University of Twente

# Improving problem detection and focus for Root Cause Analysis through Case-Based Reasoning and Group Decision Support Systems

This paper focuses on combining outputs of different IT systems to benefit Root Cause Analysis in a food production environment. By implementing elements of Case-Based Reasoning, Learning Loops, and Group Decision Support Systems, a system is created that improved problem detection and enabled better focus for Root Cause analysis. In short, quality data sets are stored into a database that links these data sets to each other. This database automatically made a month report which is visualized to the user through a dashboard. Also the database serves as a basis for a tool that gives the user the possibility to identify problems and possible root causes by linking data sets to each other.

PEACE, LOVE & ICE CREAM.

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BEN & JERRY'S

# Management Summary

The demands for Ben & Jerry's Hellendoorn are growing. The products are ordered almost more than the factory can take and therefore it produces at max capacity. To guarantee quality, data can offer a solution. This report focuses on linking outputs of different IT systems to benefit root cause analysis.

First of all a process- and data analysis is done to identify the starting point of the research. This showed that the data outputs all register in a different way which eliminates the chance of data linkage. Because of this, data analysis had to be done manually and was often skipped since it was so hard and time-consuming to do. The solution to this was to translate the data into datasets with the same characteristics or, in other words, attributes. Another problem was, that since the data was hard to read, it was also hard to communicate it to the workforce. So data had to be made readable. By integrating the data outputs into a database where data is transferred into a coherent dataset, data linkage was enabled. Then by conducting a tool that could filter and present the data, the data was made usable. A certain input can be entered into the tool and the tool then shows all the data that is related to this input. This tool gave focus for root cause analysis and it identifies problems and root causes. Also the tool can monitor what happens at the market to products that had a certain intervention.

In addition, some recommendations from this research are shown below:

- *Extent CRQS*. The inpack results of CRQS needs to be registered in SAP, since they are linked to quantity and texture problems, which hold the biggest share of complaints.
- *Standardize data registration*. The data from the carelines often holds data that is not registered correctly. For example, the batchcode, which always should end with 011, is often registered as o11. This complicates data translation and readability.
- *Collect all measurement data*. By collecting and storing all the data, the used norms can also be subject to critique.
- *Implement tools in Vispro*. To have all the data analysis at one central point, the detection tool and month report should be built in Vispro. This would also enable live data analysis for all the measurements that are registered into Vispro.
- *Revise Vispro*. All though, Vispro is considered hard to use. The usability of Vispro is low and it does not give a clear overview.
- *Extent five whys analysis registration*. The current five whys analysis misses the five steps and they are not registered accordingly. Also the form for filling in the analysis does not stimulate to do so.

# Preface

This research is performed in order to graduate from the Master Business Administration at the University of Twente. By combining my research with a working internship, managing this research project was a real challenge and opportunity to develop my educational, professional, and personal skills. Doing so, would not have been possible without the help and support of others. Therefore I would like to use this opportunity to thank everybody involved.

First of all, I would like to thank Tessa Meulensteen for hiring me for the working internship and allowing me to combine this with my research. Without the possibility and support to spend that much time on my research and the every week sparring sessions, the level of the endproduct would not have been reached. Furthermore, I would like to thank John Bestman, Leon ter Braak and Ron Strijker for their effort, support, insights and willingness to contribute to my research. During my 6 months internship, I believe to have developed myself at a professional and personal level due to their constructive feedback and guidance. But most of all I would like to thank the entire Ben & Jerry's factory for the tremendous time I have had there, it was a pleasure which I truly enjoyed.

A second word of thanks goes to Fons Wijnhoven and Matthias de Visser, for their valuable feedback and sparring sessions. Their extensive input and recommendations was crucial in defining and executing this research and writing the report. A couple of times I got stuck, but with their theoretical insights they reassured me and got me going again.

Lastly, a special word of thanks goes to my mother for her support, listening ears and inspiration, which in the end formed the basis of my success.

Jurre van Ruth

# List of abbreviations

| | |
|---|---|
| CBR | Case-Based Reasoning |
| CCpMU | Consumer Complaints per Million sold Units |
| CIT | Critical Incident Technique |
| CRQS | Consumer Relevant Quality Standard |
| DSS | Decision Support System |
| GDSS | Group Decision Support System |
| HACCP | Hazard Analysis & Critical Control Points |
| IS | Information System |
| IT | Information Technology |
| KPI | Key Performance Indicator |
| NRFT | Not Right First Time |
| RCA | Root Cause Analysis |
| SAP | Systems, Applications & Products in data processing |
| SNCR | Supplier Non Conformance Report |
| SU | Sourcing Unit |
| TPS | Toyota Production System |
| TQM | Total Quality Management |
| QA | Quality Assurance |
| QIS | Quality Information System |

# Inhoud

# 1. Introduction

In extensive and complicated manufacturing processes, several sensors and quality tests often register an abnormality during the process. The time taken, until the abnormality or failure in the process is identified and successively eliminated, results in lead-time or even unplanned production stoppage, which leads to loss of production and eventually loss of profit. When a problem occurs, many sensor signals and reports need to be analysed to find the cause of the problem. But only intervening of automated sensors can solve not all abnormalities. Frequently, human interaction is required (Weidl, Madsen & Israelson, 2005). The operator needs efficient detection of abnormalities and disturbances to come to educated decisions, based on both artificial intelligence and human experience, to identify probable root causes.

A Root Cause Analysis (RCA) is an analysis, which focuses on finding root causes of problems. According to Rooney & Vanden Heuvel (2004), analysing a root cause helps discover what, how and why a certain event occurred and results into the possibility to prevent the event from reoccurring. So in other words, a company must learn from its faults and especially the root cause of these faults. When looking at multiple of these root causes, sometimes trends can be discovered (Rooney & Vanden Heuvel, 2004). To learn from these trends, organizations should extract the right intelligence from multiple sources and transform it into useful knowledge (Smith, 2001). The approach of Case-Based Reasoning (CBR) is a problem-solving paradigm that, instead of re-lying only on general knowledge of a problem, utilizes the explicit knowledge of previous related experiences (Aamodt & Plaza, 1994). A Decision Support System (DSS) can facilitate these processes by its capability to retrieve information elements and files, create reports of these various files, and represent this data through modelling (Mcleod & Schell, 2001).

The purpose of this research is to explore how RCA can benefit from the use of a DSS to optimize finding of and learning from root causes. The goal is to come up with the best way to design and implement a DSS in RCA, in such a way that the RCA benefits the most.

To clarify the contextual influencers, a brief description of all the processes and reports will be given. This context is the setting where the research took place. To get a clear view of the theoretical background, an introduction on the concepts of RCA, CBR and DSS will be made. Subsequently, in the theoretical framework an analysis will be done on what the literature says how these three concepts should be designed and how they can be brought together.  When this is done, a model can be made that supports the new DSS/RCA system.

## 1.1 Context and Problem statement

In the food industry there are high standards on the quality of the product and production, because a minor mistake can lead to huge problems (Choi & Lin, 2009). For example, a label in a different language could lead to peanut-allergists being unable to read whether there are traces of peanuts in the product. This could lead to severe injuries or even death. That is a packaging problem, but also when the product is produced at the same line where products holding peanuts are made, this could lead to traces and this of course must be noted. But there are also problems that could harm the brand itself. For example, when there is always more ice cream in the cup than mentioned on the cup, the manufacturer is practically giving away free ice cream. Reputation wise, damaged packaging could lead to consumer complaints, which then again harms the reputation of the manufacturer (Choi & Lin, 2009). These are just some of the great amounts of consequences the production process could have.

To guarantee optimal quality and food safety, Ben & Jerry's Hellendoorn has several quality measurements and wields strict regulations on hygiene. Quality Assurance (QA) facilitates these quality checks and strives to keep the factory and the manufacturing process at the quality that is required for food standards. Then the Quality Control team checks whether quality is actually reached conform the regulations. Several teams at Unilever's HQ are in collaboration with the local QA team always searching and evolving to find the best possible measurements to guarantee the product's safety and quality. These measurements become quality measurements that are performed through the entire manufacturing process of ice cream at Ben & Jerry's Hellendoorn. Some of these measurements turn into Key Performance Indicator's (KPI's), which are indicators that tell an organization what to do to stimulate performance drastically (Parmenter, 2007).

When a problem occurs on the quality of the product of Ben & Jerry's, QA wants to know where it came from so it could be stopped and/or prevented in the future. At this moment QA takes a retrospective look and does a so-called RCA when for example a consumer complaint comes in. Several documents and stakeholders are addressed to get to the root of the problem. The addressed documents are quality measurement reports. These quality measurement reports are measured during the manufacturing process and vary from microbiological analyses to on-pack quality controls. However at this moment, the different quality measurement outcomes need to be addressed manually because the outputs cannot be linked. The outputs cannot be linked because the different originating IT systems register in different ways. So the RCA gives great amounts of over-processing and unnecessary motion of employees.

To improve the RCA at Ben & Jerry's, QA wants to integrate the documentations into one system where all the information can be found so efficiency and effectiveness of the RCA improves. The resulting question from Ben & Jerry's Hellendoorn is: *How can multiple IT system outcomes be integrated so relations can be identified, resulting in higher RCA efficiency and effectiveness?*.

The separate IT system outcomes will serve as the basis for a new to be conducted system. A system that enables higher efficiency and effectiveness of decisions is a DSS (Power & Sharda, 2007). Since a group of multiple users must have access and use the system, a GDSS is applicable. How must this integration be done so the best possible RCA for Ben & Jerry's is conducted?

RCA literature shows that a RCA can majorly benefit from access to extensive data sets (Rooney & Vanden Heuvel, 2004; Wu, Lipshutz & Pronovost, 2008; Taitz, et al. 2010). However some authors indicate that combining documentations can also lead to information overload (Chervany & Dickson, 1974; Eppler & Mengis, 2003; Bawden & Robinson, 2009). Some researchers in the field of DSS say that combining documentations minimizes the effort expenditure put into the decision-making, but that it does not influence the quality of the decision (Payne, Bettman & Johnson, 1988; Todd & Benbasat, 1992). Nonetheless, several authors do mention that DSS does enable effectiveness, so also quality is increased (Sharda, Barr & McDonnell, 1988; Leidner & Elam, 1994; Radermacher, 1994; Power & Sharda, 2007). Some authors discussed DSS for RCA (Weidl et al., 2002; 2005).

## 1.2 Current Root Cause Analysis method

At this moment the RCA at Ben & Jerry's Hellendoorn lacks a real structure. Two types of RCA can be identified at the factory. The first one; when a problem occurs, a QA officer takes a retrospective look at what happened during the manufacturing process. The officer addresses several reports that consist out of quality measurements, these can be found in table 1. Besides the QA officer addressing several data sources, a problem owner is assigned; this problem owner sometimes can also be the same QA officer. The problem owner uses its own experience to identify the root cause by doing a why why analysis. A why why analysis is a method where when a problem occurs, you ask yourself why this happened five times or until a why question cannot be answered anymore (Gano, 2007). The theory is that this will lead towards the root cause of a problem. This method results in a linear set of correlations and is based on the experience of the problem owner. Then from the analysis the officer must come up with some sort of advice on what the root cause is and how to prevent the problem from reoccurring. Figure 1 illustrates the current RCA process at Hellendoorn.

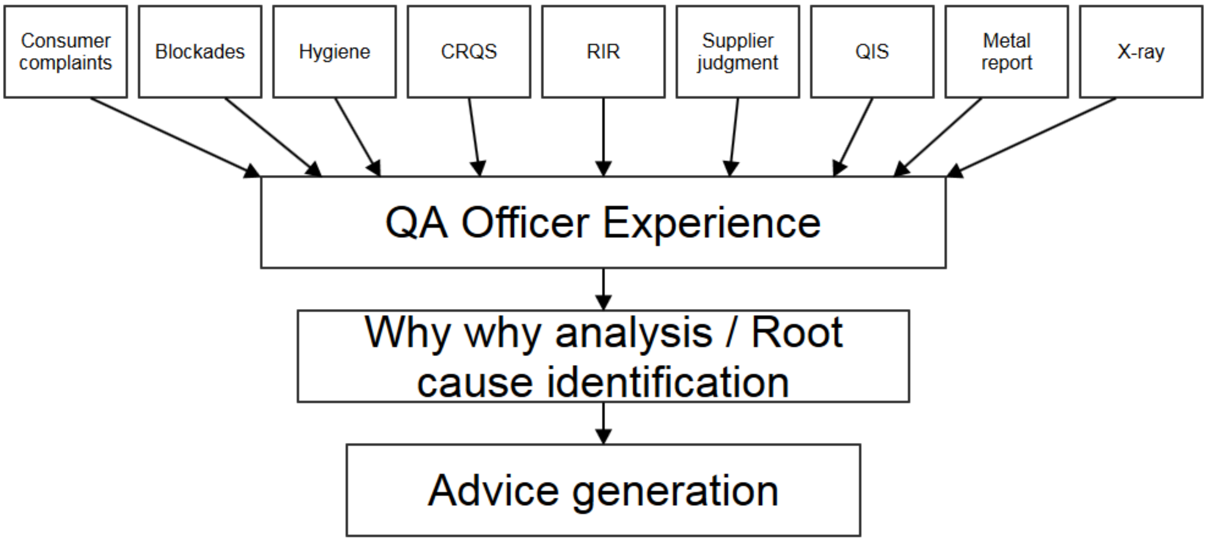



*Figure 1; Current RCA at Ben & Jerry's Hellendoorn*

As can be seen in figure 1, a why why analysis is done as a method of RCA. The why why analysis, also known as the five whys analysis, is a RCA method comparable to flowcharting but five whys starts at the final output and by asking "why questions" works back revisiting the results of processes and investigating the actions that preceded them (Robitaille, 2004). The five whys method has its origin in the world famous Toyota Production System (TPS). It is even opted that TPS is the world's most important intervention in production since Henry Ford's production line contributions (Staats & Upton, 2011). In short, TPS is about increasing production efficiency by consistently and thoroughly eliminating waste, it does so by implementing several methods including Just-in-Time manufacturing, Kanban, Kaizen and several others (Ohno, 1988). All these methods are about eliminating waste. Taiichi Ohno, one of the originators of TPS, proposed the five whys method to root out problems and fix problems for good and so reoccurrence of the problem is eliminated (Alukal, 2007). The five whys method, also when not applied to a problem, starts with the assumption that instead of thinking that an approach for a process is right, it is wrong (Staats & Upton, 2011). With this way of thinking also waste that is not obvious, since it has been part of the operation for a long time, can be tracked down. Literature also shows that the five whys method is often used as a tool for root cause problem solving to solve quality problems (Pylipow & Royall, 2001; Nelsen, 2003). The found root causes are normally deep and corrective actions at those deep levels are broadly based and long lasting. Benjamin, Marathamuthu & Muhaiyah (2009) state that even though the five whys is based on corrective action, it can be viewed as both corrective as well as preventive since it aims at deep nestled causes that, if not eliminate, would likely cause new problems. Although the name states five whys it is not necessarily five times that why needs to be asked to discover the relationship between cause and effect (Fantin, 2014).

Robitaille (2004) formulated some advantages and drawbacks for the five whys analysis. The advantage of a five whys analysis is that it is informal and easy to execute, and it uncovers causes that could easily be overseen or ignored. However, the drawbacks are that the analysis relies on other tools to validate the actual cause with facts and it is of limited value of there are multiple causes contributing to the problem. This last drawback can cause a wrong focus on merely attention is given to one cause where actually multiple are contributing to the problem, this is why it is important to store results and check whether the wanted effect occurred and learn from it. The last drawback can also be overcome by not drawing out a singular five whys line but also highlight multiple causes if applicable (Robitaille, 2004).

Then the second type of RCA that is applied focuses on data analysis. A QA officer dives into the measurements and data available at the factory and searches for certain trends. However, due to the fact that measurements cannot be linked to each other, these trends are only searched for within a certain measurement type and not between different types.

It is strived that these two RCA types are utilized together and therefore coexist. However, since the data cannot be linked to each other and data is found in different systems, the data analysis is highly time consuming and therefore is often left out.

## 1.3 Manufacturing process

To really understand the origin of the extracted information, it is beneficial to take a look at the entire process of ice cream making at Ben & Jerry's Hellendoorn. The outline of the manufacturing process is given in figure 2 and consists of five steps. These five steps are specified and expanded in appendix A.

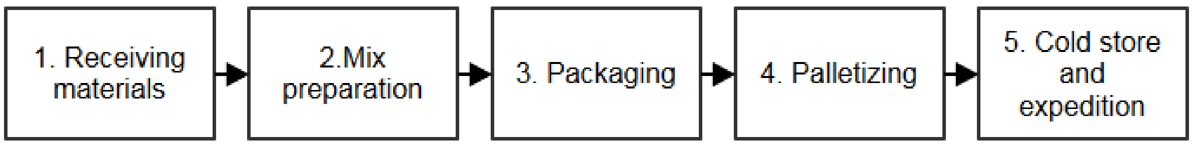



*Figure 2; Outline manufacturing process at Ben & Jerry's Hellendoorn*

The first step in the ice cream manufacturing process is the receiving of raw materials. Those received raw materials are then judged and prepared for manufacturing which consists of repackaging, labelling and storing the materials at the right place and temperature.

The second step is mix preparation. At the basis of every ice cream of Ben & Jerry's lay the same basic mixes. These mixes basically contain cocoa, condensed skim milk, cream, egg yolk, stabilizers, sugar, and water. The exact compositions of these products depend on the type of ice cream. The ingredients then are mixed, homogenized, pasteurized and cooled. Next, the mix will be flavoured accordingly. The mix is then stored in a flavour tank until further use is demanded.

After that, the mix is processed further on the production lines. At Ben & Jerry's Hellendoorn there are three lines that produce Ben & Jerry's ice cream, being B&J 1K, B&J 2L, and B&J 3M. First the kept stored mix is transferred from the flavour tank to the ice cream freezer. After freezing, the chunks and sauces are adjoined and the ice cream is injected into cups. Subsequently, lids are placed on the cup. To check whether the cups are added conformal, the cups are weighted. After this the cups immediately receive a tracing code called lot code, and shelf life-date at the bottom of the cup. Next the cups are put on a vibrating table which checks whether the lid is placed firm enough on the cup. The cup then goes into the hardening tunnel; this tunnel lowers the temperature to such an extent that the ice cream gets the right structure. When the product is hardened, the cup gets a seal on its lid to secure and guarantee integrity of the product. Then the metal detector assures that there is no metal in the final product, so consumer safety is guaranteed. At the last step op phase 3, the cups are wrapped in plastic foil and labelled in dependent compositions.

Once the cups are labelled, they move on towards the palletizing department. Palletizing is also done automatically. A robot stacks the bundles of cups on a pallet and the pallets are then wrapped and labelled.

After palletizing the pallets are moved to the right location in the cold automated storage, the warehouse where the product is kept until they are ordered and picked for distribution. The pallet is then loaded into a truck and the ice cream moves to its next destination.

## 1.4 Quality measurement reports

The information in the addressed reports is measured at different moments in the manufacturing process and consists of a widespread set of measurements. All the used reports are listed in table 1 .

*Table 1; Measurement reports and explanation of Ben & Jerry's Hellendoorn*

| Report | Explanation |
|---|---|
| Consumer Complaints | Complaints from consumers. |
| Blockades | Pallets that are blocked from being distributed because of a certain reason. |
| Hygiene | Hygiene within the factory as well as in the product and raw materials. Refers to microbiological determinations. |
| CRQS | Line tests on the quality of the product. On-pack, in-pack and in-use. Due to IT reasons, at this moment only on-pack is registered and useable in the reports. |
| Supplier Non Conformance Report (SNCR) | Judgment of the quality of the raw materials. |
| QIS | The weight- temperature and additions of the product. |
| Metal detector | Amount of metal in the product. |
| X-ray | A scan to check how the ice cream is divided in the packaging. E.g. if voids occur or whether the additions are divided equally through the ice cream. |
| Month- and week report | Contains all the above mentioned data except QIS, Metal detector, and X-ray, but then bundled for a specific month or week. |

Almost all the reports are in excel, but they originate in several different programs. The programs that are used are SAP, Vispro, QIS and LIMS.

Like previously mentioned, the different assessments of the product are measured at different moments during the production, and therefore some can influence the other. For example if the temperature of the ice cream is too low this can lead to the deformation of the packaging, because it gives less resistance to pressure. When the measurements are done can be found in table 2 and in appendix A are the measurements indicated within the entire manufacturing process. The measurements, consumer complaints, blockades, hygiene, SNCR, and month- and week report are not indicated in Appendix A because they are either done outside of the manufacturing process or its not specified when the measurement must be done during the process. And temperature is not indicated because this is measured through the entire process.

*Table 2; Placement of measurements in manufacturing process*

| | Receiving materials | Mix preparation | Packaging | Palletizing | Cold store and expedition | Market |
|---|---|---|---|---|---|---|
| *Blockades* | Can occur throughout the entire manufacturing process and from Market feedback | | | | | |
| *Consumer Complaints* | | | | | | Manually |
| *CRQS* | | | Manually | | | |
| *Hygiene* | Is measured throughout the entire manufacturing process but mainly on the end product at the Packaging phase. | | | | | |
| *Metal detector* | | | Automatically | | | |
| *Month-and weekreport* | Is conducted outside of the process and consists of all the other measurements. Is done manually. | | | | | |
| *SNCR* | Can occur throughout the entire manufacturing process and to a lesser extent from Market feedback. | | | | | |
| *QIS* | | | Automatically | | | |
| *QIS - temperature* | Is measured through the entire manufacturing process | | | | | |
| *X-ray* | | | Automatically | | | |

Of these reports some are done automatically and some are done manually. The ones that are done automatically are QIS, metal detector and the X-ray. The manual measurements are Consumer Complaints, since the complaints from the market are received and registered at a complaint centre. The CRQS is done by line operators and is filled in manually.

A couple of the measurements also feature a signal system that pushes out a product that does not meet the requirements for that test. The measurements that wield such signal systems are, the metal detector, X-ray, and the weight-, and temperature measurement, which can be found in QIS.

### 1.4.1 Consumer Complaints

What the report consumer complaints covers is kind of self-explanatory. It is a report on the consumer complaints that were done for a certain factory. These consumer complaints do not come directly to Ben & Jerry's Hellendoorn, but the complaints first to a service centre in the United Kingdom. They collect all the data into two systems called Infinity and Tableau. A consumer complaint specialist working at Unilever Benelux in Rotterdam then collects and analyses this data. He collects the data into a excel sheet of data and checks whether the factory complies with its KPI's. This worksheet of data is then shared with Ben & Jerry's Hellendoorn.

When the data is received at Ben & Jerry's Hellendoorn, a QA officer then checks whether the list contains consumer complaints that addresses ice cream originating from the factory at Hellendoorn. When this check is done, the data list is shared with the rest of the QA team. To sum the valuable data up, it contains a caseID, the date, the factory, the product type, the complaint type, the production code, and the real complaint.

