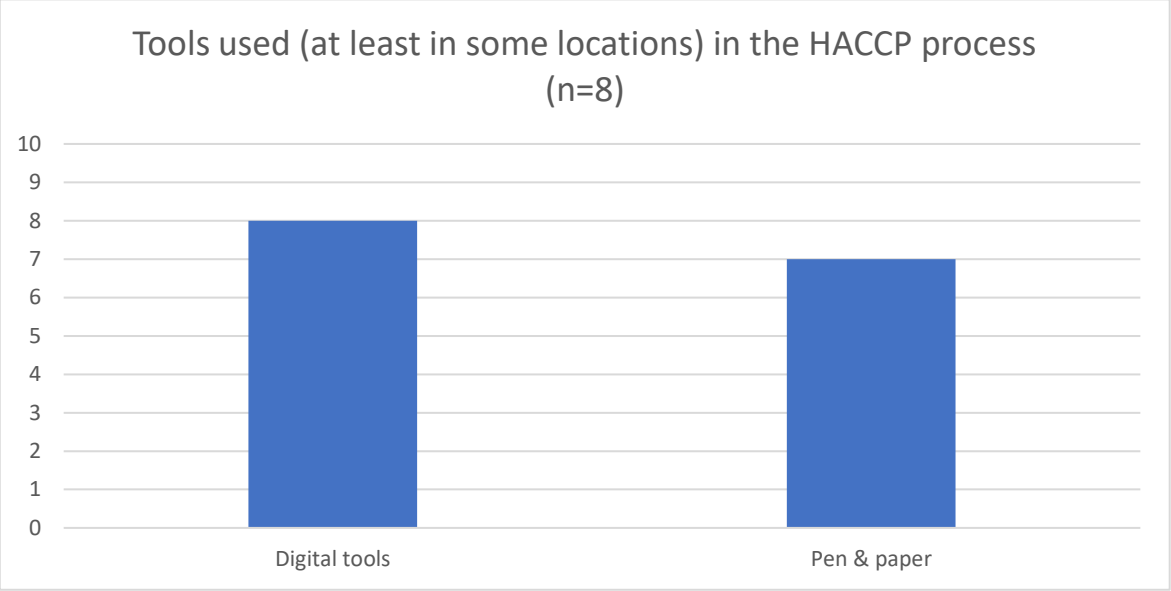

Figure 5 Tools used in the HACCP process by the interviewees' companies

The third question in the second section gathered thoughts on the digitalization of the HACCP process and its tasks. Six of the eight companies were considering the digitalized HACCP tasks as easier to perform than their traditional counterparts. Generally speaking, the interviewees would not return to the old systems they had had. As a bad side of digitalizing the HACCP tasks, some new issues have risen to the companies and municipalities which they have not faced before. These issues were the increased difficulty of performing tasks when a person was not a digitally experienced user and, in some cases, the performance issues in equipment used. The equipment, for example, was thought to have better battery life and whenever a battery had run out, the only way to document these tasks was with the traditional pen and paper. In the initial plan, there was an idea of identifying needs for improvement from the interviewees. In the end, the interviewees could not identify a concrete thing that was missing from the current digital implementation for the HACCP tasks, but it was also mentioned that typically the HACCP tasks are defined by the law and health inspectors in Finland and changes in legislation will create new needs.

To summarize the second section in the interviews, the answers were pretty much in line with the expectations: most of the companies that have digitalized their HACCP processes are not yet fully digital and are partly using the traditional methods. Also, the tasks in the HACCP plans are closely related to the ones required by the law and inspectors. It was hoped, that the sixth question, trying to find improvement ideas for HACCP tasks, would reveal areas and ideas for improvement, but this time it was not the case.

3.4.3 Digitalizing the HACCP and synchronizing data with ERP

The final section for this interview study attempted to find out what kind of benefits the interviewees' companies have gotten or will get from the digitalization of HACCP processes. Also, the benefits of synchronizing the data with ERP systems is asked from the interviewees. There were two questions asked from the interviewees: what kind of benefits you have already gotten from the digitalization of HACCP process or will get in a long period and what kind of benefits you think is possible to get by synchronizing HACCP process into ERP software systems. The first question yielded an answer by every interviewee, but the second question was hard to the interviewees.

The first question regarding the benefits of the HACCP process raised a lot of different benefits during the discussion that the companies have already gotten in a relatively short time. In figure 6, the count of each type of answer is shown. The number one benefit gained from the digitalization of HACCP process, when considering the times mentioned during the interviews, is related to the near real-time characteristic of the digital system. It was mentioned, that the fact of getting results instantly from measurements to the place where quality control data is monitored, has increased the value of these systems by making it faster to react to the inconsistencies that may occur every now and then. The traditional method of taking measurements on a paper every hour or two leaves a large time-gap for errors, according to the interviews, especially when it is not always possible to follow the plan rigorously. The real-time systems with automated alarms improve the reliability, safety and security in many places in the food storing, preparation and serving areas.

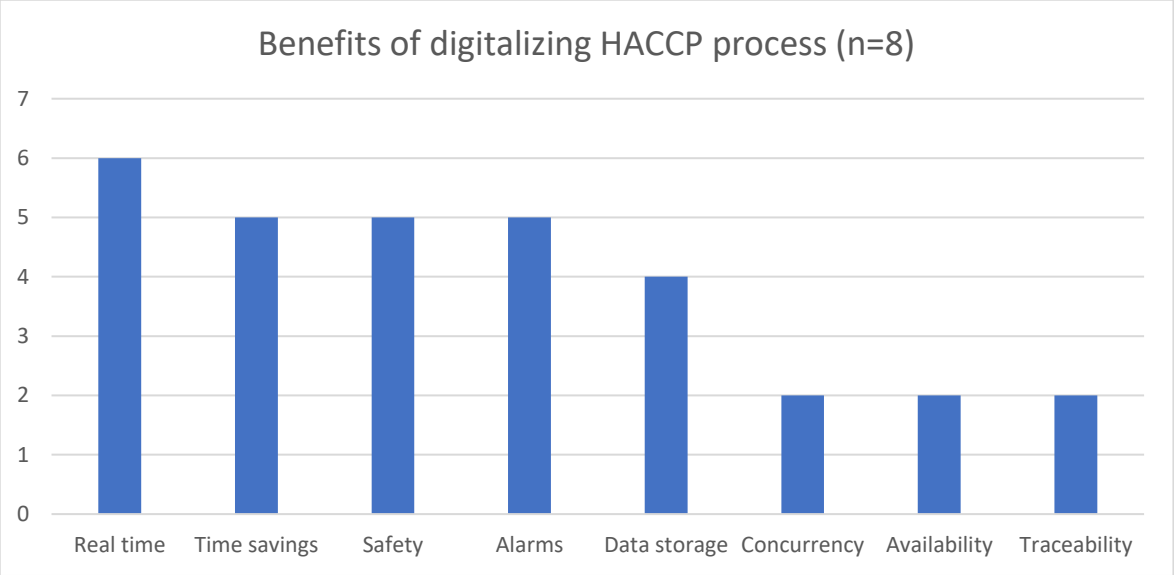

Figure 6 The benefits mentioned by the interviewees for digitalizing the HACCP process

One of the second most times mentioned benefit during the interviews were the time savings made possible by digital HACCP solutions. The mentioned cases, where the time savings were most visible, were the many times repeated tasks, such as the temperature measurements from the storage and during preparation, logistics, and serving. By having sensors doing the measurements automatically, it frees the kitchen or other personnel time to complete other tasks, indirectly saving costs by needing less workforce at the operative locations.

The two other benefits in the shared second position in the most mentioned benefits are the safety aspects and automatic alarms, which are closely related. During the everyday operations in the food industry, in many cases, it is important to have the correct operational environment (such as the temperature or humidity). Having automated alarms with configurable parameters make it possible to control the operational climate and find out whether or not the characteristics of the climate are correct. On the other hand, having a digital system in place allows the tracking of which tasks are done and which are not, and in the case of important tasks missing, reminders and notifications can be sent to ensure security in other places than the climate conditions.

The third most mentioned benefit, slightly related to the safety aspects, is the cloud-based data and document storage. By having the HACCP documents stored permanently in an off-site location, it is ensured that the documents are not lost (as opposed to the pen and paper approach, where it is possible that some documents get lost for one reason or another). Permanently storing the data in a digital format also provides better opportunities for data reporting, which was mentioned by many interviewees to be a great feature. It was said, that especially the possibility of giving the health inspectors direct access to the report data is an important and very useful feature made possible by the digitalization of the HACCP process.

