Decreasing household food waste: A study of food waste interventions

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Abstract

Households play an important role in the problem of food waste. Unfortunately, there is little evidence as to which possible interventions to reduce the amount of food wasted by households can be successful and which possible interventions do not work. Past efforts to decrease the amount of food wasted by households in the Netherlands have not had significant long-term effects. The objective of this study is to investigate the potential of possible interventions to reduce household food waste. A System Dynamics model has been developed to capture the feedback mechanisms in the system. The model represents different phases in which food waste may be generated: planning, purchasing, storing, preparing, consuming, and re-using leftovers. The results show that influencing food waste in one phase has a limited effect on the total amount of food wasted and that combinations of interventions can strengthen or weaken each other. The model shows that it is important to use combinations of interventions to address both the knowhow of a household about food waste and their willingness to reduce food waste.

Keywords

Food Waste, System Dynamics model, Households, Interventions

1. Introduction

In countries like the Netherlands, households are a major contributor to the waste of food (Griffin et al., 2009; Parfitt et al., 2010; Koivupuro et al, 2012; Silvennoinen et al., 2014). It has been estimated that on average a person wasted more than 40 kilograms of food in the Netherlands in 2016, and 14% of all food bought is unnecessarily discarded (Crem, 2017). However, there is little evidence, as to what interventions do reduce the amount of food wasted by households and what interventions do not work (Sharp et al., 2010).

It is argued by Quested et al. (2011) that the waste of food generated by a household is not behaviour in itself, but is the aggregated result of the various behaviours in the food consumption chain, consisting of different phases: planning, purchasing, storing, preparing, and consuming. Most research into food waste has focused on specific phases in which food is wasted, rather than looking at the whole process at the level of a household (Quested et al., 2013; Parizeau et al., 2015; Principato et al., 2015; Roodhuyzen et al., 2017). By considering the whole process, a better understanding of the system and of the potential effects of possible interventions may be achieved.

The objective of this paper is to investigate the food waste system in The Netherlands on the level of a household and to assess the potential effects of interventions on reducing this food waste. A System Dynamics model is developed to investigate different interventions.

The remainder of the paper is structured as follows. Section 2 discusses the food waste system by describing the main feedback mechanisms. Section 3 explains the investigated interventions. The resulting effects of these interventions based on simulations with the System Dynamics model are discussed in Section 4, and the main insights are summarized and discussed in Section 5.

2. Conceptual model of the food waste system on the level of a household

To structure the analysis, the framework developed by Roodhuyzen et al. (2017), which is based on a systematic review, is taken as a point of departure. The food waste system can be considered as a chain consisting of a number of different phases: planning, purchasing, storing, preparing, and consuming. Activities in all of the phases can contribute to food waste, not in the sense that food is actually discarded during all phases, but planning and buying too much food will also contribute to more food waste. We defined food waste as all the avoidable food that is discarded within a household during the storing and preparation of food, and the leftovers that are discarded by human members of a household, either before or after it spoils. Roodhuyzen and co-authors (2017) identified different types of factors that influence the phases. The analysis conducted by Roodhuyzen et al. was a qualitative analysis and did not have the intention to investigate the effects of interventions. In our model, we used the phases to categorize the different variables needed to represent the food system and added a re-using leftover phase. This is recognised separately in the model since interventions could be specifically geared at leftovers.

Figure 1 shows an aggregated causal loop diagram of the food waste system including the different phases as introduced above.

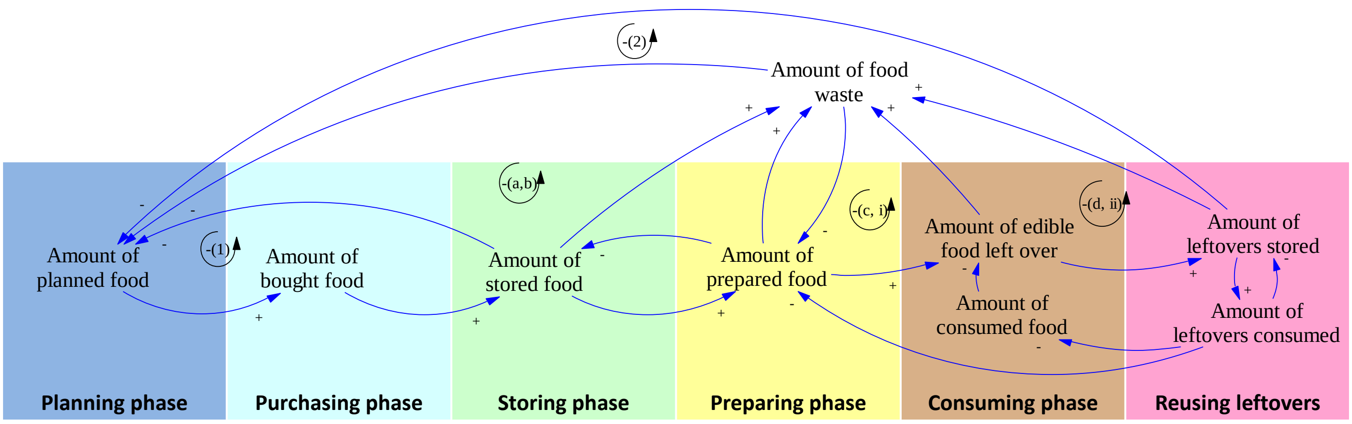

Figure 1. Aggregated causal loop diagram of the food waste system on the level of a household

The figure shows a causal chain from left to right connecting the central variables in each of the phases, i.e. the *Amount of planned food* influences the *Amount of bought food*, which influences the *Amount of stored food* etc. As illustrated at the top of Figure 1, the actual wasting of food occurs in the *Storing phase*, the *Preparing phase*, in the *Consuming phase* via the *Amount of edible food leftover*, and in the *Reusing leftovers phase*. Food can be discarded for various reasons during the storing phase, for example, because the food is spoiled, due to the inability of a household to determine if food is still edible, or a misinterpretation of the 'use by' or 'best before date' label (Ganglbauer et al., 2013; Evans, 2012; Parizeau et al., 2015; Silvennoinen, 2014; Williams et al., 2012; Jörissen et al., 2015). Food can be wasted during the preparation of food due to a lack of cooking skills (Parizeau et al., 2015). Leftovers can be discarded in the consuming phase because households either do not know how to re-use them (Cappellini & Parsons, 2012) or do not desire to re-use them (Farr-Wharton et al., 2014; Evans, 2012). During the reusing leftovers phase, not all of the leftovers that have been stored will actually be consumed.

Figure 1 shows three main feedback mechanisms. One main mechanism relates to the food stored, one relates to the food wasted, and the final one relates to food preparation. First, when planning to buy food, the amount of food that is already stored in the household is taken into account (to a certain extent). The *Amount of stored food* and the *Amount of leftover food stored* are considered when a household determines the *Amount of planned food* (Quested et al., 2013; Ganglbauer et al., 2013; Farr-Wharton et al., 2014). This consideration results in negative feedback loops; i.e. the awareness of the current *Amount of stored food* and *Amount of leftover food stored* limits or decreases the *Amount of planned food* (feedback loops 1, 2).

Second, it assumed that if a household throws away a large amount of food, this leads to adapting the planning and preparing behaviour. Households consider their *Amount of food waste* when planning how much food they need to buy. Wasting food thus results in a decrease of the *Amount of planned food*, illustrated by a negative link. This leads to a number of negative loops in which food is wasted and the planning is adjusted accordingly, leading to less food being wasted (feedback loops a, b, c, d). Finally, wasting leftover food is assumed to affect the preparing behaviour, as less food is prepared when households regularly throw away leftovers. The *Amount of edible food left over* and the *Amount of leftovers stored* lead to a lower *Amount of prepared food* (feedback loops i, ii).