The consumer complaint report is often the problem on which a RCA is then set up. But the report is also addressed for information to look for example whether more complaints on the same product came in etcetera.

### 1.4.2 Blockades

The report on blockades is a report that defines the blockades that have been applied. Blockades are applied because something was wrong with a certain product. For example, a differentiating ice cream cup has been detected during the production of a certain ice cream type. This could eventually lead to a consumer buying a cup of ice cream flavour A, but when he or she opens the cup it contains flavour B. This can lead to complaints and therefore the pallets that contain such a wrong cup are blockaded from being distributed. This is always done by a QA officer. How such a blockade can be abrogated depends on the type of problem that could be a widespread of things.

The QA officer registers a blockade in SAP. Then the blockades are extracted from SAP and placed into a list, which contains all the blockades. The data that this list contains is, a follow-up number, product code, product type, blockade type, production date, production line, production code and the blockade definition.

The blockades are divided into 4 incident types being A, B, C, and D. An A-incident is when the product is already in the market and poses a potential consumer safety or health risk. A further classification of an A-incident shows A(AU) which is an unacceptable level of risk for the Consumer and to Unilever brand equity and corporate reputation. A(AA) is a low level of risk to the consumer but still a potential risk to Unilever brand equity and corporate reputation. A(B) gives a high level of risk to Unilever brand equity and corporate reputation and authorities may even take action towards Unilever if they become aware of the problem. And final classification A(C) gives a very low or negligible risk to Unilever brand equity and corporate reputation and authorities are therefore highly unlikely to take action.

A blockade is indicated as a B-incident when a product is in the market place which is safe, but does not meet specification in terms of any or all of the following; performance, composition, functionality, appearance, taste, smell, durability, integrity, legality, or regulatory. All of this to the extent that the product poses a high level of risk to Unilever corporate or brand reputation.

A C-incident occurs when the product in the market place is safe but is substandard. The product can be used by consumers without difficulty throughout shelf life and it poses a very low level of risk to Unilever corporate or brand reputation.

Then a D-incident is still at the factory or in a distribution centre. It refers to finished formulas or finished products that do not meet agreed specifications, HACCP requirements or consumer/customer standards, resulting in finished products or formulas being placed on hold for further evaluation.

A complaint turns into an incident and eventually a blockade if any or all of the following identifications are found during the investigation of the complaint.

1. Retain/reference samples show the same defect as a complaint of the same lot code.
2. A systemic loss of control in the manufacturing process is identified.
3. Operating procedures and work instructions can be shown to not been followed.
4. Missing documentation from SU records for the affected lot(s) & therefore it is unable to verify product quality.
5. A systemic loss of control at suppliers is reported/identified.
6. Blocked product has been released inadvertently
7. Product abuse in Unilever controlled warehousing and distribution centres is identified.
8. A new product design is causing significant adverse consumer feedback above the norm expected for a new product launch. Investigation verifies that product use is problematic and causes difficulty for consumers.

### 1.4.3 Hygiene

The QA officers working at the laboratory test the factory on hygiene. Hygiene in this case refers to microbiological determinations. Swaps are taken from points through the manufacturing process, certain critical factory points and from occasional points. All the swaps are tested and the results of these swaps are noted on paper. Also the end product of every ice cream type manufacturing process is tested at several time moments on microbiological determinations. Of course the results need to satisfy some conditions. The notations are then transferred to an excel file. This file contains information on the results from the microbiological tests that are done in the laboratory. The microbiological bacteria's that are tested are all in a certain way catalyst of sickness, so to prevent people from getting sick of the product; these bacteria's are constantly measured.

### 1.4.4 CRQS

CRQS is a visual measurement on product quality. Several tests are done at the production line on on-pack and in-pack matters. On-pack refers to tests that are done on the outside of the product, for example dents in the package or seal malfunction of the lid. In-pack addresses tests that are done when the product is opened. This could be for example a void in the ice cream and division of chunks and sauce. The results of these tests are then logged into a program called Vispro. The tests can be scored in this program into green, amber or red. A test is green when it past the requirements, amber when it past the requirements but is still okay to be moved onto the market and a test is red when it failed the requirements and the product therefore is not allowed to be distributed.

A QA officer then transfers the data from Vispro to SAP. Unfortunately, the current functionalities of the used SAP transaction only allow in-pack results to be registered. This will be changed, but when is not yet determined, so in-pack CRQS results will not be addressed in this research. The data which is placed in SAP is then exported to an excel sheet and this excel sheet is the CRQS report. The data contains information on the material type, the problem category and definition, the production code and the lot code.

### 1.4.5 SNCR

The SNCR is a report on the assessment of the suppliers. Each supplier and its deliverables are constantly evaluated so Ben & Jerry's can guarantee what it promises and can guarantee a certain quality standard. All of the supplied goods are evaluated and from these evaluations sometimes come complaints that a certain standard is not met. Therefore this complaint is communicated towards the supplier. All of these complaints are documented into SAP. Also when production had already been started with the raw material, the amount that have been produced is blockaded from being distributed and so the SNCR cases that are applicable to the end product will show up in the Blockades report described in 1.4.2.

### 1.4.6 QIS

The QIS report contains both information on temperature and weight. Both of these measurements also include signals that repel a product if it does not meet the quality standards. If a product shows abnormalities it will be blocked from being distributed and therefore it will show up in the blockades report. For this reason the temperature and weight measurements will be extracted from the blockades report.

### 1.4.7 Metal detector

The metal detector shows whether there is metal present in the product. All the products containing metal are expelled from the production line. The report of this measurement shows for which time periods there was a high amount of metal traced. Products that have been manufactured in that time period will be checked whether the repel mechanism did its job and excluded all the products containing metal from the process.

### 1.4.8 X-ray

The X-ray scans the content of products and composition. Ben & Jerry's has certain standards on how the division of the contents of the ice cream should be. For example, chunks must be placed all through the product and not all of them at the bottom. And every sauce-holding product has a different way that the sauce should be placed in it, for instance swirled or cored. The X-ray report shows how much abnormalities have been detected and how much of them are rejected from pursuing the production line.

### 1.4.9 Week report

Every week a report is conducted that addresses week-to-week results on complaints, SNCR, CRQS, and blockades. This report is the week report. Besides quantitative information this also contains qualitative data being information from management on what happened during that week and some extra notes.

### 1.4.10 Month report

The month report contains several quality measurement results and how they scored over a month. Indicators that are used in the month report are recall, consumer complaints, production, blockades, sales, hygiene, CRQS, and SNCR. For almost all these reports there are KPIs to which they must comply. A clear line can be seen in this month-to-month data on how the factory performs on quality. If possible the reports are divided into factory- and production line score. The month report only contains quantitative data.

## 1.5 Current performance of Root Cause Analysis

The results of the RCA at Ben & Jerry's Hellendoorn are currently not documented. Consequently, this leads to the elimination of the chance of learning from root cause trends (Taitz et al., 2010). Also at this moment according to the QA manager, the factory misses out on problem and root cause detection in the measurements, since measurements cannot be linked to each other. Because the RCA and data analysis lacks structure, it takes a lot of time to conduct one and the process is even more delayed due to the gathering of all different reports. Also since several measurements cannot be linked to each other, cohesion between reports can hardly be illustrated and therefore the identification of root causes and problems itself is hindered.

# 2. Theory

## 2.1 Root Cause Analysis

Every problem has an origin, which is the cause of the problem. When battling a problem where the cause is not identified, it is highly likely that only the symptoms are eliminated which does not stop the problem from happening again. Because of this, it is crucial to identify the root causes of the problem and eliminate them (Wilson, Dell & Anderson, 1993; Andersen & Fagerhaug, 2000). A root cause therefore is identified as the most fundamental instigator of a problem.

A tool that helps identify possible root causes of problems is the RCA (Doggett, 2005). The origin of the RCA according to Andersen & Fagerhaug (2000) lies in Total Quality Management (TQM). They identify RCA as a problem-solving process and one of the fundamental building blocks of continuous improvement. RCA is often used across the supply chain of medical care and software development (Siekkinen, Urvoy-Keller, Biersack & Collange, 2008; Wu, Lipschutz & Pronovost, 2009; Lynn & Curry, 2011). The work by Rooney & Vanden Heuvel (2004) also states that RCA can be used in a high variety of contexts with a problem that has impact on elements like environment, health, production, safety, quality, and reliability.

RCA is not uniformly described in the same way, but some examples will be given. Berman & Maund (2003) describe RCA as a tool to systematically investigate a problem to discover and correct root causes to prevent the problem from happening again. Julisch (2003) keeps it straightforward and states that RCA has the task of discovering root causes as well as the constituents that they influence. RCA is also often referred to as " a structured investigation that aims to identify the true cause of a problem and the actions necessary to eliminate it" (Andersen & Fagerhaug, 2000, p. 12). Lastly, Doggett (2004) describes RCA as a process of discovering causal factors using a structured approach with techniques designed to deliver a concentration for identifying and eliminating problems. These are just three from the wide array of definitions that are given for a RCA. Even though, several authors use different words for the description of a RCA, the core comes down to identifying root causes of a problem and the components that these root causes affect using a structured approach and come up with ways to prevent the problem from reoccurring. So a RCA exists out of 1) identifying root causes and 2) how they influence other factors, and 3) preventing a problem from reoccurrence by tackling the root causes.

When doing a RCA it is important, according to Rooney & Vanden Heuvel (2004), to search for root causes that management can control. This means for example that operator error is not sufficient enough, but the root cause could be that the operator made the error because of inadequate instructions and even then the question can be asked why the instructions are inadequate. Then management can control these instructions. Management should decide when a root cause is deep and sufficient enough, otherwise it is possible to keep asking yourself why something happened. Taitz, Genn, Brooks, Ross, Ryan & Shumack (2010) elaborate on this statement. They argue that the propensity of humans to make errors cannot be exterminated, and instead of pointing the finger towards the individual, it is needed to discover and resolve the underlying system vulnerabilities that allowed the human error to happen. So the authors put emphasis on the fact that it is important to search for the deeper underlying root cause and that the recommendation should be complete and be learned from.

That the learning element is important in RCA is found in the work of multiple researchers. Analysing and outlining trends in root causes makes it possible to develop systematic improvements and assess the impact of these corrective actions (Rooney & Vanden Heuvel, 2004). Taitz, et al. (2010) and Kumar & Schmitz (2010) endorse this by saying that singular RCA outcomes will have little learning value, but analysing multiple RCA outcomes can have great learning capabilities. The revealed and analysed trends in problems and root causes then can be used to analyse and simulate the effect of intended actions (Weidl, Madsen & Dahlquist, 2002). Berman & Maund (2003) conclude that the identification of trends by using RCA can have great benefits in adjusting work processes in such a way that reoccurrence of problems will be prevented, which then again will lead to higher time efficiency. Besides better work processes, the usage of RCA also makes employees think of the current processes in a different way and will make them aware of the interdependencies between causes according to Carrol, Rudolph & Hatakenaka (2002). Carrol et al. (2002) takes it even further by saying that the usage of the tool will result in a shift in culture towards more trust and openness because of the increased awareness.

Like mentioned before, RCA is a structured investigation to find the root causes of a particular event to prevent the event from reoccurring. There are three questions underlying RCA; 1) What happened?, 2) Why did it happen?, and 3) What can be done to prevent it from happening again? (Wu et al., 2008; Taitz et al., 2010). Since these three questions focus on the discovery of root causes and how to prevent a problem from reoccurring, Wu et al. (2008) added an extra question to facilitate aftercare; 4) Has the risk of reoccurrence actually been reduced?. This fourth question requires recommended corrective actions and a blueprint to verify that the corrective action has the intended outcome. Then Rooney & Vanden Heuvel (2004) arrange RCA into four steps: 1) Data collection, 2) Cause charting, 3) Root cause identification, 4) Recommendation generation and implementation (figure 3).

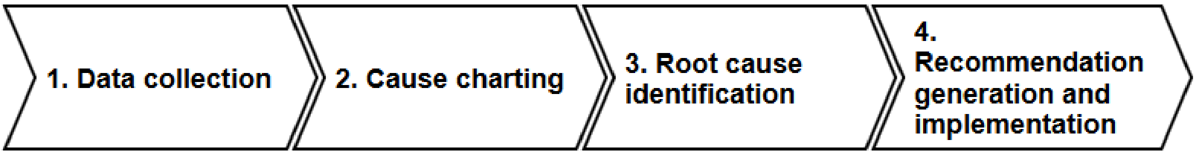



*Figure 3; Steps of Root Cause Analysis (Rooney & Vanden Heuvel, 2004)*

When employing a RCA, Anderson & Fagerhaug (2006) strongly suggest to use multiple tools to come to the root causes to guarantee reliability of the outcomes. Every tool has a single or multiple principles that it serves best, an organization should strive for the best combination so the tools complete each other. Gano (2007) underlines the use of multiple RCA tools to serve one goal to optimize the capacity and improve the RCA outcomes. Taitz et al. (2010) even suggest that recommendations should be removed from the RCA if using merely one RCA tool does the RCA. So RCA should always be done by implementing multiple tools.

Just like multiple RCA tools should be used, a problem could also have multiple root causes. Wu et al. (2008) strongly recommend keeping an eye on the greater picture. Meaning that the problem-solver should check the found singular path, but also compare it to previously similar found paths, and to not eliminate the chance of a problem having two or more root causes, meaning it is a combination. Leszak et al. (2000) agree on this matter and conclude that the final RCA result should be multiple dimensional and not just focuses on one facet of the root cause.

While the power of RCA is high, the RCA tool or tools themselves do not generate results. One of the most important aspects of RCA is the mind-set of the people engaging in the RCA. This mind-set should be a conscious attitude that comprises a relentless pursuit of improvement at every department-, or level-, or process of a firm (Anderson & Fagerhaug, 2006). Also according to Leszak et al. (2000), RCA is a never ending process that should be collaborative, continuous, and the improvement capacity of a firm should be sufficiently facilitated otherwise results will get lost.

Carrol et al. (2002) and Kumar & Schmitz (2010) emphasize that the RCA process should embody a historical timeline of events so trends can be discovered. Carrol et al. (2002) conclude that it is very important to indicate differences between similar events to check what happened last time and which countermeasures were applied, so similar ones could be applied or the countermeasure could be adjusted if the last time did not reach the envisioned results.

## 2.2 Problem detection

A lot has been discussed about having a problem and then chasing it down to the root causes. But before action can be taken to resolve the problem, the problem must be recognized or detected. The ability to detect problems can lead to more effective and timely interventions (Klein, Pliske, Crandall & Woods, 2005). Klein et al. (2005) discuss that failure of problem detection can lead to accidents and performance breakdowns if no action is initiated up until the situation where the problem has escalated to the point that recovery is impossible. Problem detection can be seen as the initial discovery that events have taken an undesirable course and may require attention (Klein et al., 2005). However, if a person is not already looking for the problem, the problem and cues to the problem are highly likely to stay invisible. This also happens in everyday life, for example when you ask someone whether he can see that your jeans are damaged and the answer is: *yes, but if someone does not know that it is damaged, he would not see it*. This is also applicable to more complex situations. With production processes becoming more and more complex, it becomes more important to facilitate a good problem or fault detection, since it becomes harder for a person to recognize a problem during their normal activities (Venkatasubramanian, Rengaswamy, Yin & Kavuri, 2003). Venkatasubramanian et al. (2003) encourage firms to detect problems as early as possible so the problem is still controllable within the firm and countermeasures can more easily be taken as opposed to where the product is already distributed. When the product is already distributed it becomes important to still recognize the problem even at this later stage and then prevent it from reoccurring or even escalating. Leszak, Perry & Stoll (2000) for their research made a RCA tool focusing on defect detection and problem prevention in software programming. By detecting defects with a retrospective approach they reduced the overall number of defects because: by repeating and learning they were able to detect defects earlier in the lifecycle, the effort to find and fix a defect was reduced, and with the tool they were able to accurately make process changes which were able to affect multiple defect root causes.

## 2.3 Learning from experiences

Like previously mentioned, RCA can be optimally utilized when a learning element is exploited. This learning element means that the users learn from the found root causes and use them to prevent future reoccurrence. The concept of single- and double loop gives great possibilities for this way of learning; these two concepts are often discussed in combination with the concept of deutero learning (Argyris & Schön, 1978). These are all forms of organizational learning. Organizational learning can be described as the ways organizations build, complement and organize knowledge and routines around their activities and within their organizational cultures, and adjust and develop organizational efficiency by improving the utilization of the skills of the employees (Dodgson, 1993). Crossan, Lane & White (1999) then assign four processes of organizational learning; intuiting, interpreting, integrating, and institutionalizing, also known as the 4Is. It is presumed that 1) learning always has positive consequences, since organizations can also learn from mistakes, 2) learning influences the knowledge of the entire workforce, and 3) learning occurs in all the elements and activities of a firm, motivating and organizing learning is an essential task of an organization in this process (Dodgson, 1993).

Deutero learning includes Single-loop learning (SLL) and Double-loop learning (DLL). SLL is the learning process where an organization adapts to changing inputs, but does this without changing the existing pre-set norms (Wijnhoven, 1995). In the context of RCA this could for example be that a certain root cause is found for the problem that the right temperature is not met, and the suggested action is to buy a new freezer. This is single-loop since it solely focusses on problem solving without adjusting the predefined norms. DLL is where an organization changes a norm. So for example that an organization changes the norm for the temperature that must be met. This results in a continuous change in a process. Wijnhoven (1995) describes this as DLL being about changing the pre-set norms due to the ineffectiveness of the existing norms. DLL is often not required when the context of an organization is stable and has low complexity, since low risk environments often discourage the search for innovation (Wijnhoven, 2001). The need to retain existing knowledge, which is done in SLL, can hinder the process of DLL, since the unlearning of old knowledge and the learning of new knowledge is required in DLL (Levinthal & March, 1993).

Defining deutero learning into one single definition is hard to do, since scholars define it in different ways. At the basis, Argyris (2003) looks at deutero learning as a combination of SLL and DLL. Wijnhoven (2001) and Thomsen & Hoest (2001) define deutero learning as an incisive form of cognitive rethinking and critical reflection on an organization's core assumptions. And on the other side, deutero learning is conceived as the institutionalization of learning processes, which is in this case the establishment of appropriate structures, capabilities, processes, and strategies to facilitate learning at the organizational level (Huysman, 2000; Geppert, 2000). However, since the article by Wijnhoven (2001), deutero learning is seen as the institutionalization of SLL and DLL.

DLL focuses mainly on reflecting on current knowledge, which can be divided into tacit- and explicit knowledge (Aamodt & Plaza, 1994). Dhanaraji, Lyles, Steensma & Tihanyi (2004) even state that when conducting research about knowledge, it is critically important to differentiate between the tacit and explicit form. To summarize the definition of tacit- and explicit knowledge like mentioned in the introduction, tacit knowledge is 'know-how' and is often reflected in personal experience and is regularly referred to as intuition or expertise, explicit knowledge is 'know-what' which is formally described in some sort of organizational documentation (Smith, 2001). Nonaka & Takeuchi (1995) opt that tacit knowledge is abstract and can only be transmitted through active involvement of the knowledge owner, but explicit knowledge is highly standardized and is therefore suitable to be communicated by the use of formal and systematic language. While an organization is built upon explicit knowledge that can be seen as building blocks, the organization cannot survive without tacit knowledge, which resembles the glue that keeps the building blocks together (Dhanaraj et al., 2004).

Since explicit knowledge is standardized and codified it is more easily transferred and exploited (Polanyi, 1966). Codification enables explicit knowledge to professionals that aim to apply the knowledge in solutions and everyday problems, through identification, capturing, indexing (Wyatt, 2001). Wyatt (2001) states to make tacit knowledge also transferrable and exploitable, the tacit knowledge is to be personalized. This means providing the knowledge owner with the means to identify and communicate effectively with others. However, according to Jasimuddin, Klein & Connell (2005), classifying knowledge into either tacit or explicit is not that easy and is influenced by two perspectives. The 'knowledge-as-a-category' perspective states that knowledge is either tacit or explicit, which makes it relatively easier to classify. But when taking the other perspective being, 'knowledge-as-a-spectrum' perspective it becomes harder to classify since the categorization of knowledge is then context dependent (Jasimuddin et al., 2005). For example, knowledge could, inside a company be seen as explicit, but externally as tacit. And even intercultural classification differences occur, for example in the West the emphasis lies on explicit knowledge, but in Japan knowledge is more often seen as tacit (Nonaka & Konno, 1998). To overcome this paradox it is important to make use of organizational documentation like manuals and methods to exclude misinterpretation (Jasimuddin et al., 2005).

Explicit knowledge according to the research by Eraut (2000) always originates from tacit knowledge. Tacit knowledge regularly stems from implicit learning, which is a learning process that focuses on the development of intuitive knowledge (Reber, 1989).Tacit knowledge then can be made explicit by reflecting on the actions taken from tacit knowledge (Schön, 1987). However, it is important to acknowledge that tacit knowledge does not always have the goal of being turned into explicit knowledge, it are not two ends of a continuum, but rather two sides of a coin (Tsoukas, 2002). The 4Is by Crossan et al. (1999) can further clarify the process from tacit knowledge towards explicit. The first phase, *intuiting*, refers to the creation of experiences, images, and metaphors; this intuitive knowledge can be seen as tacit knowledge. The intuiting process is often a preconscious recognition of patterns and possibilities. Intuiting affects the individual owning the intuitive knowledge and it only affects others when interaction is established between the knowledge owner and others. In the next phase, *interpreting*, the preconscious knowledge is transferred to words and interpreted, which often leads to the development of language, which starts the way of tacit knowledge becoming explicit. *Integration*, is the penultimate phase, here it is strived to develop shared understanding of the knowledge among individuals. The output is that coordinated action must be taken through mutual adjustment. Lastly, *institutionalizing* is the process to ensure that routinized actions occur, which makes the knowledge fully explicit. Reoccurrence is reached through defining tasks, specification of actions, and organizational mechanisms that are placed in the right way. Institutionalizing embeds learning that occurred by individuals into the organization.

However, knowledge can become outdated or superfluously. Both tacit- and explicit knowledge can be seen as obsolete when the knowledge fails to reach the desired objectives (Greenwood, 1998). Consequently, two types of responses can be expected, the first one is where the user searches for other ways of achieving the same objective, this type of response is defined as SLL because it solely focuses on changing the actions intended to lead to the same outcomes (Argyris, Putman & Smith, 1985). The second type of response is, where the user searches for alternative actions to achieve the same objectives, and with that examines the appropriateness and propriety of the chosen ends, this response can be defined as DLL, which involves reflection on values and norms (Greenwood, 1998). The concept of SLL and DLL is illustrated in figure 4 and is based on the work of Argyris (1977), Argyris, et al. (1985), and Argyris & Schön (1987).