The less frequently mentioned important aspects were concurrency, availability, and traceability. Concurrency meaning the possibility of multiple persons being online same time performing tasks, where as opposed to the paper and pen approach, in traditional methods it is typically possible for one person at a time to document the inspections in a location. Availability meaning the possibility of accessing the data from a remote location in a near-real-time manner and accessing the historical data remotely. In the traditional pen and paper approach, the documents were stored typically in the location and fetched when needed. Lastly, the traceability meaning the digital timestamps holding the information such as who has done what at what time and having the possibility of finding out what has happened exactly at a certain time and location in the history.

Some other minor aspects were mentioned by companies, which were left out of the graphs due to having a sample size of one. These aspects were the increased meaningfulness of the HACCP tasks, the approach being modern and input security. The increased meaningfulness here means how the persons' performing the HACCP tasks are feeling about the job. The approach being modern means that the person who mentioned in the interview told that digitalizing the HACCP process got them (as a company) to this decade. Lastly, the input security aspect was related to the HACCP task performers, who are sometimes not doing a very accurate job in measuring or documenting the measurements. When the digital equipment takes the measurements directly, it in many cases is not possible to change data.

The second question in the third section was trying to map potential benefits and ideas regarding the synchronization of ERP software system and HACCP process data. This question turned out to be the most difficult question for the interviewees, possibly for the reason of trying to create opinions and ideas of things that were not at the hands of the interviewees at the time of interviews. Another aspect what could have made the question difficult was the rather basic level of ERPs in use on the companies of the interviewees. When the ERP system is a very basic one, it could lack the features that could benefit from the HACCP process data and limit the thoughts and ideas. Due to that, not every interviewee had a concrete answer or an idea of what could be achieved from synchronizing the HACCP process data to ERP systems.

The general idea among the interviewees who responded to the question was that the data itself won't do much, but it should be possible to link to other features into the ERP. As an example, from a couple of interviewees, the amount of waste would be an attribute that would be used in the ERP systems in the long term. The long-term data could be used to train a machine learning model to predict the amount of food that is needed to reduce the amount of waste or to point out products that are most often thrown in the trash. This kind of knowledge from the data could reduce the amount of waste which leads to saved costs and making the business more profitable.

Another aspect mentioned by the interviewees was the increase in the credibility of the company. When data can be linked between systems, it shows a certain type of dedication for the matter and could improve the reputation in the eyes of an outsider. It can also be used in the process of getting certain quality certificates, where the requirements of a quality standard require the data to be stored in a certain way.

As an example, the ISO 22000 standard explicitly states, that the documents regarding the monitoring results need to be stored and that a traceability system needs to be in place. The standard also requires the organization to have a system in place to validate the results, to retain the documentation and a person responsible of analyzing and evaluating the results. Additionally, there are requirements of addressing the distribution, access, retrieval and use,

which are easier to fill whenever one is working with digital documents as opposed to traditional paper-based documentation. (International Organization for Standardization, 2018)

3.5 Interview conclusion

The conducted interview study revealed aspects that were not already known in the hypothesis, which was one of the target objectives of this research. These new aspects were the things considering the meaningfulness of the tasks, the trust in the measured values, increased credibility and the link to standards. Overall, the interviews were successful when considering the answers and the added value of interviews by having a case company representative present in all interviews to the case company. Most of the results were in line with the expectations and hypothesis.

4 DESIGN SETTING FOR IMPLEMENTATION

The initial implementation for this project is done with the case company's requests and requirements kept in mind. The main requirement for the implementation is that it should be done in Java. Tomcat and Spring Framework were the recommended web frameworks for this implementation project from the case company as the main tools to work with. The project working title was decided with the case company to be Sensire SAPIF (SAP Interface). The design setting was built with the co-operation of SAP Ireland and some of the design choices are suggested by the company's representatives.

4.1 Component overview

In figure 7, the general aspects of the used components of the used ERP system are described. The SAP Netweaver platform is the basis for many SAP applications. Maybe the most commonly known SAP software, the SAP ERP, is also built on the Netweaver platform. The platform provides useful functionalities that are used in this integration. The Materials Management (MM) module data contains material information, such as material descriptions, material limits and instructions, universal product code (UPC) and other identifiers. HACCP tasks can be implemented in SAP using the SAP Inspection Lot and Inspection Plan features which are both parts of the Quality Management (QM) module. SAP Gateway provides a gateway functionality to export and import data from the SAP platform and database via OData view sets. When importing data towards the ERP system, the data will need to be processed with, for example, built in Advanced Business Application Programming (ABAP) functions or other methods. The SAP Core Data Services (CDS) provides read-only access to the SAP database through OData view sets. The SAP Gateway and SAP Core Data Services features are used as an interface for the API Proxy to be built (Sensire SAPIF in the graph). The API Proxy will perform requests towards both endpoints.

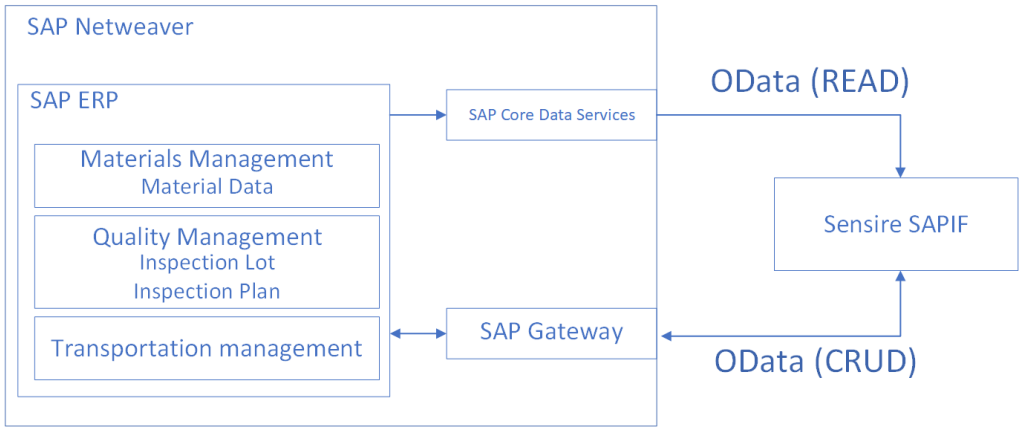

Figure 7 Overview of the components to be used in the two-way data integration

In practice, the HACCP software backend communicates with ERP systems through an API proxy (the SAPIF), which is a software service proxying requests to the clients' SAP endpoints. In figure 8, the general working principles of an API Proxy are explained. One of the main benefits of using API proxies is having a place to manage request policies. These policies can increase the value provided by a single API by, for example, providing extra security layers (access management, rate limiting), performance improvements (backend caching) and availability improvements (through having cached copies of data). In terms of development and developers, API proxies provide a way to create a heterogeneous service where the consumer of API proxy does not need to explicitly know what kind of requests are done to get the results. This allows a level of per customer customization. (S. Asano, et. al, 2016)

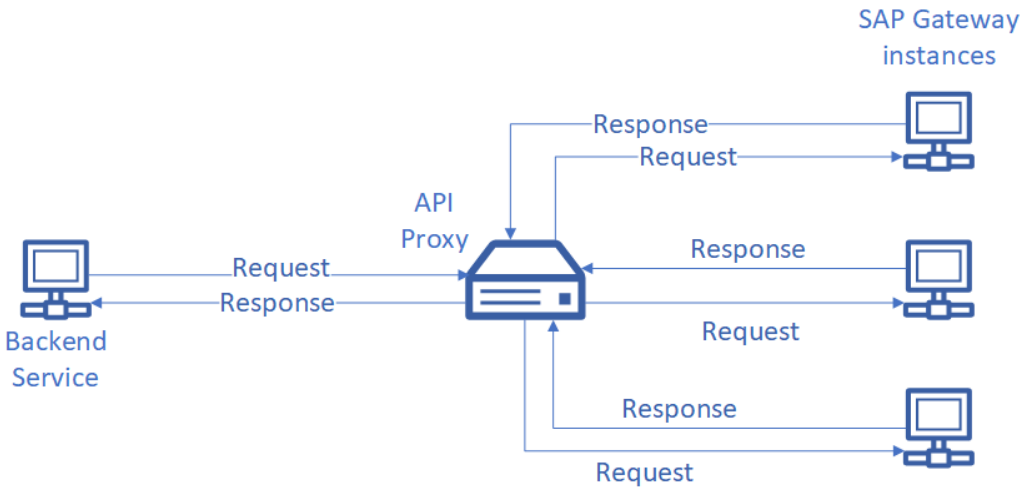

Figure 8 API Proxy overview

One key feature and requirement for this implementation is to support multi-tenancy. Multi-tenancy as a term can be described in software engineering as such: A single instance of application provides services to multiple clients. Multi-tenant application instances can be categorized in three ways: single instance, arbitrary instance, and multiple instances. If a service is non-configurable and serves multiple clients, it is a single instance service. If a service is non-configurable and each instance serves only one client, it is a multiple instance service. The arbitrary instance category is a mixed category of single and multiple categories and they are not explicitly set how many clients can access the service instance. (Ralph Mietzner, et. al, 2010)

4.2 Data overview

There are four initial data views for the SAP CDS which is used to fetch data from the ERP system. These four views are Inspection Lot view, Transportation view, Material view, and Inspection Tasks view. In figure 9, the list of fetched attributes is visualized. These four data sources are used in processing the HACCP tasks. This data can also be used in the end-to-end tracking of the business process (such as delivery and shipping).

