Gaining insight in possible actions to reduce food waste by developing a prototype monitoring tool and theoretical pilots

REFRESH D2.7

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List of abbreviations

DC	Distribution Centre
DSM	Decision Support Model
DSS	Decision Support System
DST	Decision Support Tool
ERP	Enterprise resource planning
FIFO	First in First Out
FLW	Food Loss & Waste
KPI	Key Performance Indicator
LIFO	Last in First Out
SKU	Stock Keeping Unit
FCC	Fresh Case Cover

1 Executive Summary

As part of the wider REFRESH Work Package (WP2) on Business Engagement & Frameworks of Action a Decision Support System (DSS) prototype monitoring tool, focused to facilitate effective decision-making leading to actions that will prevent and valorise waste, is developed and tested. This involved building the prototype monitoring tool (software) to register food waste data and providing the right control information with respect to food waste prevention. This control information consists of informative visualizations of the registered data, the right key performance indicators, and suggestions (decision support) for possible actions to prevent food waste.

The prototype monitoring tool:

- helps retailers to gain the right awareness of their food waste;
- presents the registered data in such a way that particular ways of reducing food waste are provided;
- is based on real waste data and contextual data.

More advanced / elaborated / dedicated scenarios to reduce food waste are addressed in so-called 'theoretical pilots'. These theoretical pilots will show potential actions such as discounting nearly expired products, dynamic shelf life for highly perishable products, including substitution in replenishment strategies, and inventory management in relation to donation of leftovers to charity.

The developed prototype monitoring tool can be used as a decision support tool that is indicative and that can be used to drive insight in the right direction towards food waste reduction. For the retailer it provides the needed insight based on the data that they nowadays are expected to be able to register with the right IT-infrastructure. The prototype monitoring tool is developed in such a way that it can be used both online and offline and all the requirements are provided that a retailer can build the functionalities fit to their own software (for example their in-house ERP system). Furthermore, the prototype monitoring tool also provides ways of reducing food waste based on the insights gathered through the monitor.

Next to the prototype monitoring tool the theoretical pilots that are researched give insight in potential prevention scenarios that cannot be obtained from the monitor. These pilots however allow in-depth investigations where the factors, which influence the retailer's performance, can be controlled. These theoretical pilots showed that food waste prevention via discounting nearly expired products, applying dynamic shelf life and including substitution behaviour in their replenishment policy are relevant actions to further explore in a real-life pilot.

The potential for further development of a food waste monitoring tool lies in the extension from monitoring to analysis. When more data is added to the database more complex analysis could be done, i.e. data mining. Also based on the available data it is relative easy to calculate the carbon effects of the registered food waste.

The same holds for the 'wider cost' like product-based-cost of procurement, labour, water, energy, et cetera.

Furthermore, the prototype monitoring tool has been developed for the usage within one stage of the supply chain, i.e. the food retailer (at central or decentral level). Supply chain stages more upstream, for example distribution centres, warehouses, chill houses and even processing companies or farmers could also be included.

Another potential of the prototype monitoring tool is that it could be used as a benchmarking tool. As a web-based tool, it could connect to a central database with input data from several retailers that will give the possibility to compare the individual retailer's performance to the average of the sector, see trends, et cetera.

2 Introduction

2.1 REFRESH

REFRESH (Resource Efficient Food and dRink for the Entire Supply cHain) is an EU Horizon2020 funded research project taking action against food waste. Twenty-six partners from 12 European countries and China are working towards the project's aim to contribute towards Sustainable Development Goal 12.3 of halving per capita food waste at the retail and consumer level and reducing food losses along production and supply chains, reducing waste management costs, and maximizing the value from un-avoidable food waste and packaging materials.

The work presented in this report was developed as part of a wider Work Package (WP2) on Business Engagement & Frameworks of Action which aimed to establish evidence for a pan-European Framework for Action through the design and validation of four national pilots. The area of focus was to design and test a Decision Support System (DSS) prototype monitoring tool focused to facilitate effective decision-making leading to actions that will prevent and valorise waste.

This report builds on an earlier REFRESH report "Gap analysis for decision support tools, models and libraries" (Wigham, M., Tromp, S., Wilson, J., and Bygrave, K. 2018), which presents the results of a gap analysis between existing tools and user requirements, taking into account business needs.

2.2 Background

2.2.1 Decision Support System: Decision Support Tools & Models

As stated in the REFRESH report (Wigham, M., Tromp, S., Wilson, J., and Bygrave, K. 2018), REFRESH is interested in Decision Support Systems (DSSs) that can help people, whether policy-makers, company CEOs or consumers, to make choices that help to reduce food waste. We therefore want to develop systems that give people information, sometimes qualitative, sometimes quantitative, about the effects of their choices in terms of both food waste and the costs entailed. This helps them to make effective decisions. However, the scope remains very large. There is a large difference between advising a government on the potential impact of abolishing best-before dates, and helping a caterer to decide how they can best dispose of their surplus product. Therefore, two types of decision support systems, decision support models (DSM) and decision support tools (DST), are defined[1].

- **DSTs:** Are aimed at decisions between options for which the effects and applicability are well understood. The scope is typically quite specific. The effects for a given user can be determined based on a specified set of data and information, which the user can easily fill in without assistance. Models may be used for calculations, but the tool itself, according to a set of logical rules, can determine the choice of model, and the inputs are also simple to fill in. The audience for DSTs is primarily businesses, retailers, food manufacturers and trade associations.

[1] Based on "REFRESH: What is a DSS?" Wageningen UR, 2016

- **DSMs:** Are used by experts to assist decision makers in producing tailored advice. The audience for DSMs is primarily technical consultants, academics and scientists. In the course of modelling different scenarios, the consultant may develop a calculation model that is sufficiently well defined in inputs, scope and applicability that it can be applied in a DST.

Therefore, DSTs and DSMs are complementary to each other and can support each other. Knowledge developed in the DSM can specify calculation models for a DST, and models and data gathered of a DST can be added as building blocks in the DSM. The DSMs and DSTs together represent a pipeline of knowledge of food waste from scientists, government and industry to individual decisions makers.

2.2.2 Focus on tool development

The GAP analysis concluded that "*in general there is a focus on DSMs whose target audience is academia and consultants, whereas a **large opportunity** lies with food businesses that will utilise **DSTs**. Consultation with food businesses is recommended to identify their requirements, and to further understand the type of DSTs, which would benefit their operations. Current user feedback is that they desire tools to cover a broad scope, and that they would prefer indicative tools, which can be used to drive insight in the right direction – rather than fewer more detailed tools and models*." (Wigham, M., Tromp, S., Wilson, J., and Bygrave, K. 2018).

Therefore, the focus of this report will be on tool development.

2.2.3 Focus on tool development for retailers

When we look at the global supply chains in the Agrifood sector, we see that the role of global buyers has been strengthened by retail concentration. As shown in Figure 1, supply chains tend to be very concentrated in the retail segment (Gereffi, 2012).

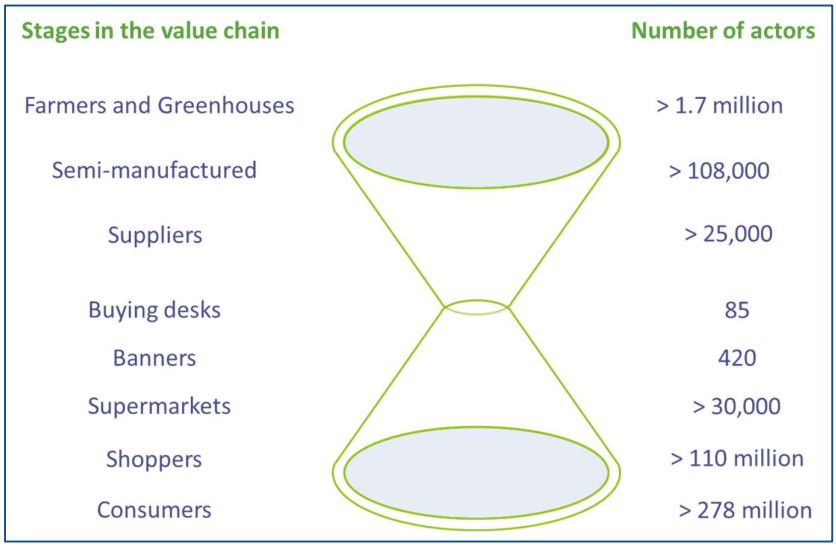

Figure 1: The Supply Chain Funnel in the Agrifood Sector (based on figures for seven Western European countries)

Retailers, more specifically supermarkets, play an important role in the food chain. They are the link between consumers and producers (where many products are produced and processed at different places all over the world) and are themselves producers with their own brands. The supermarket therefore fulfils a key centralizing function in the food chain and from this function, the supermarket can affect food waste in other chain sectors. Through their purchasing or ordering policies, marketing, discount policies, service levels, et cetera they have a lot of influence on both food consumption and food waste.

Because of this unique and 'controlling' position of retail organisations (as buying desk, banners (i.e. supermarket brand) or supermarket outlets) the focus in this task is on the development of a prototype monitoring tool for retailers, i.e. supermarket outlets.

2.2.4 Aim and objective of this work

For this report the aim is to develop and test of a prototype monitoring tool. This involved building a prototype monitoring tool (software) to register food waste data, and providing the right control information with respect to food waste prevention. This control information consists of informative visualizations of the registered data, the right key performance indicators (KPI's, for example relative or absolute waste, waste at product level or outlet level), and suggestions (decision support) for possible actions to prevent food waste.

The prototype monitoring tool will:

- help retailers to gain the right awareness of their food waste;
- present the registered data in such a way that ways of reducing food waste are provided;
- be based on real waste data and contextual data.

Testing and piloting

The prototype monitoring tool will be tested on functionality by loading the database with data from a third-party retailer.

The prototype monitoring tool will, based on the presentation of the registered data indicate ways of reducing food waste. More advanced / elaborated / dedicated scenarios to reduce food waste will be addressed in so-called 'theoretical pilots'. These theoretical pilots will show potential actions such as discounting nearly expired products, dynamic shelf life for highly perishable products, including substitution in replenishment strategies, and inventory management in relation to donation of leftovers to charity.

To summarize; the objectives are to develop and test a working prototype of a food waste information system for retailers ('prototype monitoring tool') which will identify solutions to prevent food waste and provide insights in potential prevention scenarios via so-called theoretical pilots.

3 Prototype monitoring tool

Although food waste from retail has been investigated in a number of studies, there is still a lack of reliable data (Lebersorger and Schneider, 2014). There is a lack of registration of waste data, and there is a need for defining the right control information. Such control information consists of informative visualizations of the data, indicating ways of reducing food waste. Zero waste is mostly not realistic as limited product shelf lives in combination with low demand, demand uncertainty and substantial order lead times will 'guarantee' some base level of product waste.

Only after having implemented proper waste registration, and after having defined the right control information (data visualisation, key performance indicators), the retailer will be able to set up an effective waste-monitoring and improvement program. The retailer can perform improvements in practice (for example on a pilot scale) and watch the effect on the key performance indicators in the information system. Possible improvements are for example shelf-life extension, minimum-order-quantity reduction, smart replenishment policies, and optimized promotions.

Therefore, the research objective is to develop a working prototype of a retail food waste information system (Figure 2).

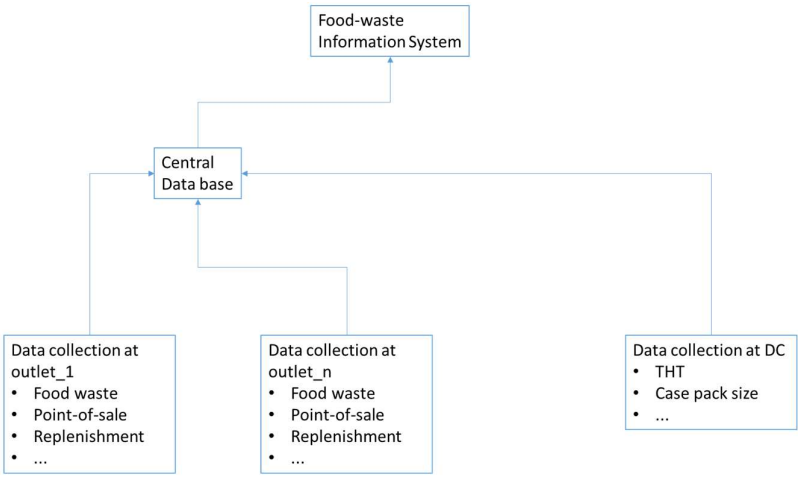

Figure 2: Blue print of retail food waste information system

During development, the prototype monitoring tool consists of a database with fictive data that a retailer nowadays is expected to be able to register with the right IT-infrastructure. Moreover, it consists of an information system, i.e. a dedicated environment in which the user can visualize interesting data (food waste data and contextual data), to monitor the progress of his food waste improvement program. The information system presents the data in such a way that ways of reducing food waste are provided.

A Requirements Document was written to support the prototype development, outlining the functional requirements of the prototype monitoring tool. The Requirements Document is found in Appendix 1 of this report.

3.1 Design and construction of prototype monitoring tool

The prototype monitoring tool is dedicated to food waste occurring at the supermarket-outlet level. Food waste occurring at the retailer's distribution centre or at the supplier is beyond the scope of this prototype. Moreover, the prototype monitoring tool is only about in-store food waste. In-store food waste occurs after the store has accepted delivered products, unlike pre-store waste which consists of items rejected by the retail outlet at delivery due to non-compliance with quality requirements. In-store food waste occurs for different reasons. For example, due to expiration date labels (expired best-before or use-by dates), unacceptable quality decay (quality as judged by sensory aspects such as visual appearance and odour) or product/packaging damage. Expired date labels are considered one of the main reasons for in-store food waste (Hanssen and Schakenda, 2011). Therefore, the prototype monitoring tool focusses on food products with an expiry date (e.g. fresh-cut vegetables and packed, fresh meat). However, food products without explicit expiry dates (vegetables and fruits) can be monitored as well with the system, as retailers mostly work with internal shelf lives in these cases.

The monitor's level of detail is that food waste is registered at product-level and at a weekly level. To be able to evaluate whether the registered waste is acceptable or not, sales data (turnover data) and out-of-stock data are important contextual data. Sales data are used to express the registered food waste as a percentage of sales, which gives a better impression of the acceptability of the registered waste. Out-of-stock data are used to analyse the balance between waste and product availability at the shelf. After all, a straightforward way to reduce food waste at the supermarket is to order less, so to reduce the replenishment at the store from the distribution centre. However, this will reduce product availability on the shelf as well, and therefore increase the probability of running out-of-stock. Therefore, out-of-stock data are important contextual data to estimate this opportunity of reducing food waste.

3.1.1 Existing tool vs. development

The development of the prototype monitoring tool is based on the idea of analysing (big) data. Tools that are (commercially) available, like PowerBI from Microsoft or Tableau, have as advantages the availability of a very powerful engine for analysing the data and that they are generically applicable. The downside of these tools is however that you not only have to become familiar with how they work, but you also must study how these tools structure the data. Furthermore, the fact that these tools are generic and therefore very extensive means that the user has to commit time and effort to understand how to formulate the right 'questions' (queries) to run the right analyses and getting the wanted outcomes.

For this task such a generic tool is not very suitable. After all, we want to show what insights and possible actions to prevent food waste can be generated based on existing (and according to us at least or minimal available data from the 'average' supermarket) retailer data. For this purpose, the development of a prototype monitoring tool will be most sufficient. Therefore, we chose a rapid construction of the prototype monitoring tool in a software environment (simple, applicable, experience, web based, ...). The main advantage of this approach is that the analyses we want to perform are already built into the tool and thus is predefined for the user without having to have background knowledge regarding the data

structuring. This makes the tool more user-friendly and intuitive. The disadvantage is that the tool will be less flexible / more specific in comparison to a generic tool. To expand the analysis the prototype monitoring tool must be adjusted.

Another relevant reason for developing the prototype monitoring tool within REFRESH instead of using / adapting an existing software tool is the fact that as a dissemination aspect we want to give insight and knowledge to the stakeholders regarding the possibilities of putting the available (retail) data into relevant information towards food waste reduction. Therefore, we make the requirements available (see Appendix 1: Requirements). When retailers want to connect this monitoring tool to for example their existing ERP-system (or even integrate it) they will probably use their own software rather than trying to interface it with the (commercial) available software tools. By developing the prototype monitoring tool, we make this transparent and possible.

3.1.2 User / target group of prototype monitoring tool

The envisioned user of the prototype monitoring tool is someone at the retailer's head office, e.g. a category manager or a sustainability manager. The envisioned application is a desktop application, although tablet or mobile applications are kept in mind during the development process.

Although the envisioned user is at the head office level, the prototype monitoring tool might be the basis of a local application as well, for example for store managers or regional managers. However, the starting point is someone at the retailer's head office who is interested in food waste at the retail outlets.

3.1.3 Design of prototype monitoring tool

To provide the user with ways of reducing food waste, the prototype monitoring tool must be able to handle the following data:

1. Weekly waste data (€) of each product-outlet combination
2. Weekly sales data (€) of each product-outlet combination
3. Weekly out-of-stock data (%) of each product-outlet combination
4. Geographical data of each outlet
5. Consumer price of each product (€) (assumed to be equal to all outlets)
6. The shelf life (d) of each product (assumed to be equal to all outlets)
7. The minimum order quantity of each product (assumed to be equal to all outlets and assumed to be equal to the incremental order quantity as well)
8. The promotion weeks of each product (assumed to be valid for all outlets simultaneously)
9. Weekly demand-uncertainty data of each product-outlet combination

In addition, the data needs to be provided to the information system in the right format. This data format is specified in Appendix 2: Format input file.

The usefulness of these data is explained as follows:

1-3. Sales data are used to express the registered food waste as a percentage of sales, which gives a better impression of the acceptability of the registered waste. Out-of-stock data are used to analyse the balance between waste and

product availability at the shelf. It is up to the retailer how to express the weekly out-of-stock data. For example, it can be the percentage of days that the shelf is empty on replenishment.