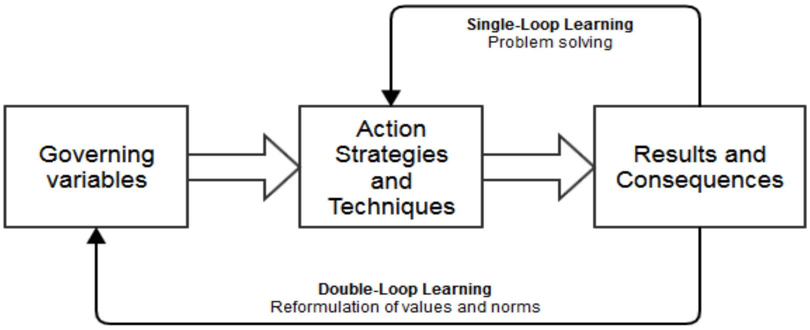



*Figure 4; SLL and DLL based on Argyris, 1977; Argyris et al., 1985; Argyris & Schön, 1987*

In short, the governing variables refer to why an organization does what it does. The action strategies and techniques can be explained to what an organization does. And the results and consequences are the outcomes and therefore can be defined as what the organization obtains. So SLL is where the results lead to adjustments in the actions taken, and DLL leads to adjustments of the standards wielded by an organization.

A concept where learning loops are constantly applied is CBR. CBR looks at past cases and the solutions that have been formed for a certain case and later on evaluates whether these cases have reached the intended goal and if the solution is also applicable to new cases. Kolodner (2014) writes that in CBR, new problems are approached by comparing and contrasting them with previous similar events. So CBR utilizes previous experiences on a topic to help solve new problems or even prevent problems from happening in the first place. By reusing solutions to similar problems CBR is an approach to sustained learning, since a new experience is collected each time a problem has been answered, making it available for future problems right away (Aamodt & Plaza, 1994). So past experiences are used for future problems, this can be seen as SLL. If the previous solution does not work, then the solution is adapted and tested, if this solves the problem, then the new experience is stored and retained to use in the future (Jonassen, Strobel & Lee, 2006), this process can be seen as DLL.

Kolodner (2014) states that CBR is not that difficult to carry out, but the difficulty lays in collecting and storing the information in the right way. People in their day-to-day lives already apply CBR, in short an example:

> *Jane plans to have a nice day off with Marc. She remembers seeing Marc ride his bicycle at a Sunday. She wonders whether he likes to ride his bike for recreational purposes or merely functional. Marc did seem relaxed on his bike and he was not in a hurry, Jane remembers. Jane is wondering whether a nice bike ride would be fun to do during their day off. She thinks*

*that a more relaxed type of bike ride would be appreciated more than an off-road mountain bike trip. Perhaps a bike ride on the country side would be nice. The bike ride goes past lakes, and Jane knows that Marc likes lakes.*

In this example, Jane is using examples and counterexamples of an idea to try and obtain an understanding of Marc's preferences. Jane is employing CBR to plan a day trip. In CBR the exploiter is remembering previous situations that are in agreement with the current situation and uses them to help solve the dilemma. So besides just remembering past experiences, CBR also is about adjusting old solutions to meet new demands, using old cases to interpret a new situation, or create an satisfying solution to a new problem, or using old cases to explain new situations, or using old cases to reflect on new solutions (Kolodner, 2014). So two of the main concepts of CBR are experience and knowledge (Jonassen et al. 2006). Knowledge in the light of learning is often divided into tacit- and explicit knowledge (Smith, 2001). Tacit knowledge is described by Smith (2001) as *"practical, action-oriented knowledge or 'know-how' based on practice, acquired by personal experience, seldom expressed openly, often resembles intuition"* (Smith, 2001, p. 314). And explicit knowledge is defined as *"Academic knowledge or "know-what" that is described in formal language, print or electronic media, often based on established work processes, use people-to-documents approach"* (Smith, 2001, p. 314). To optimize the management of knowledge and learning from knowledge, tacit knowledge should be turned into explicit knowledge to make the knowledge become part of a firm's knowledge network (Herschel, Nemati & Steiger, 2001). Linking tacit- and explicit knowledge to CBR means that this process of tacit knowledge to explicit knowledge helps store the information used for CBR and makes the knowledge for CBR more accessible.

According to Watson (1999), CBR is a methodology and not a technology, but CBR can be used alongside different technologies. At the basis of this methodology lays four main phases being; 1) Retrieve, 2) Reuse, 3) Revise, and 4) Retain (Aamodt & Plaza, 1994; Watson, 1999). These phases work as a cycle since the outcomes of CBR are used for new cases. First the user 1) retrieves the most similar case(s). Then the user 2) reuses the information and knowledge in that case to solve the problem. Following, the proposed solution is 3) revised. Lastly, the parts of this experience likely to be useful for future problem solving are 4) retained, and then the cycle starts over again for new cases (Aamodt & Plaza, 1994). However, before implementing the use of CBR it is important to gather the data that is already available, so that certain knowledge is already explicitly available (Jonassen & Hernandez-Serrano, 2002). According to Lopez De Mantaras, Mcsherry, Bridge, Leake, Smith & Craw (2005). These four stages are not sufficient to utilize CBR in the most optimal way.

Iglezakis, Reinartz & Roth-Berghoffer (2004) added two stages to the 4-stage CBR model, being 5) Review, and 6) Restore. After the retaining phase, Iglezakis et al. (2004) state that the retained experience should be 5) reviewed and subsequently 6) restored so it can be 1) retrieved again for future usage (figure 5). Arguably, phase two where reusing is strived for, can be seen as SLL since inputs for that case are changed, but the norms stay the same. In phases three till six it is all DLL, since standards are revised, adjusted and restored, so norms are changed.

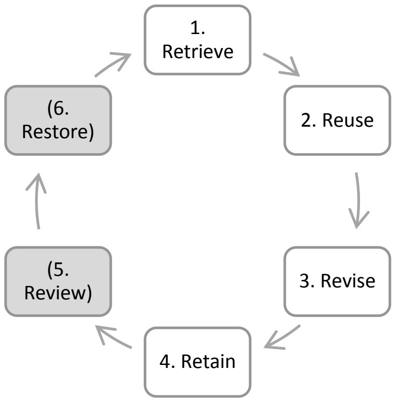



*Figure 5; Stages of Case-Based Reasoning based on Aamodt & Plaza (1994) and Iglezakis et al. (2004)*

CBR can also be very helpful when applied to problems that have not occurred before or are not similar to previous problems. According to Leake (1996), the use of CBR enables more creative problem solving. It makes the problem-solver think and lay linkages between certain actions and outcomes; this makes the problem-solver more aware of the impact of actions, which helps to discover the solution. Leake (1996) then identifies five main elements that can be reached through the use of CBR; 1) knowledge acquisition, 2) knowledge maintenance, 3) Increasing problem-solving efficiency, 4) Increasing quality of solutions, and 5) User acceptance.

A RCA can be maximally exploited when the users learn from the results from past performances; this is where the functionalities of CBR are applicable. In the concept of CBR it is important to look at past results. The tasks of CBR are often characterized into two classes; 1) interpretive CBR, and 2) problem-solving CBR (Kolodner, 2014). Interpretive CBR utilizes previous cases as a reference for organizing or distinguishing new situations. The goal is to form a decision about or classification of a new situation, by comparing and distinguishing it with cases that already have been classified (Ashley & Rissland, 1987; Leake, 1996). Problem-solving CBR uses previous cases to propose solutions that might be applicable to new situations. The goal is to employ a previous solution to produce the solution to a new problem (Leake, 1996). A situation that a user however must be wary of is that by emphasizing the previous cases, the user can miss out on slight differences (Wachter, Shojania, Saint, Markowitz & Smith, 2002).

## 2.4 Group Decision Support System

CBR is a methodology that needs storing of knowledge and analysis of this data, DSSs are appropriate for this. DSSs are systems that *"…make advanced quantitative analyses of data and simulations of possible events and consequences of decisions."* (Wijnhoven, 1995, p. 10). To get a clear view of what a DSS is, it is important to first take a step back, since a DSS is a type of information system (IS). This subchapter first, addresses IS and after that goes more specific towards the concept of DSS, and the problem-solving power of a DSS.

### 2.4.1 Information system

According to Boddy, Boonstra & Kennedy (2009), an IS is a set of people, procedures and resources that gathers data which it disseminates and converts. Computers enabled IS to become both cheaper and faster because of the data- and information processing capability of computers. However, it is important to acknowledge that an IS does need both people and technology.

Boddy et al. (2009) classify ISs into four main purposes: communication, decision support, monitoring, and operational. Communication systems enable easier exchange of information between and around organizations. They overcome barriers of distance and time. Decision support systems also known as knowledge systems, empower managers to calculate consequences of certain actions. A monitoring system assesses the performance of activities, processes or functions. Operational systems focus on process routine transactions and enable the exchange of data between organizations.

### 2.4.2 Group Decision Support System

DSS in 1971 was first named separately from management ISs by Morton (1971). He distinguished DSS from IS because DSS dealt with semi-structured and unstructured problems, while IS merely focused on structured problems. Semi-structured problems are problems that still can be modelled although involving uncertainty (Thompson, Altay, Green & Lapetina, 2006). So the structured part can be addressed with data, but the unstructured or uncertainty part must be engaged by human intuition. Following this assumption, Mcleod & Schell (2001) gave a general description of Group DSS (GDSS): a system enabling both communication and problem-solving possibilities for semi-structured problems. They also give a more specific and extensive definition of a GDSS: a system that provides information or makes suggestions regarding specific decisions, to support a group of managers or a single manager working on problem-solving of a semi-structured problem. Besides these descriptions they also created a descriptive model of a GDSS (figure 6). GDSS can be seen as a system that combines communication, computer, and decision technologies to support problem formulation and solution for a group of members (DeSanctis & Gallupe, 1987). This definition is similar to the one by Mcleod & Schell (2001) only does the definition by DeSanctis & Gallupe (1987) specify to a group of members. Bui & Sivasankaran (1989) state that the higher the task complexity, the higher efficiency and effectiveness GDSS will achieve. However, for low task complexity they found that efficiency decreased and satisfaction of usage is decreased.

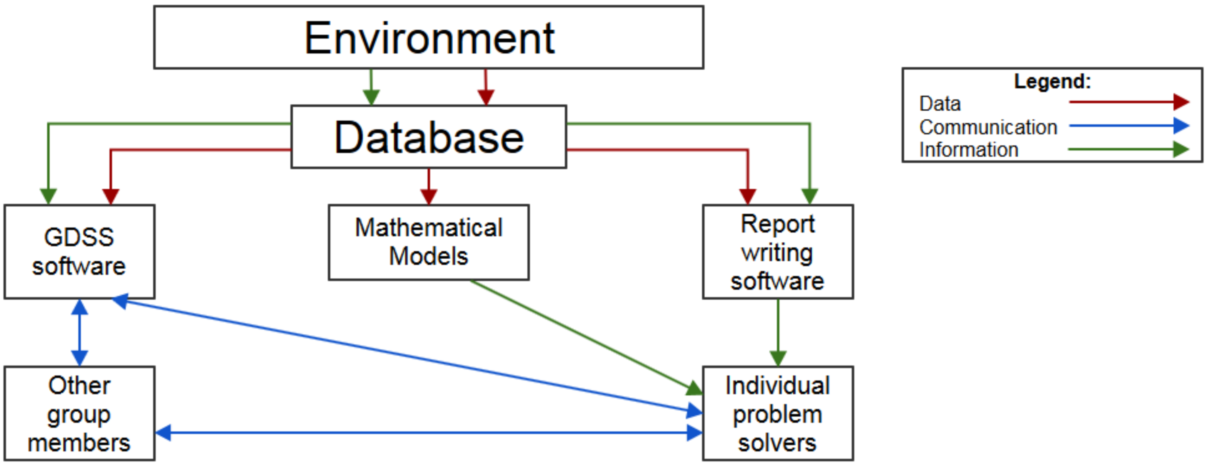



*Figure 6; Descriptive model GDSS (Mcleod & Schell, 2001)*

The purport of the explanation by Mcleod & Schell (2001) is as followed. First they distinguish three types of exchange that operate in their model, being data, communication and information, which can be found in the legend. The difference between data and information sounds vague but data refers to measurements etcetera and information refers to extra non-registered information. So information could for example be that a QA officer asks some extra questions to a production operator. Then to start, the GDSS always operates in a certain context, which in this model is identified as environment. Data and information is gathered from this environment and placed into a database. A division between data and information has been made to indicate data measured from systems and extra information that is gathered manually. The information from this database then goes to report writing software and a communication method being the GDSS software. Besides that, the data from the database then is used for the GDSS- and report writing software, and towards mathematical models. The data is processed in these three components and then the problem-solver or decision maker extracts the outcomes from this. The problem-solver can get the help of other group members by communicating directly with them or through GDSS software. The individual problem-solver then decides on the final recommendation and decision.

Unlike other authors, Sprague (1980) does not give a definition for GDSS but he opts a characteristic way of describing what a GDSS is. The characteristics suggested in the work by Sprague (1980) are: 1)

GDSS tend to be focused at semi-structured and unstructured, underspecified problems that upper level managers face, 2) GDSS attempt to conjoin the exploitation of models or analytic techniques with traditional data access and retrieval functions, 3) GDSS specifically focus on properties which make them easy to use by non-experienced people in an interactive mode, and 4) GDSS emphasize adaptability and flexibility to facilitate changes in the environment and the user's decision making approach.

McLeod & Schell (2001) discuss GDSS extensively in their book. They outline the power of GDSS in solving problems with powerful algorithms and decision rules. GDSS helps in this process by 1) retrieval of information elements, 2) retrieval of information files, 3) Creation of reports from multiple files, 4) estimation of decision consequences, 5) propose decisions, and 6) Make decisions. So it is a great facilitator of the management of knowledge. According to the research by Hosack , Hall, Paradice & Courtney (2012), GDSS enable better understanding of large amounts of data because of the interactive possibilities that a GDSS gives. This interactivity is for example the processing of algorithms with different datasets filled in. The enablement of interactivity makes it possible for the user to experiment with different datasets and see what the outcomes are, without actually applying adjustments to reality (Hosack et al., 2012).

Through recent years the availability of business intelligence and analytics systems has extended the capabilities of GDSSs to data-driven forecasting, real-time analytics, and performance management (Watson, 2005). The interactivity that these analytical systems give, according to Sprague & Carlson (1982), enabled faster analyses and interpretation of results. The use of modelling and algebraic calculations in DSS, referred to by Power & Sharda (2007) as model-driven DSS, gives great possibilities for doing analysis of a situation.

By implementing powerful quantitative models and calculations, various decision analyses can be conducted (Wang, 1997; Power & Sharda, 2007). One of such a decision analysis is comparing of different outcomes, which allows discovering, differences and weaknesses and strengths, which subsequently will lead to better inputs for future usage (Sharda et al., 1988).

Just like with RCA, the learning element is also important for GDSS according to O'Donnell & David (2012). They mention, that by getting experience in the utilization of GDSS, the benefits of GDSS also increase, so it is important to learn from the experience and outcomes. And the mental model of the user is also likely to change, since the GDSS gives new insights and helps to think creatively, so again it is important to learn from past processes.

Now a closer look is taken at the components of GDSS. Mcleod & Schell (2001) opt that a GDSS contributes to problem solving by improving communications, improving discussion focus and wasting less time. Improving communications does not mean that a GDSS actually has a communication component; it can simply be to enable the option to communicate. Power & Sharda (2007) also say that it is not necessary to build a communication component into the GDSS, when managers find such a channel unnecessary. Alternatively they can choose to communicate directly through portals or communication channels that are already at hand. According to Turban (1995) and Power (2002), GDSS consists out of four main components: 1) Model base, 2) Database, 3) User interface, and 4) architecture and network. The *model base* refers to the way the data from the database is processed and analysed. The data could be subject to for example algorithms or modelling. The *database* refers to the collection of data that is used for the decision-making. The *user interface* is the way the usage is presented to the members. This user interface includes both the way the data and models are presented and the way the communication is presented. The last component, *architecture and network* refer to the way that the network is used, so what is the communication and GDSS process used for the decision-making (Power, 2002).

Now that the GDSS components are clear, a focus can be taken on what the GDSS process looks like. So what happens at which time and how is the final decision reached. However, according to DeSanctis & Gallupe (1987) it is rather difficult to come up with a general process since every situation can vary in such a way that a process would be less applicable to a certain situation as opposed to another one. To overcome this problem DeSanctis & Gallupe (1987) took a step back and made a more general process description on how to setup a GDSS. The process can be found in figure 7.

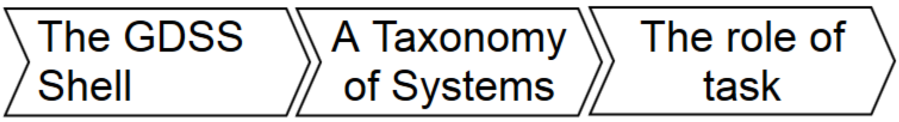



*Figure 7; General GDSS setup process (DeSanctis & Gallupe, 1987)*

The *GDSS shell* can be seen as the basis for GDSS. The shell provides a selection of features possibly useful to a variety of decision-making members. So the first three out of four GDSS components are defined and chosen in this phase. Then the second phase is the *taxonomy of systems*, this phase can be defined as the accommodation of the needs and dynamics of special group situations. Group size and member proximity is important to deal with in this phase, can the members interact phase-to-phase or are they dispersed. And whether the group is of small or large size. So during the second phase it must be decided and defined how the members are able to communicate and how much members are involved. The last phase is *the role of task*. This phase defines the particular task that confronts a group. The particular task also influences all the GDSS components since it is the primary reason why the group is together working on a certain case. A group's task can be characterized by its, criteria for success, goals, imposed time, rules, roles, and consequences of success or failure (McGrath, 1984). The role of task then also consists out of three different phases, which are found in figure 8. The phases generate, choose, and negotiate define the goals that a group must accomplish and all the phases consist out of two tasks. The first phase is about generating ideas and actions; the group should come up with action-oriented plans. And the creativity task refers to that the group needs generation of novel ideas. Then in the choose phase, the group must orientate on alternative ideas, and then the intellective task makes the group select a selection of corrective alternatives. And in the preference task, the group must come up with the best ideas. In the negotiating phase the group negotiates the residuary ideas. The cognitive conflict task involves resolution of conflicting viewpoints, and the mixed-motive tasks involve resolution of conflicting motives or interests. A GDSS should be able to provide the members during these phases with data and models to make the members able to select ideas or guide the members towards ideas (DeSanctis & Gallupe, 1987). So also in this situation, the entire group of members should have access to this system.

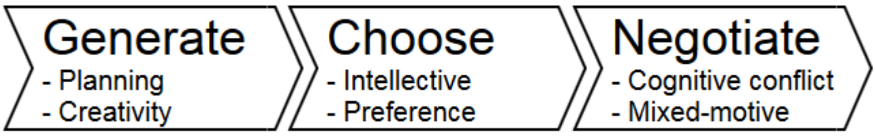



*Figure 8; Stages of role of task (DeSanctis & Gallupe, 1987)*

Shih, Wang & Lee (2004) conclude in their research that by making use of a GDSS the decision quality increases, which is also found in the experimental study by Limayem, Banerjee & Ma (2006). Limayem et al. (2006) found that when a GDSS did not have a positive influence on decisional outcomes, this could be attributed to ironic appropriation of the GDSS. This means that the GDSS did not serve the group task and was utilized in differing way than the purport of the GDSS. The most remarkable conclusion in the research by Shih et al. (2004) is not the decision quality, but that also the qualitative consensus of a group increases when a group makes use of GDSS, since the GDSS provided the members with better understanding of the motives and reasoning of others. Shih et al. (2004) also state that data collection and processing is the most time-consuming element in the decision-making process, however by making use of a specified GDSS that provides analytical processing, the GDSS can greatly limit the invested time for data collection and processing. Excel is a great and efficient tool to build such a customized GDSS, nevertheless, its inflexibility and adjustability makes Excel vulnerable, thus Shih et al. (2004) suggest to make use of a fully executed program if this is possible.

When starting to use a GDSS it is important to consider the way it is implemented. According to Dickson, Partridge & Robinson (1993), a facilitator should chauffeur the members through the GDSS to make the members comfortable with the system. Building up experience through repeated use following the work of Dickson et al. (1993) is the best way to get the members familiar with a GDSS. Therefore it is important to assign a lead user of the GDSS that will serve as the facilitator.

## 2.5 Design

Like is stated by Turban (1995) and Power (2002), GDSSs possesses a user interface element where data is presented. Smith & Mosier (1986) outlines that a poor designed user interface often needs to be compensated by extra user effort and that therefore a good user interface is critical for effective system performance. However, a design flaw, in itself, of user interface will not cause system failure, but users can only adapt to a certain extent to poorly designed interfaces (Smith & Moser, 1986). A dashboard is a tool that is utilized by management to clarify and assign accountability of data, such as KPI's, key objectives, and projects to steer the organization towards its mission statement (Gitlow, 2005). In this case, the month report will represent KPIs, but the detection tool is about representing data. The increased use of support business operations and advances in business intelligence, lets organizations monitor and analyse processes to help a firm understand where it is falling behind and how to improve (Rodriguez, Daniel, Casati & Capiello, 2010). However, data alone will not lead to better understanding, data is necessary but not sufficient, data should be presented in such a way that it becomes understandable to the user (Marcus, 2006). Besides just presenting data to measure performance, visuals can help managers access and analyse their KPIs more easily, saving time and confusion (Wyatt, 2004). The concept of dashboards has the ability to make data more understandable if it provides significant patterns of data (Marcus, 2006). How must this dashboard or user interface be designed and how can this user interface be appointed so it enables the GDSS contributions described by Mcleod & Schell (2001), being; better communication, improve discussion focus and it limits the waste of time.