Lot Data
- Lot code (number)
- Batch code
- Material ID
- Plant ID
- Storage location
- Inspection type
- Inspection points
- Creation time
- Material auth activity group

Transportation Data
- Transportation vehicle type
- Transportation vehicle identifier
- Transportation schedule (planned start / finish)
- Transportation location (planned start / finish)
- Lot/Material references

Material Data
- Material identifier
- Material description (+language)
- Material type
- Material storage condition
- Material transport group
- Material EAN / UPC
- Material inspection group

Inspection Tasks Data
- Inspection group identifier
- Inspection method
- Inspection type
- Inspection master characteristic
- Plant ID
- Description
- Target value
- Lower and upper limit
- Unit of measurement

Figure 9 Overview of the data views to be used

In figure 10, an example of an end-to-end supply chain is described. In this example supply chain figure, the steps are color-coded to show what kind of data can be used in different parts of the supply chain. The long-term goal of the case company is to track the full end-to-end cold chain including the intermediate inspection tasks and other tasks, such as dispatching and loading of products.

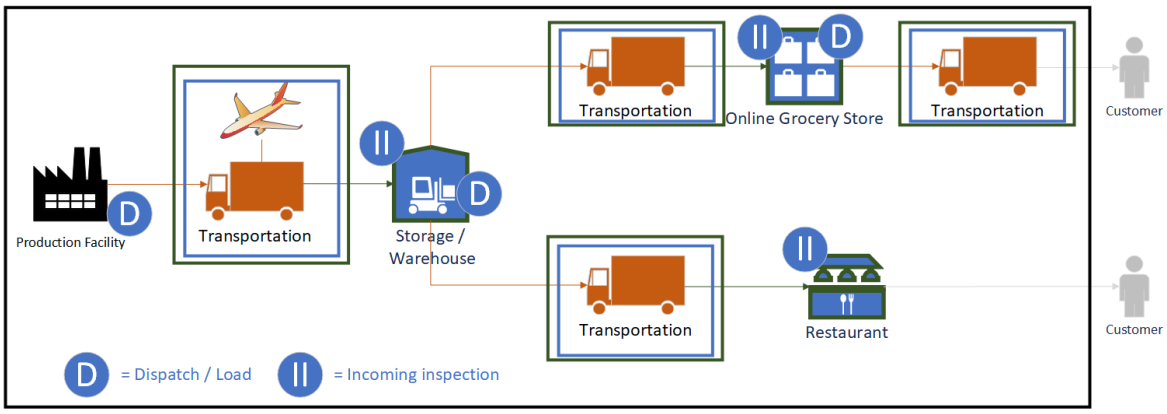

Figure 10 Example of an end-to-end supply chain

In the example end-to-end supply chain, the chain starts from the production facility, where a product is dispatched and loaded. Typically, before this step, the ERP system of the

production facility has raised and acknowledged the purchase order (PO) from the customer. The next step after acknowledging the order is to produce the products or use the stored products and load them to a transportation vehicle. Then, the product is transported using a transportation vehicle, such as a truck or an airplane. When the product arrives in a mid-way storage unit, an incoming inspection can be made to this product, to identify defects before the final delivery. If a defect is found, it can be returned to the initial sender (the production facility) and replaced in a faster manner when comparing to only inspecting the product in the final destination. After being in storage, the product is transported to a consumption location. These consumption locations can be, for example, but not limited to, restaurants or stores. When transportation arrives in a consumption location, an incoming inspection is made again to verify the quality aspects of the goods received.

In figure 11, the modeled entities are shown in an entity-relationship (ER) model. The ER model shows the relationship between different data entities. In the figure, the incoming inspection entry point shows which data is required for the whole process to start. The incoming inspection use case and user story is explained later in this chapter. The entity data can be queried dynamically with the given attribute filters from the used OData data service interfaces.

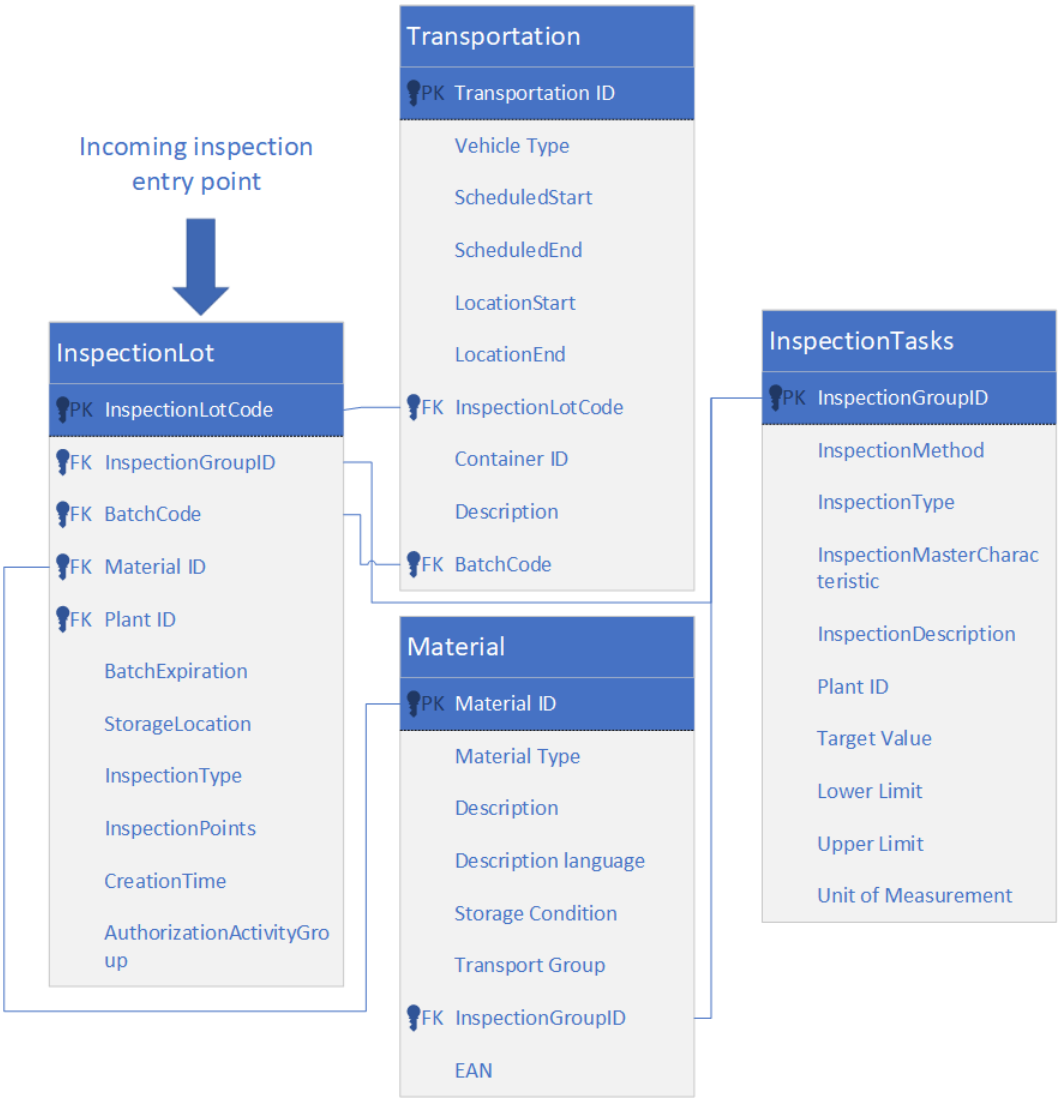

Figure 11 Entity relationship model for the incoming inspection data

4.3 User story

The user story to be fulfilled as an example implementation for this master's thesis is to an internal demo customer. The user story is based on a real customer story but generalized to provide a more suitable case for future development. The scenario to be implemented is an initial inspection which is typically executed on the receiving of products. The inspection is done with a HACCP Application. The HACCP Application is an Android-based mobile application which is used on a mobile device, for example on a smartphone or a tablet. In

addition to the mobile device, a Bluetooth tool is used to measure temperatures and read barcodes of the products to identify what kind of material is being handled.