The model thus consists of multiple negative feedback loops, and the behaviour over time is expected to lead to an equilibrium value for the food waste generated by households.

3. Adding potential interventions to the conceptual model

Food waste interventions are measures to reduce the food wasted by households. The objective of the model is to simulate the effect of a number of interventions that studies in the literature have described. We investigated a variety of measures, namely of different types (technical and behavioural-based interventions) affecting different phases, and measures which could be implemented by different parties. The following interventions were investigated:

1. *FridgeCam*. The 'FridgeCam' is an application installed on a mobile device and secured on the inside of a fridge. This application is able to take several photos, which are approachable online by the members of a household (Farr-Wharton et al., 2014). A 'FridgeCam' enables household members to consider what they have at home while buying groceries. This application may affect the planning phase and would result in a lower *Amount of planned food*, and thereby a lower *Amount of stored food*, finally resulting in less stored food being discarded.
2. *No discounts and economies of scale*. This intervention represents a situation where supermarkets provide no discounts and economies of scale (Delley & Brunner, 2017). This intervention may affect

the purchasing phase, resulting in a lower *Amount of bought food* and thereby a lower *Amount of stored food*, leading to less stored food being discarded.

3. *Spoilage knowledge campaign.* A knowledge campaign about spoilage provides information to increase the overall knowledge of food spoilage. It entails information on the difference between the 'best before' date and the 'use by' date of products (Delley & Brunner, 2017). Understanding the difference may contribute to a reduction in food waste in households (Vittuari et al. 2015). Besides, better knowledge of spoilage may result in a better skill of determining the edibility of food, even if it has passed the 'best before' date. This intervention may affect the storing phase, resulting in less food being discarded.
4. *Knowledge of the consequences of food waste campaign*. As mentioned before, it is assumed that planning and preparing behaviour are influenced by the *Total amount of food waste*. In addition, it is assumed that the planning and preparing behaviours of a household are influenced by their moral attitude towards wasting food. To account for this behaviour, the factor *Perceived food waste* is used in the model, which is influenced by *Moral attitude* and the *Total amount of food waste* (see Figure 2).

Figure 2 illustrates the possible influences of the interventions (red factors and arrows). Since households that do not care about wasting food are not willing to reduce the food that is wasted, or at least are less likely to try (Stefan et al., 2013; Graham-Rowe, et al., 2014; Principato et al., 2015), it is assumed that the *Perceived food waste* influences the effects of the interventions. By means of this mechanism, temporary feedback loops are created while applying an intervention.

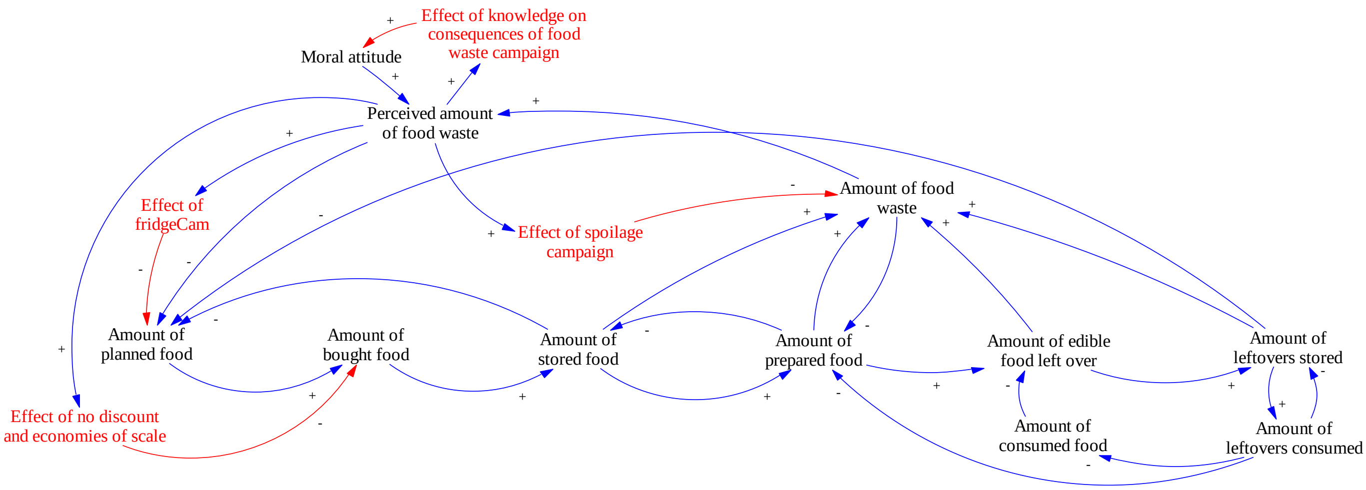

Figure 2. Aggregated causal loop diagram of the food waste system including potential interventions

4. Model Results

The final System Dynamics food waste model, which is based on a more detailed version of the causal diagram shown in Figure 2, has been represented in Vensim. Appendix A contains an explanation of each of the submodels representing the planning, purchasing, storing, preparing, consuming, and re-using leftovers phases. The model has been tested using extreme conditions, sensitivity analysis and face validation by two experts in the field (Waal, 2017).

Figure 3 shows the individual effects of the four different interventions using the model. The variable *Fraction food thrown away* represents the food waste generated by the household system. This variable is the amount of wasted food per week by a household divided by the amount of bought food per week by a household.

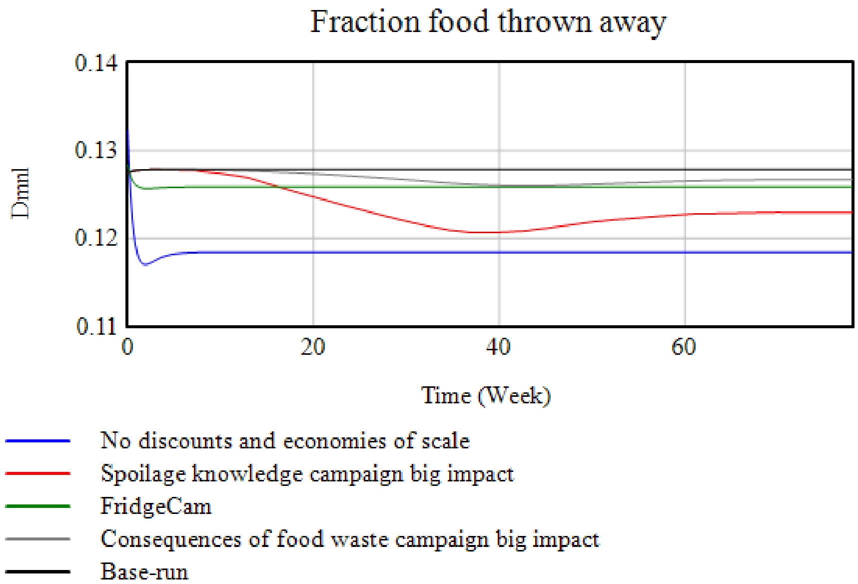

Figure 3. Effects of the individual interventions on the fraction of wasted food

All interventions reduce the *Fraction food thrown away*. However, none of the individual interventions leads to a large reduction in household food waste, which indicates that the generation of food waste is segmented. To investigate whether combinations of interventions have a larger impact, the intervention with the largest impact is combined with other interventions. The first intervention combination consists of the 'No discount and economies of scale' intervention and the 'Knowledge on consequences food waste campaign'. The second combined intervention consists of the 'No discount and economies of scale' intervention and the 'Spoilage knowledge campaign'. Figure 4 shows the first intervention combination and Figure 5 shows the second intervention combination.