According to Gitlow (2005), the benefits of a dashboard are both strategic and tactical; in short, the strategic benefits are about monitoring performance and tracking the pursuit of mission statement. The tactical benefits include the possibility to link jobs to the mission statement and improving employee's efforts on the mission statement of the organization. Marcus (2006) then highlights a pitfall, which is that dashboards might focus the attention to short-term results while ignoring long-term results. Malik (2005) formulated some dashboard presentation requirements. The requirements are divided into three areas being; 1) design, 2) layout, and 3) navigation. These areas are expanded on in the part below. 1) *Dashboard design*, a dashboard is considered well designed when it has an aesthetic appeal and it must deploy powerful visualization to convey a rich amount of information in a certain, often limited, display. Design consists out of many elements but the four main elements are; screen graphics and colours, selection of appropriate chart types, animation with relevance, and optimal content placement. The screen graphics and colours should preferably consist out of light and neutral colours. None of the graphics and colours should distract the user from the key task and information. For the same reason a company logo or graphics should not have too much prominence in the dashboard. Varying colours have been used when indicating different sections, but again the colours should not distract the user. Presentation of data and selection of appropriate chart types requires a well-balanced of analytical thinking and artistic rendering. The selection of the right visualization is heavily dependent on the core task of the dashboard and the message that it must send out. And visualization is also constraint by display area. Further, animation with relevance is important, it refers to valuable information being conveyed to the user. The animations should represent valuable information and the user should be able to adjust the animation if necessary. Lastly, the informational elements should be displayed with optimal content placement. Clutter should be prevented by preventing overloading of the display of the user, or in other words, displayed information should be limited to the mere necessary. The key elements for the 2) *Layout* of the dashboard are; number of windows/frames within the dashboard, symmetry and proportions, computer resolution considerations, and context selection. Optimal dashboards are able to create or consist out of multiple windows; this facilitates the insertion of different charts and tables and displays of information. However, it is important to not overload the user with too many windows, since every window needs further user attention. To further prevent overload, symmetry and proportions are important. Having a layout of uniformly sized windows is a good rule of thumb, since irregular sized windows, tables, graphs etcetera may unintendedly lead to highlighting and diminishing of importance of displayed information. As a starting point of the layout the computer resolution is an important consideration. Since the screen resolution will determine what information is shown in a glance. It must be strived to have as little as possible horizontal or vertical scrolling to view the dashboard information. However, vertical scrolling is preferred above displaying the KPIs on different pages. Which regulated in the context selection where the placement of content among the various windows within the dashboard is decided. It is strongly advised to consult the user on this matter to optimize dashboard usability. To ensure optimal acceptation and adaptation of the user it is wise to obtain early input and feedback from the group of users. The last area of focus for dashboard design is 3) *dashboard navigation.* Navigation includes deciding how the total information will be divided across the various dashboard elements and linking charts and reports to allow user drill-down for greater details of data. The key elements for dashboard navigation are; information grouping and hierarchy, tabs and pivots, and context drill-down. Information grouping and hierarchy refers to the fabrication of information in different dashboard groupings. Subsequently these groupings also help decide what group is at which hierarchical level, given the importance and priority of the content. Commonly dashboards consist out of two levels, where on the main page the parent level has links or tabs that link to the drill-down information. Tabs and pivots refer to the way of navigating through different windows. Tabs are common tabs that the user can click on to navigate to a different window. A pivot refers to a drop-down list that makes the user able to choose from several options. Preferably tabs are used, but when there are a lot of windows pivots can give outcome since it takes up less space. Context drill-down is very important for the navigational experience of the user. It provides to possibility to obtain additional levels of informational details when a user clicks on a specific element of the dashboard. It is important to have a relevant destination to the source, or in other words, the user must be navigated to expected data when clicking on a certain source.

The dashboard requirements mainly focus on presentation of and navigability through data, which can be seen as the user interface. Tufte & Graves-Morris (1983) came up with some guidelines for graphical display of quantitative data; 1) The design should induce the viewer to think about the substance rather than on the methodology on how to conduct and design the data, so processing of data should preferably be done automatically. 2) Avoid distorting what the data has to say, this means that the data should be presented as it is and vague presenting. 3) Present many numbers in a small space. 4) Make large data sets coherent; this way data can be linked to each other. The previous guideline links to 5) where the user should be encouraged to compare different pieces of data. 6) The data should have several layers of detail, from a bigger overview to more specific data. 7) The presentation should serve a clear purpose: description, exploration, tabulation, or decoration. And lastly 8) the system should be closely integrated with the statistical and verbal descriptions of a data set. Smith & Mosier (1986), state that the actual design of user interface is heavily depending on individual judgement, and therefore for effective task performance, displayed data must be relevant to the needs of the user.

Smith & Mosier (1986) wrote a book on guidelines for design of user interface and distinguish six functional areas, being 1) data entry, 2) data display, 3) sequence control, 4) user guidance, 5) data transmission, and 6) data protection. Below these areas are elaborated and expanded on. 1) *Data entry* refers to the way users need to enter their input into the system, and how the system reacts to these inputs. There are multiple ways that users can enter input, from just entering a number up until entering free lines of text. The system should guide to user in this process on what and how to enter the input, or in other words, improving the input logic. When the user then enters its input, there should be an explicit action that enters the input and an explicit action that can cancel the input. Besides that, the data entry should be compatible with the data display. These display areas should be predefined and when changing input this method should be consistent so the user has minimal action types. 2) *Data display* refers to the systems output and assimilation of information from such outputs. Data display is especially important when monitoring and controlling tasks. Data may be output on electronic displays or hardcopy printouts. The displayed outputs should then be limited to merely the necessary data and the data should be displayed in a usable form applicable to the user and task. Again also the data display should be consistent. Besides displaying outputs, the ability to protect the displayed data should be available, saving or printing the output should be available. 3) *Sequence control*, to a limited extent has already been addressed, but it refers to user actions and system initiative to interrupt or terminate transactions. However the need for this action should be limited to the absolute minimum. Also the users need to perform actions should be minimal and easy to execute. 4) *User Guidance* is about the system offering error messages, prompts, alarms, and instructions to help guide the user in the usage of the system. This user guidance should be smooth and not hinder the user. The user should not be disturbed in its usage if it is not necessary, so tips and tricks should be shown on the side and not for example in the field where the user needs to enter input. The objective of user guidance is to promote efficient system usage. 5) *Data transmission* refers to computer-mediated communication among system users, and also with other systems. So the data and outputs should be easily shareable among users and the system should work smoothly with other systems like for instance a database. Data transmission should however be modifiable by the user, so the user is able to add comments, pictures etcetera. When utilizing systems where information handling requires interaction among multiple users, effective communication is of critical importance. How this communication is initiated is not necessarily important but the system and especially outputs should not be impossible to share. 6) *Data protection,* attempts to guarantee the security of processes and data input and output. Besides protecting the before mentioned, data display of output, this also refers to running a usable and stable system. Data must be protected from unauthorized access and data must be protected from errors by users, in effect to protect users from their own mistakes.

However, merely focusing on guidelines is not enough according to Van Welie, Van der Veer & Eliëns (2001). They conclude in their research that guidelines can lack in applicability. Therefore design of user interface should focus on the context of a problem and solution, this way the user interface guides the user towards its goals. To a small extent, this can also be found in the above described guidelines by Smith & Mosier (1986) where focus on the user's task is advised.

To summarize, improvement of communication and discussion focus and reducing of wasted time can be achieved by having a good data entry and display, and by enabling sequence control, user guidance, data transmission, and data protection, the chance of design flaws are minimized and a high system performance is reached. Also the data should represent reality and trigger the user to think about the substance. Besides just the presentation of the data, also navigability is important to keep in mind. This must be to the point and be coherent to the expectations of the user.

# 3. Method

Now that the theoretical background is clear, a look is taken at how this will shape the research and what the research will look like.

## 3.1 Research question

Elaborating on the problem statement, the theory and the question of Ben & Jerry's Hellendoorn, the following research question is formulated:

*How can integrating Case-Based Reasoning and Root Cause Analysis into a Group Decision Support System benefit Root Cause Analysis?*

This question arises because, literature shows that RCA can benefit from access to multiple data sets (Rooney & Vanden Heuvel, 2004; Wu et al., 2008; Taitz et al., 2010) and GDSS are supposed to be able to make this access possible and do analyses with the data (Wijnhoven, 1995; Mcleod & Schell, 2001). And authors say that the use of GDSS has an influence on decision outcomes (Payne, et al. 1988; Sharda, et al. 1988; Todd & Benbasat, 1992; Leidner & Elam, 1994; Radermacher, 1994; Power & Sharda, 2007), which is in this case the discovery of root causes. Then a lot of research mentions that the biggest RCA gains are achieved through learning of outcomes and by using them (Bermand &

Maund, 2003; Rooney & Vanden Heuvel, 2004; Taitz et al. 2010), CBR focuses on storing and learning from past results to benefit future cases (Aamodt & Plaza, 1998; Kolodner, 2014).

The goal of this research is to discover how to design and implement a GDSS for RCA so the RCA leads to better outcomes; additionally elements of CBR and deutero learning are added. In this case better outcomes refer to both more founded root causes and the level of depth of these root causes.

## 3.2 Research methods

By looking at the literature, some requirements to the design come up that can be tested. These requirements, or in other words, design propositions, are referred to by Walls, Widmeyer & El Sawy (1992) as meta-requirements. Meta-requirements result in numerous criteria to analyze whether a certain tool reaches its goals and therefore the purpose of existing. Like Wijnhoven & Brinkhuis (2014) underline, that a tool simply exists, does not mean that it serves its goal and therefore its usefulness is doubtful. By testing whether users, that are utilizing the tool, actually reach their goal, points of improvement can be identified and efficiency of the tool can be tracked.

Looking at the literature and the demands of Ben & Jerry's Hellendoorn, the following criteria can be summed up. The tool must:

- Improve communication (McLeod & Schell, 2001)
- Improve discussion focus (McLeod & Schell, 2001)
- Waste less time (McLeod & Schell, 2001; Ben & Jerry's demand)
- Improve efficiency of RCA decision outcomes (Todd & Benbasat, 1992)
- Improve effectiveness of RCA decision outcomes (Radermacher, 1994; Power & Sharda, 2007)
- Link data to each other (Rooney & Vanden Heuvel, 2004; Kumar & Schmitz, 2010; Kolodner, 2014; Ben & Jerry's demand)
- Find more problems and root causes (Ben & Jerry's demand)

To test the eventual tool on the before mentioned criteria, the Critical Incident Technique (CIT) will be used. This technique involves the study of significant instances of a specific activity as experienced or observed by a research participant (Radford, 2006). Originally build as a psychological method, CIT is nowadays often used to analyse or evaluate programs and services to what their influence is on a certain situation (Radford, 2006). CIT is highly applicable in information research when the individual user has the free choice whether to use the information service or not (Urquhart, Light, Thomas, Barker, Yeoman, Cooper & Armstrong, 2003). The advantages of CIT are that; 1) it supports a straightforward qualitative approach, 2) it offers well proven, clearly defined guidelines for data collection and analysis, 3) it focuses on real-life human experiences, 4) it enables the development of practical outcomes, and 5) it is relatively flexible (Lipu, Williamson & Loyd, 2007). Within CIT, the method interview is used to extract data from the participants (Flanagan, 1954). By using interview as a method, the actual meaning of the participant is extracted and not an interpretation of the interviewer, so serendipity is increased (Downs & Adrian, 2004). Serendipity refers to getting information that was not expected by the researcher. To increase the validity of the research method, it is important to ask questions that answer the themes (Devers, 1999). In this research, the before mentioned criteria shall be used as themes, and besides that, the standard for questions in CIT by Flanagan (1954) are used to get the optimal results. The questions by Flanagan (1954) focus on the description of the situation and the impact of the intervention on the participant.

To get a clear understanding of the CIT, it is important to understand what a critical incident is, because this will be the setting of the analysis. Flanagan (1954), the founder of the CIT, states that a critical incident is an event that has a significant contribution, either positively or negatively, to the goal of the activity. Further, the critical incident must be capable of being analysed or critiqued. In general a critical incident often refers to a major turning point, however this can differ in impact (Lipu et al. 2007). A critical incident with a major impact is, for example, the 9/11 terrorist attacks. An example with a smaller impact on human kind is, for example a divorce, which will majorly impact the lives of the affected family. So a critical incident does not need to be spectacular, it should hold significance. Consequently, it can be incidents that made a person stop and think, often revisit their assumptions, or impact their personal and professional learning. In the lights of organizations, it can refer to organizational disruptions or an incident arising from disagreement among stakeholders. Originally it was the idea that the critical incidents are based on recall of a person on an actual event, nonetheless, Wilson & Allen (1999) opts that cases can also be useful when the direct approach is less likely to reach the goal of the CIT, because of unwillingness to be truthful when referring to actual events.

CIT has a clearly defined, systematic sequential approach that, developed by Flanagan (1954), consists of five consecutive steps: 1) Establish the general aims, 2) Establish plans and specifications, 3) Collect data, 4) Analyze the data, and 5) Interpret and report the data. The first step refers to defining the relevant activity that will be studied and to *establish the aim*, which indicates the objective of the activity and the expected accomplishment. This also covers the formulation of the research question. Like the word *aim* implies, also the goal of the research has to be taken into account to come up with the right setting for the research. The second step, *establishing plans and specifications*, involves the development of a detailed and defensible plan for data collection. This includes the identification of critical incidents and critical behaviour. This step consists of four steps; 1) situation, the specification of the location, the participants, and what is available for usage to the participants. 2) Relevance, specification of the critical incidents and behaviour. 3) Extent, the criteria for data collection and incidents based on their significance. And lastly, 4) observers, ensuring that all data collectors are equally informed and are capable of similar actions. The third CIT step is, *collect data,* this refers to collection of the relevant data that is studied. Standardizing questions or themes is essential to guarantee consistent data from differing participants. The fourth step, *analysing the data,* involves a clear and single way of analysing the data. According to Gremler (2004) by framing the data into categories and sub-categories a clear overview can be achieved and maintained, this can be reached through coding. Finally, the last step, *interpret and report the data*, signifies the interpretation of the data in line with the intended application of the findings. For this step it is important to extensively describe the way the first four steps are conducted.

Translating the five CIT steps to the current research, results into the following setup:

**Step 1: Establishing the aim**

The core activity of the research is using the proposed GDSS, which embodies RCA, learning loops and CBR, to contribute to RCA. Theory on this subject and desires of Ben & Jerry's Hellendoorn result in the following aim: The aim of using the proposed GDSS for RCA is to improve communication, improve discussion focus, waste less time, improve efficiency and effectivity of RCA decision outcomes, being able to link data to each other, and to find more problems and root causes. So the aim is focusing on whether usage of the GDSS reaches the design propositions. The GDSS comprises the use of the proposed RCA- and CBR tool. By making use of these two tools, the participant automatically uses the database, since the database serves as a base for the detection tool.

**Step 2: Establishing plans and specifications**

The research takes place at the ice cream factory of Ben & Jerry's at Hellendoorn. As participants, the entire QA department will participate. For each separate case one participant will be subject to analysis. They are analysed on their usage of the new GDSS. Since the QA employees are all Dutch, the interviews will be held in Dutch. The critical incidents that are used are the events that happen during the four weeks of analysis that have a substantial influence on the QA department and where usage of the GDSS is demanded as critical behaviour. Besides these events, also one case is conducted to test an important situation to QA that would have an major impact on the factory. This specially conducted case is case 1. As to the significance of the operation it is assumed that the utilization of the GDSS will be significant since it gives scope to the problem and therefore prevents a lot of invested time. There will be only one interviewer to ensure a single way of observing and extraction of information.

The themes that will be answered are centred on the design criteria for the solution. So the themes that need to be answered are, what does the participant think about:

- Communication capabilities of the tool
- How does the tool influence discussion focus
- Time invested in the tool
- Efficiency of RCA decision outcomes with the tool
- Effectiveness of RCA decision outcomes
- Data linkage
- Capability to find problems and root causes

To come to answers to these themes, the questions are focused on what the motive to use the tool is, what the tool enabled, and how the tool influences RCA. This way the impact of the tool is identified. When the participant does not include one or more of the themes in his or her question, the participant gets a question on this theme.

**Step 3: Collecting the data**

Since the single interviewer knows the purpose of the study, a biased and ambiguous data collection is prevented. The goal of the data collection is to get an answer to the aim of the research. The interviewer will be present during the usage of the GDSS and the interview will take place after the usage. It is the task of the interviewer to guarantee that all the elements of the aim are covered.

**Step 4: Analysing the data**

By using the method of coding the interviews will be classified into categories and subcategories. Every time something important to the research is told, this gets a certain code, this analysis is called open coding (Baarda, De Goede & Teunissen, 2009). The codes are then classified into categories and subcategories, which is called axial coding (Baarda et al., 2009). This way all the data is grouped to the relevant element of the aim and the best conclusion can be formed. Out of the coding process follows a coding scheme, this scheme first is conducted for all separate individuals and then merged into one scheme. This way, conclusions can be made on both an individual and a collective level. The schemes will help find relations to better answer the research question. The process of coding is done in English, even though the interviews are in Dutch. After coding it is checked with the participants whether the classification is corresponding with their initial motives. Also the used citations are translated into English.

To guarantee a high reliability of the coding process *the framework approach* by Pope, Ziebland & Mays (2000) is employed. This framework shows an approach to analyze qualitative data. The first step is *Familiarization*; during this step an orientation is done on the data to get familiar with the data. During step 2, *Identifying a thematic framework*, relations between important concepts and themes are identified. Then during step 3, *Indexing*, the assumptions extracted during the first two steps are applied to the data. This way a trend within the data on certain concepts can be found. This is where coding takes place. Step 4, *Charting*, targets ad dividing the data into ranks, to count how many times a concept occurred. However, this step is to a lesser extent applicable to this research, since a limited amount of interviews are taken. The last step, *Mapping and interpretation*, refers to the interpretation of the data and thus the results of the before taken steps.

**Step 5: Interpreting and reporting**

The findings of this study will be presented as recommendations to the factory and as recommendations/contributions to theory. The findings of the study will offer a research-based conclusion on how to use the observed GDSS and what the advantages are. Also using and implementing the found results can prevent future issues prevented and user experience can be optimized (Johnson, 2012).

## 3.3 Participants

The participants that take part of the research are all part of the QA department. For case 1 the Quality Control manager was the participant. The Quality Control manager is responsible for all microbiological tests and deals with policies and regulatory on this matter. So when a RCA needs to be done towards microbiological problems, the Quality Control manager is in charge, this is why it is important to include the Quality Control manager in the research. Case 2 was centred on the QA manager. The QA manager holds responsibility for-, and manages the entire QA department. When a RCA needs to be conducted the QA manager has the final say in what will be done. Also, the QA manager decides on the norms for all the QA measurements and on how a RCA is done. And the QA manager identified the problem that formed the basis for this research. In case 3, a QA R&D

specialist was involved. The primary tasks of this specialist are to search for new problems and trying to solve them in experimental settings. An example of a research is to check the temperature across the entire manufacturing process and what the influence of this temperature is on the formation of ice crystals. Case 4, was centred on the QA employee that holds responsibility for RCA. This employee makes sure that RCAs are done and evaluates and stores them. He also does complaint analysis. When a complaint from the market comes in, he checks what happened to the product during manufacturing and how the complaint originated. This employee is utilizing the tool the most.

The selection of participants covers the entire QA department that at the time of doing research was working there. Furthermore, the selection covers both two employees that focus more around norms and regulations, and two employees that apply and use the quality measurements for their applied work.

### 3.4 Research scope

The scope of the research is based on the argumentation of the management of Ben & Jerry's Hellendoorn, which states that there, must be focused on the measurements already present at the factory. QA wants to see how these measurements can contribute to better Root Cause Analysis. In chapter 1 an elaboration is made on what these measurements and Root Cause Analysis are about and look like. Furthermore, the development should not greatly intensify the workload of the QA officers but rather relief the officers. Also the QA officers should be able to use the development and keep on using it long after the research has been concluded. Also the research has a couple of restrictions that should be taken into account. Financial investments cannot be done and possible programs or systems should be built in Microsoft® Office Excel® since this software is available and the development of new software will cost money and besides that, will take a lot of time. Additionally, the quality and safety standards of Ben & Jerry's and Unilever should be satisfied. Further, the current RCA method, why why analysis, should be maintained.

## 4. Product Design

This chapter now discusses how the solution to the problem can be designed; this will be based on the theory section and experience. The resulting conceptual model will hold some phases like, database and model creation that will be clarified in the subsequent subchapters. In these subchapters some tools and systems are discussed on how these phases are carried out.

## 4.1 Conceptual model

As a start, a simplified model is illustrated in figure 9. This model shows how data is used to come up with a problem-solving solution and how it will result into a sustainable solution. After that, an expanded model is proposed in figure 10, which shows the steps that are taken to come up to that sustainable solution. RCA will serve as the basis and then elements of CBR and organizational learning will be added together with some minor elements from the process analysis to make the model optimally diffusible in the process.

As a basis, the manufacturing process is running and the measurements are done. This measurement data is then scored across the corresponding norm. When this results into an abnormality differing from the norm, this abnormality will turn into a signal, which is stored into a database. Then RCA is done and a solution is formed to solve the problem, so SLL is applied. Often this already solves the problem. However, if SLL is applied and still the same problem keeps reoccurring, this could mean that the norm for the data is insufficient; the norm could be too strict or too lose. As an example, complaints are filed that pieces of metal are found in the ice cream. A SLL solution is applied so all the lose metal parts are more firmly attached. However, after implementation, it appears that still complaints come in on pieces of metal in the ice cream. This could mean that the norm for the metal detector is not strict enough, resulting in missing out of pieces of metal. So then the norm is adjusted so it measures metal at an even lower metal rate, which is DLL. Then this should solve reoccurrence of the problem. This is an ongoing process of implementing problem solving solutions, but when they do not work, it is checked whether the norm should be adjusted. Figure 9 shows this process model, the numbers are explained in the description of the expanded model.

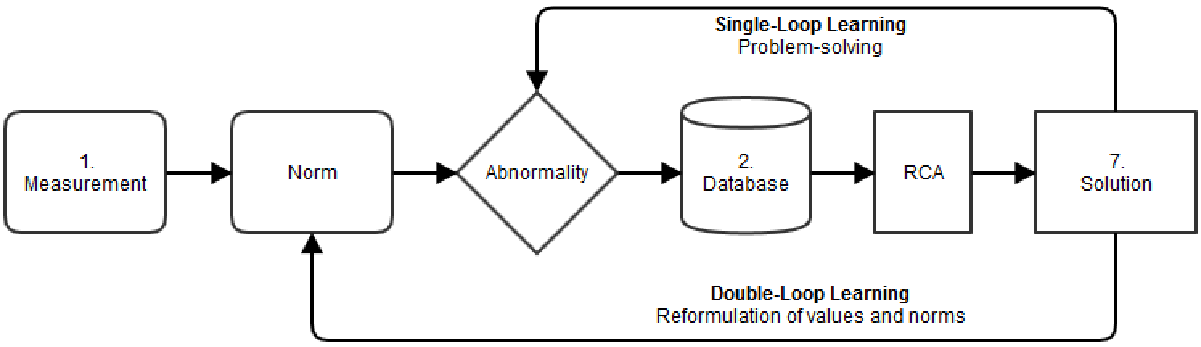



*Figure 9; Simplified conceptual model*

Now we take a look at how this simplified process is achieved by escalating it into an expanded model (figure 10). The core building blocks consist of the elements of the core task of the tool, being RCA. Like mentioned in the literature, the core of RCA comes down to: data collection, cause charting, RCA identification, and Recommendation generation and implementation. *(1)* The data is collected from the entire manufacturing process and so this process will be the starting point of the model. At this manufacturing process the quality measurements are executed and scored across a corresponding norm. After scoring across the norm, abnormalities are identified and stored into the database *(2)*. Parallel to this, a production employee informs QA about the abnormality *(3)*. QA then does a small contextual analysis and decides who the problem-owner is and who the stakeholders are. The problem-owner can be an employee from QA, production, or another relevant specialist from the factory. This is when the *(5)* detection tool is consulted, which gets the data from the database. This detection tool shows for a certain input whether abnormalities were detected in the measurements for that certain input. This is further elaborated in chapter 4.4. Next, the root cause analysis and identification *(6)*, is done through a five whys analysis, like was already employed at the factory. This RCA leads to a certain solution in the Recommendation generation and implementation *(7)*. Besides the detection tool, the month report *(4)*, is also consulted for the root cause analysis and identification, the month report is automatically calculated from the data in the database, more about this can be found in chapter 4.3.