4. Geographical data are of importance for analysing waste, sales and out-of-stock geographically. For example, to see whether urban and rural areas show different food waste levels.
5. The consumer price is of importance for translating the sales and waste from Euro's into sales in numbers.
6. The product's shelf life is defined to be equal to the number of days between the date at which the product is received at the store and the product's expiry date. A negative correlation is expected between the shelf life and the registered waste: the longer the product's shelf life, the lower the waste.
7. Especially product-outlet combinations with a low turnover may suffer from a minimum order quantity which is too large. For these product-outlet combinations a positive correlation is expected between the minimum order quantity and the registered waste: the larger the minimum order quantity, the higher the waste.
8. Promotions affect both sales and waste. A positive correlation is expected between the number of promotion weeks and the registered waste: the larger the number of promotion weeks, the higher the waste. This is explained by the fact that in case of having a promotion, supermarkets purchase high numbers of products to fulfil the expected increase of demand. However, this increases the risk of getting outdated products after the promotion weeks as well.
9. The demand uncertainty of a product-outlet combination is defined as the variation coefficient of the daily sales (in numbers) of this product-outlet combination. For a particular week, this variation coefficient is calculated as the standard deviation of the daily sales (in numbers) during this week divided by the mean of the daily sales (in numbers) during this week. A positive correlation is expected between demand uncertainty and registered waste: the higher the demand uncertainty, the higher the waste. This is explained by the fact the if demand uncertainty is high, a high safety margin is needed in the replenishment order to guarantee a high service level (product availability). However, this high safety margin will increase the risk of having outdating (waste) as well.

3.2 Functionality of prototype monitoring tool

The prototype monitoring tool can be found online (https://eu-refresh.org/). For demonstrating the functionality of this monitoring prototype, a small database with fictive data is used. This fictive, but realistic, data gives the user the possibility to see how analyse a retailer's food waste data can be analysed.

It is not possible for users to upload their own data online; this must be done via a specialist.

3.3 Evaluation of prototype monitoring tool

3.3.1 Benefits of prototype monitoring tool

The monitor visualizes the uploaded data (as described in section 3.1.3) by a number of tables and figures. Two levels of analyses are distinguished:

- The aggregated level: comparing products;
- The detailed level: comparing product-outlet combinations.

The idea behind this is that the user first compares the products on an aggregated level (summarized over all outlets), in order to select one particular product for further analysis, for example a product which has large waste compared to its sales. Subsequently the user can analyse which of the outlets are responsible for (in this example) this large waste, and which are the causes behind.

Comparing products

The prototype monitoring tool starts with the following screen (Figure 3). This screen presents a table with aggregated (summarized over all outlets) data about waste, sales and out-of-stock of each product (three products in the example below).

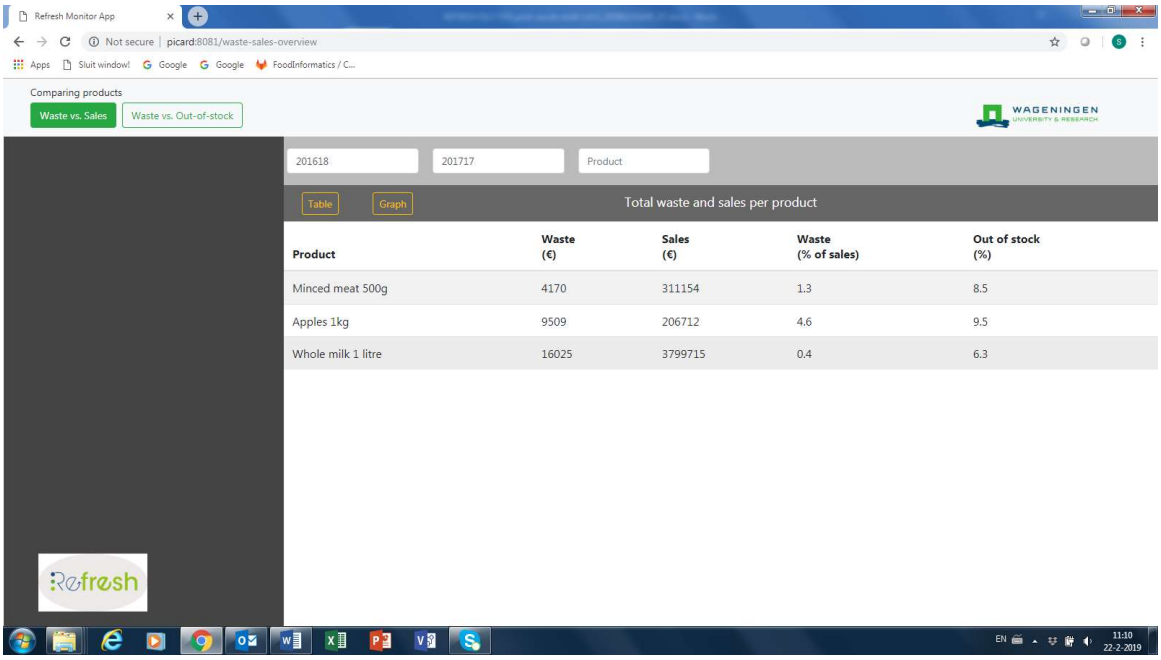

Figure 3: Table with aggregated data of each product

By pushing the 'Graph' button, a graph visualizes the waste vs. sales data from this table (Figure 4).

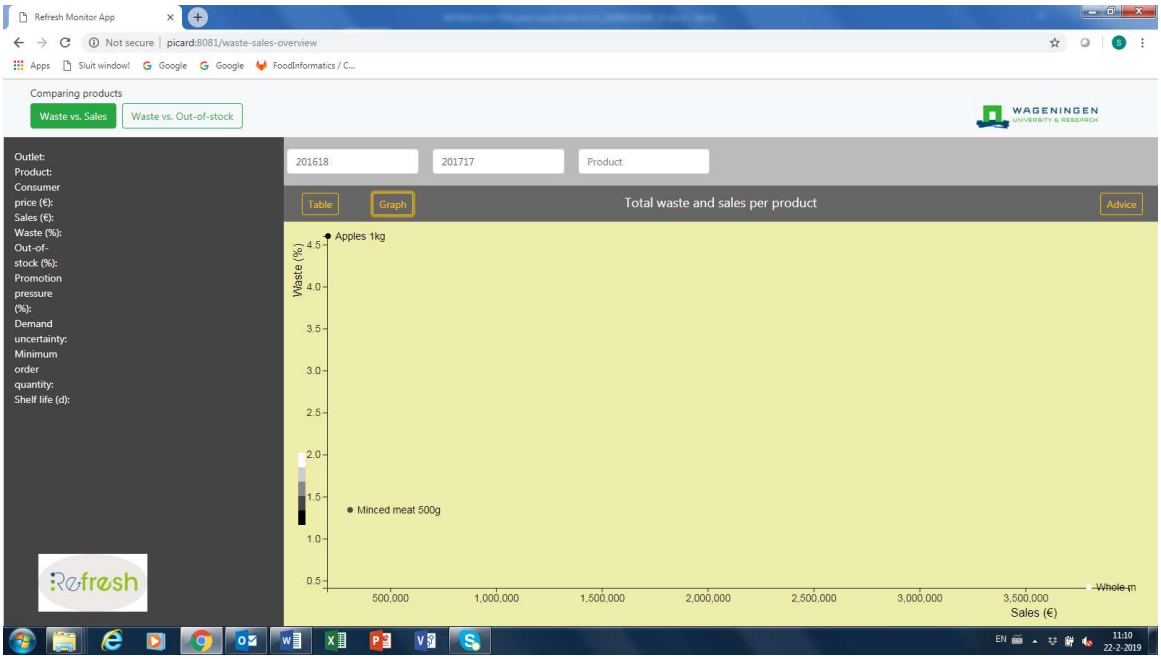

Figure 4: Graph with aggregated waste and sales of each product

The aggregated (=average) out-of-stock of each product is visualized as well, by a grey colour between white (low out-of-stock) and black (high out-of-stock).

By hovering over a particular dot (=product), the window on the left shows the following additional characteristics:

- Promotion pressure: number of promotion weeks of this product as percentage of total number of weeks during selected period;
- Demand uncertainty: average demand uncertainty (=variation coefficient of sales) of this product for all outlets during selected period;
- Minimum order quantity: average minimum order quantity of this product during selected period;
- Shelf life: average shelf life of this product during selected period.

By pushing the 'Advice' button on the right, four coloured rectangles appear (Figure 5), provided with the following texts:

- Products within one of the two green rectangles: "Products with waste percentages that fit with sales levels. However, waste differences between outlets may exist."
- Products within the orange rectangle: "Products with small to moderate sales. Waste percentage is lower than might be expected. Check out-of-stock."
- Products within the red rectangle: "Products with large sales, but with a large waste percentage as well. Give high priority to waste reduction. Analyse out-of-stock, promotion pressure, demand uncertainty, minimum order quantity and shelf life."

Note: The prototype monitoring tool only indicates the relative necessity to analyse certain products and outlets. By visualization it becomes clear which products/outlets differ from the rest, which triggers the advice to analyse these outliers in more detail. However, the prototype monitoring tool doesn't provide absolute waste targets.

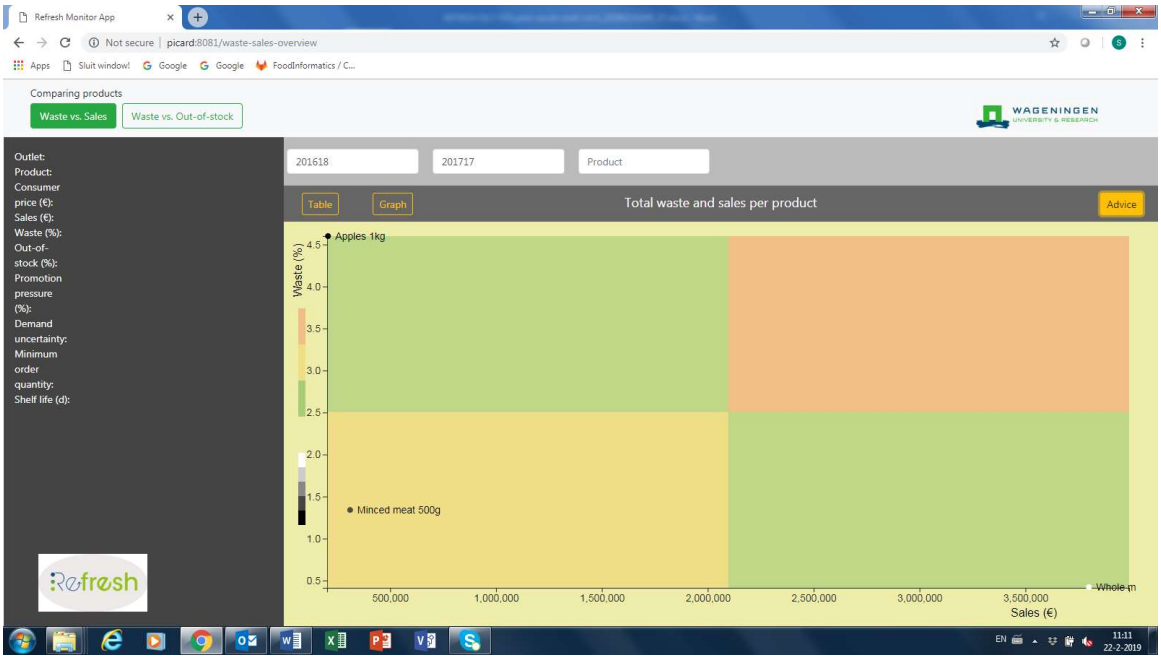

Figure 5: Graph with aggregated waste and sales of each product, provided with advice on waste prevention

The following graph (Figure 6) visualizes the waste vs. out-of-stock data from the same table at Figure 3.

By pushing the 'Advice' button four coloured rectangles appear (Figure 7), now provided with the following texts:

- Products within one of the two green rectangles: "Products with low out-of-stock and waste."
- Products within the orange rectangle: "Products with either high out-of-stock or high waste. Consider the exchange between out-of-stock and waste by adjusting the replenishment level."
- Products within the red rectangle: "Products with high out-of-stock and high waste. Analyse the replenishment policy or consider remediation."

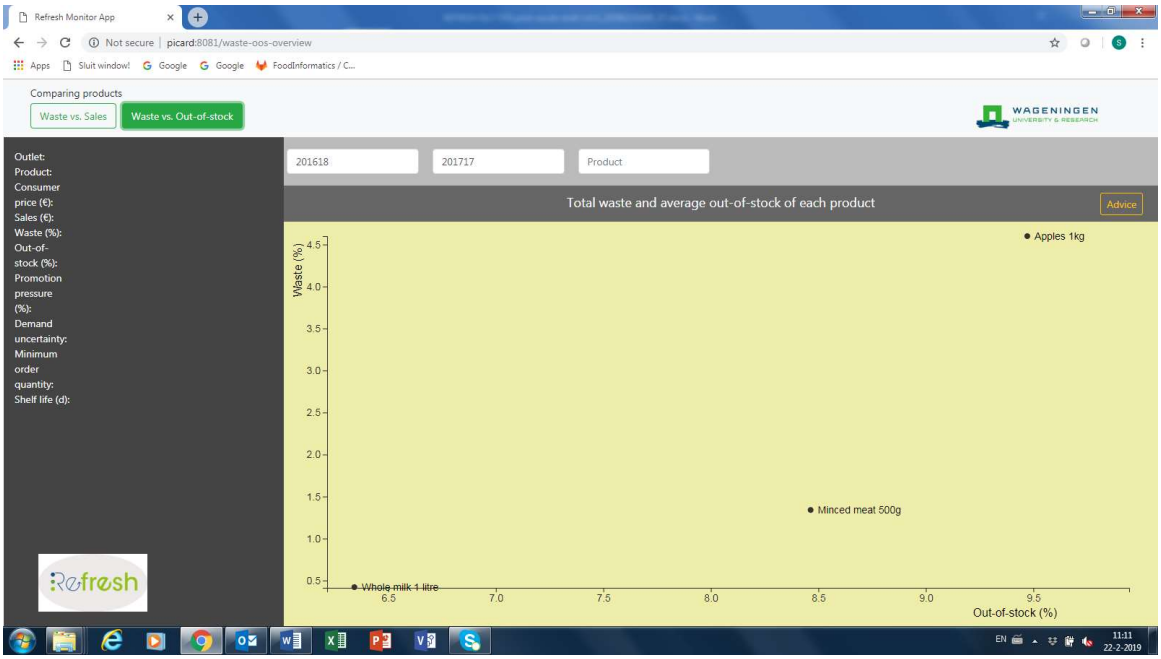

Figure 6: Graph with aggregated waste and out-of-stock of each product

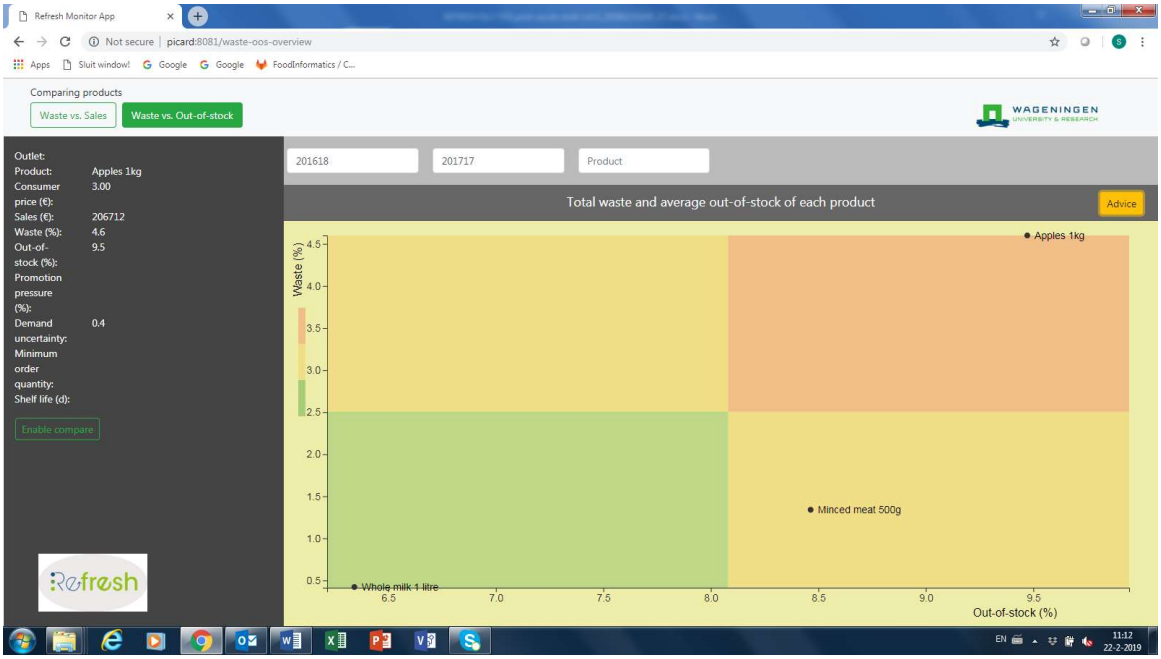

Figure 7: Graph with aggregated waste and out-of-stock of each product, provided with advice on waste prevention

Selecting one particular product by clicking on a specific row of the table at Figure 3 (or by clicking on a dot from one of the graphs), the user movers from the level of comparing products to the more detailed level of comparing product-outlet combinations. This is explained in the next section.

Comparing product-outlet combinations

The user has selected a specific product and is interested in comparing different outlets selling this product. Figure 8 appears for this in-depth analysis: comparing product-outlet combinations.