The user story done in the scenario is as follows:

1. User logs in the HACCP Application
2. The HACCP Application fetches the user information from SAP or asks SAP if login information is correct
3. The user scans the product bar code to identify the product
4. HACCP Application fetches the product data from SAP
5. The user selects vehicle type from options in HACCP Application
6. The user selects whether the transportation vehicle condition is OK or Not OK in HACCP Application
7. The user scans the batch number if available
8. The user selects the visual condition of product from predefined options (OK / NOK / Other)
9. The user measures the temperature of the product
10. User inputs/scans the expiration date from product
11. Application marks the product OK/NOK based on the measured temperature and expiration date
12. If NOK, the user types comments
13. App stores the records and sends them to SAP inspection results.

This kind of incoming inspection is a very typical process done in the food and grocery industry when receiving products or raw materials. In an incoming inspection article by Lyall, K. (2015), in a quality management magazine, it is said that incoming inspection is to protect the customer, both internal and external. In this article, it is also said, that it is important to create qualification sets appropriately and in the long term, the collected inspection data should be used to act in reducing the rejections or figuring out reasons for improper supplies.

The presented user story is used as the initial goal of this master's thesis. As a long-term goal for the case company, it is to build a full end-to-end tracking integration support between the systems to improve logistics and handling operations. Additionally, when the initial implementations are working as intended, it is quite simple to make functionalities broader in other ways. It should be kept in mind that typically ERP installations are, at least in some way, customized and a general approach can be used as a base solution for the integration problem.

5 IMPLEMENTATION OF CLOUD APPLICATION TO ERP INTEGRATION

The implementation was done with the Spring Boot framework, which is a tool to create standalone Spring applications. The decision to develop the implementation with Spring Boot was due to the requirement of using Spring Framework as the basis of this implementation and the automatic configuration features provided by the Spring Boot to reduce the workload which is most likely redundant when integrating as part of the core system in the case company. Spring is considered to be the most well-known Java web framework in the industry and has a huge ecosystem and a community around it. (Anna Monus, 2018) Spring framework is said to be the go-to tool when building enterprise-level Java applications, web services, and microservices, which makes it a very suitable tool for the task. The version selected for Spring Boot was 2.0.6 which runs the Spring Framework on version 5.0.6. The generated Web Application archive (WAR) file was deployed to Tomcat 9 application server, which serves the request incoming from the internet. All pieces of the systems are running on Java 8 SDK. In this chapter, there are references for SAP Interface (SAPIF), which means the implemented web service.

5.1 ERP integration software

In ERP software (considered as a server in the setup), it is necessary to develop services and publish pieces of the software services to reveal data to be used to the client software. The data required in this project and setup will be provided on the SAP Netweaver platform. In the platform, two data components are used: SAP Core Data Services (CDS) and SAP Service Gateways. The first, SAP CDS will be used to get data from the master data towards the case company's cloud for use. The latter, SAP Service Gateway will be used to push data from the case company's cloud towards the ERP software's database for future use, such as reporting and quality management. The main difference between a CDS based view and a Service Gateway view is that pushing data through CDS is very difficult and in most scenarios, not a smart solution due to the potential for data inconsistencies but creating a

view to fetch data is much simpler. The Service Gateway requires more configuration and extra steps when comparing against the CDS views but, in the end, provides a better approach when the goal is to push data towards the ERP software. In the Service Gateway approach, the pushed data needs to go through the ERP software's business logic which is an important aspect when considering the data consistency and durability of services within the ERP software.

5.1.1 SAP Core Data Services

SAP Core Data Services are SAP's data modeling infrastructure which allow defining and consuming of data interfaces on the database layer of SAP instead of the application server. In addition to providing data modeling tools, CDS also offers support for conceptual modeling, defining relationships, built-in functions, and extensions. CDS simplifies and harmonizes the definition of data models regardless of the data consumption software. CDS provides a data definition language (DDL) for defining database tables and views for entities. SAP CDS is natively supported for both, ABAP based SAP platforms and HANA based platforms. (Tushar Sharma, 2017)

To define an SAP CDS entity, a data definition or metadata extension needs to be created. For this master's thesis project, four data definitions were defined in the ABAP data definitions for the user story described in section 4.3, one for each data view. The data definitions are defined in DDL, which is very close to the SQL language but has additional features, such as support for expression, associations, and annotations to enrich the data model. After creating a data definition in ABAP Workbench (with SAP UI or Eclipse) the CDS view needs to be registered as an OData service and then exposed as a web service. The prementioned operations are done in the SAP UI using the transaction code "/IWFND/MAINT_SERVICE". After exposing the CDS view as an OData service, the service should be viewable with a browser. The URLs typically follow the next pattern but may vary between SAP installations: https://{{*SAP-HOST*}}:{{*SAP-SSL-PORT*}}/sap/opu/odata/sap/{{*DATA_DEFINITION*}}_CDS/{{*CDS_VIEW_NAME*}}
(SAP Github, 2018)

5.1.2 SAP Gateway Services

SAP Gateway Services functionality is used to push data towards the ERP system. To define a new service in the gateway services system, SAP recommends the usage of SAP Gateway Service Builder (transaction code SEGW in SAP UI). With the gateway service builder, it is possible to create a project, which hosts all project related data models and functionalities. There are multiple ways to import data models: they can be imported from a description file, a data dictionary (DDIC) or business object repository (BOR). Regardless of the importing method, entity types need to be defined for each data model. For each entity type an entity set containing operations, such as CRUD, is defined. After implementing the entity types and entity sets in a data model, the service implementation can be generated. After generation, the generated services need to be exposed to the internet like the SAP CDS views using the transaction code "/IWFND/MAINT_SERVICE". (SAP Help Documentation, 2018)

5.2 Integration API Proxy

The web service developed for this project acts as an API Proxy between the case company's cloud and the clients' ERP software. The API Gateway will be hosted in a single location to provide an easier way to configure both endpoints to consume the service when considering the security aspects. This means, that the firewall systems for both ends can be configured to allow traffic only from one IP-address. Additionally, both ends require authentication with either API keys, username, and password or other means to provide sufficient security context. The API Proxy will be referenced as SAPIF in the context of this master's thesis.

The implemented web service is based on the Spring Framework. As a supportive module, Spring Boot was used in making the basic configuration easier and faster while providing the needed development options. In the long term, this API Proxy can be integrated with the case company's backend software which has its own configuration done and managed. The

flowchart of processing every request is described generally in figure 7. In the next subchapters under this heading, each step of processing the request is explained.

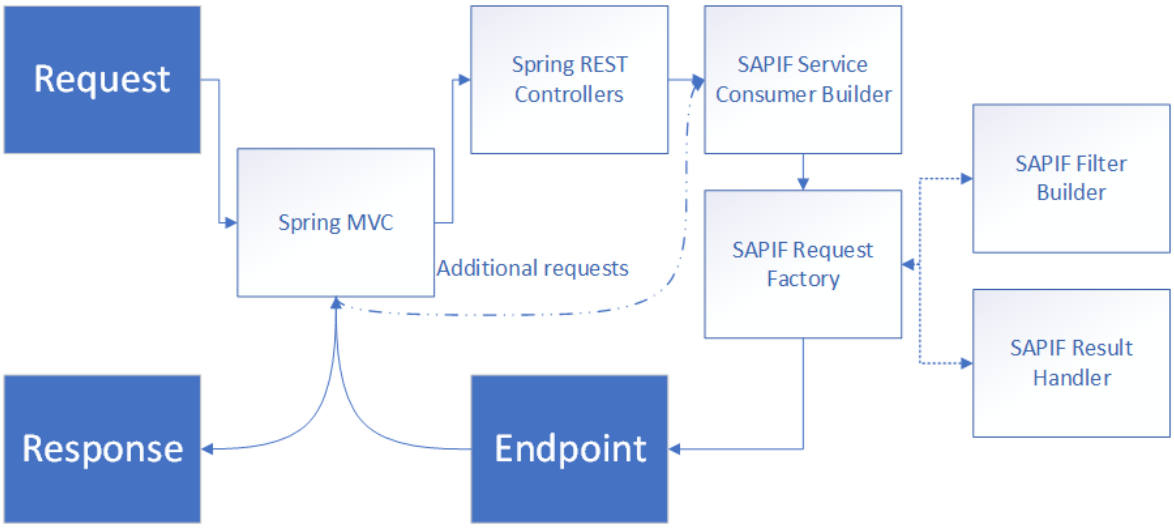

Figure 12 SAPIF component flowchart

5.2.1 Spring MVC

Spring MVC is the core component of the Spring Framework. It is built on Apache Tomcat Servlet API and its main job is handling the request processing. When considering the model view controller (MVC) pattern related to Spring MVC, the request is delegated to controllers based on the request path. The reason for selecting Spring MVC as the request handler framework is the flexibility provided with it. Spring MVC supports servlet level configuration, meaning that every servlet can have a different configuration, for example, in the context of security and access management. The processing logic of Spring MVC is described in figure 13. The first step when a request is made is mapping to a correct controller. These controllers can be, for example, security or model controllers. In this master's thesis project, Spring MVC is executed mostly with default configuration. An exception is made with security configuration: all views require either API key as an authentication method or username and password. The security configuration is implemented by extending AbstractPreAuthenticatedProcessingFilter, which is a part of the Spring Framework security module, to authenticate every request based on the request

header data. When the request is successfully authenticated and authorized, it will be routed towards a REST controller based on the request path. For each path of the SAPIF implementation, there exists a controller that handles the requests forwards in the process. The paths created for this project are linked with the data to be retrieved: material, lot, inspection tasks or transportation data. After the controller has processed the request, the controller data is sent to view resolvers for processing. In this master's thesis project, the data is presented in a JSON format due to the requirement from the case company's requirement. Typically, the view resolvers prepare the data to be used in a suitable format for templating software to generate the views shown on web pages. In this scenario, a RESTful API using a REST Controller was created, which means that the view does not need to be rendered in any way, and the resolver data is presented in the response data as JSON.