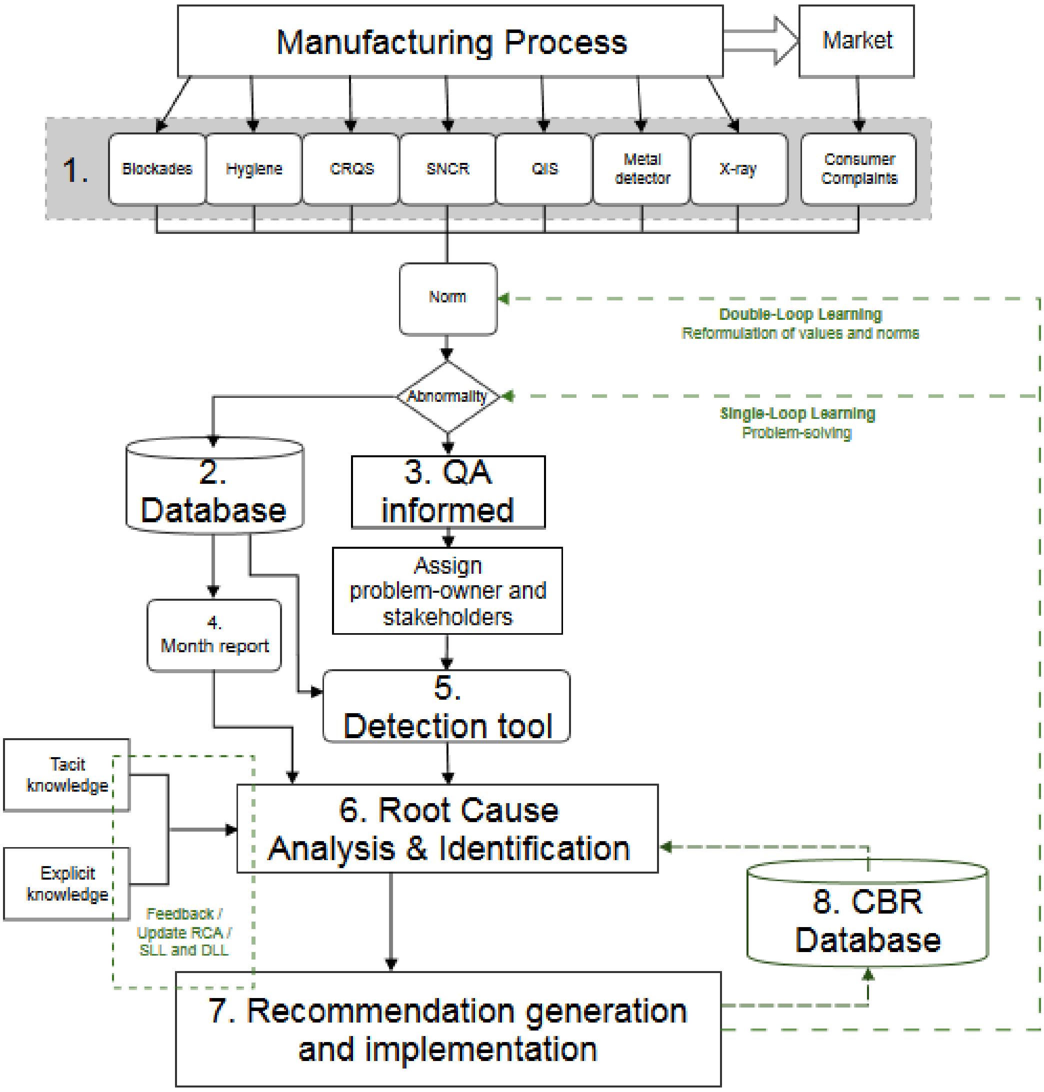



*Figure 10; Expanded conceptual model*

The formed solution is then stored as a case in the CBR database *(8)*, which is reused for future RCA. The reused cases, if necessary, are revised, retained, reviewed, and restored. This is necessary when the past solution did not reach the desired effect. It is important to emphasize that CBR is not merely focused on the storage of the proposed solution to the problem, but in the case of RCA it also stores the path towards the root causes.

Collateral to the storage of the solution is the implementation of the solution. This could be SLL or DLL. The SLL is directed straight at the problem to solve it; this could for example be that the camera of the right cup camera needs to be cleaned. In the model, the SLL points straight at the abnormality, but it is important to emphasize that the reason for the abnormality could have occurred during the measurements, manufacturing process, or even before that. So the solution will then be implemented there. This goes the same for the DLL. This is directed at the norm for the measurements, but the solution could also imply that the norm during the manufacturing process should be changed, for example that operators should wash their hands for four minutes instead of two.

What can also be found in this figure 10, are the tacit- and explicit knowledge that are used for the root cause identification. Tacit knowledge refers to the experience from the QA officer and if applicable the problem owner, which is the production operator that encountered a problem. If the problem occurred during the manufacturing process, the production operator is also consulted and involved in the RCA. When the problem comes from the market, a production operator is not involved. Explicit knowledge is the working methods and norms for RCA at Ben & Jerry's Hellendoorn. The tacit- and explicit knowledge is constantly updated. The green elements in figure 10 are the applied learning elements. On the left, the ongoing process of feedback and learning loops results in updated knowledge for RCA. This process is a vicious cycle that keeps on going as long as the RCA is employed, since every application of the RCA results in for instance higher experience, which can be seen as the start of tacit knowledge. That certain user then applies this intuitive tacit knowledge to the RCA. When this intuitive knowledge works, the knowledge needs to be interpreted, integrated, and eventually institutionalized to become explicit knowledge. By making the tacit knowledge of a certain user explicit, this knowledge can be shared and wielded by multiple RCA users. SLL also influences this process of RCA method development. A SLL for RCA is the case when the RCA fails and a single solution needs to be executed, for example that the data needs to be updated. DLL occurs when the norms for conducting the RCA fail and thus need to be adjusted. These learning loops also lead to the development of tacit- and, eventually, explicit knowledge. A user comes for example to the conclusion that the databases need to be updated, for future performances he then knows that in such a case the data needs to be updated. When this knowledge is institutionalized, it can become the standard when a certain problem occurs, that the data needs to be updated.

An example of the process: During the manufacturing process a cup goes through the right cup camera and the camera scans the code. This code is then tested to a norm and this identifies that the cup contains a code that differs from the code that should be on the production line. The cup is then rejected from the production line and the signal is stored. An operator then makes sure that the pallet containing surrounding cups of the rejected cups is blocked from distribution. That the pallet is blocked together with the signal is then stored in the database. After blocking the pallet, QA is informed about the incident by the operator from the production line. QA then does a small contextual analysis and assigns one or more problem owners. The problem owner and a QA officer then start with the RCA. The problem owner does five whys analysis to find out how it was possible that the cups got mixed up. The QA officer does relevant data analysis with the detection tool. This can be, that for the similar cups it is analysed whether often complaints are filed on, for example cups containing different ice cream from what the package says. Or analyse whether similar mix-ups occurred in the past and in what frequency. The data analysis is based on stored signals from the past, which are analysed through modelling and based on previous cases. The problem owner then reports the five why analysis to the QA officer and it is decided what the root causes are. Then action is taken on what to do. Sometimes the solution can be formulated within the factory, but it can also happen that the supplier of the cups mixed two flavours up. So then the problem is reported to the relevant supplier. The identified root causes and solutions are then stored in the CBR database.

## 4.2 Database or Data warehouse

To make the data from all the measurements readable and generalizable, an excel-based database is designed. This database, indicated with a 2 in the conceptual model, transforms the original strings of data into equivalent data. This way, measurements can be linked to each other. It is important to be able to link data together since measurements can also influence each other. This does not mean the measurement itself, but the element that is measured, for instance the temperature of the ice cream could influence the forming of bacteria's, which is analysed in Hygiene/microbiology. So then for the ice cream where bacteria's are found the linkage can be made to the temperature report and it can be identified whether the temperature was abnormal.

The database also takes away actions that the QA officers have to do. The database makes it possible to count and calculate numbers automatically which then do not have to be done manually anymore. The database facilitates a better findability of data and the possibility to conduct better data-analysis.

An entity relationship model serves as the basis for the database. According to Tahaghoghi & Williams (2009), an entity relationship model is a popular approach to conceptual design of a database. They divide a database into entities that can have relationships with other entities, and these entities can hold characteristics, which are referred to as attributes. A database is typically used to store attributes of the entities. For example, a customer is an entity and the email address, and phone number of the customer are attributes. The following model (figure 11) indicates the used entities, relationships, and attributes of the database. The entities are highlighted in grey, the attributes are summed up, and the relationship is indicated in the diamond. Tahaghoghi & Williams (2009) state that when an attribute consists of multiple attributes itself, it can be decided to make this main attribute, an entity. This is why the four lateral entities are described as such. So it is important to highlight that the Ice cream pot is the main entity that can hold measurements from the other four entities. An ice cream pot always contains microbiology measurements and the score can be positive or negative. Blockades, complaints and CRQS are only registered when an abnormality is filed; this is why the relationship with the Ice cream pot is 'possibly contains'. A description of all the attributes is found in appendix B. When an N is indicated, this means that the entity always refers to one of the other entity, so for example, a consumer complaint always refers to one ice cream pot. When an M is indicated this means that the entity can refer to multiple other entities, this means for example, one ice cream pot can have multiple complaints.

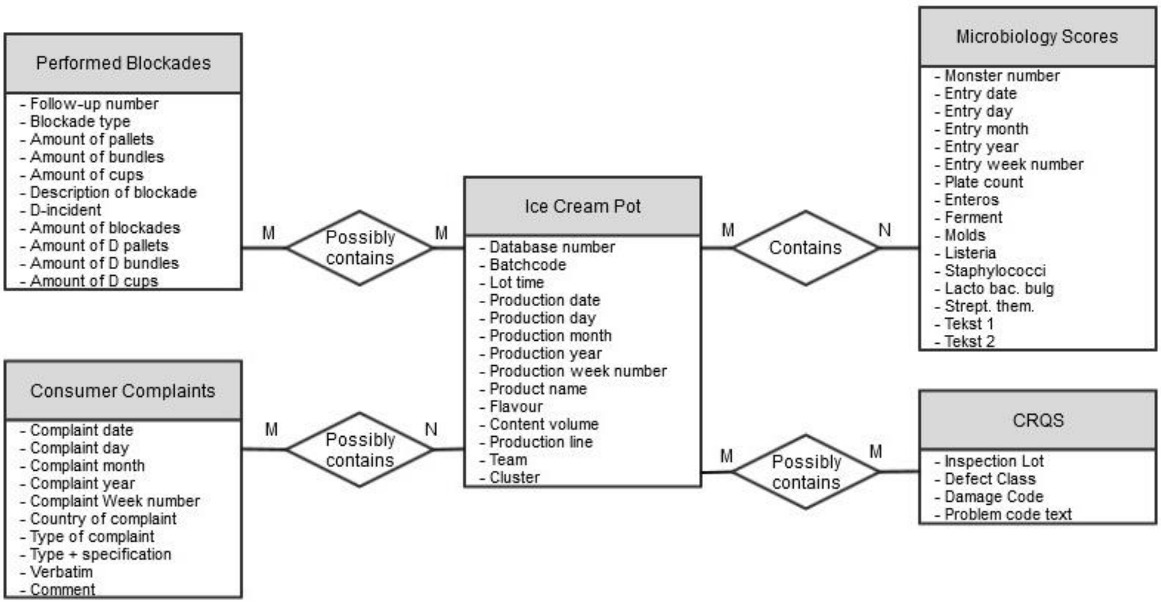


*Figure 11; Entity Relationship model for the database*

## 4.3 Month report

The month report can be found in the conceptual model at number 4. Since the before creation of the month report was done manually and needed a lot of work, it is decided to overhaul this report. By linking the report to the database it is made possible to automate the calculation of KPIs. With the old month report it occurred that filling was forgotten, not prioritized, or calculated in the wrong way. To prevent this from happening the new month report is standardized and filling is done automatically. The month report is transformed into a dashboard for QA where KPI's can be tracked. The layout was adjusted to the likings of the users and the dashboard literature.

The new month report gives a month-to-month overview to which extent targets are reached. Also the new month report holds more in-depth information. In the new month report information, quantitative data is shown on 1) Production- and sales numbers, 2) Market incidents, 3) Consumer Complaints, 4) Blockades, 5) Hygiene, 6) CRQS, and 7) Supplier judgment. Every component holds a separate page holding data and graphs to keep track of the KPIs. Also for every production line there is a separate report containing line specific data.

Figure 12 shows the main screen of the month report. All the numbers are completely fictional so no conclusions can be made on the numbers. The main screen holds the KPIs for every subject, red and green colours indicate the relation to the target. Light and neutral colours are used to minimize distraction. To maintain a clear overview the user can navigate to different subjects and drill-down by clicking the brownish buttons on the left, an example can be found in figure 13. On the upper left are the buttons to navigate towards the separate production line reports. At the column to the far right are the targets for the different subjects, besides consumer complaints. Consumer complaints track the difference to the previous year and the goal is to reach a lower CCpMU than the previous year. All the data that is seen is extracted automatically from the relevant databases. Besides this automation, the sheets are also protected from change and therefore correct calculations are guaranteed since no one can adjust anything. This way the user does not have to think about the calculations but can just focus on the actual scores. Also the month report is only accessible by the QA department and therefore protected from unauthorized access.

Like previously mentioned, figure 13 shows the drill-down information on a topic, in this case CRQS. Charts and tables give a more in-depth overview of the same data if applicable and useful. This way the mere necessary is presented and overload of information and therefore distraction is prevented. It differs per topic to what extent more detail of information is given. The user can adapt the graphs and figures by adjusting the month at the top. With the buttons, the user can then again easily navigate back to the other screens.

### 4.3.1 Production & Sales

The amount of production and sales are submitted to Ben & Jerry's by a global data centre of Unilever. Therefore, these numbers are still filled in manually.

### 4.3.2 Market incidents

Market incidents refer to incidents that could possibly lead to recalls. However, these market incidents almost never occur, therefore also this is filled in manually.

### 4.3.3 Consumer complaints calculation

The numbers for the consumer complaints refer to the total amount of complaints and CCpMU, which is the KPI for this consumer complaint. The amount of consumer complaints is divided into complaints on products fabricated in Hellendoorn and complaints that are filed in Europe. This is indicated separately since the factory at Hellendoorn also distributes to countries outside of Europe. CCpMU refers to consumer complaints per million sold units, which leads to the following calculation per month:

*Total amount of complaints / (total sales / 1.000.000) = CCpMU*

The total amount of complaints is calculated by adding all the filed complaints for that specific month, which is tracked by the attribute *'complaint date'* from the entity *'Consumer complaints'*.

### 4.3.4 Blockades calculation

The calculations that are done for the blockades are the same for every line, but filtered on that specific line. Further, the blockades consist of a bruto score and a netto score. However, the only score that is enforced is the blockade score for the factory overall. Per month the calculations go as followed, the variables are specified to a line when this is required:

*Total amount of cups blockaded / Amount of produced cups = Bruto blockades*

*Amount of D-incident cups / Amount of produced cups = Netto blockades*

The amount of cups blockaded refers to the total of the attribute '*amount of cups*' and for the D-incident '*amount of D cups'* both from the entity *'performed blockades'*. The month is tracked by the attribute *'production* date' from the entity *'Ice cream pot'*.

### 4.3.5. Hygiene in the factory calculation

Hygiene in the factory is focused on the score for enteros. The score shows the amount of monsters that where clean versus the amount of monsters that scored too high on enteros. The KPI for factory result and the Grade A indicators per line are calculated in the same way only specified. The Swabs contain of a different type of calculation. Both calculations are indicated below:

*Amount of monsters from endproducts with too much enteros / Amount of monsters with enteros conform the norm*
*= Factory result and Grade A*

*Amount of swabs with too much enteros / Amount of swabs with enteros conform the norm*
*= Swabs score*

Based on the attribute *'product name'* of the entity *'Ice cream pot'* it is extracted whether it concerns an endproduct or a swab. Further whether the enteros are too high or conform the norm is extracted from the score on the attribute *'Enteros'* from the entity *'blockades'*.

### 4.3.6 CRQS calculation

The calculations that are done for the CRQS are the same for every line, but filtered on that specific line. Further, the CRQS consist of a green score, an amber (yellow) score, and a red score. Per month the calculations go as followed, the variables are specified to a line when this is required:

*Total amount of defects / Amount of scored cups = % Green score*

*Amount yellow defects / Amount of scored cups = % Yellow score*

*Amount of red defects / Amount of scored cups = % Red score*

The total amount of defects is calculated by counting the amount of red and yellow scores on the attribute *'defect class'* of the entity *'CRQS'*. The amount of scored cups is the total amount of CRQS tests that are done. The yellow and red score is calculated by limiting the *'defect class'* to just yellow or red.

### 4.3.7 SNCR supplier judgment

This score is extracted from a different database since they do not refer to an ice cream pot, this database is however not included in this research. The supplier judgment is calculated by dividing the amount of filed complaints through the total amount of supplies.

Fabriek

Lijn 1 K | Lijn 2 L

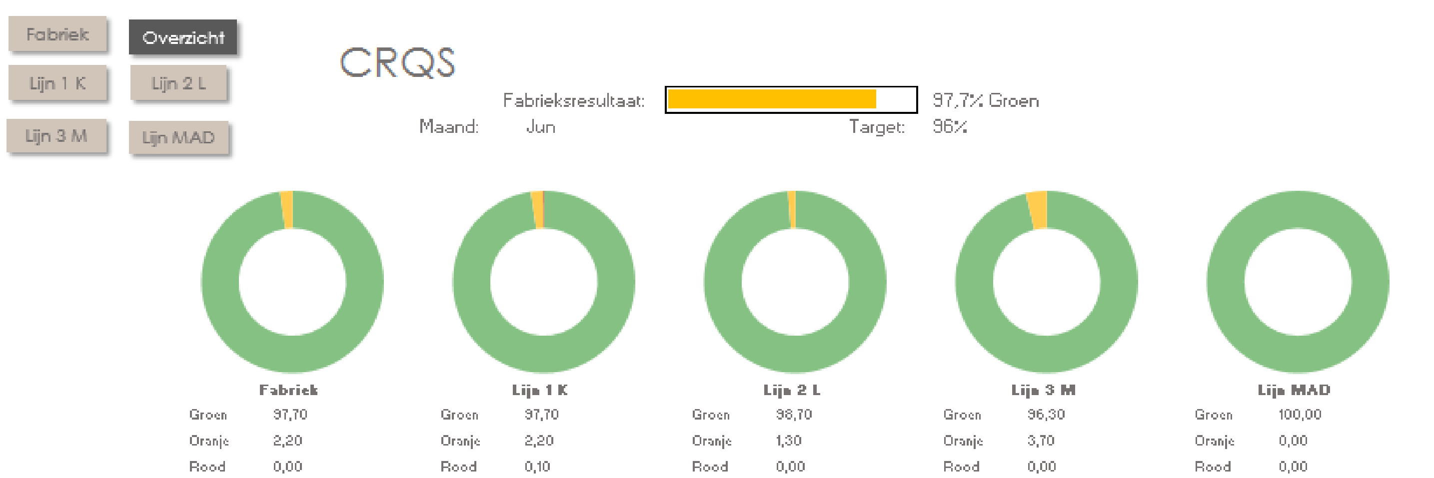
Lijn 3 M | Lijn MAD

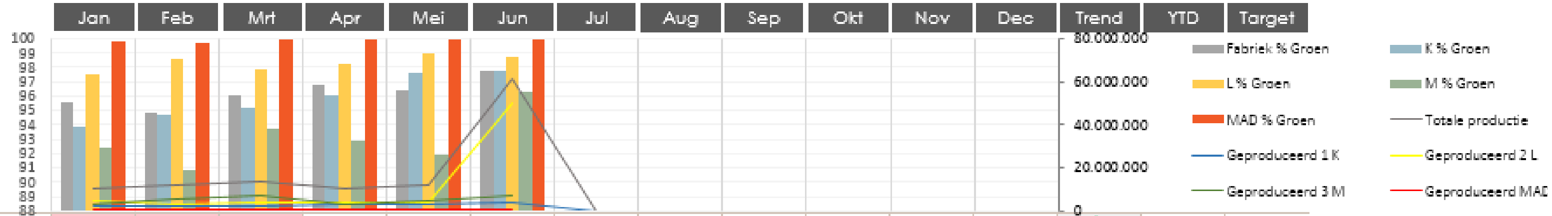
## Overzicht resultaten Kwaliteit B&J's Hellendoorn