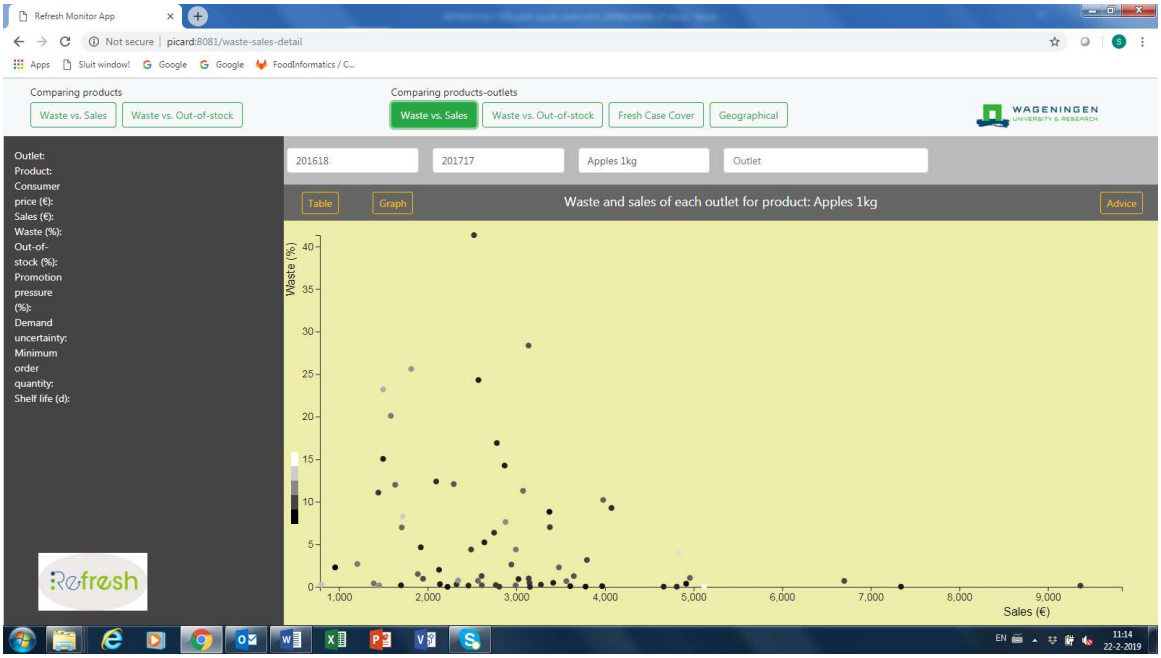

Figure 8: One product has been selected (in this case Apples 1kg). Waste and sales of each outlet are visualized

So, the analysis is now on the product-outlet level. We started with comparing different products, then selected one specific product and now we are interested in comparing the outlets regarding this product. We are interested to know why some of these outlets contribute more than others to the waste of the selected product and hope to find ways of reducing the product waste at these outlets.

Figure 8 presents waste vs. sales data of each retail outlet for the selected product. By pushing the 'Advice' button, the following screen appears (Figure 9), provided with the following texts:

- Outlets within one of the two green rectangles: "Outlets with waste percentages that fit with sales levels. However, improvements might be possible. Click on a specific outlet for further analysis."
- Outlets within the orange rectangle: "Outlets with small to moderate sales. Waste percentage is lower than might be expected. Check out-of-stock."
- Outlets within the red rectangle: "Outlets with large sales, but with a large waste percentage as well. Give high priority to waste reduction. Click on a specific outlet for further analysis"

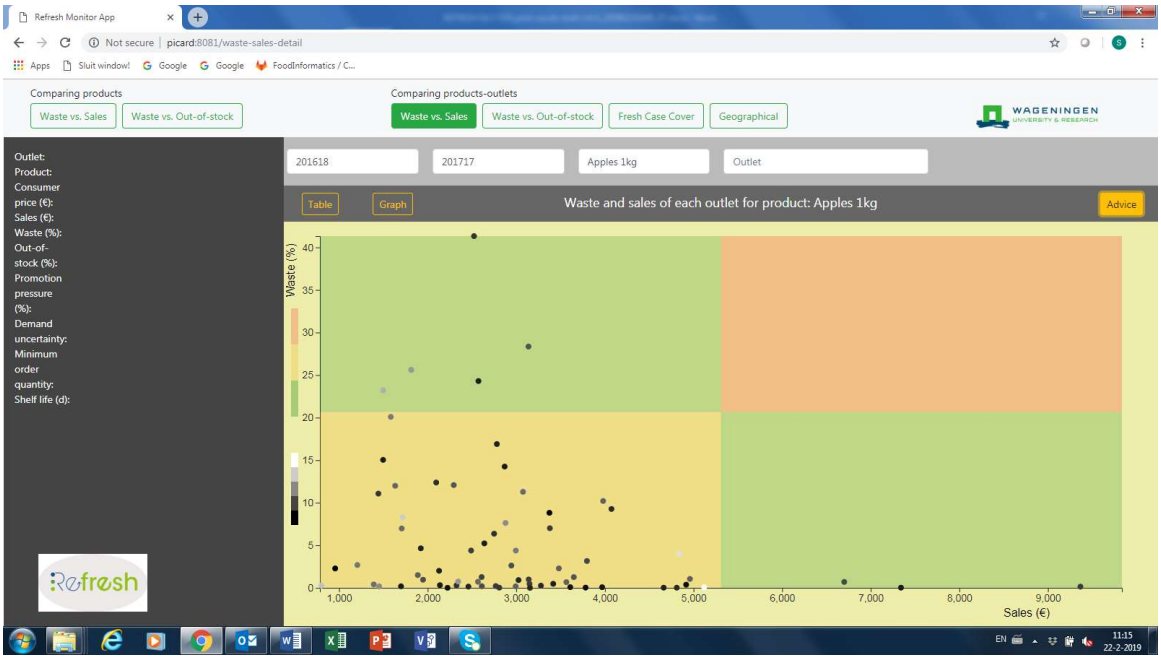

Figure 9: One product has been selected (Apples 1kg). Waste and sales of each outlet are visualized. Advice on waste prevention is provided

Moreover, Figure 9 gives the user the opportunity to compare outlets in pairs. For example, the user may be interested in comparing two outlets with similar sales (of the selected product) but with quite different waste percentages. By hovering over both dots, the screen on the left (Figure 10) is populated with relevant contextual data, besides sales and waste, of both selected outlets:

- Out-of-stock (%): the average out-of-stock percentage of the selected product-outlet combination during the selected period. If out-of-stock % is low the product availability is large. Waste can be reduced by lowering replenishment levels.
- Promotion pressure (%): the number of promotion weeks as a percentage of the total number of weeks during the selected period. If promotion pressure is large, probably waste can be reduced by lowering promotion pressure.
- Demand uncertainty: the sample standard deviation of the demand per opening day divided by the average demand per opening day. If demand uncertainty is large, consider demand forecasting, increasing order frequency and reducing lead times.
- Minimum order quantity: the average minimum order quantity during the selected time window, which commonly equals the case pack size. If the minimum order quantity equals one, the outlet selected can order single items of the selected product. If the minimum order quantity is too large this may cause food waste.
- Shelf life (d): The average shelf life in days of the selected product at the selected outlet. This number includes the day of replenishment and the day at which the product is wasted according the retailer's policy (commonly the product's expiry date). If the shelf life is too small this may cause food waste.

Note: Figure 11 about the so-called Fresh Case Cover provides dedicated advice on reducing the minimum order quantity and the shelf life as suitable means to reduce food waste at the retail outlet.

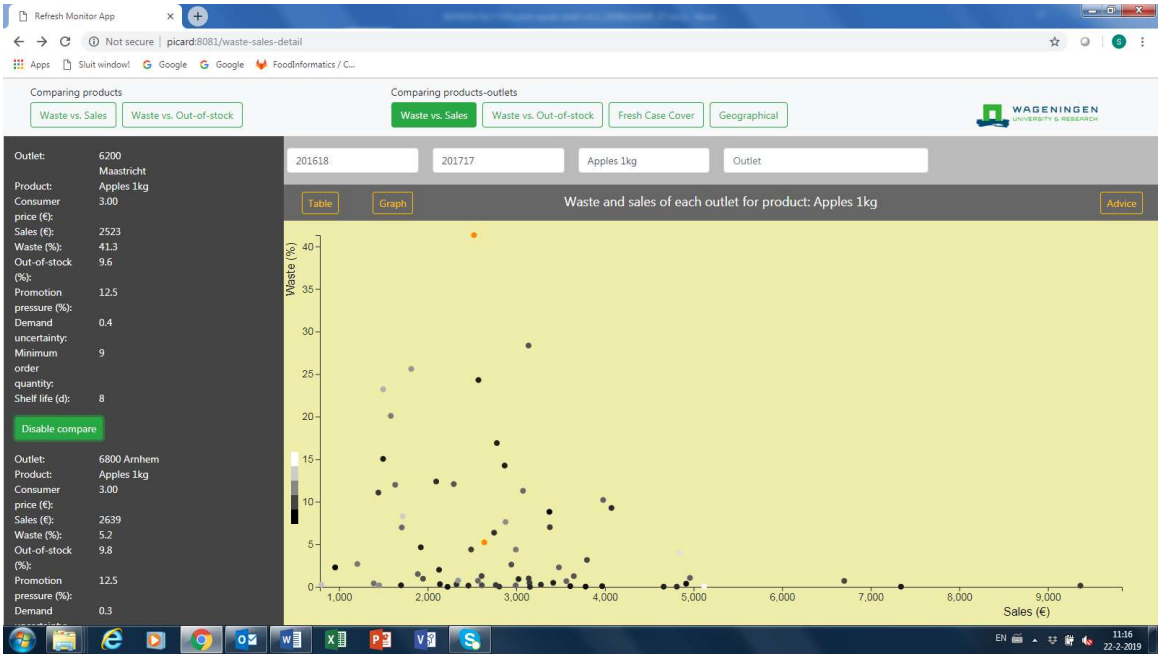

Figure 10: One product has been selected (Apples 1kg). Waste and sales of each outlet are visualized. Advice on waste prevention is provided. Two outlets are selected for comparison

Figure 11 visualizes waste vs. the Fresh Case Cover which is explained in Appendix 3: Fresh Case Cover. The Fresh Case Cover gives specific information on how the minimum order quantity and the shelf life effect product's waste at the retail outlet.

By pushing the 'Advice' button, the following explanations are provided:

- Outlets within one of the green rectangles: "A FCC value below 0.5 will only generate low waste levels."
- Outlets within the orange rectangle: "An FCC value between 0.5 and 1 will still generate moderate waste, because of turnover variability. Consider decreasing the minimum order quantity and/or increasing the product's shelf life for these outlets."
- Outlets within the red rectangle: "A FCC value >1 indicates that on average the minimum order quantity is too large compared to the product's shelf life and the product's daily turnover. High waste might occur. Consider decreasing the minimum order quantity and/or increasing the product's shelf life for these particular outlets."

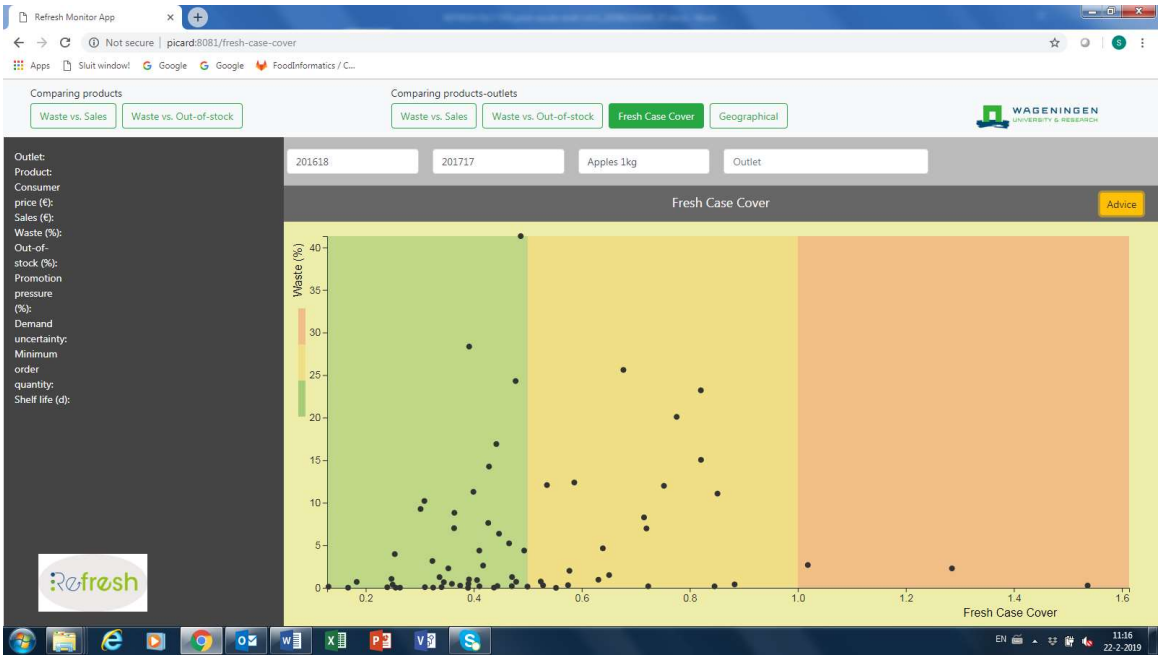

Figure 11: Fresh Case Cover analysis, with advice on waste prevention

Another way of analysing product-outlet combinations is by analysing them in time (historical data): for example, certain peaks in waste may coincide with deviations in sales, out-of-stock, promotion pressure, demand uncertainty, minimum order quantity and / or shelf life? To be able to answer this kind of questions, the following figure has been developed (Figure 12).

Note: a hairline is added to support the analysis of what occurs at a certain moment in time (week).

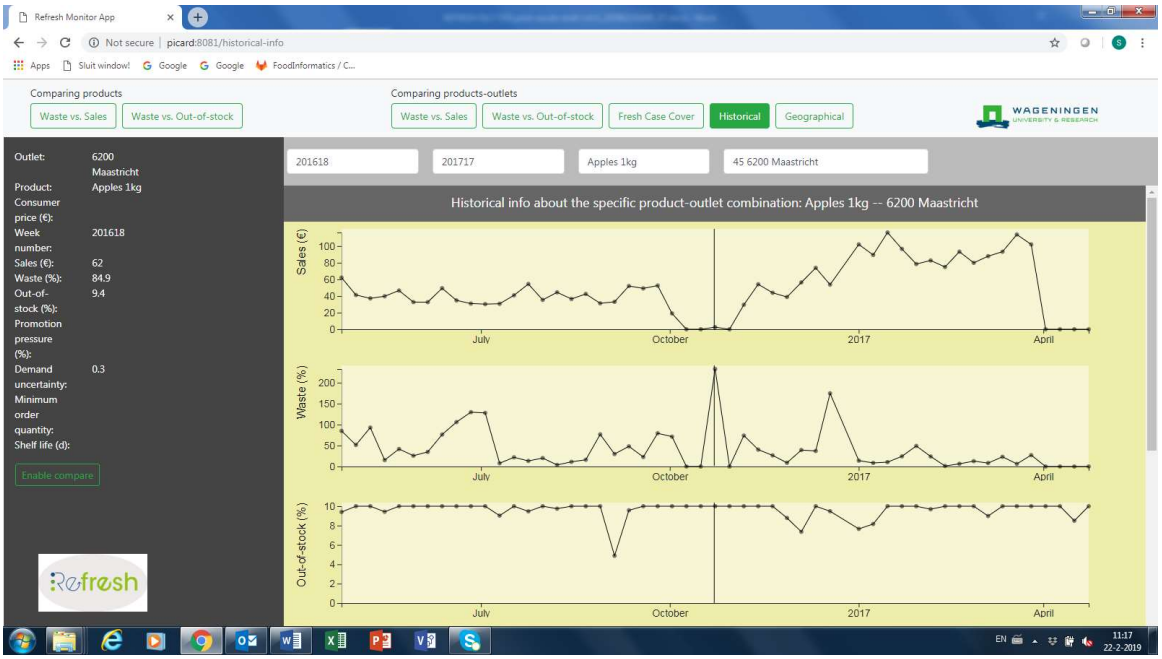

Figure 12: Historical analysis of product-outlet combination

Finally, the quantities wasted, sales and out-of-stock can be analysed geographically (Figure 13). In this way it is possible to analyse differences between urban and rural areas for example.

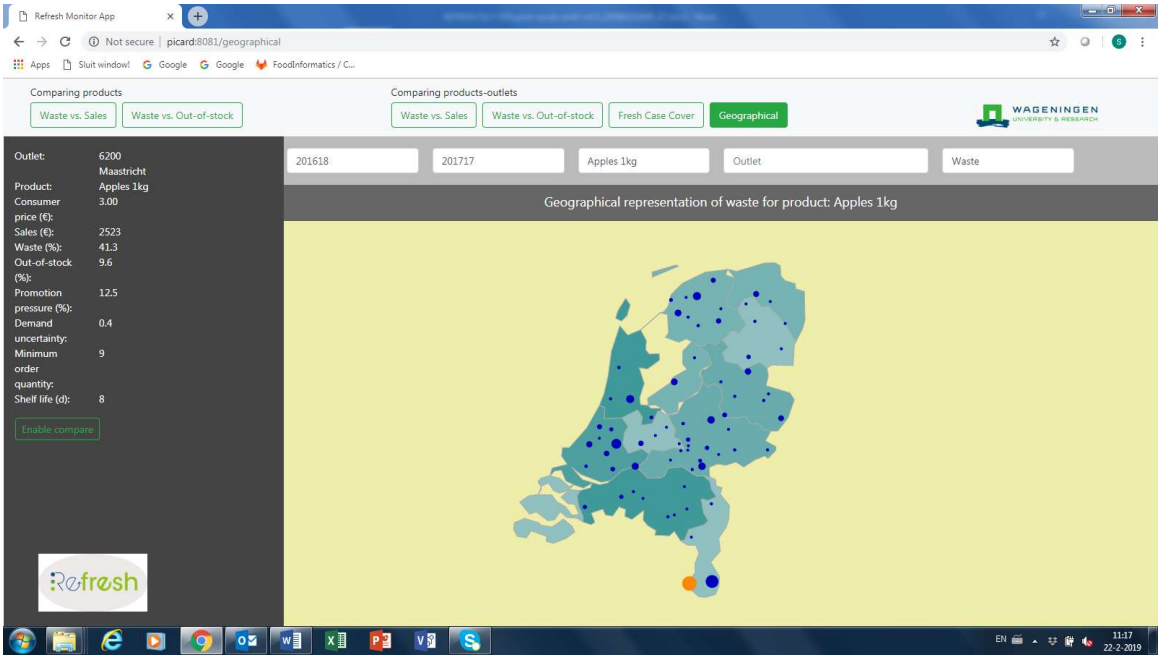

Figure 13: Geographical analysis of the selected product

3.3.2 Testing the prototype monitoring tool

The prototype monitoring tool can be found online (https://eu-refresh.org/). During development the prototype monitoring tool was connected to a real-size 'proxy database', which contained fictive data. When the prototype was finished, a testing process was performed by filling the database with real supermarket data (made available outside the REFRESH project). This testing process consisted of the following steps:

- Data collection: collecting the raw data;
- Data transformation: putting the raw, limited data in the right format as described in Appendix 2: Format input file;
- Data analysis: analysing the transformed data using the prototype monitoring tool.

Note that the testing process included the step of putting the collected data in the right format. In practice, data sets are commonly limited and/or in a different format. Therefore, data transformation is needed to obtain a data set in the right format.