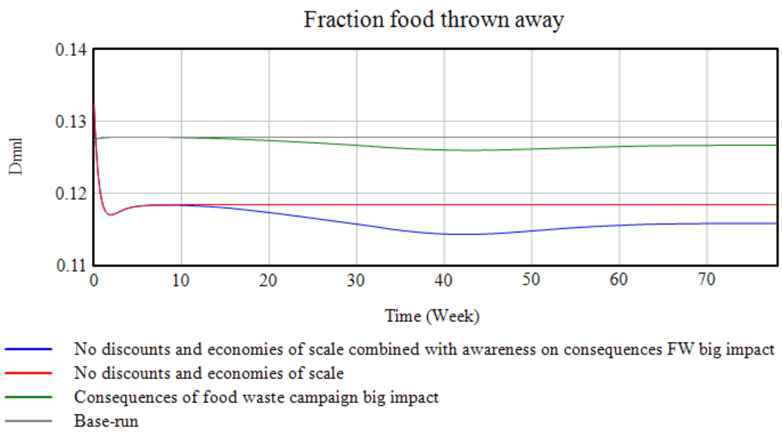

Figure 4. Impact of the combination of no discounts and knowledge on consequences compared to individual interventions on the food wasted

Figure 4 shows that for the first combined intervention the reduction in *Fraction food thrown away* is larger than the sum of the impacts of the individual interventions (the reduction shown by the blue line is more than the sum of the reductions shown by the red and green lines). This can be explained by the mechanism that the ‘Knowledge on consequences food waste campaign’ has a positive influence on the *Moral attitude,* and thereby a positive influence on the effect of the ‘No discount and economies of scale’ intervention via the increased *Perceived food waste*. In addition, planning and preparing behaviour are affected. A decrease in the *Amount of planned food* and the *Amount of prepared food* finally results in a decrease of the discarded stored food and leftovers.

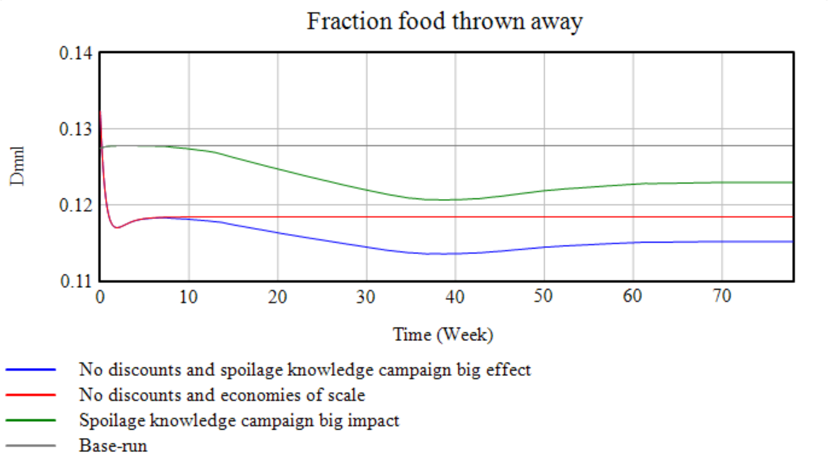

Figure 5. Impact of the combination of no discounts and spoilage knowledge compared to individual interventions on the food wasted

The impact of the second combined intervention, however, is smaller than the sum of the impacts of the individual interventions (the reduction shown by the blue line in Figure 5 is smaller than the sum of the reductions shown by the red and green lines). If a household is able to reduce food waste due to one intervention, the *Perceived Amount of food waste* decreases due to the intervention. In the model, this results in a lower urgency to further reduce food waste. Consequently, the effect of another intervention is smaller than when that intervention would be applied individually.

However, we have to be very careful to draw conclusions from these model results, as yet little research has been conducted on causal relations regarding the waste of food on the level of a household (Roodhuyzen et al., 2017). In addition, the literature uses different definitions of food waste, ranging for example from food waste, food loss, avoidable, possibly avoidable, to spoilage (Parfitt et al., 2010; Schneider, 2013). These different definitions result in different approaches being used for how food waste is studied, measured, and presented. This finally results in a domain of which the results are hard to compare (Koivupuro et al., 2012; Parfitt et al., 2010; Silvennoinen et al., 2014). Data is therefore lacking and making a lot of assumptions is inevitable. To investigate the influence of some of these uncertainties, the robustness of the first combined intervention has been investigated by varying multiple uncertain parameters (*Degree of over planning*, *Use by date*, *Provision Factor*, *Effect on Household*) by + and -50%. Figure 6 shows the results of the multivariate robustness analysis. The impact of the combined intervention is still visible, but the actual size of the effect is uncertain.

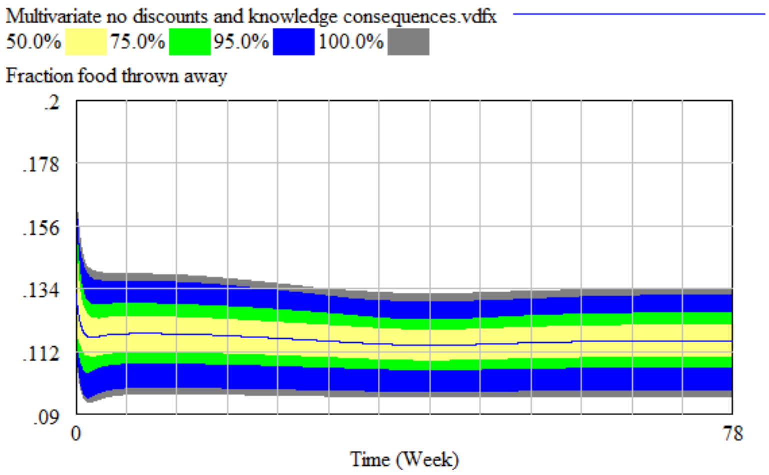

Figure 6. Multivariate robustness of the combined intervention consisting of the ‘No discount and economies of scale’ intervention and the ‘Knowledge on consequences food waste campaign’

5. Conclusions and discussion

A System Dynamics model has been developed to investigate the potential effects of interventions to mitigate the food waste generated by households in The Netherlands. The model distinguishes a number of related phases: planning, purchasing, storing, preparing, consuming, and re-using leftovers. Households tend to plan to buy more food than actually needed (Evans, 2012; Quested et al., 2013). While planning how much food to buy, a household partly considers the food and leftovers that are stored. Households tend to buy even more food than they initially planned (Evans, 2012; Ganglbauer et al., 2013; Koivupuro et al., 2012). The food that has been bought is stored, however, more food is stored than needed for the preparation of food. This results in food that is stored for longer periods. Storing food for longer periods may result in food waste because it is no longer edible. Besides, households may discard food because it has reached the ‘use by’ or ‘best before’ date. Furthermore, households tend to prepare more food than actually needed (Jörissen et al., 2015, Williams et al. 2012, Silvennoinen et al. 2014). The difference between the prepared and consumed food results in edible food leftover. If households throw away leftovers, it directly leads to food waste. If households store the resulting edible food leftover, it can be partly eaten and partly thrown away.

The food waste system on the level of a household involves multiple feedback mechanisms. An identified storage feedback mechanism includes planning to buy more food which results in more stored food. This amount is considered when next planning to buy food, resulting in a decrease in the amount of food planned. An identified food waste feedback mechanism includes the wasting of food affecting the planning and the preparing behaviour in a household, which finally lowers the amount of food wasted. Multiple balancing loops are present in the food waste system on the level of a household.

The model has been used to investigate the impact of four different types of interventions: 1) a technical intervention with a camera and app, which provides information on food stored in the fridge, 2) an intervention improving the knowledge on food spoilage, 3) an intervention avoiding discounts on food, and 4) an intervention improving the awareness about food waste. Applying interventions to reduce food waste results in adding temporary feedback loops in the model. The model results show that none of the individual interventions has a large impact on the reduction of household food waste.