Tips

| | Jan | Feb | Mrt | Apr | Mei | Jun | Jul | Aug | Sep | Okt | Nov | Dec | Trend | YTD | Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Productie & Verkoop** | | | | | | | | | | | | | | | |
| Productie cijfers | | | | | | | | | | | | | | | |
| Geproduceerd K 500 | 2.100.000 | 2.300.000 | 2.000.000 | 3.000.000 | 3.200.000 | 3.800.000 | | | | | | | | 2733333 | |
| Geproduceerd K 4500 | 40.000 | 28.000 | 35.000 | 23.000 | 37.000 | 51.000 | | | | | | | | 35667 | |
| Geproduceerd K Totaal | 2.140.000 | 2.328.000 | 2.035.000 | 3.023.000 | 3.237.000 | 3.851.000 | 0 | 0 | 0 | 0 | 0 | 0 | | 2769000 | |
| Geproduceerd L 500 | 4.500.000 | 3.100.000 | 4.000.000 | 3.500.000 | 3.800.000 | 49.800.000 | | | | | | | | 11450000 | |
| Geproduceerd M 100/150 | 3.200.000 | 5.800.000 | 6.900.000 | 2.800.000 | 4.800.000 | 6.900.000 | | | | | | | | 5066667 | |
| Geproduceerd MAD | 750.000 | 690.000 | 650.000 | 780.000 | 500.000 | 650.000 | | | | | | | | 670000 | |
| Totaal | 10.590.000 | 11.918.000 | 13.585.000 | 10.103.000 | 12.337.000 | 61.201.000 | 0 | 0 | 0 | 0 | 0 | 0 | | 19955667 | |
| Verkoop cijfers | | | | | | | | | | | | | | | |
| # CU 150ml | 2.000.000 | 2.100.000 | 3.300.000 | 3.300.000 | 2.900.000 | 3.500.000 | | | | | | | | 2850000 | |
| # CU 500ml | 4.000.000 | 5.300.000 | 6.900.000 | 6.500.000 | 6.700.000 | 75.000.000 | | | | | | | | 17400000 | |
| # CU 4500ml | 40.000 | 31.000 | 28.000 | 50.000 | 48.000 | 64.000 | | | | | | | | 43500 | |
| Totaal | 6.040.000 | 7.431.000 | 10.228.000 | 9.850.000 | 9.648.000 | 78.564.000 | 0 | 0 | 0 | 0 | 0 | 0 | | 20293500 | |
| **Markt incidenten** | | | | | | | | | | | | | | | |
| Aantal incidenten | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | 0 | |
| **Consumenten klachten** | | | | | | | | | | | | | | | |
| Totale aantallen | | | | | | | | | | | | | | | |
| Totaal absoluut aantal H'drn | 316 | 306 | 447 | 438 | 446 | 411 | | | | | | | | 394 | |
| Totaal absoluut aantal B&J EU | 316 | 306 | 447 | 438 | 446 | 411 | | | | | | | | 394 | |
| CCpMU EU 2015 | 53 | 51 | 60 | 43 | 45 | 41 | | | | | | | | 49 | |
| CCpMU EU 2014 | 51 | 75 | 71 | 45 | 32 | 35 | 26 | 38 | 60 | 50 | 40 | 32 | | 46 | |
| **NRFT (Blokkades)** | | | | | | | | | | | | | | | |
| Fabriek Netto blokkades | 1,24% | 0,48% | 0,23% | 0,30% | 0,35% | 0,01% | | | | | | | | 0,44% | 0,72% |
| Lijn 1K Bruto blokkades | 0,37% | 0,19% | 1,56% | 0,37% | 0,54% | 4,87% | | | | | | | | 1,32% | |
| Lijn 1K Netto blokkades | 0,33% | 0,19% | 0,78% | 0,11% | 0,13% | 0,07% | | | | | | | | 0,27% | |
| Lijn 1K 500 Bruto blokkades | 0,22% | 0,10% | 1,49% | 0,26% | 0,43% | 4,94% | | | | | | | | 1,24% | |
| Lijn 1K 500 Netto blokkades | 0,22% | 0,00% | 0,70% | 0,00% | 0,10% | 0,07% | | | | | | | | 0,27% | |
| Lijn 1K 4500 Bruto blokkades | 8,32% | 15,93% | 5,31% | 12,70% | 10,18% | 0,00% | | | | | | | | 10,49% | |
| Lijn 1K 4500 Netto blokkades | 5,72% | 15,93% | 5,31% | 18,50% | 3,39% | 0,00% | | | | | | | | 9,77% | |
| Lijn 2L Bruto blokkades | 13,72% | 8,91% | 14,12% | 13,38% | 8,84% | 0,00% | | | | | | | | 11,79% | |
| Lijn 2L Netto blokkades | 0,07% | 0,00% | 0,00% | 0,04% | 0,19% | 0,00% | | | | | | | | 0,10% | |
| Lijn 3M Bruto blokkades | 3,97% | 3,25% | 1,03% | 0,83% | 1,44% | 8,05% | | | | | | | | 3,10% | |
| Lijn 3M Netto blokkades | 3,77% | 0,80% | 0,23% | 0,12% | 0,65% | 0,06% | | | | | | | | 0,94% | |
| Lijn MAD Bruto blokkades | 0,00% | 0,94% | 0,41% | 8,54% | 2,39% | 0,00% | | | | | | | | 3,07% | |
| Lijn MAD Netto blokkades | 0,00% | 0,94% | 0,00% | 2,88% | 0,00% | 0,00% | | | | | | | | 1,91% | |
| **Hygiene in de fabriek (Grade A < 10 entero's** | | | | | | | | | | | | | | | |
| Fabrieks resultaat | 99,23 | 99,80 | 99,20 | 95,70 | 97,80 | 95,40 | | | | | | | | 97,85 | 99 |
| Swabs kritische plekken (% positi | 0 | 0 | 3,6 | 0 | 6,25 | 7,69 | | | | | | | | 2,92 | |
| Grade A K 4500ml | 100,00 | 100,00 | 100,00 | 100,00 | 98,80 | 100,00 | | | | | | | | 99,80 | 99 |
| Grade A K/L 500ml | 97,80 | 98,74 | 99,80 | 99,60 | 97,20 | 92,30 | | | | | | | | 97,57 | 99 |
| Grade A M 150ml | 99,80 | 96,80 | 99,75 | 95,46 | 92,98 | 99,60 | | | | | | | | 97,40 | 99 |
| Grade A MAD | 100,00 | 100,00 | 100,00 | 99,60 | 99,20 | 99,35 | | | | | | | | 99,69 | 99 |
| **CRQS** | | | | | | | | | | | | | | | |
| Fabriek % Groen | 95,6 | 94,8 | 96 | 96,8 | 96,4 | 97,7 | | | | | | | | 96,16 | 96 |
| Fabriek % Amber | 4,1 | 4,9 | 3,8 | 3,2 | 3,6 | 2,2 | | | | | | | | | |
| Fabriek % Rood | 0,2 | 0,3 | 0,3 | 0,1 | 0 | 0 | | | | | | | | | |
| K % Groen | 93,9 | 94,7 | 95,2 | 96 | 97,6 | 97,7 | | | | | | | | 96,15 | 99 |
| K % Amber | 5,2 | 4,8 | 4,4 | 3,9 | 2,3 | 2,2 | | | | | | | | | |
| K % Rood | 0,9 | 0,5 | 0,5 | 0,1 | 0,1 | 0,1 | | | | | | | | | |
| L % Groen | 97,5 | 98,6 | 97,9 | 98,3 | 99 | 98,7 | | | | | | | | 98,57 | 96 |
| L % Amber | 2,5 | 1,4 | 1,9 | 1,7 | 1 | 1,3 | | | | | | | | | |
| L % Rood | 0,1 | 0 | 0,2 | 0 | 0 | 0 | | | | | | | | | |
| M % Groen | 92,4 | 90,8 | 93,7 | 92,9 | 91,9 | 96,3 | | | | | | | | 92,43 | 93 |
| M % Amber | 7,4 | 8,8 | 6 | 7 | 8,1 | 3,7 | | | | | | | | | |
| M % Rood | 0,1 | 0,5 | 0,3 | 0,1 | 0 | 0 | | | | | | | | | |
| MAD % Groen | 99,8 | 99,7 | 100 | 100 | 100 | 100 | | | | | | | | 99,92 | 99 |
| MAD % Amber | 0,2 | 0,3 | 0 | 0 | 0 | 0 | | | | | | | | | |
| MAD % Rood | 0 | 0,1 | 0 | 0 | 0 | 0 | | | | | | | | | |
| **Leveranciers beoordeling** | | | | | | | | | | | | | | | |
| Beoordeling | 98,3 | 97,9 | 96,5 | 85,6 | 92,6 | 95,3 | | | | | | | | | |

*Figure 12; Month report*




| | Jan | Feb | Mrt | Apr | Mei | Jun | Jul | Aug | Sep | Okt | Nov | Dec | Trend | YTD | Target |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabriek % Groen | 95,6 | 94,8 | 96 | 96,8 | 96,4 | 97,7 | | | | | | | | 96,16 | 96 |
| Fabriek % Oranje | 4,1 | 4,9 | 3,8 | 3,2 | 3,6 | 2,2 | | | | | | | | 0,00 | |
| Fabriek % Rood | 0,2 | 0,3 | 0,3 | 0,1 | 0 | 0 | | | | | | | | 0,00 | |
| K % Groen | 93,9 | 94,7 | 95,2 | 96 | 97,6 | 97,7 | | | | | | | | 96,15 | 99 |
| K % Oranje | 5,2 | 4,8 | 4,4 | 3,9 | 2,3 | 2,2 | | | | | | | | 0,00 | |
| K % Rood | 0,9 | 0,5 | 0,5 | 0,1 | 0,1 | 0,1 | | | | | | | | 0,00 | |
| L % Groen | 97,5 | 98,6 | 97,9 | 98,3 | 99 | 98,7 | | | | | | | | 98,57 | 96 |
| L % Oranje | 2,5 | 1,4 | 1,9 | 1,7 | 1 | 1,3 | | | | | | | | 0,00 | |
| L % Rood | 0,1 | 0 | 0,2 | 0 | 0 | 0 | | | | | | | | 0,00 | |
| M % Groen | 92,4 | 90,6 | 93,7 | 92,9 | 91,9 | 96,3 | | | | | | | | 92,43 | 93 |
| M % Oranje | 7,4 | 8,8 | 6 | 7 | 8,1 | 3,7 | | | | | | | | 0,00 | |
| M % Rood | 0,1 | 0,5 | 0,3 | 0,1 | 0 | 0 | | | | | | | | 0,00 | |
| MAD % Groen | 99,8 | 99,7 | 100 | 100 | 100 | 100 | | | | | | | | 99,92 | 99 |
| MAD % Oranje | 0,2 | 0,3 | 0 | 0 | 0 | 0 | | | | | | | | 0,00 | |
| MAD % Rood | 0 | 0,1 | 0 | 0 | 0 | 0 | | | | | | | | 0,00 | |

*Figure 13; Expanded CRQS page of Month report*

## 4.4 Detection tool

In the expanded conceptual model, the detection tool is indicated with number 5. The RCA method, that will serve as a basis at the factory, is the five whys analysis. By using the five whys it is strived to find the root cause(s). To complement this process and guide it in a certain way, a detection tool is developed. This detection tool shows for a certain input whether abnormalities occurred in the manufacturing process by consulting the measurements, thus in the new situation the database. Besides detecting whether abnormalities occurred, the detection tool can also serve as a starting point for new to be started RCAs, because when certain trends are found, it gives reason to start a RCA to find out where this correlation comes from and how it can reduce problems. So the detection tool will not be the RCA itself but serve as a contributing tool resulting in better RCA.

An impression of the detection tool is found in figure 14. The tool has been designed entirely to the likings of the QA manager and the user interface and dashboard guidelines found in the literature, and is further developed by the main author of this research. The figure shows the first navigational page of the tool. Here the user can choose what kind of analysis he or she wants to perform. The analysis can be done on the attributes of the ‘ice cream pot’ entity. The flavour analysis is to compare abnormalities between different flavours, which compose all the type of products that are manufactured. The batchcode is then a specific code for a certain pot production, so this way the user can search as specific as is possible with the available data. Then there are three analyses that can be done on time span. To further drill-down the information extracted from these analyses, the user can utilize the advanced analysis, where the user can freely experiment with the data. Lastly, there are two ‘total’ analyses, here the user finds a list with all the batchcodes and flavours and the corresponding registered measurements. This enables easy sorting of data and identification of batchcodes or flavours where the amount of abnormalities is highest.

The main page is straight to the point so the user is not immediately distracted by irrelevant information. He or she can choose the topic and then start the analysis. Colours are used to indicate the different topics and these colours are coming back throughout the use of the detection tool to always have a clear indication what topic is addressed. Figure 15, shows one of the pages that contain a specific report with fictional data. The reports can then be shared with others through the email button, where the conducted report can be send, or in a different way to the likings of the user. Also the report can be printed with the print button. Since the tool is accessible to others, multiple users can experiment with the data and try several things, this way several users can come to the best possible conclusion. Also the user has the possibility to save, print or directly email the report to other users.

The tool keeps distractions to a minimum by categorizing the different topics per page. Everything is automated and therefore the usage is worriless. The analysis is straightforward and the user can actually see what happens with the input. Then when the user wants to experiment with the tables, drill-down, and 'go advanced', the user can navigate to the advanced page (figure 16) and there the user can select which table or tables must be added by simply clicking where the table must be placed and then clicking the wanted table button on the left. The advanced page is like a blank page that can be painted entirely to the likings of the user. After that the user can add graphs and figures accordingly. Further, in the entire tool the user can always intervene when something needs to be cancelled and everything can be adjusted, subsequently, the system indicates when a certain input did not show any results by greying out the area. Lastly, the user can always find help in the help area. At the help area the user is step-by-step guided towards achieving the goal of the detection tool. Looking at the report in figure 15, the division of topics or tables and figures is divided equally to prevent unintentional highlighting and prioritizing of information.

From the different reports, the user can also navigate to the month report and the RCA database, which in this research is referred to as CBR tool. The CBR tool is elaborated in 4.5. It is important to acknowledge that the tool serves as a detection tool and an entire RCA cannot be based solely on the tool, further investigation is needed. Like mentioned before, the tool serves as a detection tool where focus areas for RCA, and problems that will lead to RCA are identified. Again, also the detection tool is protected from unauthorized access and the system is also protected so adjustment of the systems is close to impossible. The users of the tool also get a short training on how to use the tool so a stable system that has added value is guaranteed.

The advanced report in figure 16, needs some explaining. One situation is elaborated to explain the functions of the advanced analysis. Two tables are illustrated; one shows the complaints that are filtered on 4batch 5029, complaint type quantity, and flavour Greek Blueberry shortcake. The table shows that several complaints have been filed of which six, indicated with the crosses, are on missing of a cookie swirl. The table below shows the blockades that have been applied during manufacturing. The blockades have also been filtered on 4batch 5029 and flavour Greek Blueberry shortcake. It shows that the product has been blockaded because of possible insufficient graham sauce, graham sauce to the consumer is known as cookie swirl. This means that during production the product has been blocked because of insufficient cookie swirl and has been tested and rechecked accordingly. After rechecking, the product has been given free for distribution. But now still complaints are filed that a cookie swirl is missing in the product. This could mean that the recheck has not been done properly or that the norm for rechecking on a missing component is inadequate.

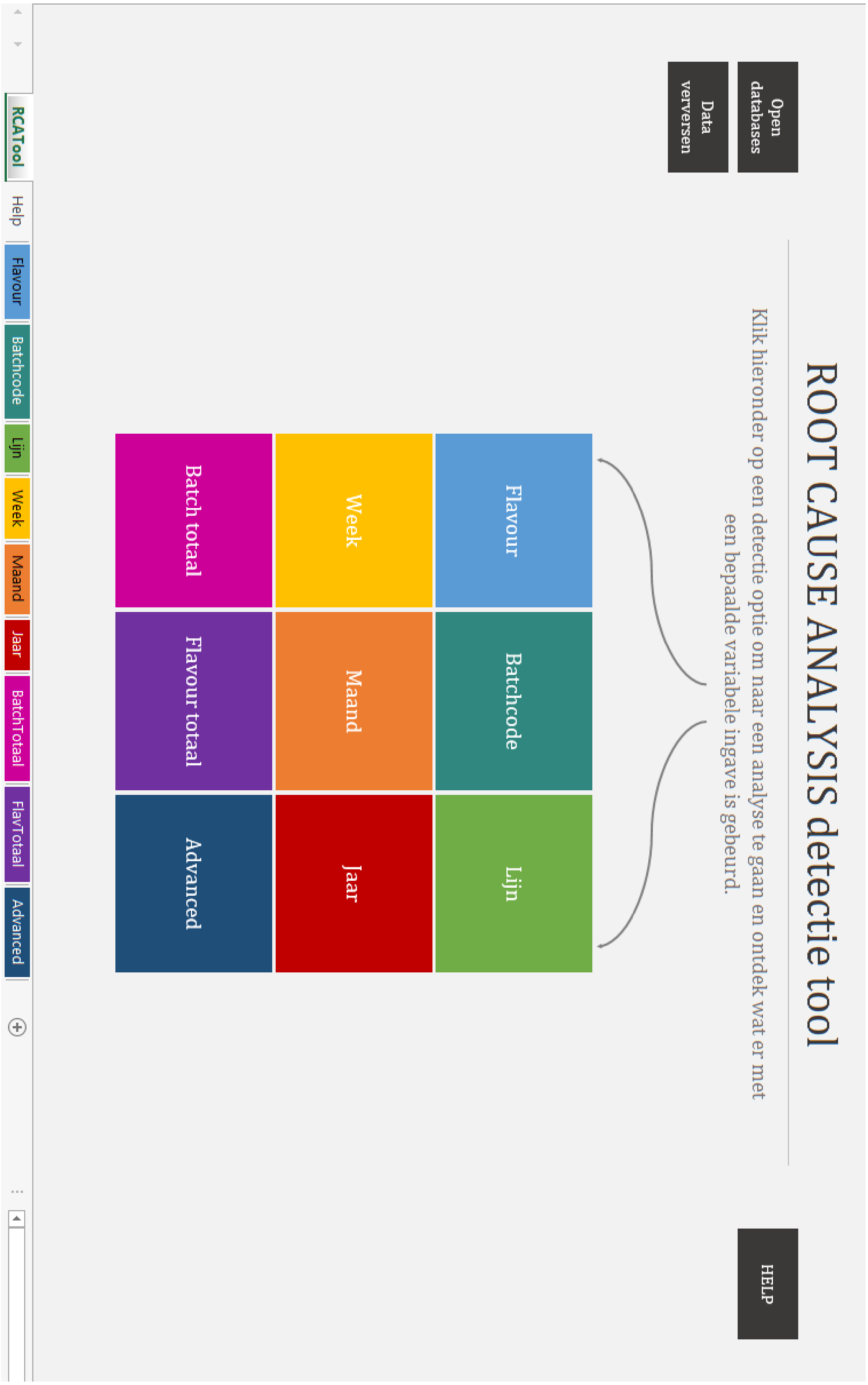



*Figure 14; Main page Detection Tool*


*Figure 15; Month of production analysis applied to march 2015*

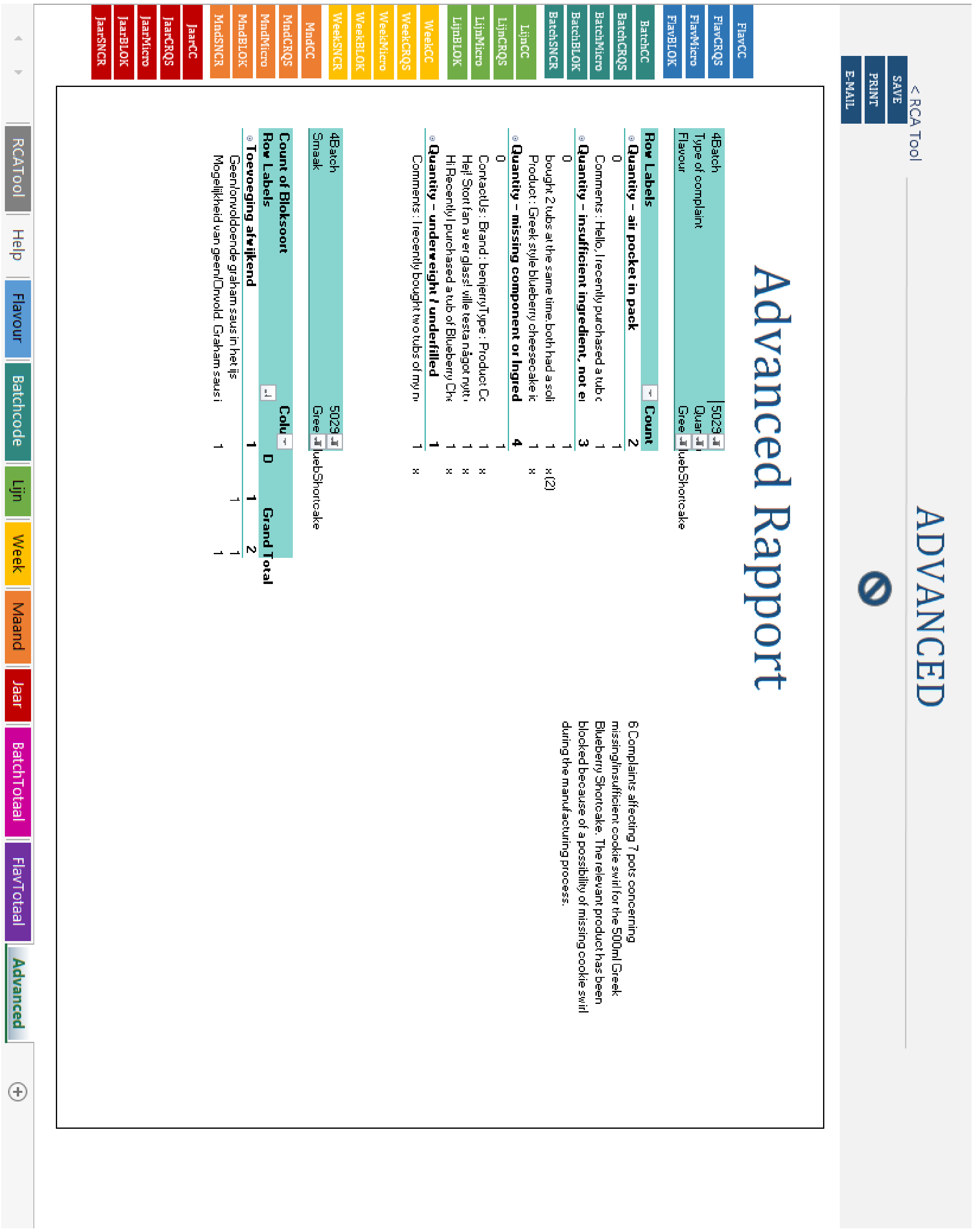



*Figure 16; Advanced page of detection Tool without input*

## 4.5 CBR tool

The CBR tool, indicated in the model with number 8, is based around the storage of cases. By storing the cases it gives possibilities to not only analyse the measurements from the factory, but also analyse solutions to problems. The cases are in this situation the way towards the root causes and the suggested solution. So then when new similar problems arise, the problem owner can check old similar cases and when the solution gave the desired results, it can be applied again, or it can be adjusted so the solution does reach the required result. Also the CBR database opens the possibility to keep track of the implemented solutions and check whether it cured the problem. This way you store the knowledge attained from previous RCAs and can use this knowledge for future RCAs. Through storage the knowledge is then not only available to the person that performed the genuine RCA, but also to others.