Data collection

The raw data covered:

- Two products: Broccoli and Raspberries 125g
- 85 numbered outlets, not further specified

The following data were collected:

Raspberries 125g:

- Sales (€) per outlet per day for weeks 37-40 of 2017
- Waste (€) per outlet for weeks 27-52 of 2017
- Promotion weeks during weeks 27-52 of 2017
- Shelf life during weeks 27-52 of 2017
- Minimum order quantity during weeks 27-52 of 2017
- Consumer price during weeks 27-52 of 2017

Broccoli:

- Sales (€) per outlet per day during 4 November 2017 – 30 November 2017
- Waste (€) per outlet for weeks 14-40 of 2017
- Promotion weeks during weeks 14-40 of 2017
- Shelf life during weeks 14-40 of 2017
- Minimum order quantity during weeks 14-40 of 2017
- Consumer price during weeks 14-40 of 2017

Note that

- *the sales data are only available during a limited time-period compared to the rest of the data;*

- *the time periods of the available other than sales data differ between Raspberries 125g (weeks 27-52) and Broccoli (weeks 14-40);*
- *no data are available about out-of-stock and demand uncertainty.*

Data transformation

The dataset we used for testing shows that there is only limited sales data (i.e. limited number of weeks) available. To be able to use the sales data despite these limitations, for both products the following data transformation was done. First the average sales per week were calculated. Subsequently this average number was assumed (extrapolation) to be the input value for each week during the whole period of week 27-52 of 2017 (Raspberries 125g) and the whole period of week 14-40 of 2017 (Broccoli).

In this way a data file was achieved according to the data format specified in Appendix 2. Only out-of-stock and demand uncertainty data were not available, so these input sheets stayed empty.

Subsequently this data file was uploaded to the prototype monitoring tool.

Data analysis

The output of the prototype monitoring tool was compared to slides including excel-charts which were made before the prototype monitoring tool had been developed. For the product Raspberries 125g, the slides were the following (Figure 14, Figure 15, Figure 16). For the product Broccoli, the slides were similar (Figure 17, Figure 18, Figure 19).

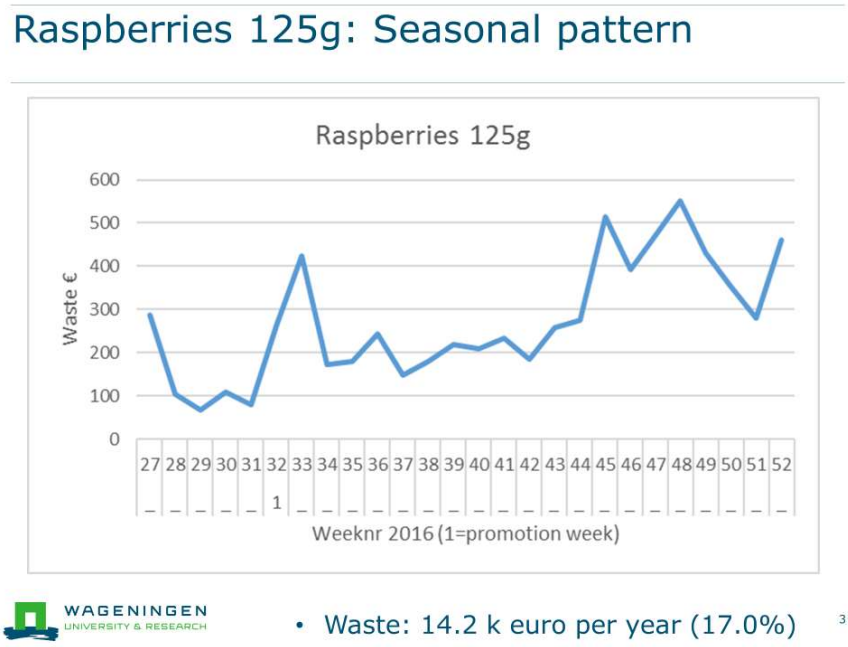

Figure 14: Seasonal pattern, Raspberries 125g

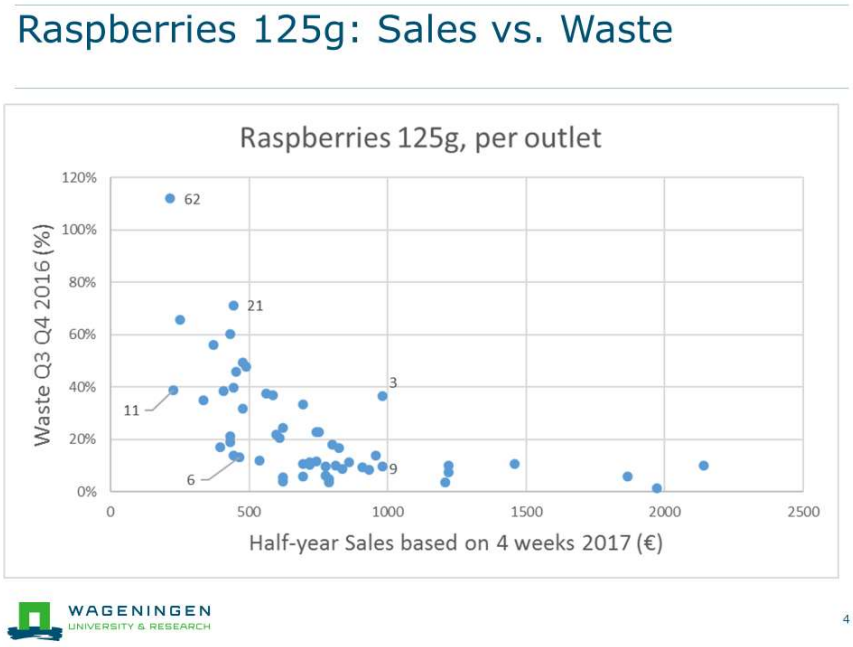

Figure 15: Sales versus Waste, Raspberries 125g

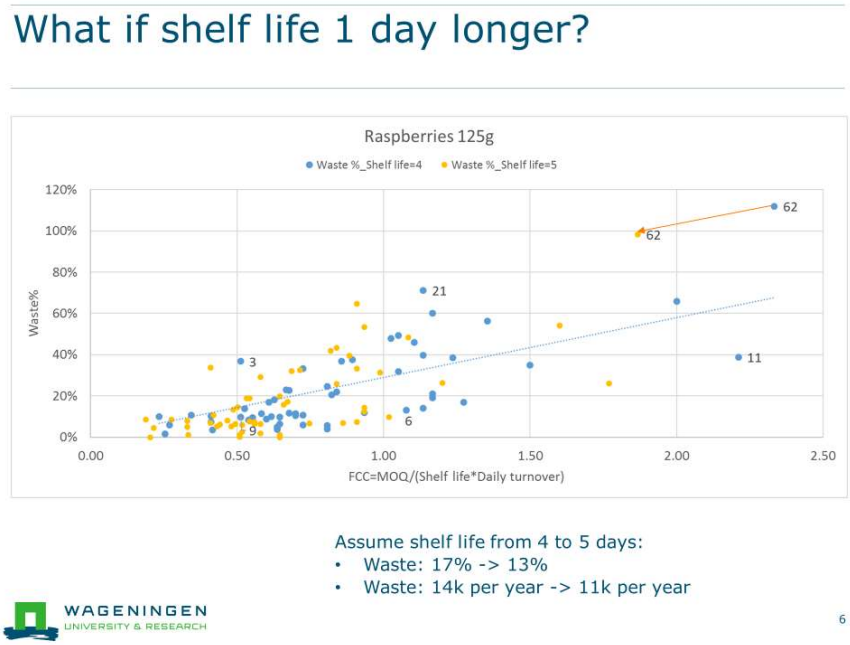

Figure 16: Fresh Case Cover, Raspberries 125g

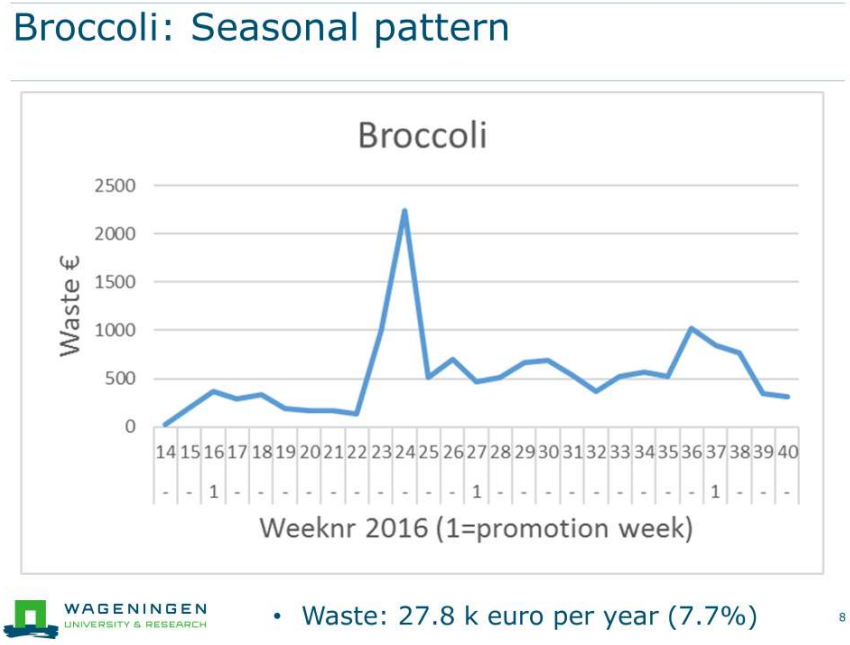

Figure 17: Seasonal pattern, Broccoli

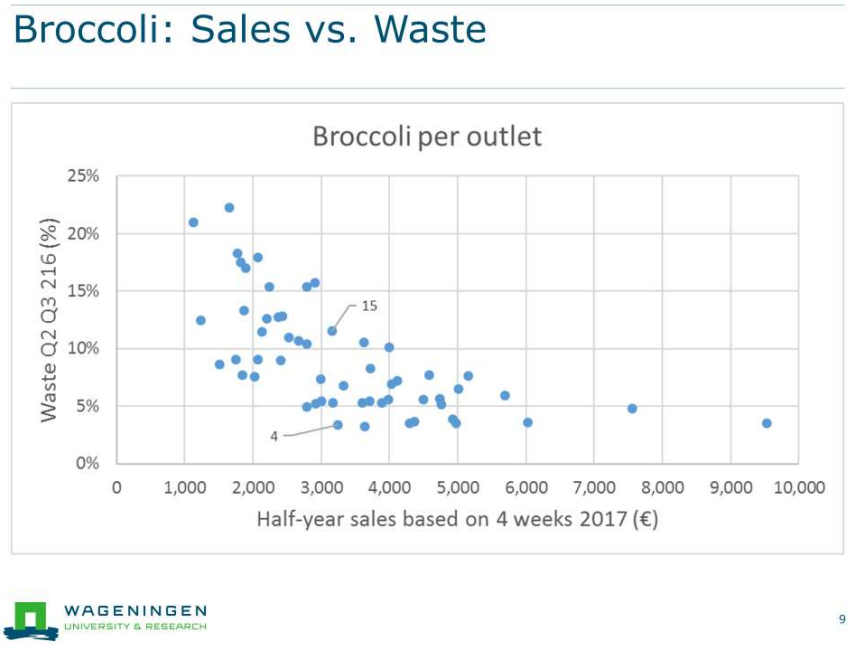

Figure 18: Sales versus Waste, Broccoli

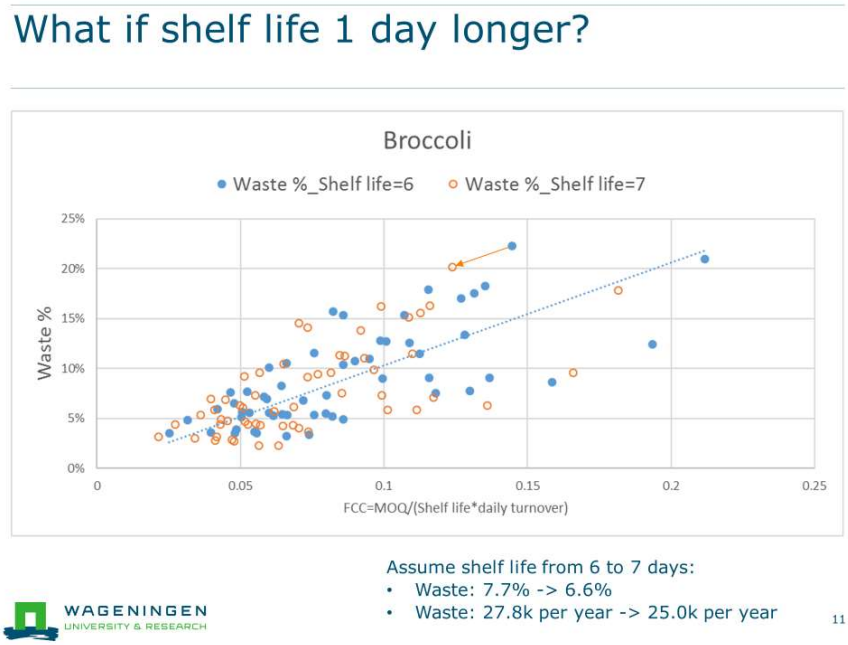

Figure 19: Fresh Case Cover, Broccoli

The prototype monitoring tool provides us with the following information (Figure 20). The values from Figure 20 more or less match with the values presented at Figure 14 and Figure 17, so for both Raspberries 125g and Broccoli. In the remainder of this section only the product Raspberries 125g. is being compared, because the stories are the same for both products.

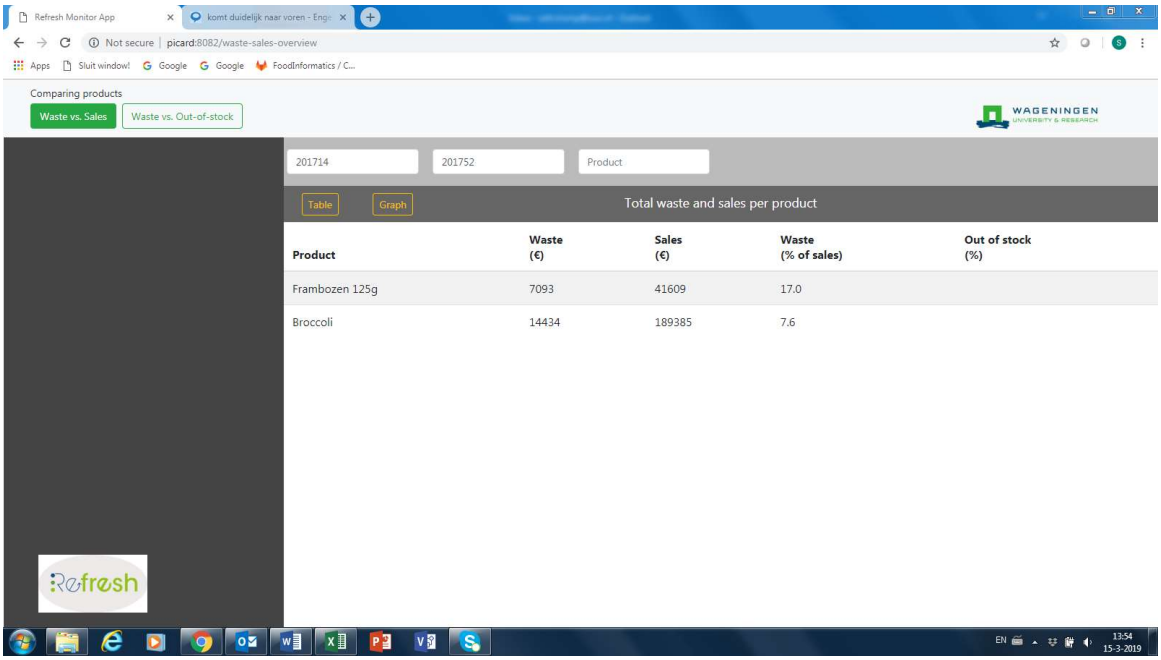

Figure 20: Table with aggregated data of each product

Compared to Figure 14, the prototype monitoring tool can present a seasonal pattern as well, but only at the level of an individual outlet (Figure 21). The prototype monitoring tool is not yet able to provide a seasonal pattern at an aggregated level, such as provided at Figure 14.

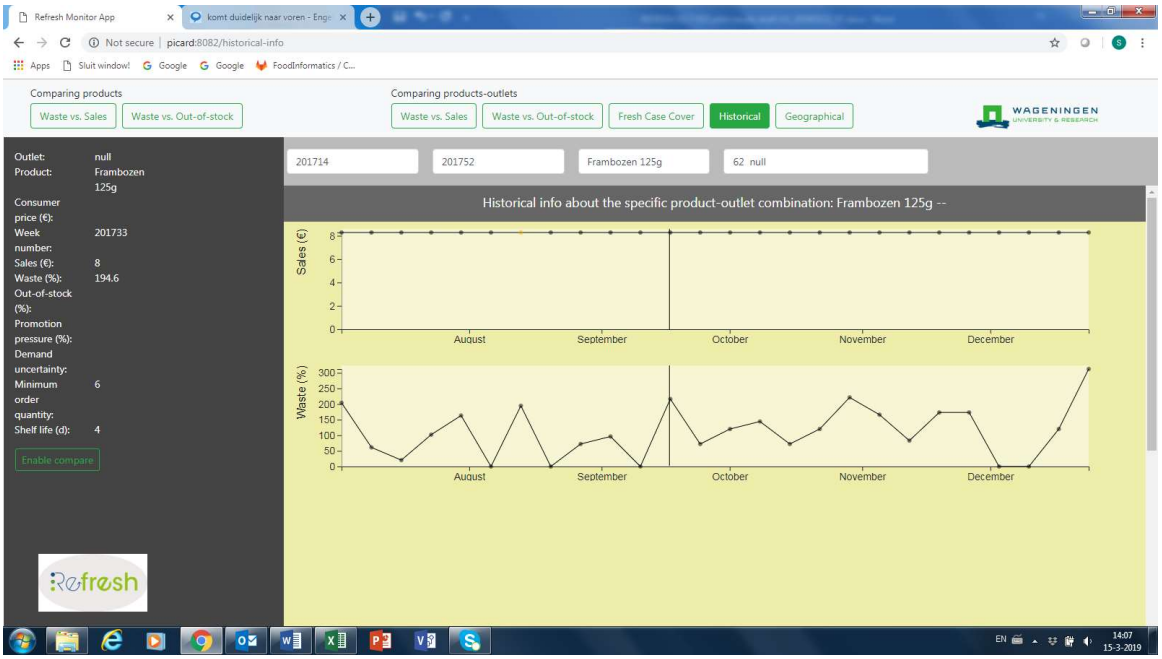

Figure 21: Historical analysis of product-outlet combination

For analysing waste versus sales, Figure 22 matches with Figure 15, and the prototype monitoring tool provides us with advice as well (Figure 23).