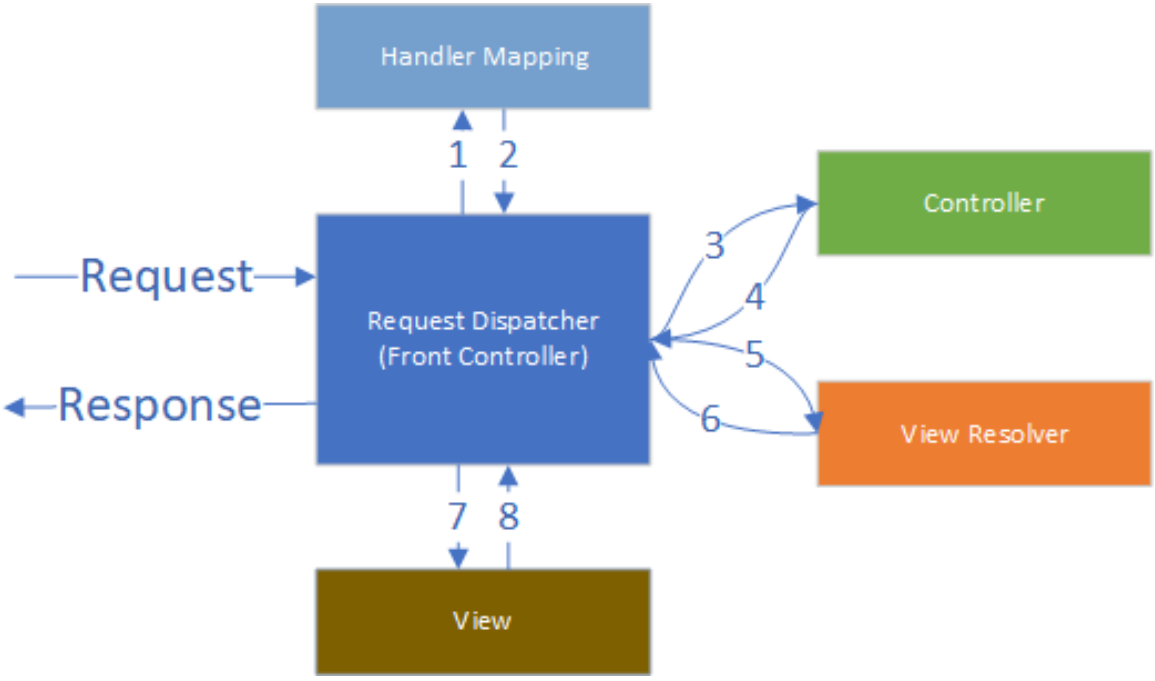

Figure 13 Spring MVC working principle

5.2.2 Spring REST Controllers

Spring Framework typically ships with two different types of request controllers: a (normal) controller and a REST controller. The difference between these types of controllers is the

way they treat the views and the process of resolving views. In the first case of using a normal controller, the modeled data from the controller is rendered via a view resolver to a template which produces a rendered view, such as a complete web page. The second case, the usage of a REST controller, will pass the view resolving process and returns the controller data directly to the response without rendering it into a view. The benefit of using a controller to generate pages with normal controllers is the possibility of generating data based, human-readable web pages. REST controllers, on the other hand, provide the benefit of generating computer-readable data from the modeled data. The underlying technology for handling Java objects to JSON or XML conversion is the usage of the Jackson project. Jackson is formerly known as the standard JSON library for Java but also support conversion to XML. (Jackson Github, 2018)

5.2.3 SAPIF Service Consumer Builder

The SAPIF Service Consumer Builder is an object initiator pattern built to generate a service consumer for the data interfaces. In practice, this means that based on the request parameters, the data is being fetched from an endpoint. The endpoint details are constructed based on the target endpoint. In table 1 below, the needed data to construct a proper service consumer is described.

Endpoint host	The FQDN or IP address of the host. For example, sap-1.example.com or 192.168.10.1
Endpoint port	The port which the endpoint listens to. For example, 44300.
Endpoint protocol	The protocol used to communicate with the endpoint. For example, https.
Endpoint service	The service that is consumed. For example, Z_MATERIALS_CDS.
Service view	A view in the endpoint service for fetching the data. For example, Z_Materials.

Authentication username and password	If authenticated using username and password, a basic authentication header is generated using the username and password.

Table 1 SAPIF Service Builder required parameters

The service consumer builder is responsible for making sure that the data to be fetched or pushed will be made towards a correct place and authentication will be done correctly. After a service consumer has been built, the service consumer object is returned to the REST Controller. The REST controller then continues with the execution flow and passes the request towards the request factory.

5.2.4 SAPIF Request Factory

SAPIF Request Factory is the entity in the data fetching and pushing process that is responsible for doing the actual data transfer operations. Before requesting the data from the endpoint with the previously built service consumer, the request factory will check if it is necessary to include additional filters in the request. After this, whether or not filters were added to the request parameters, the request will be executed and sent to the consumed service endpoint. After receiving a response from an endpoint, the results will need to be handled. The received OData entities will be parsed and eventually converted to Java objects from the fetched data. During the conversion, it is possible to need additional data from another endpoint and the process may need to be iterated again. The related components and the relationship between the SAPIF Request Factory and other components are explained in figure 14. The views, which the data is being fetched from, are built in a way that requires as few data fetching operations (iterations) as possible due to the quickly increasing latency of fetching from multiple endpoints.

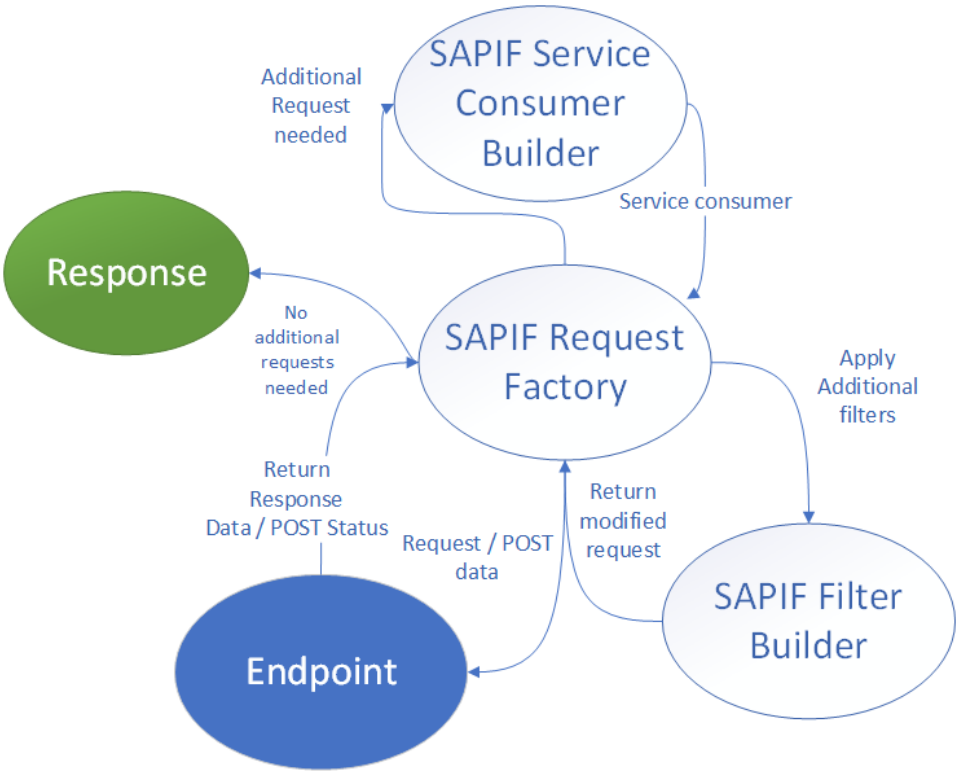

Figure 14 SAPIF Request Factory component relationship chart

After all of the data is fetched from the endpoint(s) and processed from OData entities to Java objects, they are being prepared to be sent back to the requester. The preparation process consists of converting Java objects to the representation format that is used. In the context of this project, the JSON format is used. When conversion of objects to representation format is done, the JSON serialized data is inserted into the HTTP response data package and then returned to the requester for processing.