Combining interventions can either have an impact that is greater than the sum of the individual interventions, or smaller. Therefore, in order to reduce the amount of food waste effectively, households should (i) know how to reduce the waste of food and (ii) be willing to reduce food waste. Combining an intervention that provides know-how with an intervention that increases the willingness of a household results in synergy, as their combined impact is greater than the sum of their separate impacts. Focusing multiple interventions on know-how only, results in a combined impact which is smaller than the sum of the individual impacts.

This study tried to capture the factors that affect the waste of food generated at the level of a household. There is yet limited knowledge about the causal mechanisms related to food waste at the level of a household, and multiple definitions of food waste are used in the scientific field, resulting in different ways of measuring and presenting food waste. Assumptions and simplifications are inevitable, which results in a high aggregation level of the model. This implies that simulating interventions only provides a general indication of the impacts of the interventions on food waste on the level of a household. To cope with the multiple assumptions, we considered a number of important uncertain parameters when testing the robustness of the interventions. The model behaviour resulting from the interventions seemed to be robust. Further research into the causal mechanisms in the food waste system is needed in order to be able to draw conclusions about the size of the the impacts of possible interventions to reduce household food waste.

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Appendix A

Explanation and formulation of the SD food waste model

The food waste SD model consists of submodels representing the planning, purchasing, storing, preparing, consuming, and re-using leftovers phases. Each of these submodels is explained below. Following the discussion of the submodels, the general part of the model in which the amount of food waste is determined based on the submodels will be explained. At the end of this Appendix an overview of the complete stock-flow diagram is provided.

Planning

The stock-flow diagram of the submodel representing the planning phase is shown in Figure A1. The variables relating specifically to this phase are shown in colour. The transparent variables belong to other phases which are connected to the planning phase.

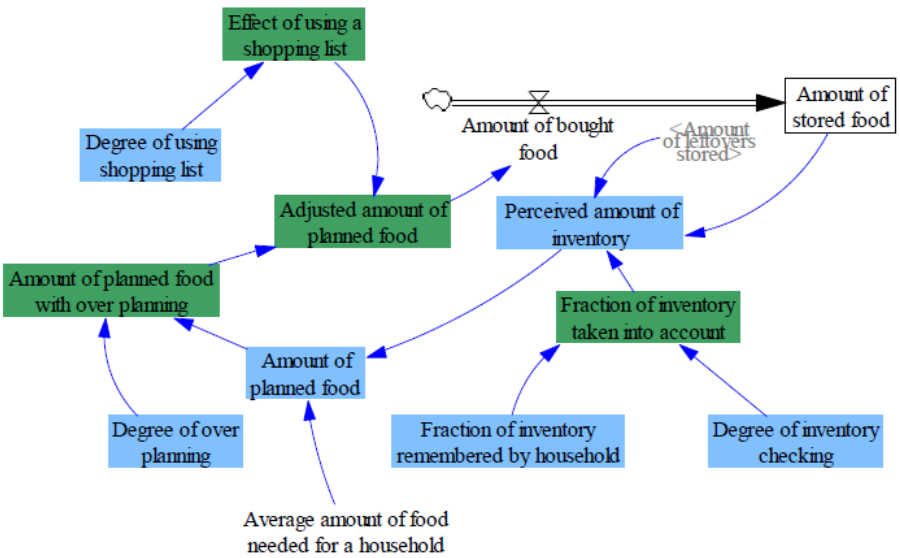
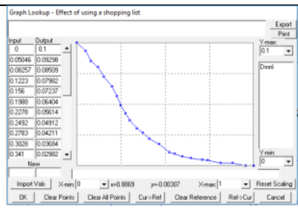


Figure A1. Planning phase submodel

The central variable of the planning phase is the *Adjusted amount of planned food* which influences the flow of the *Amount of bought food*. The *Adjusted amount of planned food* will be affected by the *Degree of using shopping list*. People who use a shopping list buy fewer unnecessary things that they already have or do not need at all. In general, people tend to plan to buy more food than actually needed. This implies that there is a certain *Degree of over planning* of the *Amount of planned food*. In the model the *Amount of planned food* is determined by the *Average amount of food needed for a household* minus the *Perceived amount in the inventory*. The *Perceived amount of inventory* depends on the *Degree of inventory checking* and the *Fraction of inventory remembered by the household*.

Variable/parameter	Description	Value/equation
Degree of inventory checking	No scientific data is available on this topic, therefore an estimation is inevitable. Regarding the average Dutch household, it is be assumed that products that are being used a lot will also be checked more. It is assumed that on average household checks the *Amount of stored food* and the *Amount of leftovers*	0.5 [dmnl]

	stored 50% of the time before going to the supermarket.	
Degree of over planning	There is no information available in the scientific literature on the exact amount of food people tend to plan to buy more, therefore is estimation used. In order to represent the wishes to have more food than needed a percentage of 10% is used for Dutch households. This value of this parameter represents the fraction planned more than actually needed.	0.10 [dmnl]
Degree of using shopping list	In Karlsruhe as well as in Ispra, 70% of the households surveyed use a shopping list. When using a shopping list, the amount of food thrown away per capita is lower by about 20% in Karlsruhe and 25% in Ispra (Jörissen et al., 2015). On average, it is assumed that households use a shopping list 70% of the time.	0.7 [dmnl]
Fraction of inventory remembered by household	When people buy groceries, it is possible that they remember what they have in their storage, even when they do not make a shopping list. It is assumed that a household is able to remember around 80% of the inventory.	0.8 [dmnl]
Adjusted amount of planned food	Is influenced by the variables *Amount of planned food with over planning* and the *Effect of using a shopping list*. Using a shopping list will increase the approximation of the *Amount of planned food*; using a shopping list is correlated with food waste (Jörissen et al., 2015). Therefore it is assumed that using a shopping list will reduce the *Amount of planned food*. This is represented by multiplying the *Effect of using a shopping list* with the *Amount of planned food*.	$(Amount\ of\ planned\ food\ with\ over\ planning * Effect\ of\ using\ a\ shopping\ list) + Amount\ of\ planned\ food\ with\ over\ planning$ [kg/week]
Effect of a shopping list	Is influenced by the variable *Degree of using shopping lists*. It is assumed that never using a shopping list will increase the *Amount of bought food* with 10% and using a shopping list will result no extra food bought. The x-axis represent the *Degree of using shopping lists* and the y-axis represents the effect of the use of these shopping lists.	
Amount of planned food with over planning	Is influenced by the variables *Amount of planned food* and the *Degree of over planning*. This amount can be calculated by multiplying these variables by one another combined with the original *Amount of planned food*.	$Amount\ of\ planned\ food + (Degree\ of\ over\ planning * Amount\ of\ planned\ food)$ [kg/week]
Amount of planned food	Is influenced by the variables *Average amount of food needed for a household* and the *Perceived amount of stored food*. The actual food needed is the *Average amount of food needed for a household* minus the *Perceived amount of inventory*. To consider the fact that having a lot food stored, which is more than the needed, an IF THEN ELSE function is needed. This function ensures that the planning will not go negative, which is not possible in reality.	$IF\ THEN\ ELSE(Perceived\ amount\ of\ inventory >= Average\ amount\ of\ food\ needed\ for\ a\ household, 0.1, (Average\ amount\ of\ food\ needed\ for\ a\ household - Perceived\ amount\ of\ inventory))$ [kg/week]

Perceived amount of inventory	Is influenced by the variables *Amount of stored food*, *Amount of leftovers stored*, and *Fraction inventory taken into account*. The *Fraction inventory taken into account* is multiplied with the *Amount of stored food* and the *Amount of leftovers stored*.	$(Fraction\ of\ inventory\ taken\ into\ account) * (Amount\ of\ stored\ food + Amount\ of\ leftovers\ stored)$ [kg/week]
Fraction of inventory taken into account	Is influenced by the variables *Fraction of inventory remembered by household* and the *Degree of inventory checking*. It will result in a fraction of the inventory that will be taken into account between 0 and 1. In order to not check more than 100% of the inventory, the *Degree of inventory checking* should cover the part that is not remembered by the household.	$Fraction\ of\ inventory\ remembered\ by\ household + ((1-Fraction\ of\ inventory\ remembered\ by\ household)*Degree\ of\ inventory\ checking$ [dmnl]

Purchasing

Figure A2 shows the submodel relating to the purchasing phase. The variables relating specifically to this phase are shown in colour. The transparent variables belongs to phases connected to the purchasing phase. The behaviour of interest is that people tend to buy even more food than actually planned, which was already more than actually needed, ending up with too much food available for consumption.