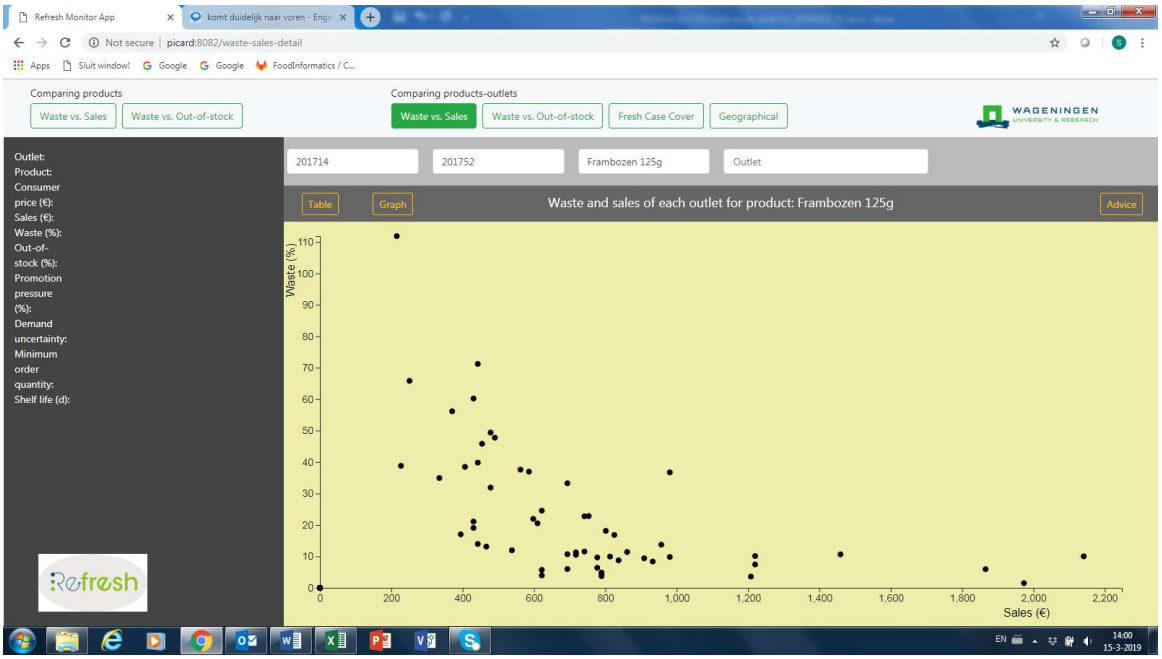

Figure 22: One product has been selected (in this case Raspberries 125g). Waste and sales of each outlet are visualized

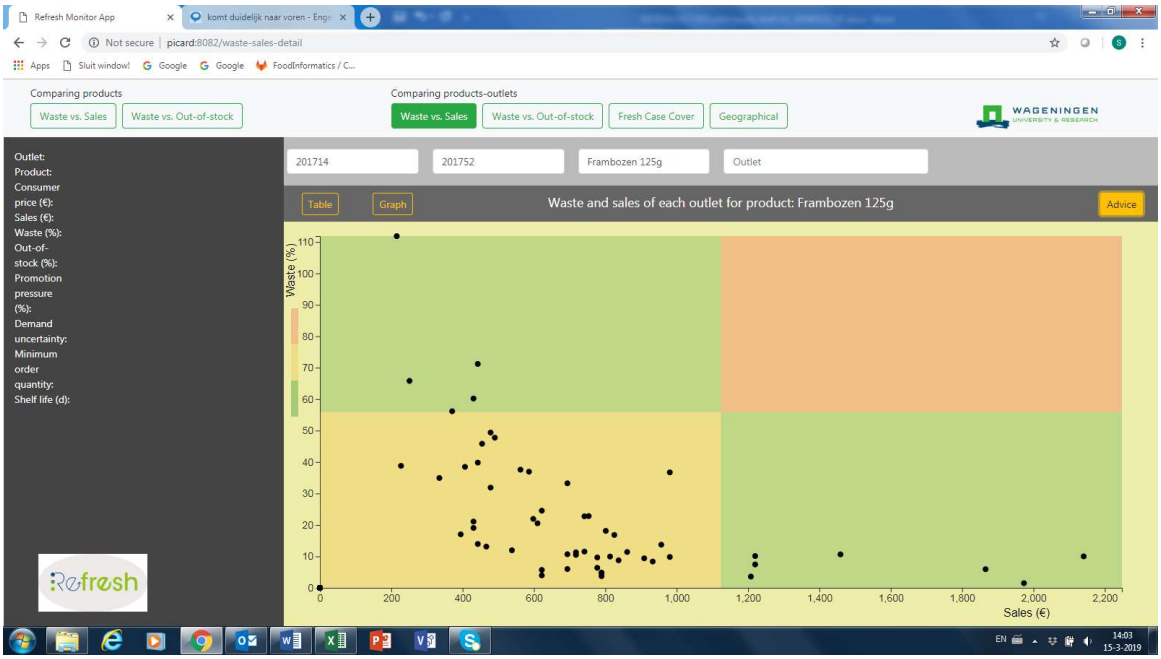

Figure 23: One product has been selected (Raspberries 125g). Waste and sales of each outlet are visualized. Advice on waste prevention is provided

Compared to Figure 16, the prototype monitoring tool can provide us only with an FCC analysis of the current situation, including an advice (Figure 24). The prototype monitoring tool is not able yet to analyse what-if questions such as presented at Figure 16.

Finally, the prototype monitoring tool can present the data geographically, which is an important advantage compared to excel. However, for both test products no geographical data were collected.

It is concluded that the prototype monitoring tool provides the user with almost the same information as formally generated with excel. The current prototype is not yet able to provide:

- historical information (seasonal patterns) at an aggregated level;
- what-if questions based on the FCC analysis.

However, the prototype monitoring tool provides the user with the following additional information which was not available when making charts with excel:

- comparison analysis;
- advice on interventions;
- selecting different time windows;
- historical information (seasonal patterns) on outlet level;
- geographical information;
- on-line monitoring (of for example a waste-reduction program).

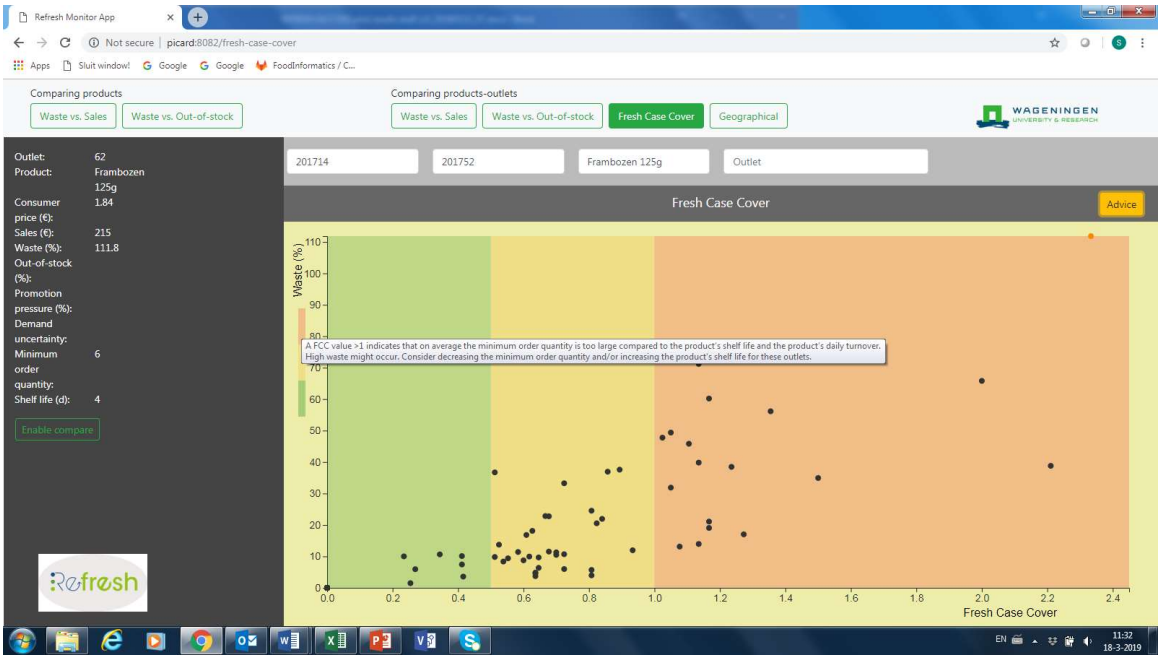

Figure 24: Fresh Case Cover analysis (with advice)

3.3.3 Further development of prototype monitoring tool

The following aspects are foreseen for future development of the prototype monitoring tool:

- Adding one analysis level at the beginning: the level of comparing product categories. Retailers commonly work with product categories: each product belongs to one category. After having added this level, the monitor starts by comparing categories instead of comparing products. After the user has selected a specific category of interest, the user can compare the different products belonging to this particular category.

  Adding this level would result in the following levels of analysis:

  - Comparing categories;
  - Comparing products;
  - Comparing outlets.
- Populating the database with data from different retailers simultaneously, rather than just one, such that benchmarking between retailers becomes possible. This benchmarking functionality can used in two ways. For the researcher this will be of interest by looking for example to causalities and generalisations. For this 'research functionality' the data and information will not be disclosed. The other individual researcher benchmarking can also be of interest and an option that could be built into the monitor were an individual retailer can view his data relative to the (anonymous) average.

- Integrating artificial intelligence into the monitoring system, such that the monitoring system gives certain 'waste alerts' which can be tailored to the requirements of the user.
- Going from a weekly level to a daily level. If so, it becomes possible to compare waste on Mondays with waste on Tuesdays for example.
- Adding ordering data (replenishment data) from the retail outlets to the database, such than it can be analysed if a certain waste peak is caused by a replenishment peak for example.

4 Turning insight into actions

With the prototype monitoring tool, a retailer can evaluate his performances in terms of waste. It shows where are the bottlenecks are e.g. for which products the most waste is produced. Moreover, it gives some indication to where possible improvements can be made (see chapter 3). In this chapter, we will look at several opportunities to reduce food waste at the retailer.

There are many root causes of food waste at retailers. In a study of Teller et al. (2018) experts are interviewed, which resulted in a list of eleven root causes. The main causes are related to demand patterns and in-store behaviour of consumers and the product shelf life. Therefore, we selected four different actions in this study to reduce the food waste of the retailer, all related to these root causes. The four different actions are tested in so-called theoretical pilots. These theoretical pilots consist of a simulation model which represents the studied actors (in most cases the retailer). By simulating the processes at a retailer, a good evaluation can be made of the effects of the proposed action. The data used as input for the simulation models is based on real data from practice.

4.1 Possible actions and their effect

The four actions to reduce food waste, which are tested within REFRESH, are:

- discounting nearly expired products;
- applying a dynamic shelf life;
- including substitution in replenishment strategy;
- donating leftover food to charity organizations.

The actions described below are described in more detail in the following scientific papers:

- Buisman, M.E., Haijema, R., Bloemhof-Ruwaard, J.M., 2017. Discounting and dynamic shelf life to reduce fresh food waste at retailers. International Journal of Production Economics. https://doi.org/10.1016/j.ijpe.2017.07.016
- Buisman, M.E., Haijema, R., Hendrix, E.M.T., Product substitution to increase profit and reduce food waste at retailers. Unpublished Work. Wageningen University.
- Buisman, M.E., Haijema, R., Akkerman, R., Bloemhof, J.M., 2019. Donation management for menu planning at soup kitchens. European Journal of Operations Research. 272, 324–338. https://doi.org/10.1016/j.ejor.2018.06.005.

For more in-depth information on the (simulation) models used, we refer to those papers.

4.1.1 Discounting nearly expired products

Perishable products by law have a use-by or a best-before date. This date is set by the producer and makes sure the consumer will consume a product that meets the

minimum quality requirements set by the producer and retailer and meets the food safety requirements in the end. However, as some consumers prefer "new/fresh" to "old/less fresh", this shelf life does trigger the purchase of products with the longest shelf life. Consumers who buy the products with the longest shelf life are purchasing according to the so-called Last-In-First-Out (LIFO) principle. From a waste perspective it would be more beneficial for a retailer if consumers purchased according to the First-In-First-Out (FIFO) principle, thus buying the products that will expire first. In this case, the probability increases that the retailer will sell the older products before they expire instead of having to discard them as waste at the end of the shelf life.

A way to stimulate consumers to purchase the older, nearly expired, products is to give a discount on those products. Consumers tend to be price sensitive and product quality influences their willingness to pay. Products close to expiration are perceived to be of less quality than the newer, fresher products. When retailers give a discount on the nearly expired products, the price sensitivity and the willingness to pay of consumers will make them more eager to purchase the products which are close to expiration.

Retailer

The effects of discounting close to expiration are tested for products with 5, 8 and 10 days of shelf life. From the moment the products are produced by a producer, the shelf life is set. The products are transported to a distribution centre (DC), from which they are further transported to a retail outlet. The retailer sells the products to the consumers, most of them with a normal price, but at the last day of the shelf life, a discount is given. It was assumed that the percentage of consumers changing from LIFO to FIFO purchasing, equals the discount percentage given. If a discount of 20% is applied, 20% of the LIFO customers will shift towards a FIFO purchase. A full range of discounting percentages was evaluated to see the impact on waste generation and profit levels.

Discounting products will not increase the profit levels, as too many products are sold at a lower price. Also, the larger the discounts, the greater the profit decrease is for the retailer. Both occur due to the assumption that the response rate of consumers equals the discount given. With low discount percentages, this causes hardly any consumers to shift, where at higher discount percentages most of the consumers shift, but the retailer will not make any profit on these products. The largest gains are in terms of waste. The reductions are significant, even at discounting percentages until 40%.

Moreover, notice that price-based substitution might occur when products are discounted. Besides consumers who decide to purchase the discounted product instead of the non-discounted product, there might be consumers purchasing the discounted product instead of a different product. This reduces the demand for those other products. As they are probably highly perishable as well, a reduced demand can cause extra waste for these products due to overstocking.

Supply chain perspective

From a chain perspective, discounting only affects the last two stages of the food supply chain, the retailer and the consumer. Buying the freshest item in the store allows the consumer to store the product at home for several days. Depending on

the shopping frequency of the consumer, this might be very convenient. If consumers buy products which are close to the expiration date, they will have to consume the products soon. As consumers might not always can do so, these products might still end up as waste.

4.1.2 Dynamic shelf life for highly perishable products

The best-before date on products is set by a fixed date. As explained in the previous section, this shelf life is set by the producer. The producer will estimate the shelf life of the product based on several parameters. One of the most important parameters is the chain temperature, but light exposure, moisture level and other factors all play a role in the quality reduction of perishable foods. The producer must estimate these factors to give a best-before or use-by date to the product. As there might be some variation along the supply chain and for accountability reasons, most producers tend to set the shelf life rather conservative. In this way the product might still be of good quality and safe to eat at, or even after the expiry date.

There is a downside to this conservative determination of the shelf life. When the product is stored and transported as it should be, or even better than expected, the product will still be of very good quality at the moment the shelf life ends. Thus, the product might still be suitable for consumption after the set date and good products will be thrown away. With a best-before/use-by date that is updated to the actual product quality and product safety, this can be prevented.

A shelf life that corresponds to the actual shelf life is called a "dynamic shelf life". There are several methods to measure or calculate the actual product quality. Sensors, which measure the gas composition of the products, can give an indication of the product quality (Heising 2014). Time Temperature Indicators can measure the temperature of the product, and with that information the quality can be estimated.

Retailer

By comparing waste and profit levels for a meat product with a fixed and dynamic shelf life, the benefits of applying a dynamic shelf life are evaluated. The dynamic shelf life is implemented by the means of a microbiological growth model, which predicts the quality of a meat product.

The results show that a dynamic shelf life can significantly reduce food waste at the retailer. Products with a dynamic shelf life have, on average, a longer shelf life than the one given by the producer. Because the shelf life is now directly linked to the actual product quality, there is no need to build in some safety margin to ensure a good quality product for the consumers. As a result, there is an extra day to sell the product.

Moreover, the effects of implementing a dynamic shelf life are larger when the shelf life of products is shorter. The waste reductions obtained for products with a shelf life of approximately 5 days are higher than for the products with an average 10 days. In addition, due to the reduction in food waste, the average profit levels of the retailer will increase. However, potential costs for implementing a dynamic shelf life are not incorporated in the analysis. The average profit increase found within the theoretical pilot is €0.04 per product. If the costs for a sensor are at or below

this price, the retailer's profit does not decrease by implementing a dynamic shelf life.

Supply chain perspective

Although there is huge potential from using a dynamic shelf life, it is currently not allowed due to EU legislation. Likewise, consumers might need some time to accept this new way of setting the shelf life of a product, when implemented.

Implementing a dynamic shelf life requires changes at the producer as well. A sensor to measure or calculate the shelf life needs to be added after producing the product, preferably as soon as possible.

4.1.3 Include substitution in replenishment strategy

Retailers must decide for every product they sell how many products they want to have in stock. The stock levels are often determined by a forecast of demand, and some safety stock, to cope with an unexpected increase in demand. However, demand can also be lower than expected, which results in many products left at the end of the day. Leftover non-perishable products can still be sold in the next days, but for (highly) perishable products this is not always possible. As retailers try to avoid stock outs, the safety stocks can cause quite a lot of waste. However, when products are not available, consumers might purchase a different product that serves as a substitute for the non-available product. This substitution behaviour of consumers is usually present in supermarkets, especially for highly perishable products (Van Woensel et al. 2007).

Therefore, a way to reduce food waste at the retailer is to include the expected substitution behaviour of consumers into replenishment decisions. This will cause a reduction in the safety stock of particular products. The safety stock of a specific product can be reduced as the variation in the demand for that product can be fulfilled by another product, which is still available.

Retailer

The theoretical pilot in which we tested the inclusion of substitution for the retailer, describes two perishable products. One of the products is a substitute of the other product. To find the optimal stock level of these two products, the profit for both products combined is optimized. Besides maximizing the profit, we also monitored the service level, i.e. the fill-rate.