5.2.5 SAPIF Filter Builder

The SAPIF Filter Builder acts as a utility for making more accurate (and useful) requests. The OData views that are consumed by SAPIF can be filtered to include only the data required, which improves the responsiveness and performance of the communication between the systems. The filters are passed to the OData endpoints in the request URI (Unique resource identifier) like described in the standard. As an example, with the Z_Materials view, a request filtering material with the material type (type equals 00003)

would have a URI like this: https://sap-1.example.com:44300/sap/opu/odata/sap/Z_MATERIALS_CDS/Z_Materials?$filter=MATERIAL_TYPE%20eq%20‘00003’.

The example above has a single filtered attribute but according to the standard, multiple filters can be linked to create a very specific query. By utilizing efficient and flexible filtering, it is possible to use the same endpoints for multiple use cases. The possibility of fetching only the needed piece of data can be done with a relatively fast operation. Another use case of prefetching a large amount of different data can be done by using a wide filter to get a lot of results.

Depending on the request type (being either GET or POST request), the filters are applied either by the request path or by the request body. In the first case, when using the request path and GET requests, typically very simple queries fetching an only a small amount of data is done. The second case, when using the request body and POST requests, is typically used when fetching a larger amount of data (or when there are very specific filters needed). In appendix 2, there is an example POST request body for fetching lot data above the given numbers with an expiration date after the 30th of December 2018. The number of filters to be applied is not limited to provide the highest flexibility possible.

5.2.6 SAPIF Result Handler

SAPIF Result Handler is a component used to convert results from the backend to ERP compatible format. This component is only used when posting results from the backend to ERP software. Typically, this process includes converting attribute values and names and in some scenarios data structures to ERP compatible format. Additionally, parameters can be added, such as in the case of SAP OData interfaces usually requiring a client identifier, a vendor identifier or data indexes (such as incrementing result numbers).

The result handler takes the POST request data as JSON and converts it to JSON, XML or other representation format that is required by the receiving endpoint. The data is then

returned to the Request Factor (or any other function caller). After this step, the request body is ready to be sent to the endpoint.

5.3 Integration Backends

The software components (both integration backends) creating requests towards the API Proxy, are being considered as both, clients and servers, depending on the operation, in this context when considering the client-server model of a typical over the internet distributed computing structure. This client-server scenario uses a request-response type of messaging pattern, which is very common when communicating through the internet. The client, a backend which needs to read or write data, sends an HTTP request towards the API Proxy. The API Proxy then reads the request and creates another request towards the correct endpoint of another backend. This backend then returns the requested data (or response code if writing data) as a response back to API Proxy. The data then gets modified into a correct format in the API Proxy and then returned as a response to the initial requester backend. The data handling of each backend is abstracted due to a vast number of different operations possible. As an example, based on the use case story described in chapter 4.3, a simple request to get inspection material details from the ERP software's backend can trigger a function to store the data in the HACCP software's backend and then show the data in the HACCP application on the mobile device.

6 RESULTS AND DISCUSSION

The implemented software in this master's thesis was used to demonstrate one of the possible technology stacks making possible the information transfer between a cloud application and ERP software. The full list of software components for the implementation in this master's thesis is described in the fifth chapter, which was built using the design described in the fourth chapter. The resulting Java based web applet is a concrete example of the technology stack that enables the desired information transfer. Http-based communication is used over the internet or another network to reach a Tomcat web server which is then dispatched to Spring Framework for processing.

The processing starts by request validation and after the request data has been validated it gets processed. A more in-depth description of each request processing piece is explained in the fifth chapter. Briefly speaking, the created applet works as an API Gateway and creates the additional client-server type of communications based on the request to fulfill the initial request. The requests are using OData based interfaces when communicating towards an ERP system and JSON based REST requests when communicating towards the cloud application. After all, the information has been fetched from the endpoint(s), the response is being built which is in the end sent back to the requester (client).

There can be different types of added value gained by the HACCP application provider from the cloud-to-ERP integration. The deeper integration into the client's production systems makes it possible to have a more up to date data available in the HACCP applications, which improves the usability of the application. Businesswise, a client who is investing into this kind of integration, is most likely more attached to the HACCP application provider and the willingness to switch service provider is reduced (or it would at least cancel the benefits of previous investments). HACCP related aspects are typically only one piece in the operations of a company. By having a successful initial integration with the HACCP process, it is possible to amplify the integration to include other processes, such as logistics operations, for example, and have a whole end-to-end process tracking integrated between a cloud application and an ERP system. The ability to integrate the application into a complex ERP

system provides the application provider chances to offer new services, based on this integration, for larger customers using these kinds of ERP systems as well.

The benefits for the industry that are required to perform the HACCP process is the saving in time and man-hours in keeping the records in two different places or manage the data synchronization manually. In larger corporations using ERP systems, there are typically quality control and inspection data in the system which is used in quality management processes. Additionally, the HACCP tasks need to be set in the HACCP application if they cannot be fetched from an ERP system, for example. By having the HACCP process data in the ERP system, it is possible to take advantage from the ERP software's data management, reporting, and analysis tools, which would increase the value of the stored data in the long term. The possibility of linking the HACCP process data into the other processes in the ERP system provides an added value of increasing the visibility of all processes connected to the ERP system.

When considering both, the HACCP application provider (the case company) and the industry required to perform HACCP process, the biggest value added by linking the cloud application with the ERP software systems is related to time. Transferring the data between these systems is possible to do by hand (all though in the large scale it does not make sense), but automating it saves time and improves the data accessibility. When the data is accessible in both systems, it is possible to analyze this data and process it in a way that the companies want. Indirectly, by saving time, the company performing the HACCP process will economically benefit from having less work to do manually with the HACCP application. This economical added value is something that makes it possible to put a price tag for this kind of integration for the HACCP application provider (which will add monetary value to the HACCP application provider). The first requirement of making it possible to integrate the HACCP application with the ERP software system is the digitalization of the HACCP process.

The benefits of digitalizing the HACCP process were discussed and approximated in the hypothesis of this master's thesis and the interviews that were done in the qualitative

research part were used in confirming or denying the hypothesis. It was found out during the qualitative research that the digitalization does not only provide added value to the larger companies but to the smaller ones also. The most concrete example of a benefit were the time savings. This time saving will provide indirect value to the processes of the company by freeing the employees to do some other tasks. The most mentioned benefit was the real-time availability of the data, which has reduced the need for manually checking the monitored places and inspection visits in the locations. The real-time characteristic of the digital HACCP system makes it possible to set alarms, which can improve the safety of operations without the need for increasing the work hours put into the process. Digitalizing the data collection also makes it easier to use the data in a future need, which are, for example, data analysis and usage of data in decision making and machine learning. This adds the value to the company performing digital HACCP process by providing a potential way of identifying places to improve their process and possibly finding ways to add value even more. By storing the HACCP process data in the cloud, it is possible to increase the availability of the data by giving access to all peers required, such as the employees, quality and health inspectors, managers or other peers. Having the data in a digital format makes it easier to find deviations. The traceability of data is improved by having sensors do the measurements more frequently than is reasonable to do manually.

The empirical part of this master's thesis was a success, the goal of synchronizing the cloud application with an ERP software system was fulfilled. The technology stack used in the integration shows that the generally available software can be used to communicate with complex ERP systems without the need for expensive tools. Before starting on this master's thesis project, it was not clear if it would even be possible but as it turned out, the interfaces provided by the modern ERP systems typically follow standards, such as the OData protocol. The developed prototype application was able to fetch data from the ERP software using the SAP IF and push inspection results back. In figure 15, there is an example of how the link between the prototype application and the SAP ERP system works. The inspection results are recorded to inspection lot results.