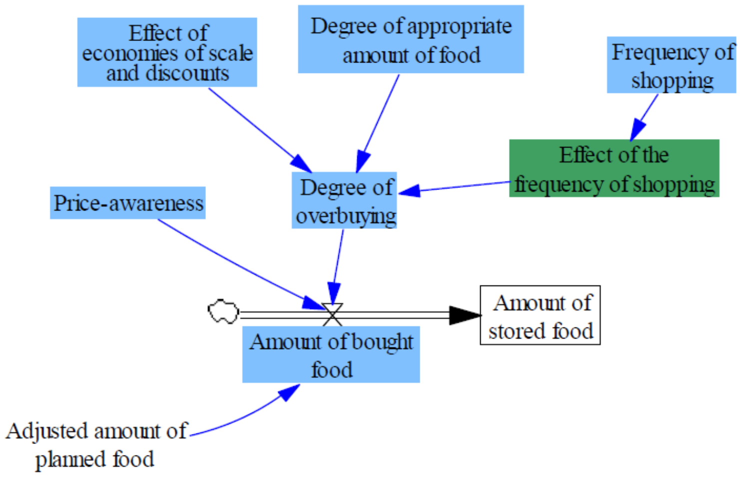
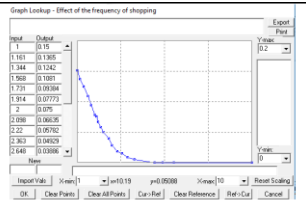


Figure A2. Purchasing phase submodel

The *Amount of food bought* is the central variable in this phase. The *Amount of bought food* is a result of the *Price awareness, Degree of overbuying,* and the *Adjusted amount of planned food.* Households with a high *Price awareness* have the tendency to buy no more food than needed. The variable *Degree of overbuying* is dependent on three variables; the *Effect of economies of scale and discounts*, *Degree of appropriate amount of food,* and the *Frequency of shopping*. A higher *Degree of appropriate amount of food* leads to a lower *Degree of overbuying*. Households tend to buy more food if the correct package is not available. People also tend to buy more food due to the *Economies of scale and discounts*, resulting in a higher *Degree of overbuying.* The *Frequency of shopping* is connected to the *Degree of overbuying,* a higher *Frequency of shopping* leads to a better estimation of the food needed for a household.

Variable/parameter	Description	Value/equation
Price-awareness	It is assumed that the *Price-awareness* is not that high in a developed country like the Netherlands. It is assumed that households do not tend to	0.95 [dmnl]

	waste food due to financial problems. An average value is chosen of 5% in this study. It is assumed that 5% of the fraction of the *Degree of overbuying* is compensated by the *Price-awareness* in the System Dynamics model. In other words, 95% of the actual *Degree of overbuying* is used.	
Effect of economies of scale and discounts	Quantity discounts can result in too much unneeded food, which not will be eaten in the end and end up as food waste. It is assumed that given a standard Dutch household, people do tend to buy 10% more on average than needed, since no data is available on this topic.	0.10 [dmnl]
Degree of appropriate amount of food	It is assumed that people tend to buy too much food rather than not enough, resulting in food that not will be prepared or eaten in the end. It has been argued that this is mainly the case for households with one person (Evans, 2011; Koivupuro et al., 2012; Ganglbauer et al., 2013; Jörissen et al., 2015). In the Netherlands, around 38% of the households is a one person household. We assume that 1/3 of the time these households have to buy more food than needed, which is 50% more than needed each time. This can be represented by a fraction of food that has been bought too much, which can be calculated by 0.38*0.33*0.5.	0.0627 [dmnl]
Frequency of shopping	Shopping more is assumed to lead to less wasted food. In this study it is assumed that people tend to shop 3 times a week. Based upon an online survey provided by the ING. Based upon 64000 households, it has been stated that the average Dutch household shops 3 times a week on average in order to buy the food needed.	3 [dmnl]
Amount of bought food	Is influenced by the variables *Amount of planned food*, *Price-awareness*, and *Degree of overbuying*. The *Degree of overbuying* will be compensated by the fraction of the *Price-awareness*. These values will be multiplied by each other.	$(Adjusted\ amount\ of\ planned\ food * Degree\ of\ overbuying * \text{"}Price{-}awareness\text{"}) + Adjusted\ amount\ of\ planned\ food$ [kg/week]
Degree of overbuying	Is influenced by the variables *Price/Kg ratio, Degree of appropriate amount of food*, and the *Effect of the frequency of shopping*. All the variables will lead to a higher percentage of overbuying and can be added.	$((Effect\ of\ economies\ of\ scale\ and\ discounts + Degree\ of\ appropriate\ amount\ of\ food) * (Effect\ of\ the\ frequency\ of\ shopping)) + (Effect\ of\ economies\ of\ scale\ and\ discounts + Degree\ of\ appropriate\ amount\ of\ food)$ [dmnl]

Effect of the frequency of shopping	Jörissen et al. (2015) state that the difference between households that go every second day, twice a week, and every week isn't that large; around the 130, 140, and 150 gram food waste per person. Households in Germany have thus shown a small decrease regarding the waste of food, while increasing the number of trips; Williams et al. (2012) state also that more Swedish households increase the Amount of food waste when decreasing the number of trips, with an average food waste of 2kg (purchase seldom) and 1.25 kg (purchase often). Taking into account that going to the supermarket more often will lead to a lower amount of food waste, it is assumed that doing more groceries will result in lower amount of bought food. The x-axis represents the *Frequency of shopping.*	

Storing

The behaviour of interest is that people need to store the food that has been bought, which will result in two types of food waste, i.e. edible food that is discarded and inedible food that is discarded. Figure A3 shows the storage submodel.