The results show possibilities to decrease the waste levels for both products, while increasing the profit levels. When the fraction of consumers willing to substitute increases, waste reductions become larger. When the willingness to substitute is very high, it can be beneficial for the retailer to only stock the product that serves as a substitute, meaning the demand of the two products is combined and the relative variety will decrease. This means products in stock are sold more often and do not have to be discarded at the end of their life time. However, by not having the original product in stock, the consumer will always have to buy the substitute. This can cause consumers to switch store in the long run, and thus a loss of demand for the retailer.

Even when the retailer still wants to stock both products, a reduction in waste can be obtained. Figure 25 shows that there is a clear trade-off between the obtained

waste levels and the obtained service levels for individual products. However, with service levels around 80-90%, waste percentages are still low, and profit levels are good.

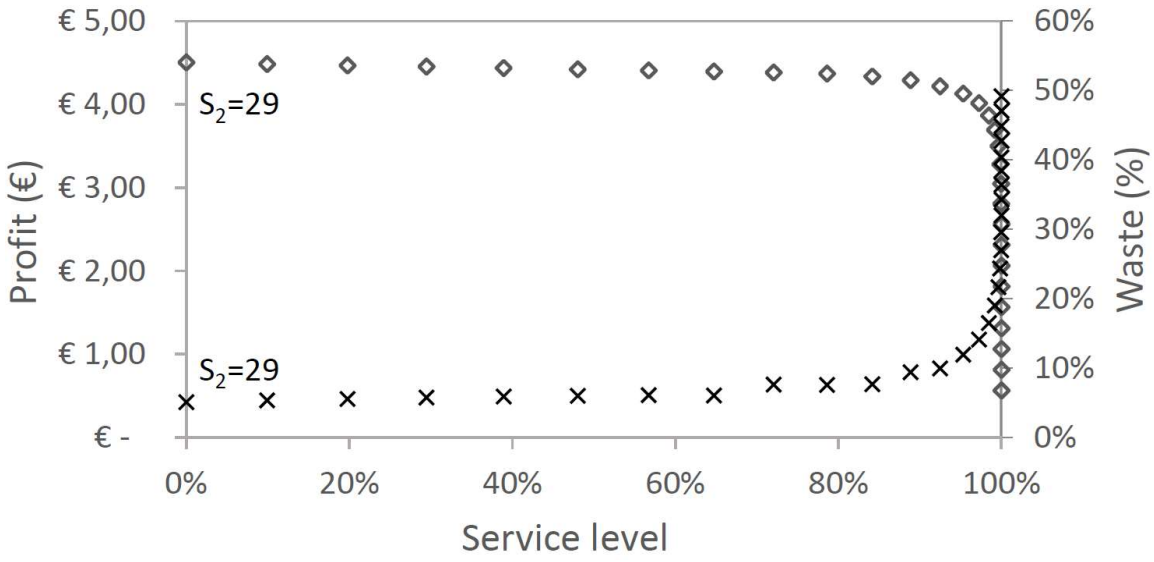

Figure 25 Trade-off between service level, waste (x) and profit (◊).

Moreover, incorporating substitution in the replenishment policy does affect the profit and waste levels when the shelf life of the product is between 1 and 4 days. With a longer shelf life the effect reduces significantly. As products with a short shelf life can only be sold for a few days, it is harder to have the right amount in stock.

Mostly retailers are not keen to reduce the number of products in stock, and risk a stock out, due to losing the consumers to the competitor. However, by informing the consumer on the reason why products are not available, they might be more open to choosing another product. For example, the retailer could suggest which products to buy in case of a stock-out, which enables the retailer to direct the consumer towards certain products.

4.1.4 Donation of leftovers to charity

Due to the demand variety, food waste at a retailer will never be reduced to zero. Another action was evaluated in which leftover food is re-used in soup kitchens. Soup kitchens are organizations providing meals for those on a tight budget, and therefore not always able to provide themselves with enough to eat. As the clients of soup kitchens can be highly dependent on the provided meals, the soup kitchen ideally provides nutritious and appetizing meals. Soup kitchens usually deal with small budgets, so they are very happy with the possibility of receiving leftover food from supermarkets. However, the main question is whether such donations are always suitable and can be used or not. If donations arrive at soup kitchens but cannot be used, the leftovers will still become food waste.

Soup kitchen

To determine the quantities and which donations can be used by soup kitchens, a menu-planning model was developed. A menu-planning model composes a meal based on the available ingredients (i.e. the leftover food that was donated) and the possibility to buy extra ingredients. By offering varying menus, the meals provided by the soup kitchen can be both appealing and healthy. in addition to the development of the menu-planning model, different quantities of food donations are evaluated.

Results of the study show the benefits of receiving food donations to a soup kitchen. Overall costs are reduced for the soup kitchen, which allows for serving more clients for the same costs compared to a situation where no food is donated. In addition, the donation of food products allows greater variety between the meals served. The optimization in the menu-planning model is based on a cost minimization, and thus the cheapest recipes will be selected, which are fulfilling the restrictions set on reusing similar recipes within a week.

Donations to the soup kitchen should align with the number of meals they provide on a daily basis. When donations quantities are too large, these cannot be used in time, whereas at the other end of the scale, very small donations are difficult to incorporate into meals. Likewise, the remaining shelf life of the donations is important; when the shelf life is long enough, donated food items may be used later in the week, rather than just on the day of donation. This will give much more flexibility to use all the donations, and thus less products will be wasted. Soup kitchens benefit more when the donated items are the more expensive items such as meat products.

Supply chain perspective

The optimal use of leftover food is highly dependent on the remaining shelf life of the donated products. When donations are on the last day of shelf life, it is difficult for a soup kitchen to fit them into the meals. Depending on the strategy of the retailer, products might be removed from the shelf before the end of shelf life. Some retailers assure at least 2 days of shelf life for the consumer, and thus remove products with less than 2 days of shelf life. Retailers also tend to deliver consumers very fresh products which they can still consume for several days. In these situations, products that are removed from the shelves, are still suitable for consumption and can easily be used by organizations such as soup kitchens or food banks. The ideal situation would be an agreement between the retailer and the charity organization where a more structured collaboration can be formed.

4.2 From insight to actions

The evaluated actions are all showing great potential to reduce food waste at the retailer. As already stated, demand patterns, in-store consumer behaviour and the product shelf life are main root causes of waste at the retailer. By applying a discount to products which are close to the expiration date, a retailer can influence the in-store behaviour of the consumer. More consumers might buy the 'older' products, and this will cause a waste reduction at the retailer. The incorporation of substitution behaviour in the replenishment decisions of the retailer also relates to in-store consumer behaviour and demand patterns. It is shown that consumers do substitute (e.g. Gruen et al. 2002), thus it would be a natural inclusion in the replenishment strategy of the retailer. This will improve both the product availability, and the waste levels at the retailer. The other two actions evaluated are

more related to the shelf life of the product. By implementing a dynamic shelf life, the shelf life will be estimated more accurately and will be longer compared to a fixed shelf life. This gives the retailer in most cases more time to sell the products. Products that cannot be sold in time, might be donated to charity organisations, however they should be still suitable for consumption.

In the previous section, the actions tested are all evaluated by theoretical pilots. Theoretical pilots allow for in-depth investigations where the factors which influence the retailer's performances can be controlled. Sales at retailers are for example influenced by weather conditions, which can be excluded in a theoretical pilot. In addition, a pilot allows for innovative ideas to be analysed which can show the retailer the potential benefits of these ideas without immediately implementing it (at a cost to the retailer). Retailers might be reserved towards innovative actions, and an evaluation in a theoretical pilot can convince them of the benefits of implementing the action.

After a theoretical evaluation of the actions, it is recommended these are implemented on a pilot scale, to demonstrate the actual improvements that can be made at a specific retailer. For this, the waste monitor described in Section 3 can be of great help. A base line can be found by the waste monitor before any action is implemented. After the implementation of the action, the waste monitor can show the improvements at the retailer. Moreover, as the input data for the waste monitor is like the type of input data of the models used for the theoretical pilots, the models can be improved by the data of the waste monitor. By comparing the performances of the retailer before and after implementing the action, the models can be updated to better represent reality. Furthermore, the outcomes of the waste monitor might give indications for other possible actions to test with a theoretical pilot.

5 Potential for a food waste monitoring tool

The potential for a food waste monitoring tool is threefold:

1. From monitoring to analysis:
    a. Data mining
    b. Calculations
2. Extension of scope:
    a. Value chain / supply chain
    b. valorisation
3. Benchmarking

From monitoring to analysis

Data mining

The prototype monitoring tool as developed presents the existing data in such a way that these data become information. The prototype monitoring tool not only presents the data in an 'intelligent' way. The tool facilitates the comparison of food waste of different actors (e.g. stores or departments), or against a benchmark or target. It allows to set Pareto curves towards and to analysis causes of food waste through data mining is. Further as a diagnostic, instrument it also adds 'advice' (i.e. indicating particular ways of preventing food waste).

When more data is added to the database more complex analysis could be done, i.e. data mining. Data mining is the process of discovering patterns in large data sets. For methods like machine learning and statistics database-oriented systems are used. To use this potential the usage of (commercial) available software (see 3.1.3) could be considered.

Calculations

From the report 'Gap analysis for decision support tools, models and libraries' (Wigham, 2018) we learn that two calculations are considered to be useful by the potential users:

- Estimate the carbon impacts of, and carbon offsets achieved, through food redistribution and how this differs within and between product categories;
- Wider costs of food waste reduction for a business i.e. procurement, labour, water, energy.

Based on the available data in the information system it is relative easy to calculate the carbon effects of wasting these products. Extra data that is needed is the 'carbon footprint' of each product and the used packaging. The same holds for the 'wider cost'. For each product data could be added related to de product-based-cost of procurement, labour, water, energy, et cetera.

Extension of scope

Value chain / supply chain

From the report 'Gap analysis for decision support tools, models and libraries' (Wigham, 2018) we also learn that warehouse/chill house and logistics are the gaps in the food supply chain that are currently not covered in the available tools. The prototype monitoring tool has been developed for the usage within one stage of the supply chain, i.e. the food retailer (at central or decentral level). Supply chain stages more upstream, for example distribution centres, warehouses, chill houses and even processing companies or farmers could also be included.

The potential is twofold. Firstly, the monitoring tool can also be used within one stage of the supply chain to get company specific information other than for the retailer. Information for the producer, the distribution centre, transporter et cetera will then be available. Secondly the monitoring tool can be used to monitor the total supply chain which gives the opportunity to analyse relations and effects between different stages within the supply chain. In this case, aspects like the willingness to share data, alignment of definitions and measuring systems, et cetera should be addressed.

Valorisation

The monitoring tool gives insight in when which product is wasted where. It also indicates ways of food waste prevention. Valorisation analysis of the wasted food is not part of the existing prototype. But this could, as a first step, be realised by 'connecting' tools. For example, the top 10 of foodstuffs wasted according to the monitoring tool (based on volume) could be used as input for the REFRESH decision making support tool for using former foodstuffs as farm animal feed (https://eu-refresh.org/animal-feed-tool). In this way the retailer gets insight in the possibilities of valorisation for animal feed. Moreover, WRAP created a step-by-step mapping tool for food and drink manufacturers to map out the wastes and by-products generated through the manufacturing process, identify which are unavoidable, and prioritise those that could have greater value to the business. (http://www.wrap.org.uk/content/getting-more-value-food-and-drink-products-and-wastes?_ga=2.110687493.1837941448.1548332895-1665633419.1548332895).
The Valorisation business case toolkit (http://www.wrapcymru.org.uk/register-download-valorisation-business-case-toolkit) could be connected by using the output of the monitoring tool as input for the above mentioned toolkits.

Benchmarking

The prototype monitoring tool developed in this task can be used as a stand-alone application and as a web-based tool. As a stand-alone application it runs on a single computer or in a specific company without connection to a central system or database. As a web-based tool this connection and central database is one of the key aspects of the tool. By, for example, centralising the input data from several retailers the possibility is created to compare their own performance with the average of the sector (see also paragraph 3.3.3).

6 Conclusions

The GAP analysis (Wigham, M., Tromp, S., Wilson, J., and Bygrave, K. 2018) showed that a large opportunity lies within food businesses that will utilise a decision support tool that is indicative and that can be used to drive insight in the right direction towards food waste reduction. The developed prototype monitoring tool does just that. For the retailer who holds a unique and 'controlling' position in the food supply chain a tool is developed that can provide the needed insight based on the data that retailers nowadays are expected to be able to register with the right IT-infrastructure. This prototype is developed in such a way that it can be used both online and offline and all the requirements are provided that a retailer can build the functionalities fit to their own software (for example their in-house ERP system).

The prototype monitoring tool also provides ways of reducing food waste based on the insights gathered through the monitor. The theoretical pilots give insight in potential prevention scenarios that cannot be obtained from the monitor. Theoretical pilots allow in-depth investigations where the factors, which influence the retailer's performance can be controlled. These theoretical pilots showed that food waste prevention via discounting nearly expired products, applying dynamic shelf life and including substitution behaviour in their replenishment policy are relevant actions to further explore in a real-life pilot. Rather than controlling inventory levels for individual products, food waste can be saved by controlling stock levels ate the group level next to the individual product level. Retailers might be reserved towards innovative actions, and an evaluation in a theoretical pilot can give them the convincement needed to implement the action. The models developed as part of the theoretical pilots include for retailer's relevant performance measures, like such as profits and service level (product availability), next to waste levels. After implementation the retailer can see the actual improvements via the monitoring tool.

6.1 Possible contribution to policy

Self-monitoring

The prototype monitoring tool is based on the data that retailers nowadays are expected to be able to register with the right IT-infrastructure. Therefore, the monitoring tool, if implemented at all retailers, also could also function as a self-monitoring tool which presents all the food waste data in a generic and standard format. If the monitoring tool also would fit supply chain stages more upstream, for example distribution centres, warehouses, chill houses and even processing companies or farmers self-monitoring could be extended throughout the supply chain.

Legal obligation to donate unsold food

In several countries (e.g. France) a law is introduced which forces large retailers to donate excess food products to charity organisations and forbids them to waste food. The idea is being mooted to introduce similar laws in other European countries to re-use leftover food and reduce the amount of food waste obtained at retailers. The theoretical pilot "Donation of leftovers to charity" not only shows the large benefit of food donations for charity like soup kitchens related to cost. It also

shows that donating perishable products with 1 or 2 days of remaining shelf life increases the possibility to maximise the usability of the donations.

Best-before and Use-by dates

The theoretical pilot "Dynamic shelf life for highly perishable products" shows the impact of shelf life, and how the consumer responds to that, on food waste at the retailer. Knowing that the use-by date on food is about safety and "best-before" dates are about quality (i.e. not safety) trying to get at least the best-before as realistic as possible taking the supply chain conditions (time, temperature) and the consumer stage (time-temperature profile during transport and storage in the refrigerator) into account. Because of the strongly fluctuating situations efforts could be set on dynamic best-before dates (sensor / time-temperature indicators, product liability, ...)

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Appendix 1: Requirements document

This requirements document covers a food-waste information system for retailers (Figure 26). The idea is to develop a database and fill this database with data that a retailer should nowadays be able to register with the right IT-infrastructure (food-waste data and contextual data). Subsequently, we will develop a working prototype information system, i.e. a dedicated environment in which the category manager can visualize these data, to monitor the progress of his food-waste improvement program. Moreover, the system presents the data in such a way that ways of waste reduction are suggested.

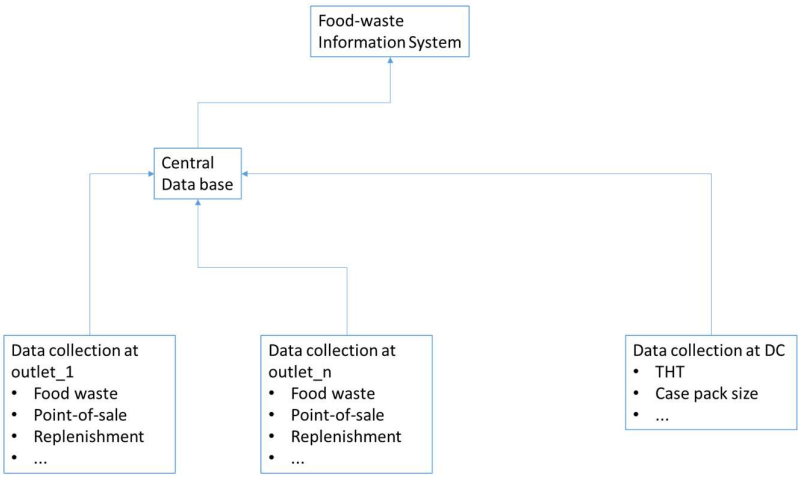


Figure 26: Food-waste information system for retailers

The envisioned user of the food-waste monitor is someone at the retailer's head office, e.g. a category manager or a sustainability manager. The envisioned application is a desktop application, although tablet or mobile applications are kept in mind during the development process. The envisioned application is filled with data of only one retail organisation with all the relevant products and all the relevant stores. Relevant products are perishable food products (i.e. fruit, vegetables, meat, cheese, ...), preferably provided with a date label.

Although the envisioned user is at the head office level, the waste monitor might be the basis of a local application as well, for example for store managers or regional managers. For the time being we assume as a user someone at the retailer's head office who is interested in food waste at the retail outlets.

Appendix 1: Requirements

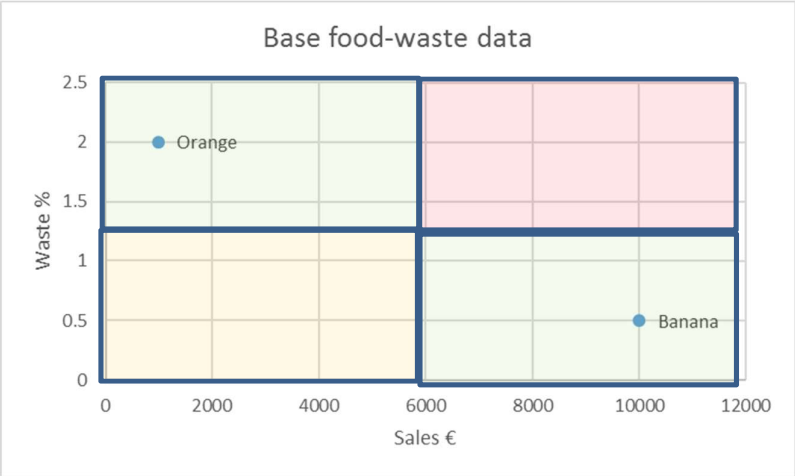
1.1 Screen 1: Product-level food-waste data_table

Screen 1: Product-level food-waste data_table

Product	**Waste (€)**	**Sales (€)**	**Waste (% of sales)**		Out-of-stock (%)	**Select Period**
Orange	20	1000	2.0		2	April 2018
Banana	50	10000	0.5		7.1	
…	…	…	…			

This screen provides the user with basic data. The user selects a certain historical time-period, for example the last month or last year. Subsequently, the total food waste (summed up for all outlets) of each product is reported, both as a percentage of the sales, and in euro's. Moreover, the total sales of each product during this period is reported in euro's, and the average out-of-stock as well. Notice that these data cover aggregated data, added up for all retail outlets under consideration.