The CBR storage works as followed, data from the performed RCA is stored in an excel file as so called cases. Every RCA is a separate case. This file contains information on the examined problem, the process towards finding the root cause, the solution, and the taken action. Besides this stored information from the RCA it gets an extra element, which contains information on whether the action reached the actual intended effect. By adding the achievement of the intended effect, an user can reason whether to adjust the root cause or the solution, or not. By continuously improving these cases, optimal solutions can be formulated which also often can be implemented directly, so effort in time is reduced. Also the cases enable tracking of results so faults or holes in procedures etcetera are revealed. Furthermore, the CBR tool enables tracking of trends in RCA, problems and solutions. By standardizing these elements the data can render trends in the RCA. For example, do certain problems often reoccur, does a certain action that solves its targeted problem, always introduces a different kind of problem. So in terms of literature, it is strived to enable learning from RCA by implementing CBR. What the CBR tool looks like can be found in figures 17, 18, 19, 20. The line is cut into two because otherwise the text would be unreadable. The tool is straight to the point and contains only the mere necessary information. Since the tool and its data is constantly under development, because CBR is about developing past cases to serve new cases, it is chosen to construct the tool straight to the point and only with the mere necessary information. This way the information is more easily adjustable and understandable to the user. To prevent all the users from adjusting existing cases, there is one 'super-user' that can adjust the existing cases; others can only add new cases. If an existing case needs to be changed, the initiator needs to contact the super-user on how and why to change the existing case.

The CBR tool is divided into two windows. One window contains RCA based on the blockages that where applied at the factory (figures 17 and 18) and the other window contains cases based on important outputs of the detection tool mentioned in 5.5 (figures 19 and 20 ). The detection tool cases also have a link towards the saved outputted reports. As can be seen in figures 17, 18, 19, 20, the CBR tool is constructed as a database. The data in the figures is fictional. The actual CBR tool contains a multitude of cases.

| RCA_databaseNR | 4Batch | Date | Followup number | Problem | Problemdescription | Flavour | Problem-owner | RCA | Production-Line |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4151 | 1-5-2014 | 3856 | Missing component | Missing/insufficient graham saus in the product | Greek BlueBerry Shortcake | John Doe | The sausdispensor experienced failure because an employee pushed the wrong button. It was a temporary worker from the employment agency. The training from the employment agency appeared to be insufficient. | K |
| 2 | 4243 | 1-8-2014 | 3857 | Foreign matter | Hair in ice | Chocolate Chip Cookie Dough | John Doe | Peete wore a broken hairnet. The hairnets are tested and appeared to break easily. | L |

*Figure 17; RCA based on blockades part 1*

| Locatie | Occurence | Proposed solution | Solution Code | Action | Expected result | When is a result expected? | When should the problem completely | Solution implemented | Result reached |
|---|---|---|---|---|---|---|---|---|---|
| Fruitfeeder | Malfunction | Adjust training from employment agency | Adjust training | Training is going to be adjusted in association with an employee from B&J | Better educated temporary workers to prevent future reoccurence. | 1-2-2015 | 1-3-2015 | Yes | Yes |
| Clothing | Damage | Purchase new hairnets | Purchase new clothing | QA manager is going to search for new hairnets that satisfy stricter regulations durability. | No more hair in ice cream caused by damaged hairnets | 1-10-2014 | 1-11-2014 | No | No |

*Figure 18; RCA based on blockades part 2*

| DatabaseRCA_NR | 4Batch | Date | Analysis | Flavour | Production line | Problem | Problem area | Problem subarea | Led to | Led to subarea |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4151 | 1-5-2014 | Advanced | Greek Blueberry shortcake | K | Graham saus | Blockades | Missing component | Complaints | Quantity - Missing component or ingredient |
| 2 | 4243 | 1-8-2014 | Batch | Fairly Nuts | L | Ice texture | Temperature | | Complaints | Texture - Ice crystals |

*Figure 19; RCA based on detection Tool part 1*

| Problem description | Problem owner | Solution | Action | Expected result | When is a result expected? | When should the problem completely | Solution implemented? | Result reached |
|---|---|---|---|---|---|---|---|---|
| During manufacturing, the product has been blocked because not enough graham saus in the product. The product has been subject to the relevant procedure, but still relatively a lot of relevant complaints are filed. | John Doe | Monitor situation and adjust the procedure for blockades with insufficient graham saus. | QA officier revises the procedure. | No reoccurence of the problem | 1-2-2015 | 1-8-2015 | Yes | Yes |
| During manufacturing, the product has temperature measurements within the norm. But still a lot of complaints come in on temperature related complaings. Also the complaints come from multiple varying locations. | John Doe | Revise the temperature norm | Send to R&D | For this product no more relevant complaitns. | 1-4-2015 | 1-7-2015 | Yes | No |

*Figure 2019; ; RCA based on detection Tool part 2*

# 5. Results

First the results for the separate cases are discussed. Next, a look is taken at what the tool overall achieved, so how did the tool satisfy the tool criteria. The outcomes of the interviews serves as a basis for these results. The tool that is used for analysis is the detection tool in combination with the CBR database. It is tested what the impact is of the tool on the identification of problems and root causes, subsequently the criteria for the tool are tested. The before mentioned criteria are important so the best RCA solution can be generated and implemented. It is tracked whether the tool improves RCA by consulting whether the tool enabled higher RCA efficiency and effectiveness. Besides this, literature states that a GDSS should improve communication and discussion focus (McLeod & Schell, 2001). This way problem-owners and stakeholders can better discuss the problem. Further, Ben & Jerry's Hellendoorn demanded that the tool must link data to each other, increase efficiency, and should result into more identified problems and causes.

## 5.1 What did the tool enable in the cases

Case 1, is a fictional case to test how the tool would hold during a microbiological problem, and how QA can use those results to start doing a RCA and prepare for a recall of the product. The question was to what extent the tool can help in such a case and how it would withstand. The case stated that complaints came in that customers had gotten sick after eating a product manufactured at Ben & Jerry's Hellendoorn. Of course in such a case it is uncertain whether this happened due to the product, but it is simply too dangerous to do nothing.

The participant wanted to check whether there were abnormalities during the manufacturing process for the targeted range of products. He found some microbiological and blockade indications. The product was tested positive on a microbiological test, and the product was then blocked from continuance. By resampling, the product was retested and then tested negative and therefore was given free. However, still complaints on illness came through which could be caused by these bacteria's that were tested on. A little remark, the word "could" should be highlighted since a causal correlation cannot be identified in this case, since the consumer could have gotten sick because of something else. Nevertheless, the participant now had an indication to recheck the retention sample for that certain product and then start an RCA. In the interview the participant stated that the tool enabled a great overview of what happened to the product at all different levels. By filtering and linking data to each other, the participant could easily see what happened and by detecting the abnormalities, the participant now had a better focus for starting the RCA. As suggested by the participant, the tool enabled a great increase in efficiency, since before, the data had to be extracted from different systems and then be linked by hand, which was a job that was simply too much and therefore was often skipped: *"In the past all the data was lose and we had to search separately. But now we are able to combine the data…" (participant 1).* Since the tool is easy to use and clearly organized, the participant was also able to get this data himself. The participant expects that by getting more familiar with the tool and with the different results and therefore building experience, the tool can become even more powerful.

The participant now has focus to start a RCA. Like suggested, the tool is complementary to RCA. An RCA can be conducted with more knowledge on what happened and therefore a better overview can be made to see where to focus the RCA on. The tool gives insights in multiple datasets and therefore also the datasets that are not expected at first but could also be important. In a case like this, normally the employee focuses on the microbiological results, but other results could also be important, in this case the blockades report. When all the results from the tool are in, the user can start the RCA. Besides the quantitative data from the measurements, the participant now gets more information from the desired actors. The participant states that building on practical experience and guidelines, he wants to look at qualitative data as well to come to the best RCA and therefore solution. The tool gave the participant focus on what to focus the discussion on and it enabled the participant to communicate the results from the tool in a complete way. So not only, reason why something is as it is, but also back it up with figures that are easy to read.

Case 2, was centred on a problem where a certain component was missing in the ice cream tub. By using the tool it was analysed whether there where similar complaints from the market and what happened during the manufacturing process for products where such complaints occurred.

Using the tool, the user was able to get a visualization of the abnormalities during the manufacturing process. A lot of complaints came in about a missing component for the same code. After consulting the tool it appeared that all the missing component complaints were about lack of cookie swirl in one specific flavour of ice cream. It appeared that this was already detected during manufacturing and that the product was blocked from distribution. However, after testing the product, the blockade was then released again for the market. But now the results from the market show that this abnormality was still detected by the consumer. The user then highlighted: *"… if we score that the product is good, does the consumer also think that the product is good enough?" (participant 2).* The participant then described that by utilizing the tool, a basis for continuous improvement exists: *"… by linking for example blockages to complaints, and we find a lot of complaints, we maybe should revise our* *blockade policy. If we get this right we are at the start of continuous improvement and that is absolutely beautiful!" (participant 2).* Also by getting a clearer overview of the situation during the manufacturing process the RCA, according to the participant, can have better focus. For example in this case, normally the RCA would focus on why was the cookie swirl absent for this product, and the outcome would be that a fruitfeeder was broken. However, with the tool, it is shown that this was already detected during the manufacturing process, and so yes that fruitfeeder should not have been broken, but it was already detected and therefore the product should never have been given free if the cookie swirl was missing. So, the RCA should focus on how it had happened that an insufficient product was still given free. Because otherwise the factory could just as well throw all the products away when it is blockaded if the blockade policy is sufficient and still products containing flaws are distributed.

The participant also emphasized that by storing the results of the detection tool, trends should be discovered and therefore the importance and the magnitude of the problem is shown. If for example it occurred multiple times before that one or multiple product(s) had been blockaded and still relevant complaints come in, it says more about the blockade policy. Further, the tool enables better communication about such problems. The participant indicates that production employees often are laconic about blockages and retesting of products, and by simply communicating that it is important this is not powerful enough. But as the participant indicates: *"… plus, what this tool beautifully does, you are able to really clearly communicate to the production site that everything we do really has an impact. You can invigorate the statement with actual data and figures." (participant 2)*. Adding to this, the user states that you can actually make clear to the production employees, that evaluating the product is important and that it does not give unnecessary work load. If the evaluation is not done right, it really does give consumer complaints. The tool makes it able to better underpin statements.

Case 3, occurred when a lot of texture complaints came in. The QA employee wanted to check in the tool how much texture complaints are assigned to certain days of production and what the trend in these complaints are. Alongside this search, since texture problems are often the result of temperature abuse, the employee also wanted to check whether temperature abnormalities were registered during the manufacturing process for the corresponding products. If applicable, the employee was willing to start a RCA.

By checking the tool the participant was able to clarify the abnormalities during the manufacturing process for products with texture complaints and for products that have been on a temperature blockade. A temperature blockade occurs when a product does not have the right temperature, but it is still acceptable. The product is then stored in the cold store for two extra days. The analysis showed that usually when a lot of texture complaints are filed, those products have not been blockaded during the manufacturing process. In this case it is hard to ascribe the texture complaints to the manufacturing process, since temperature abuse can also occur at the market or at home, but still as a company Ben & Jerry's wants to minimize the chance that the temperature abuse happened at the factory. The results from the test show that no temperature abnormalities were detected during the manufacturing process for those products. However, according to the participant, this does not mean that the temperature abuse did not happen at the factory: *"At this moment, the focus is on testing the temperature when the products gets out of the freezing tunnel. Maybe it is important to put the focus somewhere else. So what happens during the manufacturing process and what happens to the product after it gets out of the freezing tunnel" (participant 3).* The ease of linking data to each other and the efficient way of doing so, was especially highlighted as being really helpful. According to the participant, besides that the tool gives information on what is measured during the manufacturing process, it also makes one think what should be added to this. And that data should be outputted in an uniform way so linkages can be made.

By storing the results from the tool and from RCA's, the participant states that, insights can be gathered on what has already been done to solve the problem and what the results were. This way a better focus can be taken what to focus on. Also the tool makes it easy to share reports and data, which makes it easier to discuss the data.

Case 4, was centred on a blockade that had been applied to a product which eventually had been given free for the market. To track whether relevant complaints came in from the market, the QA officer wanted to use the tool. If relevant complaints were found it is analysed whether further investigation was needed. The participant analysed the blockade, it was a foreign matter blockade because of plastics, and found that relevant complaints came in. However, when further drilling down on the information it appeared that the complaints were filed on a different type of plastic than the blockade was on. The analysis of such a blockade is important to, among others, check whether the blockade procedure was done correctly. When it is detected that the product is holding plastics, it could be that other nearby products also contain plastic, the QA team then has to decide how big of a range of products is blockaded. To check whether relevant complaints came in, the QA team can analyse whether the range was big enough or not. Besides that, QA can also analyse whether the procedure is sufficient or executed correctly. To analyse this, data linkage is needed, and this is what was valued the most by the participant. Adding to this, the singular way of working and getting to results was considered critical, because this way multiple users always come to the same results. Because of this, aftercare of products is optimized as well, since users can keep track wat happens on the market with the product in terms of complaints.

As for RCA, the participant believes that by making use of the tool more, root causes will be found and therefore the tool decreases the chance of finding causes that are not the root. This means that RCA can be done to a deeper and more relevant level. And since the data is presented clearly and to-the-point multiple users will interpret the data in the same way: *"… the tool is univocal, so when Jantje, Pietje or Klaasje uses it, the result will be the same. And this is important, even when a colleague gets sick or something, someone else can continue his work," (participant 4)*. Lastly the tool results into a great increase of efficiency.

## 5.2 Achievement of tool criteria

Now that the contribution of the tool to the separate cases is identified, a closer look is taken at if the tool achieved the tool criteria. By linking the results to the criteria, an overview is created how the criteria are reached. Tables 3 and 4 show how often a certain statement about a criterion is given by all the four participants together. The criteria are divided into two tables because of spatial limitations. Both tables serve as an indication and the explanation of the statements are elaborated in the text. Since, the criteria waste less time and improve efficiency are really similar, these two are combined. An explanation for the used codes can be found in appendix C.

*Table 3; Statement versus criteria matrix part 1*

| **Improve communication** | | **Improve discussion focus** | | **Waste less time / increase efficiency** | |
|---|---|---|---|---|---|
| Easy to share results | 4 | Clarify situation | 6 | Efficient search on specific variables | 4 |
| Complete information | 3 | Importance of data | 3 | Quick output | 3 |
| Looks professional | 3 | Helps identify where to put focus | 8 | Easy to use | 7 |

As for the first criteria that the tool should improve communication, it seems that the tool did achieve this. All four participants emphasized this; participant 4 stated that *"the tool enables easy sharing of the results".* Also since the information was considered complete, the participants were better able to underpin their messages, which made the messages more clear. It seemed that since the visualization of the information was clear and professional, the data could be better interpreted and that made it easy to communicate the data.

The tool also enabled better discussion focus. Discussion focus can be closely linked to finding more problems and root causes since the discussion focus can also be seen as better focus where problems and root causes can be found. Also better discussion focus can lead to better discussion outcomes. The results also show that the participants accentuate that the tool helps identify where the discussion should focus on. The clarification of the situation also makes it that the discussion focus improved. Since all the abnormalities during the manufacturing process for a specific product are displayed, the user knows better where to focus on, *"…we can really quickly visualize what happened..., which is why we get a more complete image." (participant 3).*

A criterion that was valued as really important and above all as a huge relieve from the previous situation is the saving of time. The tool enables extracting information with just a few clicks and gets the data from multiple different IT systems that therefore don't all have to be addressed anymore: *"… saves time since with just a few clicks you can retrieve the correct information, while previously you had to search for the information at all different places…" (participant 1)*. Also the tool is easy to use and thus the tool does not result into slack. Consequently, getting to all this data has become a quick job that does not reserves a lot of time and thus the job is actually done and not skipped anymore. The job of searching all this data was previously often skipped because it covered too much time.

*Table 4; Statement versus criteria matrix part 2*

| Improve effectiveness of RCA decision outcomes | | Link data to each other | | Find more problems and root causes | |
|---|---|---|---|---|---|
| The tool guides where to focus on | 6 | Identify correlations | 6 | Able to revise processes | 8 |
| | | Cause-effect | 6 | Identify products with most complaints | 3 |
| | | Comparison to similar production | 6 | Combine information with data | 5 |
| | | Monitoring products | 7 | Filter and combine data | 15 |

The criterion of improvement of effectiveness is harder to answer. Let's first define how the criteria, applied to this research, will occur. The criteria focuses on how the tool contributes to the effectiveness of the RCA. So in other words, to what extent is the user more capable of conducting a good RCA after utilizing the tool. This criterion is closely related to the criteria of finding more problems and root causes. Testing of the tool showed that the participants find that the tool increases RCA effectiveness since it guides the user where to focus on, which is found in the statement of one of the participants on how the tool contributes to RCA: *"The tool gives us a better image on where we should put our focus and where we should track and control things." (participant 3)*. The same participant also states that by getting to know what already has been tested and applied, the department then knows what has been done and what the outcomes were. By knowing this, the user then knows that the new to be conducted RCA and solution should focus on something else if the before applied solution did not result into the desired outcomes.

Data linkage was one of the most heard advantages of the tool and was appreciated and considered valuable. All the participants emphasized that before this had to be done manually and separately for all separate measurements. With thousands of measurements, this process is simply too much and therefore was often skipped, but know with a simple click on a button the employees can get insights on a specific variable. Participant 1 takes it even further by saying: *"In fact, we now only need this tool pertaining to all the different IT systems that were utilized in the past"*. Later on he does put a side note: *"This is however a bit nuanced, since we need all those other IT systems to gather the data"*. The data linkage enabled better tracking of what happens to certain products. By checking what happened to a product that has received a complaint, or the other way around, what happens to a product that had some uncertainties or even abnormalities during the manufacturing process. Also the tool enables comparison of products or abnormalities to each other. And by comparison, also some cause-effect can be identified. For example, what happens or happened to product A as compared to product B, what are the differences and how do they correlate. By checking multiple of these cases, a cause-effect can be discovered: *"The tool helps to get an image on what happened, what the consequences are of certain actions and this way we are better able to apply improvements and through this eliminate the cause." (participant 2)*.

Then for the last criteria, find more problems and root causes. All the before mentioned criteria contribute to this one, since the goal of the tool is to come to better RCA. However, filter and combine data was also mentioned in relation to being able to find more problems or root causes, this is also why this one is mentioned that often. Since this tracking was possible, the participants mention, that because they are able to track the problems, they are able to analyse and improve processes and policies: *"… if there is a correlation between a certain blockade and complaints, and this occurs for multiple cases, then we should revise our blockade policy." (participant 2).* This for example means that if a blockade is applied and eventually given free, but this still results into a lot of complaints relating to the blockade, then something possibly needs to be revised in the blockade process or policy. Also by identifying correlations between products and complaints, problems can be identified on specific products and then processes can be compared, as participant 2 states: *"If we get this right we are at the start of continuous improvement..."*. Lastly, it is stated that by having more data available during the RCA, the users are able to get to better root causes since more data is available to illustrate the situation.

So it appears that the product design did lead to the fulfilment of the pre-set criteria. Especially the linkage of data seemed to be appreciated and valuable. Of course, the tool is designed to meet those criteria, but it is always the question whether it can and will reach these criteria and goals.

# 6. Conclusion and Recommendations

To come to a conclusion to this research, first the research question will be answered. Then it is analysed how the outcomes of this research can be applied in different contexts. Following, a closer look is taken at how this research contributes to the literature. Last but not least, recommendations and limitations are discussed. Part of the recommendations is the answer to the company question.

## 6.1 Research question

The research question of this research; *How can integrating Case-Based Reasoning and Root Cause Analysis into a Group Decision Support System benefit Root Cause Analysis?*, can be answered by looking at both the product design and the results. The research question can be divided into how CBR influenced RCA, and how GDSS contributes to RCA. The proposed conceptual model and tools are then the facilitation of all these processes and the results are the outcomes.

The proposed conceptual model of figure 10, shows the phases how the manufacturing process can lead to an abnormality and what happens with such an abnormality to eventually become subject to RCA. To integrate the outcomes of different IT systems, a new database was needed to link these outcomes to each other. This database then enabled the formulation of a month report and appliance in the detection tool. The month report enables the QA department to keep track of the KPI's and whether these KPI's are reached. The score of the factory on these KPI's can lead to an alert that a RCA needs to be done. For example, when starting from February the performance on CRQS keeps going down, this means that something is occurring that causes this decrease. So then the CRQS can stimulate to start a RCA. Then the utilization of the detection tool is what most influenced the detection of problems and the focus of RCA. The detection tool is designed as a GDSS and comprises elements of CBR. And the goal of the detection tool is to contribute to RCA. By testing the detection tool in several cases it showed that the detection tool and therefore GDSS and CBR led to multiple advantages for RCA. The tool enabled better communication between actors, which contributes to the overall cohesion of all the actors' view on the problem. This is achieved since the communicated information is clear and easy to share, which makes it possible that all the involved people have access to the same information. Sharing this clear information between actors resulted into better discussion focus since the situation is clarified and deviations can be tracked. The clarified situation was the consequence of the access to the same data for each variable input and by seeing what happened to this certain input during the manufacturing process in terms of abnormalities. This way the employee knows exactly what was registered in terms of abnormalities during the manufacturing process, which makes it possible to find correlations. Consequently, problems and root causes are identified. Also CBR helps in this process. CBR enabled storing of past cases and using them for future cases, so by storing the different root causes or problems, certain trends can be identified which again can reveal correlations.

By making the involved tools and systems clear and to the point, and by linking data to one another, the usage of the tools were considered as being efficient. Where in the past several IT systems and quality reports needed to be consulted, now only the detection tool needs to be addressed. Further, to identify correlations, data needs to be linked. This linkage of data was highly valuable for Ben & Jerry's Hellendoorn, because they can exactly detect what happened for an input, blockades can be linked to complaints, microbiology scores to sickness complaints, et cetera. By linking this data, QA can discover what abnormalities or characteristics are, for example, instigators to a certain complaint. Like before mentioned, this linkage of data is the basis for all the other tools and therefore the linkage of data enabled better RCA.

Now to form a concise answer to the research question: by integrating outcomes from different IT systems into a GDSS and adding elements of CBR, the newly formed system can contribute to RCA by 1) improving communication, 2) improving discussion focus, 3) wasting less time and therefore increasing efficiency, 4) increasing RCA effectiveness, 5) linking data to each other, and finally the overall contribution 6) finding more problems and root causes. All these advantages resulted into the QA department being better able to do RCA.

The conceptual model and the tools can easily be implemented in different contexts. It is already asked to do so. As for the conceptual model, the only thing that would be different in an alternative context is the manufacturing process and the related data measurements that are done, because a different type of manufacturer will need different measurements. The rest of the conceptual model stays the same. Also different types of RCA can be implemented in the conceptual model without the model actually needing to change. As long as the main condition of the conceptual model and solution is satisfied this solution can be implemented at other factories. This main condition is to make the data matching, by making the outputs of different IT systems coherent, or like in this research, create a database that does this for you. Then with this data, KPI's can be calculated and the data can be applied in the detection tool. Subsequently, this will lead to better problem detection and focus for RCA.