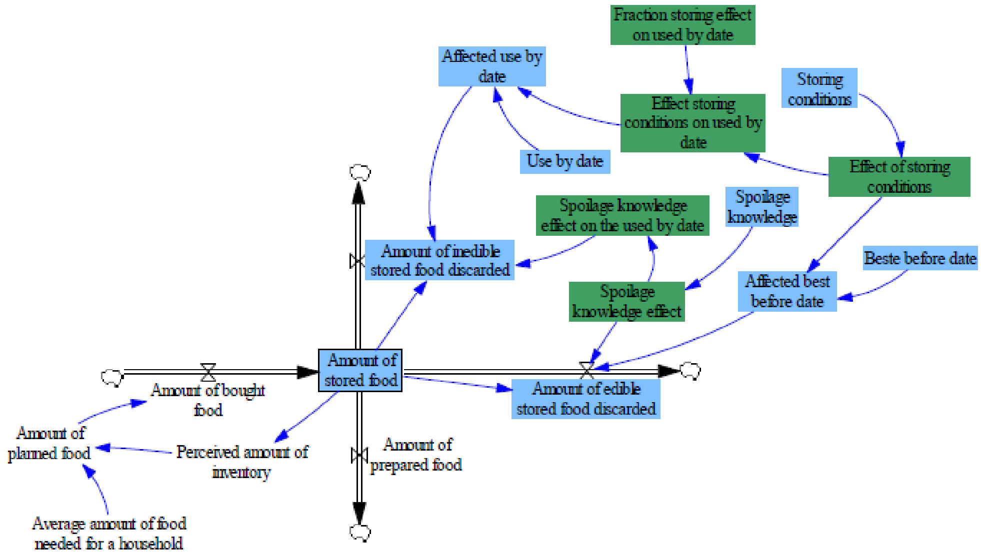
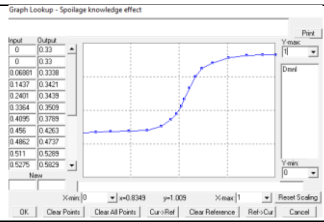


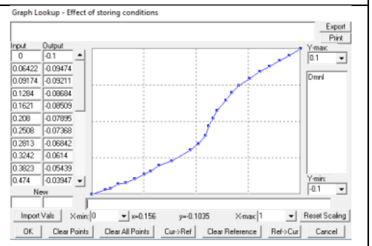
Figure A3. Storage phase submodel

The *Amount of stored food* needed for a household is the central variable in this phase. The *Amount of bought food* will flow into the storage and the *Amount of prepared food* be an outflow of the storage. Most of the stored food will be prepared, but some of the stored food will be discarded. In this phase there are two food waste variables; *Amount of edible stored food discarded* and *Amount of inedible stored food discarded.* There is a difference between the *Use by date* and the *Best before date.* The *Use by date* represents the safety of food and this date must be followed strictly. The *Amount of edible stored food discarded* is dependent on the on the *Affected best before date* and the *Amount of inedible stored food discarded* is dependent on the *Affected use by date*. Better *Storing conditions,* such as using fridge and freezer effectively at the right temperature, result in a higher *Affected best before date* and *Affected use by date* due to the effects of the improved conditions.

Households with more *Spoilage knowledge* are better at deciding if food is still edible, which will result in less edible food being discarded.

Variable/parameter	Description	Value/equation
Storing conditions	These conditions represent the quality in which food is stored. In the current literature, no average level of for storing conditions can be found. In the Netherlands, it can be assumed that people are well educated on how to store their food and almost every household does have the right measures to store food; a freezer and a fridge. Therefore a value of 0.7 has been chosen.	0.7 [dmnl]
Spoilage knowledge	Knowing the difference between what is actually spoiled and what is still edible, even when it has passed the best-by date or the use-by date is not known well enough within the Netherlands. It has been estimated that only 50% of the households actually knows how to cope with these aspects. It is possible that households throw food away when it has passed the best-before date while it still is edible. Therefore a value of 0.5 will be used.	0.5 [dmnl]
Use by date	Regarding the data of the *Best before date* and *Use by date* no average is given due to the difference between the dates per many types of food. The *Best before date* is longer for canned products than for example dairy produce. Therefore the following rule is applied: the *Best before date* is three times as much as the *Use by date* in the System Dynamics model. In this study it has been assumed that the *Use by date* is 1 week. It will take 1 week on average before the *Use by date* has been reached and the food needs to be thrown away.	1 [week]
Best before date	The best before date should be higher than the use by date. Since there are many types products possible and due to the fact that an average will be taken into account during this study, a specific estimation is hard to make. As mentioned at the *Use by date,* the *Best before date* will be 3 times as much. Therefore a rough estimation has been used of 3 weeks . Food might still be edible when it has passed the *Best before date.*	3 [week]
Fraction storing effect on used by date	This variable is needed in order to represent a different effect on the different kinds of dates. Where *Storing conditions* have a bigger impact on the *Best before date*, a smaller impact is expected on the *Use by date*. The U*se by date*	0.1 [dmnl]

	is about safety. Therefore, the *Use by date* cannot be stretched too much. It is assumed that having storing conditions will have 1/10 of the effect on a used by date regarding the *Best before date*.	
Amount of stored food	Stock initialised close to equilibrium	Initial value 1.635 [kg]
Amount of inedible stored food discarded	Is influenced by the variables *Amount of stored food, Affected use by date*, and the *Spoilage knowledge effect on the used by date. The Amount of stored food /Affected use by date* will be multiplied with the *Spoilage knowledge effect on the used by date*. Where the knowledge effect is larger, less food will be thrown away on the short term, represented by the used by date, resulting in less food waste.	$(Amount\ of\ stored\ food\ /$ $(\text{Affected}\ used\ by\ date) *$ $(Spoilage\ knowledge\ effect$ $on\ the\ use\ by\ date)$ [kg/week]
Amount of edible stored food discarded	Is influenced by the variables *Amount of stored food, Affected best before by date,* and the *Spoilage knowledge*. The *Amount of stored food* divided by the *Affected best before date* will be multiplied with *Spoilage knowledge effect*. Where the effect is bigger, more food will be thrown away on the longer term represented by *the best before date*, resulting in less food waste.	$(Amount\ of\ stored$ $food/\text{Affected}\ best\ before$ $date) * Spoilage\ knowledge$ $effect$ [kg/week]
Spoilage knowledge effect on the used by date	Is dependent on the variable *Spoilage knowledge effect*. Having a higher Spoilage knowledge will result in a shift from being dependent on the *Best before date* rather than on the *Use by date*. This will represent a shift in the average time before food will be thrown away. Increasing the *Spoilage knowledge* will thus increase the average time it takes before food will be discarded. In order to be less dependent on the *Used by date*, the spoilage knowledge effect should be compensated.	$1 - Spoilage\ knowledge$ $effect$ [dmnl]
Spoilage knowledge effect	Having more spoilage knowledge will result in a higher *Effect of spoilage knowledge*. *Spoilage knowledge* can vary from nothing with the input value (0%) and to full knowledge with the input value 1 (100%). The behaviour regarding the effect is assumed to be s-shaped.	
Effect storing conditions on used by date	Is influenced by the variables *Effect of storing conditions* and *Fraction storing effect on used by date*. This variable is needed in order to represent the lowered effect on the used by regarding the best before date. Because the effect is 1/10 of the original effect, it can be calculated by multiplying the influencing variables.	$Effect\ of\ storing$ $conditions * Fraction$ $storing\ effect\ on\ used\ by$ $date$ [dmnl]

Affected best before date	The *Affected best before date* is *the Best before date*, which is influenced by *Effect of storing conditions*. 100% of the effect will be taken into account.	$(Best\ before\ date * Effect\ of\ storing\ conditions) + Best\ before\ date$ [week]
Affected used by date	Is a product of *Effect storing conditions on used by date* and *Used by date*. The Affected use by date is the Used by date, which is almost not influenced by Effect of storing conditions. Only 10% of the effect will be taken into account.	$Use\ by\ date + (Use\ by\ date * Effect\ storing\ conditions\ on\ used\ by\ date)$ [week]
Effect of storing conditions	Having no storing conditions will have a negative effect, resulting in an output of 10%, which has the value of -0.1. Having perfect storing conditions will lead to a positive effect, which is 10%, accompanied with a value of 0.1. Between these values, a lookup has been estimated.	

Preparing

The behaviour of interest is that people need to prepare the food that has been stored, which will result in one food waste variable, the amount of inedible prepared food discarded. Figure A4 shows the submodel related to the preparing phase.