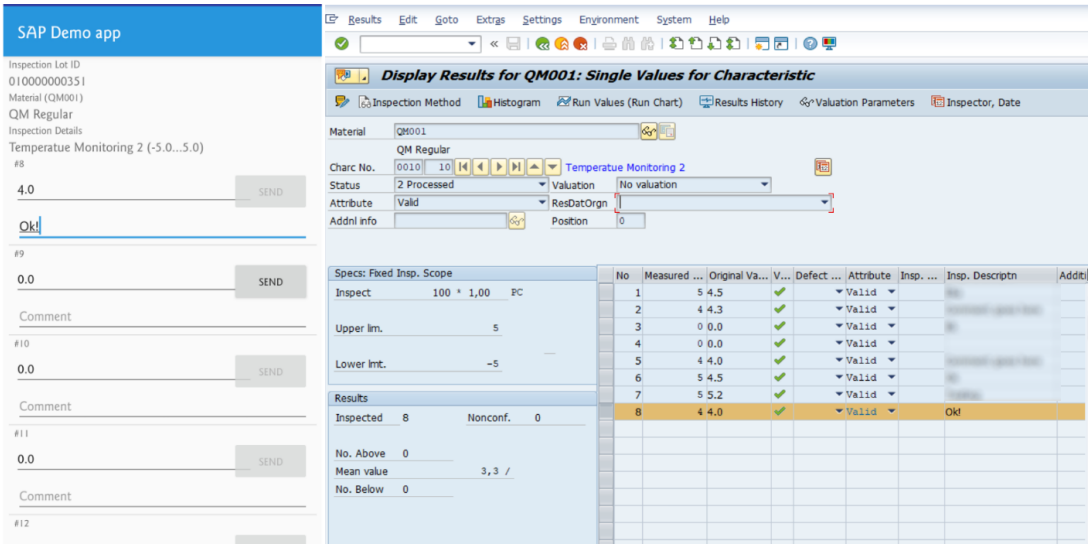

Figure 15 An example of the implemented data synchronization in a prototype Android application and SAP ERP (transaction QA32)

The benefits of integrating the cloud application with an ERP system was quite difficult question to find opinions from the interviewees and most likely the results are biased due to the small number of opinions available. The benefits for the cloud application provider mentioned in this master's thesis were from the perspective of the case company and most likely biased. In addition to the bias, the sample size of one limit the credibility of the thoughts, although there is no denying that the capability of integrating with a large ERP system, such as SAP, will provide new business opportunities that provide value for the company. The benefits for the companies performing the HACCP process mentioned earlier are more reliable due to the higher sample size. It should be noted that the sample size of eight (of which six had an ERP system in use) is very small when considering the number of companies who perform the HACCP process and therefore the results are not statistically significant. The results, however, can be used to describe what kind of opinions and thoughts there are among the food industry about the HACCP process and its integration into an ERP system.

The benefits of digitalizing the HACCP process seem to be coinciding quite nicely with the typical benefits of digitalizing a process. As additional benefits, which were not anticipated, were the security and safety aspects which were appreciated by the companies performing the HACCP process. In the long term, the data can be used to find valuable aspects of the process and reveal unknown things.

7 CONCLUSIONS

This master's thesis project was based on the case company's research and development assignment and the integration tries to provide solutions to real business cases. The first steps on the process were the definition of the problem and delimiting the challenge to a sensible amount of work to be done in a master's thesis, which was described in the first chapter. After this, the basic insight was gained for the process to be integrated and the technologies by conducting a literature research among the subjects, which were explained in the second chapter of this master's thesis. After the basic insight among the subject was gained, the design setting for the initial implementation for the cloud application to ERP software integration was planned and created with the assistance of SAP Ireland, which is documented in the fourth chapter. During the design setting creation process, the interviews for the qualitative research were planned, and shortly after the plans had been finalized, they were executed. This was documented in the third chapter. When the design setting for the implementation had been finalized, the implementation was developed in an agile way, doing changes in the requirements as there were needs to do so (such as the changes in the use cases or more insight was gained to the process). When the integration was developed to a working state, a prototype application for the HACCP process integration was developed to demonstrate the ability to fetch and push data between the cloud application and the ERP system with the chosen technologies. The integration implementation is discussed in more detail in the fifth chapter, and the results are discussed in the sixth chapter.

The integration challenge turned out to be little more challenging than it was initially thought in the head of the master's thesis worker but with the help from the professionals at SAP Ireland and colleagues from the case company the job was manageable. The created integration solution works well with the generalized demo scenarios but most likely real customers in the future have more accurate needs and changes are necessary. The limitations set by the case company turned out to be a lesser issue than it was initially thought. As stated earlier, the tools used in this integration project are not the only ones working but were used for the convenience of the case company being familiar with at least some of them. This is an important aspect since the developed integration is only a part of the whole end-to-end

process tracking which is the long-term goal for the case company. In the future, the initial implementation is planned to be used in a wider ERP system integration with SAP Global Track and Trace, which is a platform for the next-generation business process tracking and tracing including the status monitoring of objects.

The qualitative research by interviewing persons who are performing the HACCP process in their companies showed that there are indeed benefits in the digitalization of the process. The actual benefits, however, are potentially biased due to the use of elite interviewees in the interviews. A potential research subject for the future would be to get a higher number of interviewees (or to conduct a quantitative research) to confirm or deny the thoughts raised in the small sample size qualitative interview research. Another potential subject for future research is the automatization of the HACCP record validation which includes not only validation of the correct temperatures but also visual inspections and other tasks. Technology wise this could be a machine learning study to identify mold in an inspection sample of a product (a picture, in practice) or perhaps using an electrical nose to identify bacteria which could potentially be included in the same sensor devices measuring which are used in the climate attributes.

REFERENCES

Anna Monus, Raygun.com (2018), 17 Popular Java Frameworks, 2018 Edition: Pros, cons and more [online] [Referenced 6.11.2018], Available from: https://raygun.com/blog/popular-java-frameworks/

Arik Ragowsky, Toni M. Somers (2002) Enterprise Resource Planning, Journal of Management Information Systems, 19:1, pp. 11-15, DOI: 10.1080/07421222.2002.11045718

Berry, J. M. (2002). Validity and reliability issues in elite interviewing. PS: Political Science & Politics, vol. 35(4), pp. 679-682. Retrieved from http://www.jstor.org/stable/1554809

Cheng Hsu, et. al., (2007), Service Enterprise Integration: An Enterprise Engineering Perspective, Troy, NY, USA, Springer

David Orenstein (2000), Application programming interface, Computerworld, vol. 34(2), pp. 66.

Deloitte (2018), Your guide to a successful ERP journey: Top 10 change management challenges for Enterprise Resource Planning implementations [online], [Referenced 19.2.2019] Retrieved from https://www2.deloitte.com/content/dam/Deloitte/mx/Documents/human-capital/01_ERP_Top10_Challenges.pdf

Dinarle Ortega, Elluz Uzcátegui and Maria M. Guevara (2009), Enterprise Architecture and Web Services, 2009 Fourth International Conference on Internet and Web Applications and Services, Venice, pp. 24-29, DOI: 10.1109/ICIW.2009.12

Fielding R. T. (2000), Representational State Transfer (REST) [online], [Referenced 8.10.2018] Retrieved from https://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm

Finnish Food Safety Authority (Evira), (2008), HACCP-JÄRJESTELMÄ, periaatteet ja soveltaminen [online], [Referenced 25.10.2018], Retrieved from https://www.evira.fi/globalassets/tietoa-evirasta/lomakkeet-ja-ohjeet/omavalvonta/eviran_ohje_10002_haccp.pdf

Garriga, M. (2016). RESTful service composition at a glance: A survey. Journal of Network and Computer Applications, 60(C), pp. 32-53. DOI: 10.1016/j.jnca.2015.11.020

Guynes, C.S. & Windsor, J. 2011, Revisiting Client/Server Computing, Journal of Business & Economics Research, vol. 9, no. 1, pp. 17-22, https://search.proquest.com/docview/848788984

IBM Developer documentation (2014), Types of APIs [online], [Referenced 5.10.2018] Retrieved from https://developer.ibm.com/apiconnect/documentation/api-101/types-apis/

IBM Developer documentation (2011), Event-driven web development, Part 5: Reverse Ajax, [online], [Referenced 5.10.2018] Retrieved from https://www.ibm.com/developerworks/library/wa-reverseajax5/wa-reverseajax5-pdf.pdf

International Organization for Standardization (2018), ISO 22000 family – Food safety management systems — Requirements for any organization in the food chain, [Referenced 18.2.2019] Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:22000:ed-2:v1:en

Jackson Github (2018), Jackson Project Home [online], [Referenced 9.11.2018] Retrieved from https://github.com/FasterXML/jackson

Krasner, G. E., & Pope, S. T. (1988). A description of the model-view-controller user interface paradigm in the smalltalk-80 system. Journal of object oriented programming, 1(3), 26-49. [Online] [Referenced 16.11.2018] Retrieved from: https://www.researchgate.net/publication/248825145_A_cookbook_for_using_the_model_-_view_controller_user_interface_paradigm_in_Smalltalk_-_80

Lee, I., Lee, K. (2015), The Internet of Things (IoT): Applications, investments, and challenges for enterprises, Business Horizons, Vol 58 (4), pp. 431-440, DOI: 10.1016/j.bushor.2015.03.008.