1.2 Screen 2: Base waste-sales data_graph



Screen 2: Base waste-sales data_graph

One liner: Total performance per product

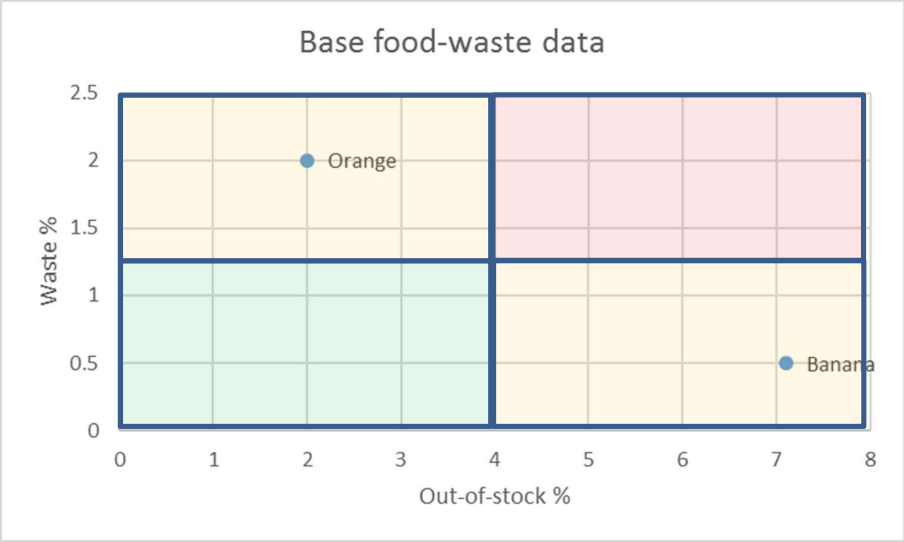
Explanation: Each dot covers a particular product. Total waste and sales of each product are visualized (summed up for all outlets). By clicking on a dot, one particular product is selected for further analysis.

This screen visualizes waste vs. sales.

- Each dot is provided with a product-name label.
- By hovering a dot (a product), the following information appears on the left of the screen:
  - Product: <product name>
  - Consumer price: <consumer price>
  - Sales (€): <total sales (€) of all outlets during selected period>
  - Waste %: <total food waste of all outlets as percentage of sales, during selected period>
  - Out-of-stock (%): <average out-of-stock percentage of all outlets during selected period.> Show the following message: "If out-of-stock is low, probably waste can be reduced by lowering replenishment levels"
  - Promotion pressure (%): <number of promotion weeks as percentage of total number of weeks, during selected period>. Show the following message: "If promotion pressure is large, probably waste can be reduced by doing less promotions."
  - Demand uncertainty: <average demand uncertainty of all outlets during selected period>. Show the following message: "If demand uncertainty is large, consider demand forecasting, increasing order frequency or reducing lead times."
  - Minimum order quantity: <average minimum order quantity during selected period>. Show the following message: "If MOQ is large, probably waste can be reduced by decreasing the MOQ."

    - Shelf life (d): <average shelf life during selected period> Show the following message: "If shelf life is large, probably waste can be reduced by increasing the shelf life."
- Two different dots (products) can be compared, by selecting two dots and by showing the information from above of both dots (products) simultaneously.
- The coloured rectangles appear via an advice button.
- The coloured rectangles are based on the middles of the two axes, where the length of these axis is determined by the minimum and maximum value.
- By hovering the red rectangle, the following text appears: "Products with large sales, but with a large waste percentage as well. Give high priority to waste reduction. Analyse out-of-stock, promotion pressure, demand uncertainty, minimum order quantity and shelf life. Click on a specific product for further analysis."
- By hovering the orange rectangle, the following text appears: "Products with small to moderate sales. Waste percentage is lower than might be expected. Check out-of-stock. Click on a specific product for further analysis."
- By hovering each of the green rectangles, the following text appears: "Products with waste percentages that fit with sales levels. However, waste differences between outlets may exist. Click on a specific product for further analysis."
- The colour of each dot is on a grey scale, dependent on the out-of-stock percentage. In order to achieve this, the out-of-stock percentages are normalized (max out of stock = 1, min out of stock =0). Subsequently each dot is coloured as follows:
    - $0 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 10% grey
    - $0.1 \leq$ Normalized out-of-stock percentage < 0.2: dot is coloured 20% grey
    - $0.2 \leq$ Normalized out-of-stock percentage < 0.3: dot is coloured 30% grey
    - $0.3 \leq$ Normalized out-of-stock percentage < 0.4: dot is coloured 40% grey
    - $0.4 \leq$ Normalized out-of-stock percentage < 0.5: dot is coloured 50% grey
    - $0.5 \leq$ Normalized out-of-stock percentage < 0.6: dot is coloured 60% grey
    - $0.6 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 70% grey
    - $0.7 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 80% grey
    - $0.8 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 90% grey
    - $0.9 \leq$ Normalized out-of-stock percentage ≤ 1: dot is coloured black

1.3 Screen 3: Base waste-out-of-stock data_graph



Screen 3: Base waste-out-of-stock data_graph

One liner: Total waste and average out-of-stock of each product

Explanation: Each dot covers a particular product. The total waste (summed up for all outlets) of each product is visualized and the average out-of-stock as well (average of all outlets). By clicking on a dot, one particular product is selected for further analysis.

This screen visualizes waste vs. out-of-stock.

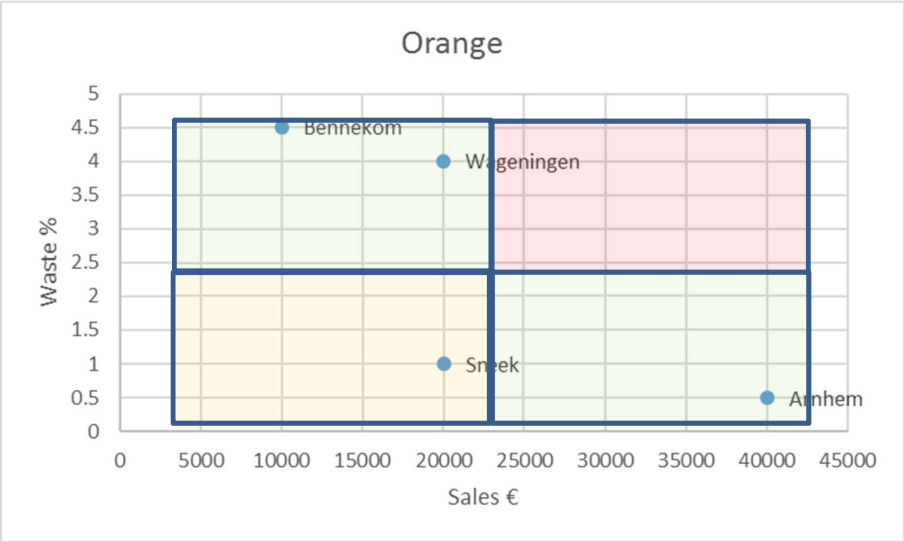
- The coloured rectangles appear via an advice button.
- The coloured rectangles are based on the middles of the two axes, where the length of these axis is determined by the minimum and maximum value.
- By hovering the red rectangle, the following text appears: "Products with high out-of-stock and high waste. Analyse the replenishment policy or consider remediation."
- By hovering an orange rectangle, the following text appears: "Products with either high out-of-stock or high waste. Consider the exchange between out-of-stock and waste by adjusting the replenishment level."
- By hovering the green rectangle, the following text appears: "Products with low out-of-stock and waste."

1.4 Screen 4: Product-outlet-level food-waste data_table

Screen 4: Product-outlet-level food-waste data_table

Outlet	**Waste (€)**	**Sales (€)**	**Waste (% of sales)**		Out-of-stock (%)	**Select Period**
Wageningen	800	20000	4		1	April 2018
Sneek	…	…	…		…	
…	…	…	…			

1.5 Screen 5: Product-outlet combinations_graph



Screen 4: Product-outlet combinations_graph

One liner: Waste and sales of each outlet for product.

Explanation: One product has been selected. Each dot covers a particular outlet. The waste and sales of each outlet are visualized. By hovering or clicking a dot, additional information about the selected outlet is obtained

This screen provides the user with a graphical overview on how the different outlets (retail stores) perform on both sales and waste regarding the selected product. For example, each dot of the example screen above represents one particular retail outlet which sells the selected product (oranges). The outlet in Wageningen has sales of oranges of 20,000€ (during the selected period), while 4% is wasted during the same period (as a percentage of sales, so the waste value equals 800€). The outlet in Sneek shows the same sales, while only 1% is wasted.

- On smart-search, each dot is provided with an outlet-id and an outlet-name label.
- The coloured rectangles appear via an advice button.
- The coloured rectangles are based on the middles of the two axes, where the length of these axis is determined by the minimum and maximum values.
- By hovering the red rectangle, the following text appears: "Outlets with large sales, but with a large waste percentage as well. Give high priority to waste reduction. Click on a specific outlet for further analysis"
- By hovering the orange rectangle, the following text appears: "Outlets with small to moderate sales. Waste percentage is lower than might be expected. Check out-of-stock."
- By hovering each of the green rectangles, the following text appears: "Outlets with waste percentages that fit with sales levels. However, improvements might be possible. Click on a specific outlet for further analysis."

- Screen 6 (Product-outlet combinations_table) represents the screen that appears to the user on hovering a dot (particular outlet).
- Two different dots (outlets) can be compared, by selecting two dots and by showing the information from screen 6 of both dots (products) simultaneously.
- By clicking on a dot, additional historical information is obtained (Screen 9 (Product-outlet combinations_historical info))
- The colour of each dot is on a grey scale, dependent on the out-of-stock percentage. In order to achieve this, the out-of-stock percentages are normalized (max out of stock = 1, min out of stock =0). Subsequently each dot is coloured as follows:
    - $0 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 10% grey
    - $0.1 \leq$ Normalized out-of-stock percentage < 0.2: dot is coloured 20% grey
    - $0.2 \leq$ Normalized out-of-stock percentage < 0.3: dot is coloured 30% grey
    - $0.3 \leq$ Normalized out-of-stock percentage < 0.4: dot is coloured 40% grey
    - $0.4 \leq$ Normalized out-of-stock percentage < 0.5: dot is coloured 50% grey
    - $0.5 \leq$ Normalized out-of-stock percentage < 0.6: dot is coloured 60% grey
    - $0.6 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 70% grey
    - $0.7 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 80% grey
    - $0.8 \leq$ Normalized out-of-stock percentage < 0.1: dot is coloured 90% grey
    - $0.9 \leq$ Normalized out-of-stock percentage ≤ 1: dot is coloured black

1.6 Screen 6: Product-outlet combinations_table

Screen 6: Product-outlet combination_table

Outlet	Sneek	
Mon	8:00-20:00	
Tue	8:00-20:00	
Wed	8:00-20:00	
Thu	8:00-20:00	
Fri	8:00-20:00	
Sat	8:00-20:00	
Sun	12:00-18:00	
Product	**Orange**	**Select Period**
Sales€	20000	Week 201631-201640
Waste%	1.0	
Out-of-stock%	1.5	
Promotion pressure%	0.2	
Demand uncertainty	1.6	
Minimum order quantity	4	
Shelf life	5	

One liner: Information about this specific product-outlet combination

Explanation: The presented values are average values during the selected time period

By hovering on each item in the left column (except 'product', 'outlet' and 'Mon' – 'Sun'), for each item the following explanations are given in a pop-up window:

Screen 6a: Sales€_explanation

The registered sales (€) for the selected product-outlet combination during the selected period.

Screen 6b: Waste%_explanation

The waste percentage of the selected product-outlet combination during the selected period.

Screen 6c: Out-of-stock%_explanation

The average out-of-stock (%) of the selected product-outlet combination during the selected period. If out-of-stock % is low the product availability is large. Waste can be reduced by lowering replenishment levels.

Screen 6d: Promotions_explanation

The promotion pressure (%) of the selected product at the selected outlet. This is the number of promotion weeks as a percentage of the total number of weeks during the selected period. If promotion pressure is large, probably waste can be reduced by lowering promotion pressure.

Screen 6e: Demand uncertainty_explanation

The demand uncertainty of the selected product at the selected outlet, during the selected period. This demand uncertainty is calculated as the sample standard deviation of the demand per opening day divided by the average demand per opening day. If demand uncertainty is large, consider demand forecasting, increasing order frequency or reducing lead times.

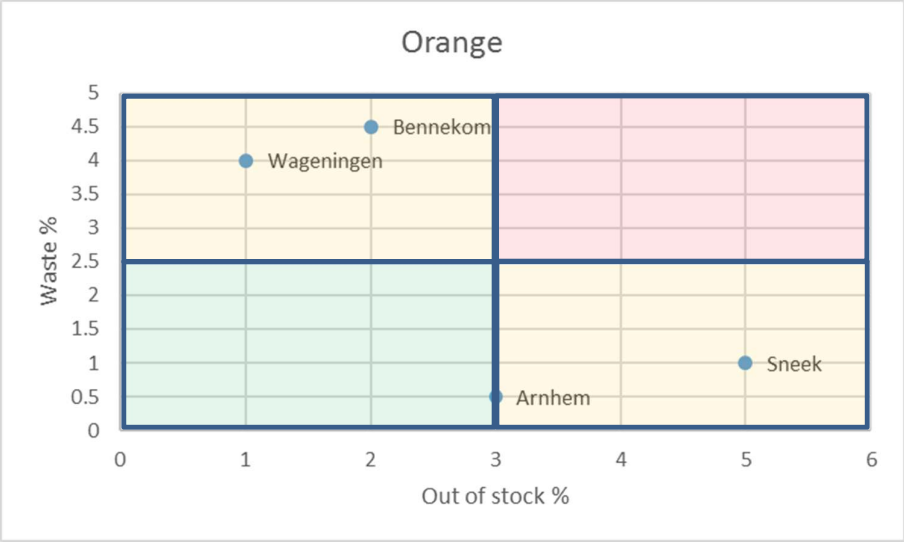
Screen 6f: Minimum order quantity_explanation

The average minimum order quantity, which commonly equals the case pack size. If the minimum order quantity equals 1, the outlet selected is able to order single items of the selected product. If the minimum order quantity is too large this may cause food waste.

Screen 6g: Shelf life_explanation

The average shelf life (d) of the selected product at the selected outlet. This number includes the day of replenishment and the day at which the product is wasted according the retailer's policy (commonly the product's expiry date). If the shelf life is too small this may cause food waste.

1.7 Screen 7: Product_waste vs. out-of-stock_graph



Screen 7: Product_waste versus out-of-stock_graph

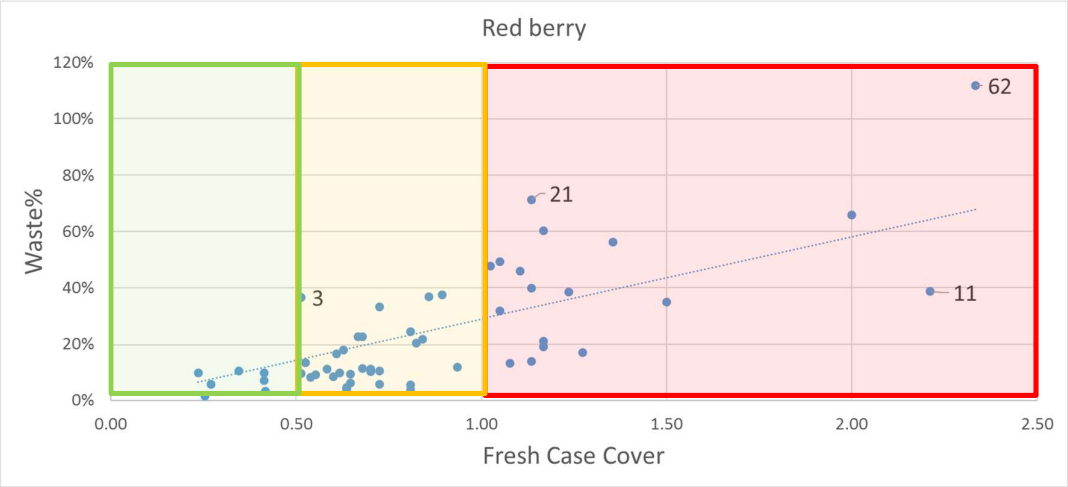
One liner: Waste and out-of-stock of each outlet for product: ...

Explanation: One product has been selected. Each dot covers a particular outlet. The waste and out-of-stock of each outlet are visualized.

This screen provides the user with a graphical overview on how the different outlets (retail stores) perform on both out-of-stock and waste regarding the selected product.

- The coloured rectangles appear via an advice button.
- The coloured rectangles are based on the middles of the two axes, where the length of these axis is determined by the minimum and maximum value.
- By hovering the red rectangle, the following text appears: "Product-outlet combination with high out-of-stock and high waste. Analyse the replenishment policy or consider remediation."
- By hovering an orange rectangle, the following text appears: "Product-outlet combination with either high out-of-stock or high waste. Consider the exchange between out-of-stock and waste by adjusting the replenishment level."
- By hovering the green rectangle, the following text appears: "Product-outlet combination with low out-of-stock and waste."

1.8 Screen 8: Fresh Case Cover_graph



Screen 8: Fresh Case Cover_graph

One liner: Fresh Case Cover

Explanation: One product has been selected. Each dot covers a particular outlet. The Fresh Case Cover (FCC) is on the horizontal axis. It is calculated by dividing the product's minimum order quantity by the product's shelf life and the average product's daily turnover. Large FCC values indicate that waste is reduced by decreasing the minimum order quantity or increasing the shelf life.