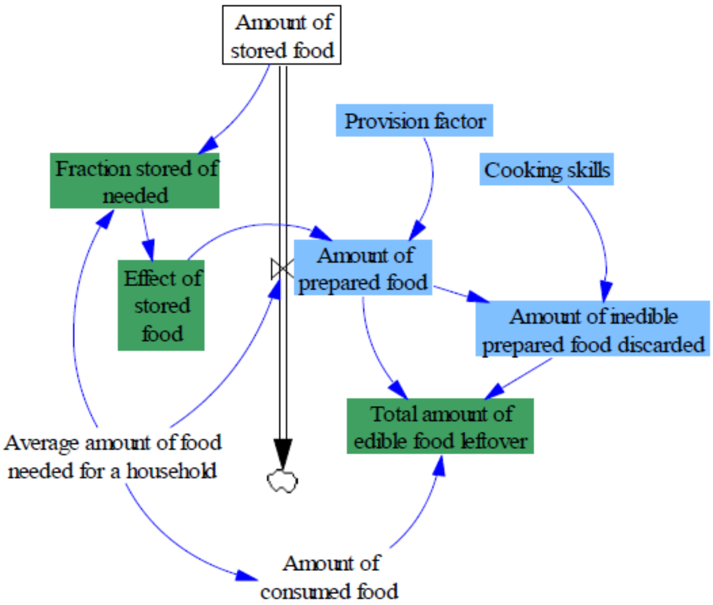
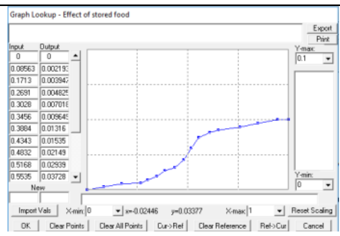


Figure A4. Preparing phase submodel

The *Amount of prepared food* needed for a household is the central variable in this sub-model. The *Amount of prepared food* is a result of the *Provision factor, Average amount of food needed for a household,* and the *Amount of stored food.* The *Provision factor* illustrates the fact that households tend to prepare more food than they actually need. A higher *Amount of stored food* has a small positive influence on the *Amount of prepared food*. Having more food results in making more food. One type of food waste in this phase is the *Amount of inedible prepared food discarded*. This food waste is a combination of *Cooking skills* and the *Amount of prepared food*. If a household is better at preparing food, less food will become inedible during the preparation. The *Amount of edible food leftover* is the difference between the *Amount of prepared food* and the *Amount of consumed food* from which the *Amount of inedible prepared food discarded* is subtracted.

Variable/parameter	Description	Value/equation
Provision factor	Households prefer to make too much food in order to make sure that everyone eats enough. No data is available regarding this topic. Given that households tend to prepare more food than needed, but not too much it is assumed that the average household will use an additional percentage of 5% above the *Average amount of food needed for a household* .	0.05 [dmnl]
Cooking skills	No scientific literature on the *Cooking skills* of the average household within the Netherlands is available, therefore it is assumed that on average, the food is not edible 1/40 of the time (including breakfast, lunch, and dinner). In order to represent this value a cooking skill of 97.5% will be used, which represents the fraction of the times that the cooking does succeed.	0.975 [dmnl]
Amount of prepared food	Is influenced by the variables *Average amount of food needed for a household, Provision factor*, and the *Effect of the storage*. Regarding the *Effect of the storage*, the amount resulting from the multiplication of *Provision factor* and the *Average amount of food needed for a household* will be multiplied by this factor. An IF THEN ELSE function is needed in order to model the decision of the household that they cannot prepare more food than is available in the storage.	$IF\ THEN\ ELSE\ (Amount\ of\ stored\ food > 0, (Average\ amount\ of\ food\ needed\ for\ a\ household - Amount\ of\ leftovers\ consumed) + ((Average\ amount\ of\ food\ needed\ for\ a\ household - Amount\ of\ leftovers\ consumed) * (Provision\ factor + Effect\ of\ stored\ food)), 0)$ [kg/week]
Amount of inedible prepared food discarded	Is influenced by the variables *Amount of prepared food* and *Cooking skills*. The *Amount of prepared food* will be used as input for the *Amount inedible food prepared*. A fraction of the *Amount of prepared food* will not be edible based upon the *Cooking skills* of the household, which is calculated by multiplying these variables.	*Amount of prepared food-(Cooking skills*Amount of prepared food)* [kg/week]
Total amount of edible food leftover	*The Amount of edible food leftover* is the difference between the *Amount prepared food* and the *Amount of consumed food* minus the *Amount of inedible prepared food discarded*	*IF THEN ELSE(((Amount of prepared food-Amount of inedible prepared food discarded)-Amount of consumed food) >=0, (Amount of prepared food-Amount of inedible prepared food discarded)-Amount of consumed food, 0)* [kg/week]

Effect of stored food	This fraction represents the fraction of the total amount of food needed for a household that is present within the storage. In order to estimate the effect of the storage on the *Amount of prepared food*, a look-up function will be used. Having full storage, having more than a full meal for all members within a household for a week will result in an additional 5% of prepared food. Having no food at all stored will result in no increase. The x-axis represents the fraction of meals present in the storage.	
Fraction stored food of the total amount of food needed for a household	This fraction represents the amount of meals that are present within a household. The *Amount of stored food* will be divided by the *Average food needed for a household* in order to calculate the fraction	*Amount of stored food/Average amount of food needed for a household* [dmnl]

Consuming

The behaviour of interest is that households need to consume the food that has been prepared, which will result in one food waste variable, the amount of leftovers discarded directly. Figure A5 shows the submodel of the consuming phase.

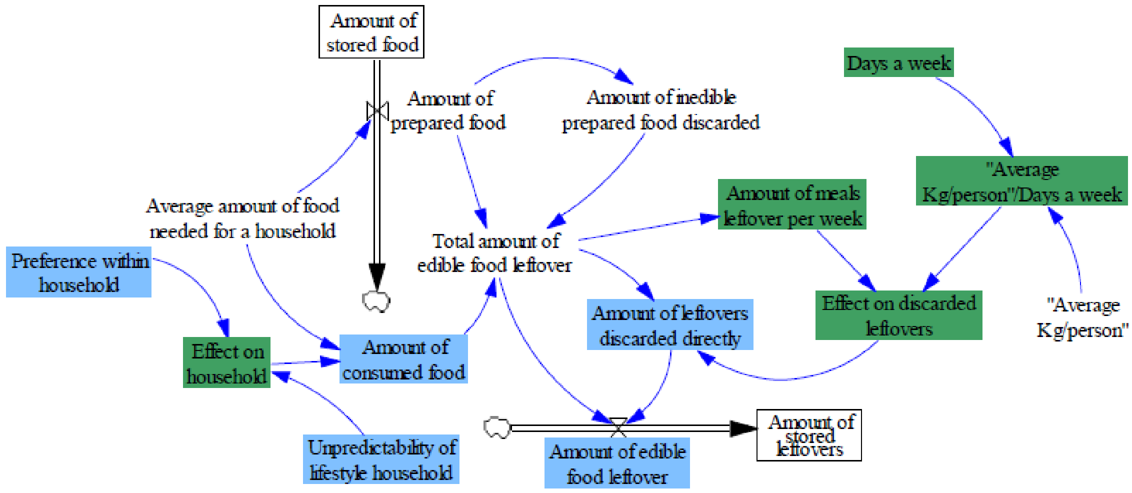
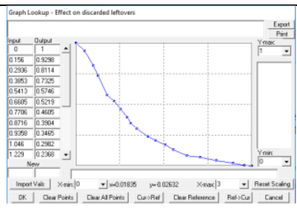