## 6.2 Contributions to literature

This research started with a couple of contradictions found in the literature. Some authors said that the usage of a GDSS would only lead to increased efficiency (Payne, Bettman & Johnson, 1988; Todd & Benbasat, 1992), but others said that both efficiency and effectiveness increases (Sharda, Barr & McDonnell, 1988; Leidner & Elam, 1994; Radermacher, 1994; Power & Sharda, 2007). The outcomes of this research suggest that both efficiency and effectiveness increases when a GDSS is utilized. Especially, being able to communicate results and decisions to multiple involved users was scored as valuable. The presented multitude of data from different IT systems was considered value adding since then an overall view of the situation could be obtained. This presentation of different IT system outcomes was considered as valuable and did not lead to an information overload as was suggested by Chervany & Dickson (1974), Eppler & Mengis (2003), and Bawden & Robinson (2009). That the tool led to increased efficiency, effectiveness and was considered advantageous could be assigned to that the tool was designed completely towards its criteria and the user needs. Like was stated by Limayem et al. (2006) if a GDSS is designed so it serves the group task and it is utilized accordingly, the GDSS will have a positive influence on decisional outcomes. This is why it was important to align the design not only to the literature, but also to the user needs.

According to Love, Li, Irani & Faniran (2000) who did research towards TQM in organizations, to reach competitive advantage, continuous improvement is important, it is essential for organizations to learn from their mistakes and adapt to. This study supports continuous improvement by tracking and evaluating implemented solutions. Further, the study contributes to high quality management by improving the internal process quality, which according to Sousa & Voss (2002) results in fewer defects and improved operational performance. Putnik, Varela, Carvalho, Alves, Shah, Castro & Ávila (2015) add to this by suggesting that extensive data sets and analysing techniques are highly important for high quality production management.

## 6.3 Contributions to practice

To practice, this study shows that data collection goes beyond merely gathering of data. If data collection is done, the data should be stored in an univocal way. This way data can be linked to each other so relations can be found. By making data univocal, relations were identified and the illustration of an overview of what happened to a certain variable was enabled. One of the participants even stated that by backward- and forward tracking of products, continuous improvement is realized. The tool enabled to check what happened to a product that had been blockaded but given free, at the market. Does it lead to relevant complaints? And also the other way around, when complaints come in on a string of pots, what happened during the manufacturing process that might have caused this. By empowering the user to get this information, more problems and root causes were identified, which resulted in improved RCA. The detection tool also makes it possible to track whether implemented solutions resulted into a decrease of relevant complaints. This way past solutions can be evaluated and if necessary be subjected to change.

## 6.4 Recommendations

To come to the best recommendation, first the company question is answered, *How can multiple IT system outcomes be integrated so relations can be identified, resulting in higher RCA efficiency and effectiveness?*.

- The answer to the first part of the question how outcomes can be integrated so relations can be identified is short and simple, by matching data outputs. This means that all the data can be linked to the same characteristic, which could for example mean, to the same week, the same product, or the same batchcode. The result of this is that for a certain batchcode, you know what is registered in the different IT systems. By doing so, one can see what happened to a specific input. And this way it can be tracked what, when, and where something occurred, which leads to better focus for the RCA. Since all the IT systems have different outputs that could not easily be adjusted, a database is conducted where all the output is processed so the output does match and can be linked. Data linkage then serves as a basis for the increased RCA efficiency and effectiveness. The detection tool then makes it easy and efficient to come to comparisons and analysis of the matched data. Both being able to compare data and doing this without a lot of effort, and the identification of focus points makes it that RCA efficiency and effectiveness increased. The QA manager even stated that employing the detection tool in the right way start the road towards continuous improvement for the Ben & Jerry's factory. The recommendation on this matter is then also, to keep using the detection tool and doing this in line with the RCA need. To facilitate this, the databases need to be maintained.

- To make the tool even more powerful an expansion of CRQS is needed. The tool showed that the most complaints are filed on quantity and texture, which are both inpack problems. However, inpack problems are not registered in SAP. If these inpack defects are registered, correlations on quantity and texture problems can be identified.
- Also the database shows that consumer complaints are often registered in a varying way, or information is filed incorrectly or even not filed at all. The care lines that process these complaints therefore need to receive feedback on this matter. What would be most convenient is to standardize input, just like is already happening at SAP.
- Another recommendation on the data collection is to collect all the data of the quality measurements. This means also the data that is not registered as an abnormality. By doing so, the measurements that are considered conform the norm can also be evaluated.
- Vispro at this moment is the main wielded program at the factory, which holds a lot of data. The detection tool and month report should be integrated into Vispro. This makes the tool and report more compatible with the data.
- However, Vispro has got a lot of potential, but it does far from reach this potential. The user interface is not usable and does not give a clear overview. Also extraction of data should be simplified and more adjustable.
- Also the five whys analysis often fails. The steps of all the whys are not registered or even done at all. To come up with the best analysis and to be able to enable further usage, the five whys analysis needs to be applied and registered more extensive.

## 6.5 Limitations and future outlook

This research also has its limitations, for once the suggested solution is only tested in 4 cases and only at one factory, so contextual factors might have influenced the results. By testing the solution at different sites and in multiple different cases, the generalizability can be increased.

The conceptual model and therefore solution can be further expanded. At this moment the suggested tool is focused on detection of problems. The next step could be to design the tool with not only abnormalities, but with all measurements, this way the user can see what happened. In such a way also faults can be detected in what is considered right at the factory, but does still give problems. However, this was not possible for this research since not all the measurements are permanently stored. Besides this, currently the tool gives abnormalities.

A step further could be to implement a cause-effect diagram. So when the detection tool detects a certain situation, the user gets forwarded to a cause-effect diagram, which he then can follow to come to the root cause. However, this is tricky since in for example the Ben & Jerry's factory a lot is done manually and it is hard to standardize human action, since humans are more vulnerable to mistakes or errors. But this would open the way from merely detecting problems and contributing to RCA, to actually always detecting root causes from certain problems without extra needed discussion.

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# Appendix

# Appendix A; Specified overview of manufacturing process at Ben & Jerry's Hellendoorn

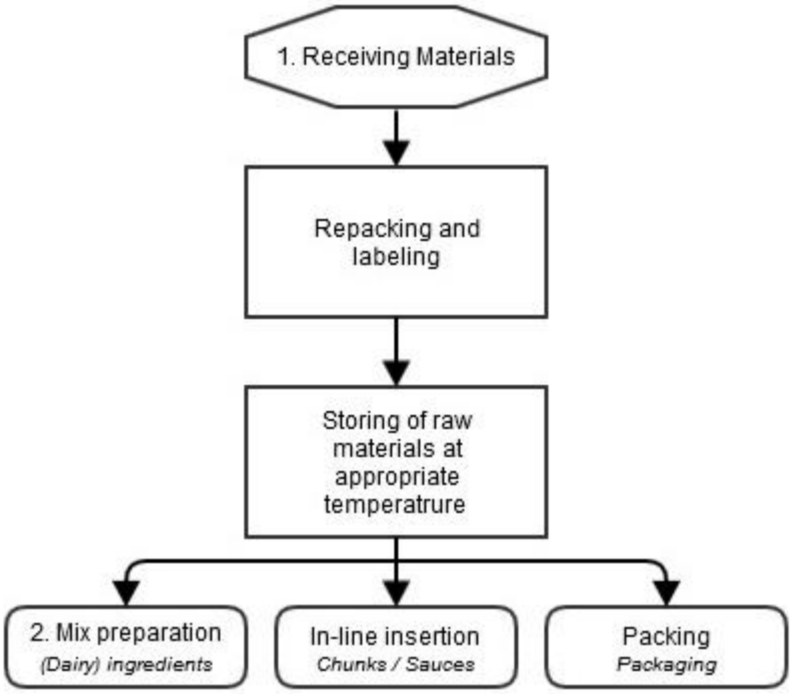
Blue: product remains unchanged

Green: optional

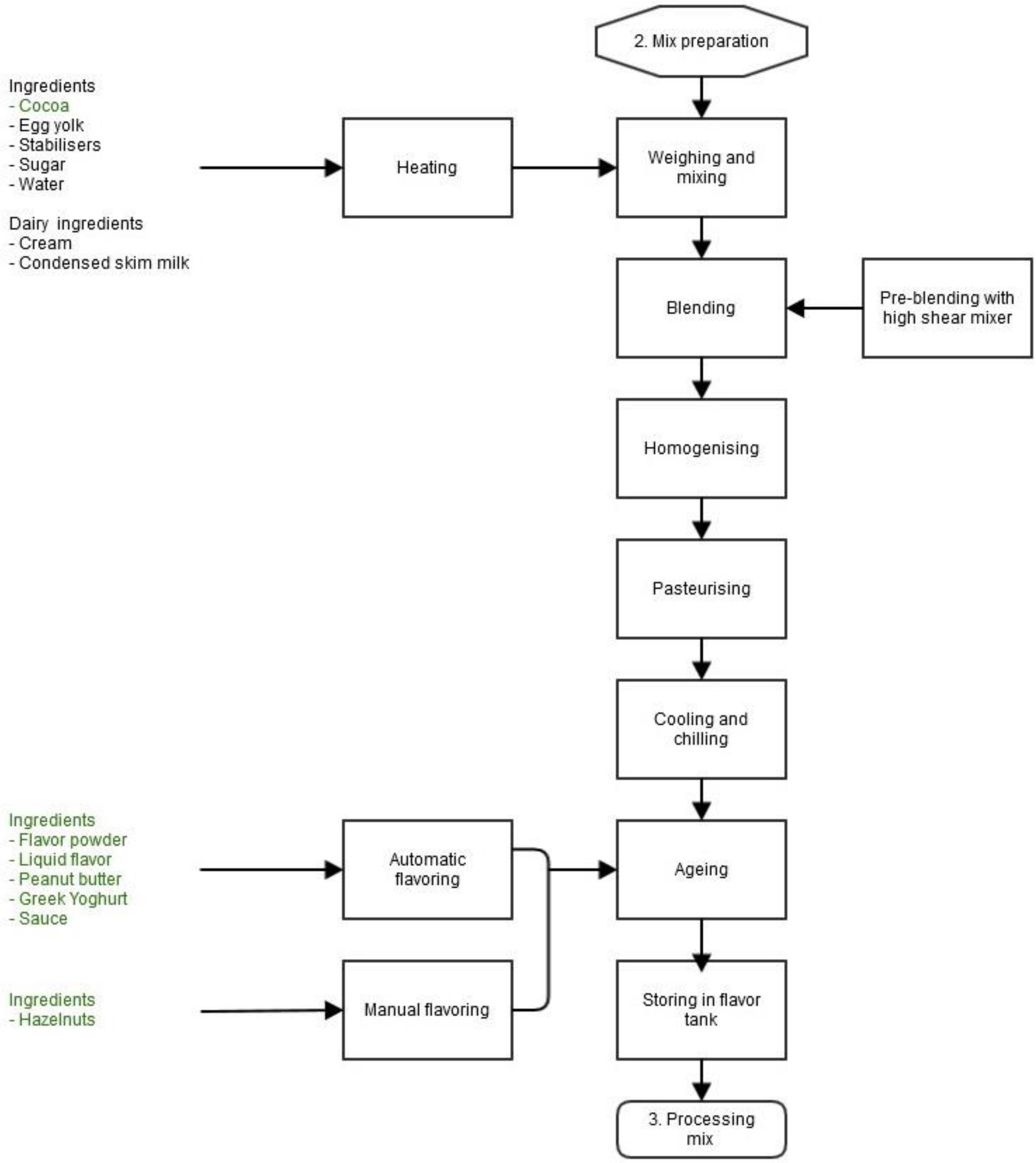
Red: quality measurement

Order of the processes of A3 may differ per production line

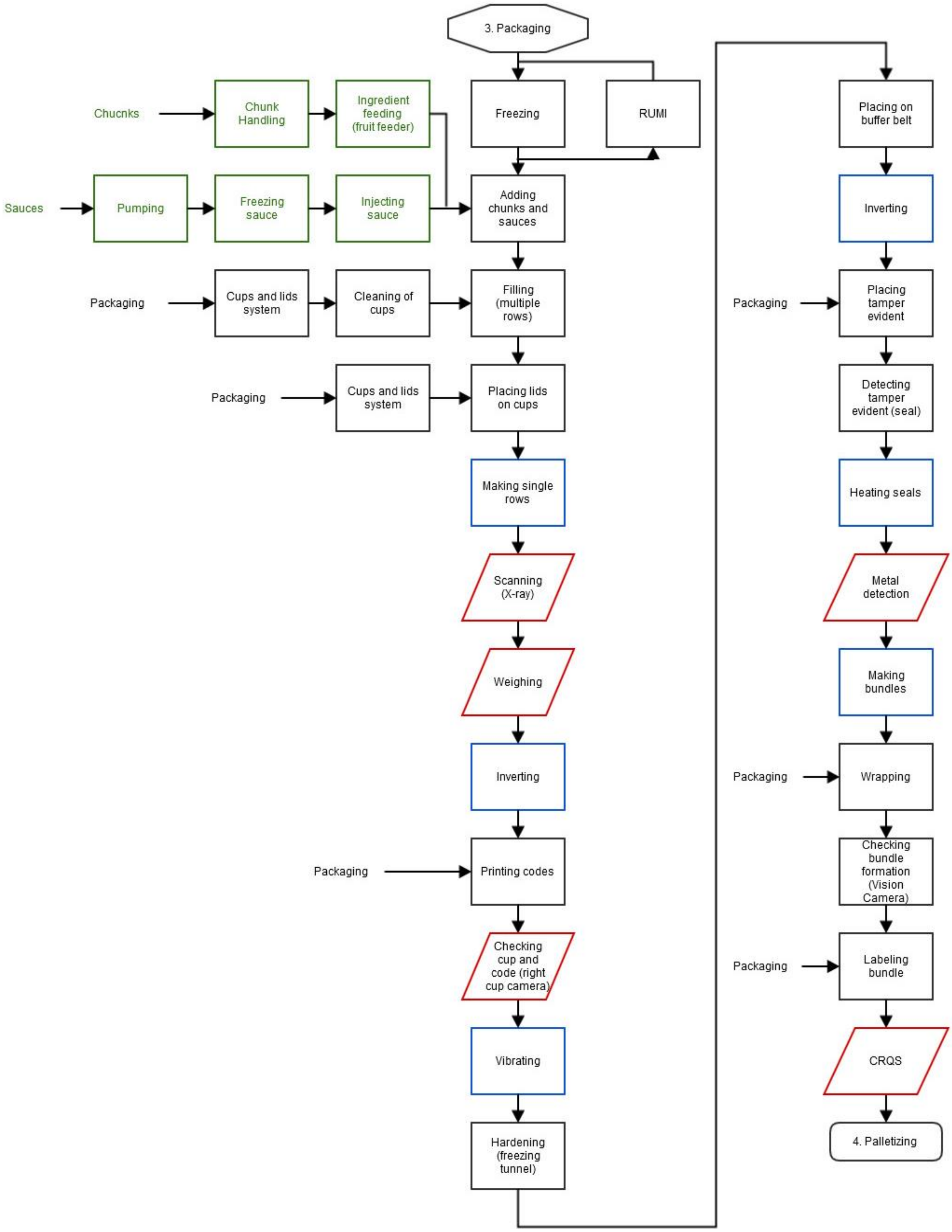
## Appendix A1; Receiving materials



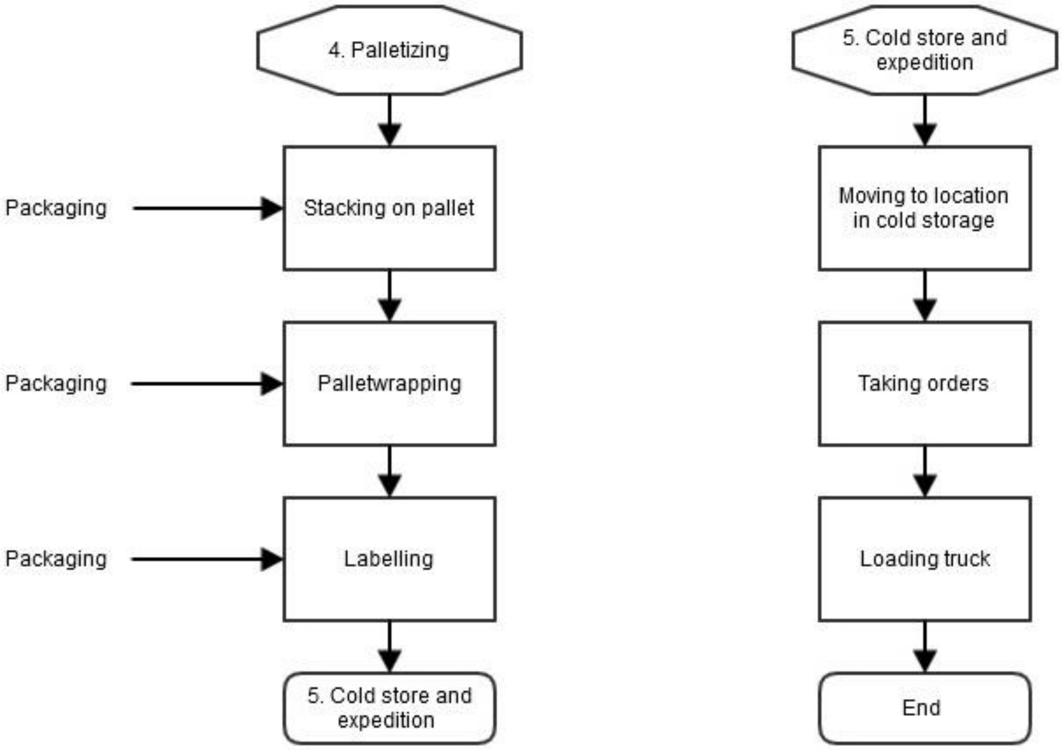
## Appendix A2; Mix preparation



# Appendix A3; Packaging



## Appendix A4; Palletizing & Cold store and expedition



# Appendix B; Description of database attributes for each entity

## Appendix B1; Ice Cream Pot attribute descriptions

| Data name | Description |
|---|---|
| Database number | A number that indicates the count of data, and serves as navigation |
| Batchcode | A code that is printed at the ice cream cup that indicates the moment and place of production |
| Lot time | The time that the batch code is printed at the cup |
| Production date | The date of production |
| Production day | The day of the month that the product is produced |
| Production month | The month of the year that the product is produced |
| Production year | The year that the product is produced |
| Production Week number | The week number of the year that the product is produced |
| Product name | Indicates the type of product |
| Flavour | Indicates the flavor of the product |
| Content volume | The volume of the product |
| Material code | The code of the type of product |
| Production line | The production line where the product is produced |
| Team | The production shift that the product is produced in |
| Cluster | The cluster that the product is produced in. |

## Appendix B2; Performed blockades attribute description

| Data name | Description |
|---|---|
| Follow-up number | The follow-up number of that specific blockade |
| Blockade type | The type of blockade |
| Amount of pallets | Amount of involved pallets |
| Amount of bundles | Amount of involved bundles |
| Amount of cups | Amount of involved cups |
| Description of blockade | A description of the reason for blocking |
| D-incident | Whether the blockade is a D-incident or not (see 1.4.2) |
| Amount of blockades | Amount of involved blockades |
| Amount of D pallets | Amount of pallets marked as D-incident |
| Amount of D bundles | Amount of bundles marked as D-incident |
| Amount of D cups | Amount of cups marked as D-incident |

## Appendix B3; Consumer complaints attribute description

| Data name | Description |
|---|---|
| Complaint date | The date that the complaint was filed |
| Complaint day | The day that the complaint was filed |
| Complaint month | The month that the complaint was filed |
| Complaint year | The year that the complaint was filed |
| Complaint week number | The week number that the complaint was filed |
| Country of complaint | The country that the complaint came from |
| Type of complaint | The type of complaint |
| Type + specification | The type of complaint plus a small description |
| Verbatim | A summary of the complaint |
| Comment | The complete complaint |

## Appendix B4; Microbiology scores attribute description

| Data name | Description |
|---|---|
| Monster number | The unique monster number of that sample |
| Entry date | The date that the microbiological score was entered |
| Entry day | The day that the microbiological score was entered |
| Entry month | The month that the microbiological score was entered |
| Entry year | The year that the microbiological score was entered |
| Entry week number | The week that the microbiological score was entered |
| Plate count | The score for the plate count |
| Enteros | The score for enteros |
| Ferment | The score for ferment |
| Molds | The score for molds |
| Listeria | The score for listeria |
| Staphylococci | The score for staphylococci |
| Lacto bac. Bulg | The score for lacto bac. bulg |
| Strept. Them | The score for strept. them |
| Tekst 1 | Extra information for that monster |
| Tekst 2 | Extra information for that monster |

## Appendix B5; CRQS attribute description

| Data name | Description |
|---|---|
| Inspection lot | Inspection lot of that filed CRQS |
| Defect class | The classification of the defect (Yellow or Red) |
| Damage code | The code of the defect |
| Problem code text | The description of the defect |

# Appendix C; Explanation of used codes

| Criteria | Code | Example citation |
|---|---|---|
| Improve communication | Easy to share results | *The tool enables easy sharing of the results* |
| | Complete information | *You can easily show, this is what we've done and that works easily.* |
| | Looks professional | *… and the reports have a professional layout* |
| Improve discussion focus | Clarify situation | *…we can really quickly visualize what happened…, which is why we get a more complete image.* |
| | Importance of data | *Now we've got a tool with data that is univocal,…, the result stays the same. And that is important…* |
| | Helps identify where to put focus | *The tool gives us a better image on where we should put our focus and where we should track and control things* |
| Waste less time / increase efficiency | Efficient search on specific variables | *…saves time since with just a few clicks you can retrieve the correct information, while previously you had to search for the information at all different places…* |
| | Quick output | *In fact, we now only need this tool pertaining to all the different IT systems that were utilized in the past.* |
| | Easy to use | *First of all, it is easy to use and works really fast.* |
| Improve effectiveness | The tool guides where to focus on | *The tool gives us a better image on where we should put our focus and where we should track and control things* |
| Link data to each other | Identify correlations | *… we had a contamination, or a product blockaded, we can track what happens when these products are on the market.* |
| | Cause-effect | *The tool helps to get an image on what happened, what the consequences are of certain actions and this way we are better able to apply improvements, and through this eliminate the cause.* |
| | Comparison to similar production | *We can compare measurement scores for different productions to each other and check whether a relation is there.* |
| | Monitoring products | *… we can measure things very well and monitor whether we book progress.* |
| Find more problems and root causes | Able to revise processes | *… if there is a correlation between a certain blockade and complaints, and this occurs for multiple cases, then we should revise our blockade policy.* |
| | Identify products with most complaints | *We can easily check for the variables where the most complaints are….* |
| | Combine information with data | *… plus, what this tool beautifully does, you are able to really clearly communicate to the production site that everything we do really has an impact. You can invigorate the statement with actual data and figures.* |
| | Filter and combine data | *You can get your data and filter. That is a big advantage…* |