- The Fresh Case Cover on the horizontal axis is calculated by dividing the average value of the product's minimum order quantity by the average value of the product's shelf life and the average product's daily turnover. The average product's daily turnover equals the average weekly sales divided by the product's consumer price and divided by 7 (=number of days per week).
- On smart search, each dot is provided with a unique outlet ID and a unique outlet-name label
- The coloured rectangles appear via an advice button.
- A red rectangle occurs for FCC>1. By hovering the red rectangle, the following text occurs: "A FCC value >1 indicates that on average the minimum order quantity is too large compared to the product's shelf life and the product's daily turnover. High waste might occur. Consider decreasing the minimum order quantity and/or increasing the product's shelf life for these outlets."
- An orange rectangle occurs for 0.5<FCC<1. By hovering the orange rectangle, the following text occurs: "A FCC value between 0.5 and 1 will still generate moderate waste. Consider decreasing the minimum order quantity and/or increasing the product's shelf life for these outlets."
- A green rectangle occurs for FCC<0.5. By hovering the green rectangle, the following text occurs: "A FCC value between below 0.5 will only generate low waste levels."

1.9 Screen 9: Product-outlet combinations_historical info

One liner: Historical info about the specific product-outlet combination and the selected time period

Explanation: Information is provided about the following factors besides sales and waste: out-of-stock, promotions, demand uncertainty, minimum order quantity, and shelf life. These factors may contribute to an explanation of the observed waste percentage of the considered product-outlet combination.

Each sub-screen has a one liner and an explanation (see the following graphs).

Screen 9 (a-g): Product-outlet combinations_historical info

Screen 9a: Sales€_historical info

One liner: Sales history

Explanation: The registered sales (€) per week for the selected product-outlet combination during the selected period.

Screen 9b: Waste%_historical info

One liner: Waste history

Explanation: The registered waste % per week for the selected product-outlet combination during the selected period.

Screen 9c: Out-of-stock%_historical info

One liner: Out-of-stock history

Explanation: The registered out-of-stock % of the selected product-outlet combination during the selected period.

Screen 9d: Promotions_historical info

One liner: Promotions history

Explanation: The registered promotion weeks for the selected product during the selected period.

Screen 9e: Demand uncertainty_historical info

One liner: Demand-uncertainty history

Explanation: The demand uncertainty for the selected product at the selected outlet, during the selected period.

Screen 9f: Minimum order quantity_historical info

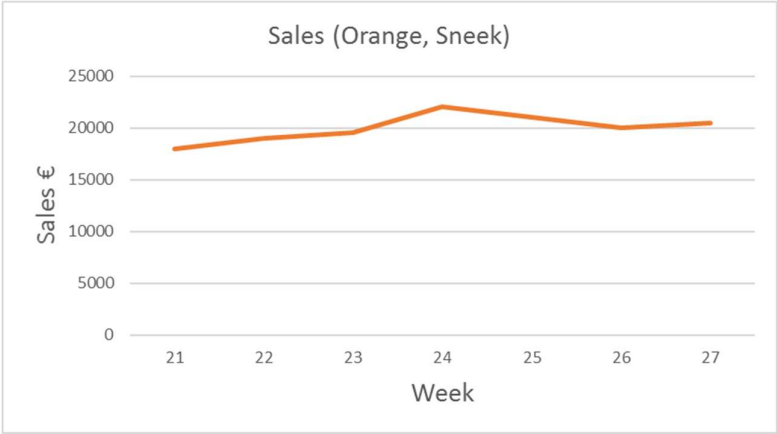
One liner: Minimum-order-quantity history

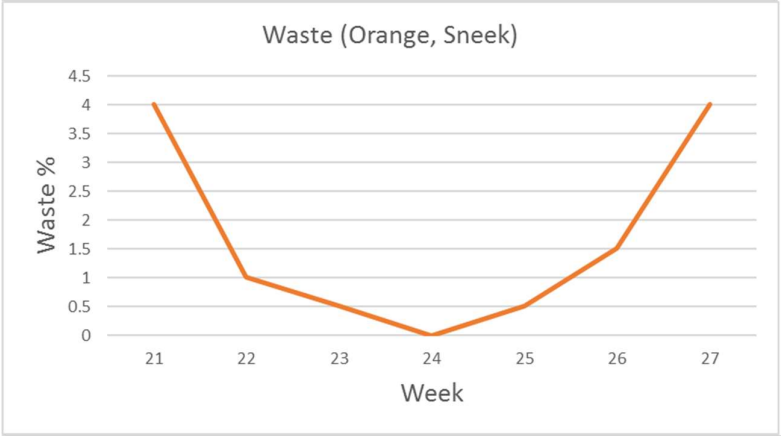
Explanation: The registered minimum order quantity of the selected product during the selected period.

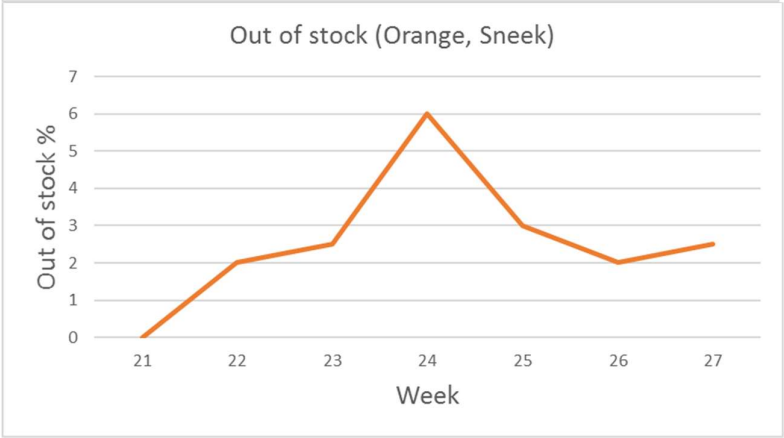
Screen 9g: Shelf life_historical info

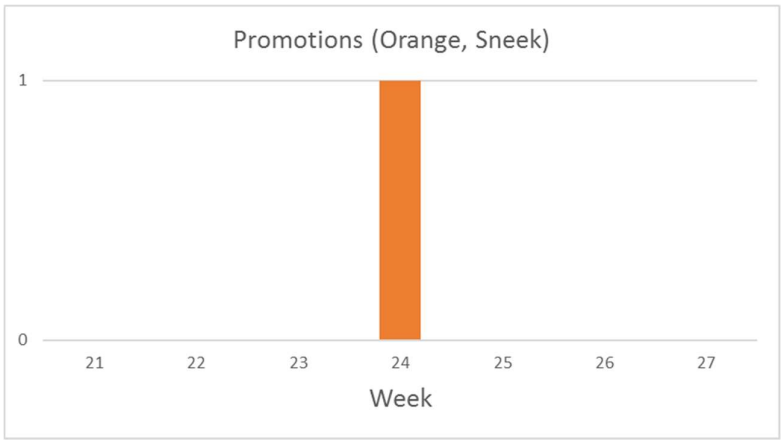
One liner: Shelf-life history

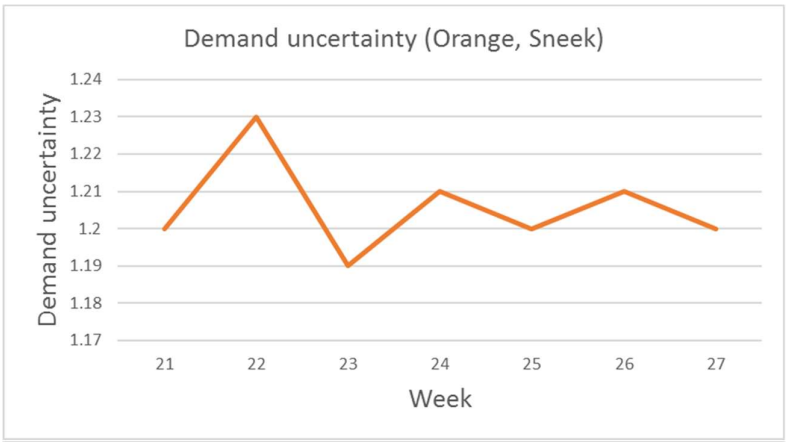
Explanation: The registered shelf life of the selected product during the selected period.

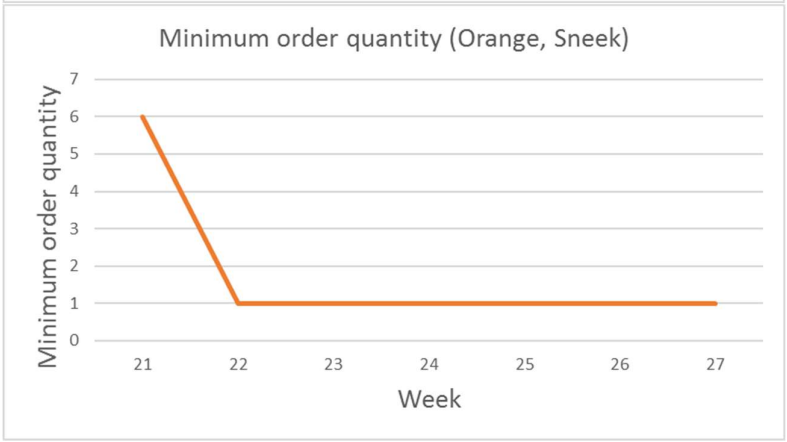

Sales (Orange, Sneek)
25000
20000
15000
10000
5000
0
Sales €
21
22
23
24
25
26
27
Week

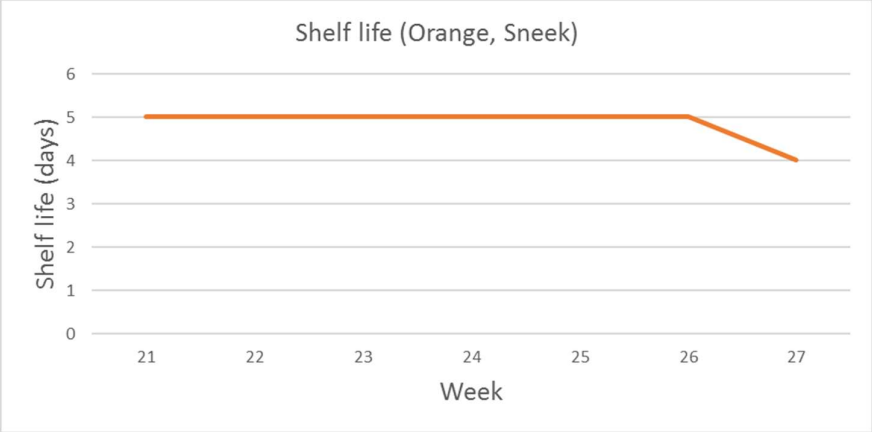

Waste (Orange, Sneek)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Waste %
21
22
23
24
25
26
27
Week


Out of stock (Orange, Sneek)
7
6
5
4
3
2
1
0
Out of stock %
21
22
23
24
25
26
27
Week

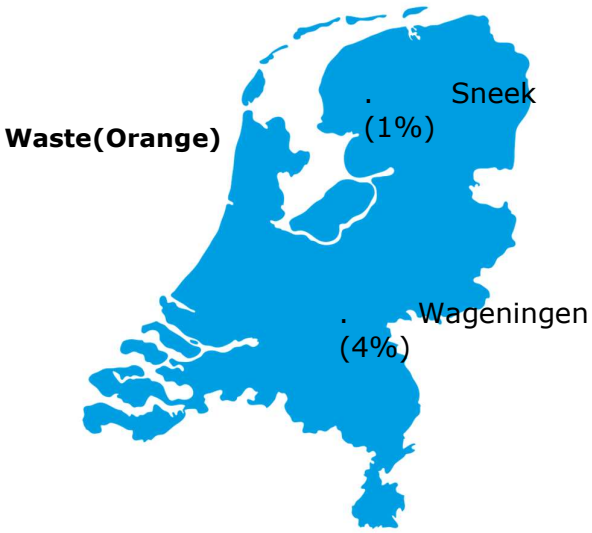

Promotions (Orange, Sneek)
1
0
21
22
23
24
25
26
27
Week


Demand uncertainty (Orange, Sneek)
Demand uncertainty
1.24
1.23
1.22
1.21
1.2
1.19
1.18
1.17
21
22
23
24
25
26
27
Week


Minimum order quantity (Orange, Sneek)
Minimum order quantity
7
6
5
4
3
2
1
0
21
22
23
24
25
26
27
Week


Shelf life (Orange, Sneek)
Shelf life (days)
6
5
4
3
2
1
0
21
22
23
24
25
26
27
Week

1.10 Screen 10: Geographical analysis_graph



Select Quantity

1. Sales€
2. Waste%
3. Out-of-stock%

Screen 7: Geographical analysis waste_graph

One liner: Geographical representation of waste

Explanation: One product has been selected. Each dot covers a particular outlet, with the value of waste between brackets.

- Each dot is provided with a product-name label and a unique ID.
- By clicking on the button 'Select Quantity', the user can select a different quantity to be visualized geographically (out of the set Sales€, waste% or out-of-stock%).
- Each dot is provided with the value of the selected quantity
- Each dot is coloured from black (relatively large waste) to white (relatively low waste), by normalizing the waste values. Same if a different quantity is selected.

Notice that in the one liner and the explanation the word 'waste' is replaced when a different quantity is selected.

6.2 Summary: blue print of user interface

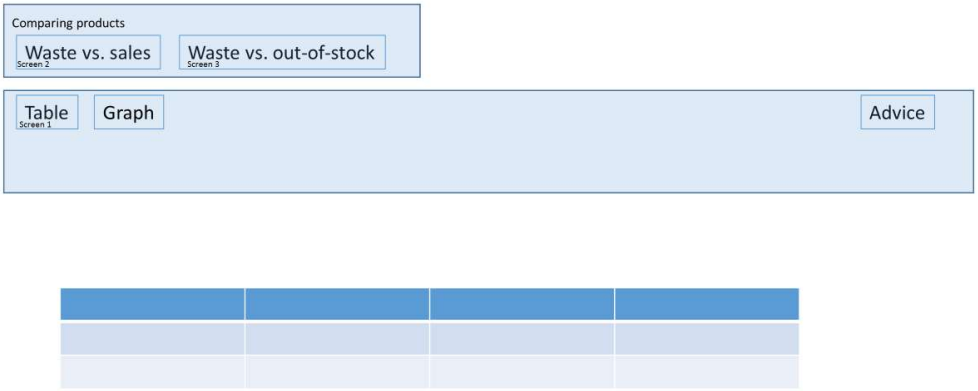


Figure 27: Aggregated level

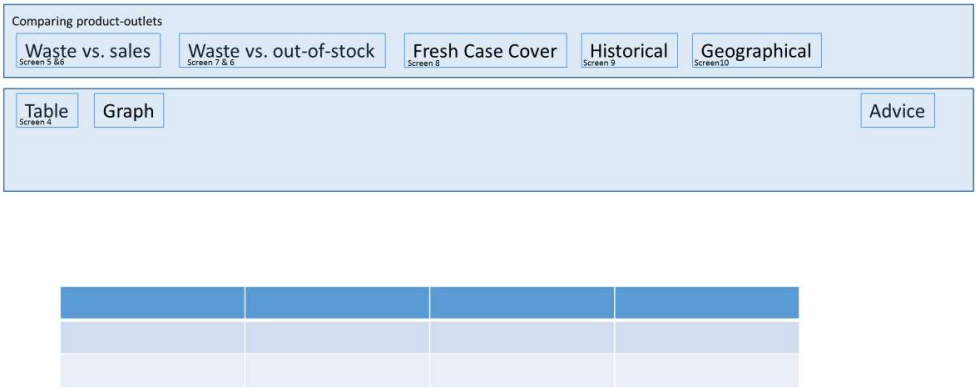


Figure 28: Detailed level

Appendix 2: Format input file

Data have to be provided according to te following format:

1. Data are provided in an Excel file;
2. The excel file contains several worksheets. The format of each sheet:
    a. On the first row the name and the function of the sheet
    b. Row 2 the version number of the format and the date of the last modification
    c. Row 3 and 4 can be used for additional information, or are left empty
    d. On row 5 the headers of the columns
    e. From row 6 the actual data
    f. The first column contains the ID of the data
3. Sheet 1: Outlets
    a. Contains the fixed data per retail outlet
    b. Each outlet on one row
    c. Columns:
        i. outlet_id
        ii. zip code
        iii. city
        iv. longitude
        v. latitude
        vi. opening time Mon
        vii. closing time Mon
        viii. opening time Tue
        ix. closing time Tue
        x. opening time Wed
        xi. closing time Wed
        xii. opening time Thu
        xiii. closing time Thu
        xiv. opening time Fri
        xv. closing time Fri
        xvi. opening time Sat
        xvii. closing time Sat
        xviii. opening time Sun
        xix. closing time Sun
4. Sheet 2: Products
    a. Contains the fixed data per product
    b. Each product on one row
    c. Columns:
        i. product_id
        ii. name
        iii. consumer price
5. Sheet 4: Product parameters
    a. Contains the variable properties of products
    b. Each product has at least one row with initial values
    c. If a property is modified, a row is added, with only product_id, date of modification, and the new parameter value in the right column. The other fields on the same row stay empty.
    d. Columns:
        i. product_id
        ii. date (yyyymmdd)

iii. shelf life (#)
iv. minimum_order_quantity (#)
v. promotion (y/n)

6. Sheet 5: Sales
    a. Contains the sales (€), per week per product per retail outlet
    b. Columns:
        i. product_id
        ii. outlet_id
        iii. week nr (yyyyww)
        iv. week nr (yyyyww)
        v. etc.
7. Sheet 6: Waste
    a. Contains the waste (€) per week per product per retail outlet
    b. Columns:
        i. product_id
        ii. outlet_id
        iii. week nr (yyyyww)
        iv. week nr (yyyyww)
        v. etc.
8. Sheet 7: Out-of-Stock
    a. Contains the out-of-stock (%) as percentage of opening time, per week per product per retail outlet
    b. Columns:
        i. product_id
        ii. outlet_id
        iii. week nr (yyyyww)
        iv. week nr (yyyyww)
        v. etc.
9. Sheet 8: Demand Uncertainty
    a. Contains the demand uncertainty, per week per product per retail outlet
    b. Columns:
        i. product_id
        ii. outlet_id
        iii. week nr (yyyyww)
        iv. week nr (yyyyww)
        v. etc.

Appendix 3: Fresh Case Cover

The Fresh Case Cover (FCC) has been introduced by Broekmeulen & van Donselaar (2017), defined as the minimum order quantity divided by the average demand during the shelf life.

$$Fresh\ Case\ Cover\ (FFC) = \frac{Minimum\ order\ quantity}{Average\ demand\ during\ shelf\ life}$$

A FCC value above 1 means that on average the minimum order quantity is too large compared to the product's shelf life and the product's daily turnover, with waste as a consequence.

A FCC value below 1 might still generate waste, because of turnover variability.