Lyall, K. (2015), Eliminate Waste in Incoming Inspection: 10 Ideas Where to Look for Waste in Your Process, Quality Magazine, vol. 54(9), pp. 16-17

Mämmelä, A. (2006), Introduction to Research Methodology, VTT Oulu, Retrieved from http://www.infotech.oulu.fi/GraduateSchool/ICourses/2006/phd/lecture3-oulu.pdf

Oasis, (2014), OData Version 4.0 Part 1: Protocol [online], [Referenced 9.10.2018] Retrieved from: http://docs.oasis-open.org/odata/odata/v4.0/os/part1-protocol/odata-v4.0-os-part1-protocol.pdf

P. Vijaya Vardhan Reddy, Lakshmi Rajamani, (2014), Performance Evaluation of Hypervisors in the Private Cloud based on System Information using SIGAR Framework and for System Workloads using Passmark, International Journal of Advanced Science and Technology, vol.70, pp.17-32, DOI: 10.14257/ijast.2014.70.03

Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2017). Tackling the digitalization challenge: how to benefit from digitalization in practice. International journal of information systems and project management, vol. 5(1), pp. 63-77.

Philip, G. C, (1998), Software design guidelines for event-driven programming, The Journal of Systems & Software, vol. 41(2), pp. 79-91. DOI: https://doi.org/10.1016/S0164-1212(97)10009-7

Rafal Cupek, Lukasz Huczala (2015), OData for service-oriented business applications: Comparative analysis of communication technologies for flexible Service-Oriented IT architectures, 2015 IEEE International Conference on Industrial Technology (ICIT), Seville, 2015, pp. 1538-1543. DOI: 10.1109/ICIT.2015.7125315

Ralph Mietzner, Frank Leymann & Tobias Unger (2011), Horizontal and vertical combination of multi-tenancy patterns in service-oriented applications, Enterprise Information Systems, vol. 5(1), pp. 59-77, DOI: 10.1080/17517575.2010.492950

Raouf Boutaba, Nelson Fonseca, Dzmitry Kliazkovich, Noura Limam (2015), Cloud networking and communications II, Computer Networks, vol. 93(3), pp. 405-407, DOI: 10.1016/j.comnet.2015.10.001

Research-methodology.net, 2018, Convenience Sampling [online], [Referenced 20.12.2018] Available from https://research-methodology.net/sampling-in-primary-data-collection/convenience-sampling/

Ruivo, P. (2015). The ERP Surge of Hybrid Models - An Exploratory Research into Five and Ten Years Forecast. Procedia Computer Science, 64(C), pp. 594-600.

S. Asano, T. Yashiro and K. Sakamura (2016), A proxy framework for API interoperability in the Internet of Things, 2016 IEEE 5th Global Conference on Consumer Electronics, Kyoto, pp. 1-2, DOI: 10.1109/GCCE.2016.7800450

S. Dowell, A. Barreto, J. B. Michael and M. Shing, (2011), Cloud to cloud interoperability, 2011 6th International Conference on System of Systems Engineering, Albuquerque, NM, pp. 258-263, DOI: 10.1109/SYSOSE.2011.5966607

SAP Github, S4/HANA CDS – Creating Odata Service [online], [Referenced 8.11.2018] Retrieved from: https://github.com/SAPDocuments/Tutorials/blob/master/tutorials/s4hana-cds-creating-odata-service/s4hana-cds-creating-odata-service.md

SAP Help Documentation, SAP Gateway Service Builder [online], [Referenced 8.11.2018] Retrieved from: https://help.sap.com/doc/saphelp_gateway20sp12/2.0/en-US/1b/c16e1e20a74746ad386bc10b60b6c3/content.htm?no_cache=true

Sinha, A. (1992), Client-server computing, Communications of the ACM, vol. 35(7), pp. 77-98, DOI: 10.1145/129902.129908

Subashini, S., Kavitha, V., (2011), Journal of Network and Computer Applications, vol. 34(1), pp. 1-11, DOI: 10.1016/j.jnca.2010.07.006

Riswadkar, A. V. (2000), An introduction to HACCP. Professional Safety, vol. 45(6), pp. 33-36. Retrieved from https://ezproxy.cc.lut.fi/docview/200456743?accountid=27292

Thoma, M. (2014), REST-based sensor networks with OData, 2014 11th Annual Conference on Wireless On-demand Network Systems and Services (WONS), pp. 33-40, DOI: 10.1109/WONS.2014.6814719

Tushar Sharma (2018), ABAP Core Data Services – Introduction (ABAP CDS view) [online], [Referenced 7.11.2018] Retrieved from: https://blogs.sap.com/2017/09/09/abap-core-data-services-introduction-abap-cds-view/

W3C Working Group (2004), Web Services Architecture [online], [Referenced 22.10.2018] Retrieved from: https://www.w3.org/TR/ws-arch/

Zhao, H. (2009), Towards Automated RESTful Web Service Composition, Web Services, 2009, ICWS 2009, IEEE International Conference on Web Services, pp. 189-196. DOI: 10.1109/ICWS.2009.111

APPENDIXES

APPENDIX 1. Source code for a material view in SAP CDS

```
@AbapCatalog.sqlViewName: 'Z_MATS'
@AbapCatalog.compiler.compareFilter: true
@EndUserText.label: 'Material records'
@OData.publish: true

define view Z_Materials as select distinct from mara
{
   key mara.matnr as MATERIAL_NR,
   mara.matkl as MATERIAL_TYPE
}
```

APPENDIX 2. An example request body to apply filters

```
{
        "filters":[
                {"attr":"lotcode", "value":"010000000150", "filter":"gt"},
                {"attr":"expiration", "value":"2018-12-30T00:00:00.000", "filter":"gt"}
                ]
}
```

APPENDIX 3. The question form sent to the interviewees (in Finnish)

Haastattelukysymykset omavalvontaan ja toiminnanohjausjärjestelmiin liittyen

Osio 1: Yrityksen suhde toiminnanohjausjärjestelmiin

Tavoitteena on selvittää, kuinka yritys suhtautuu toiminnanohjausjärjestelmiin yleisesti, millaisia toiminnanohjausjärjestelmiä yritys käyttää, jos käyttää. Tavoitteena on myös saada kuva yleisistä ajatuksista ja tunteista toiminnanohjausjärjestelmiin liittyen.

1. Kuinka kuvailisit yrityksen suhdetta toiminnanohjausjärjestelmiin? Miten tärkeässä osassa toiminnanohjausjärjestelmät ovat päivittäisessä liiketoiminnassa?

2. Sanoisitko, että toiminnanohjausjärjestelmä on yrityksen liiketoiminnan ytimessä? Kuvaile miten se näkyy päivittäin.

3. Mitkä ovat yrityksen nykyisten toiminnanohjausjärjestelmien vahvuudet ja heikkoudet?

Osio 2: Elintarvikkeiden omavalvonta yrityksessä

Tavoitteena on selvittää elintarvikkeiden omavalvonnan suoritukseen liittyviä asioita. Näitä asioita ovat prosessin suoritus ja siinä käytettävät työkalut ja tavat. Myös yrityksen suhtautuminen omaan prosessiinsa on arvokasta tietoa, jolla voidaan selvittää mahdollisia tulevaisuuden ratkaisuja.

4. Kuinka yritys suorittaa nykyisiä omavalvontaprosessiin liittyviä tehtäviä?

5. Minkälaisia työkaluja yritys käyttää omavalvontaprosessissa? Huomioi, että työkalu voi olla joko digitaalinen tai fyysinen työkalu (kuten paperille tehtävä dokumentointi).

6. Sanoisitko, että nykyinen lähestymistapa on modernein ja paras tapa prosessiin? Ole hyvä, ja perustele näkemyksesi.

Osio 3: Omavalvonnan digitalisointi ja yhteys toiminnanohjaukseen

Tavoitteena on selvittää minkälaisia taloudellisia hyötyjä (laadulliset, ajalliset, rahalliset, muut resurssit?) omavalvonnan digitalisoinnilla on saavutettu tai voidaan saavuttaa. Myös ajatukset omavalvonnan liittämisestä toiminnanohjaukseen halutaan selvittää.

7. Sanoisitko, että omavalvontaprosessin digitalisoinnilla saavutetaan hyötyjä? Jos saadaan, niin mitä ja millä aikavälillä. Käytännön esimerkki?

8. Sanoisitko, että omavalvontaprosessin synkronointi toiminnanohjausjärjestelmiin voi lisätä arvoa yritykselle lyhyellä tai pitkällä aikavälillä?

Sensire

12.1.2019
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