Figure A5. Consuming phase submodel

The *Amount of consumed food* is the central variable in this phase. The *Amount of consumed food* is determined by the following variables: *Preference within a household, Unpredictability lifestyle household,* and *Average amount of food needed for a household.* The *Preference* represents the likes and dislikes of the members regarding the food. If a household has a higher preference among its members, less food is eaten. There is also a relation between the *Unpredictability of a household* and the *Amount of consumed food*. Households which have more predictable lives have a more constant consumption pattern. The *Amount of consumed food* influences the *Amount of edible food leftover* as households tend to prepare more food than they actually need. Also, food is wasted in this phase; food that is left over after a meal may be discarded directly if a small amount is left over. This food waste is represented by the variable *Amount of leftovers discarded directly.*

Variable/parameter	Description	Value/equation
Preferences within household	The level of preferences influences the amount of food eaten by households. A household with a high preference will dislike a lot of food and therefore not eat it. Since no literature is available on this topic it is assumed that than a household will not eat 1.5% due to the preferences present within a household.	1.5% [dmnl]
Unpredictability lifestyle household	A life that is predictable will lead to a normal average of food that is being consumed by a household. It is assumed that the unpredictability is 1.5%.	1.5% [dmnl]
Days a week	Needed for transformation purposes	7 [day/week]
Amount of consumed food	The variables *Preference within household* and *The unpredictability of lifestyles household* have has been taken together in the variable *Effect on the household*. This value represents a deviation of the normal amount of food that should be eaten. In order to calculate the *Amount of consumed food* the *Average amount of food needed for a household* minus the *Amount of leftovers consumed* should be compensated by the *Effect on the household.*	*(Average amount of food needed for a household-Amount of leftovers consumed)-(Effect on household*(Average amount of food needed for a household-Amount of leftovers consumed))* [kg/week]
Effect on household	Is the sum of the *Unpredictability of lifestyle household* and *Preference within the household*	$(Predictability\ of\ lifestyle\ household + Preference\ within\ household)$ [dmnl]
Amount of leftovers discarded directly	Is influenced by the variables *Total amount of edible food leftover* and the *Effect on discarded leftovers directly*. These values can be multiplied by each other in order to calculate the *Amount of leftovers discarded directly*.	$Total\ amount\ of\ edible\ food\ leftover * Effect\ on\ discarded\ leftovers$ [kg/week]
Effect on discarded leftovers	Is dependent on the variable *Amount of meals left over per week*. It is assumed that if not more than 1/3 of a meal is left over after dinner, there will be a high probability that more leftover food will be thrown away directly. Otherwise, it will be stored and eventually eaten at a later stage**.**	
Amount of meals left over per week	This represents the food that is left over per week given the normal amount a person would eat in a day. This variable is used as input in order to calculate the *Effect on discarded leftovers*.	$Total\ amount\ of\ edible\ food\ leftover$ /"Average Kg/person" [(person*day)/week]
Average Kg of food per day per person	Needed for transformation purposes	"Average Kg/person"/Days a week [kg/(person*day)]
Amount of edible food leftover	The value of this variable can be calculated by subtracting the *Amount of leftovers discarded directly* from the *Total amount of edible food leftover*	$Total\ amount\ of\ edible\ food\ leftover - Amount\ of\ leftovers\ discarded\ directly$ [kg/week]

Re-using leftovers

The behaviour of interest is that households may or may not use the food that is left over, potentially resulting in food waste. Figure A6 shows the stock-flow diagram of this phase in the model.

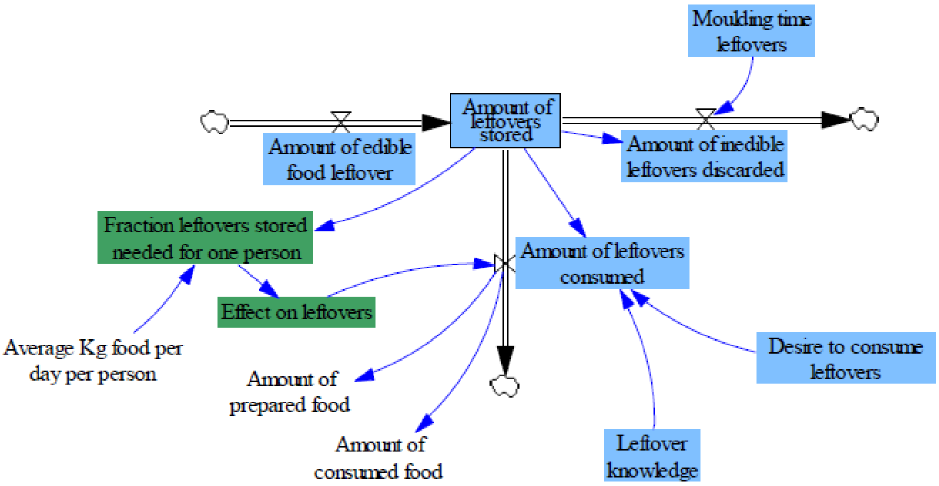
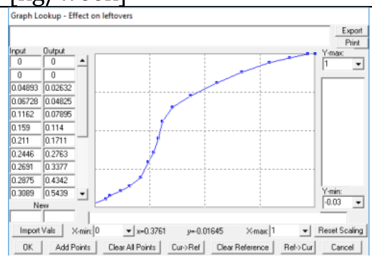


Figure A6. Re-using leftovers phase submodel

The *Amount of leftovers stored* and the *Amount of leftovers consumed* are the central variables in this phase. The *Amount of leftovers stored* is affected by the following variables: *Amount of edible food leftover, Amount of leftovers discarded,* and *Amount of leftovers consumed. The Amount of leftovers consumed* is affected by the *Desire to consume leftovers, Leftover knowledge,* and the *Amount of leftovers stored*. Households tend to not always eat leftovers. To consider this behaviour, the variable *Desire to consume leftovers* is added. *Leftover knowledge* is the counterpart that is needed since households have to be able to re-use and consume these leftovers. Having more knowledge results in more opportunities regarding the re-use of leftovers. A longer *Moulding time leftovers* results in a lower *Amount of leftovers discarded*.

Variable/parameter	Description	Value/equation
Desire to consume leftovers	A higher value represents the willingness to eat leftovers. There is no data available on this topic and therefore it is assumed that a household has an average value of 0.5. Meaning that a household is willing to consume leftovers 50% of the time.	0.5 [dmnl]
Leftover knowledge	Represents the knowledge on how to re-use leftovers. A higher value will lead to a higher ability to re-use. No data is available on this topic. It is assumed that a household has a knowledge level of 0.8. Meaning that 80% of the time, a household knows how to re-use food.	0.8 [dmnl]
Moulding time leftovers	Since the quality of leftovers deteriorates quickly, a smaller decay time has been chosen than the *Used by date* and the *Best before date.* It is also hard to take an average time	3/7 [week]

	for leftovers since the time before it decays is dependent on the type of food, therefore a decay time of 3 days has been chosen.	
Amount of leftovers stored	Stock initialised close to equilibrium	Initial value 0.1566 [kg]
Amount of leftovers discarded	Is influenced by the variables *Amount of leftovers stored* and *Moulding time leftovers.* The same approach will be used as during the storage phase, but now, no difference is made between the *Best-before-date* and *Used by date*. These are together in a *Moulding time of leftovers* variable.	$Amount\ of\ leftovers\ stored/\mathrm{Moulding}\ time\ leftovers$ [kg/week]
Amount of leftovers consumed	The consumption of the leftovers is dependent on desire and knowledge. Multiplying the desire and the knowledge will result in the fraction of the leftovers that will be eaten. Based on the amount of leftovers available, an extra amount will be eaten if a lot of leftovers are being stored. The fraction of the total amount of food that is extra being eaten initially is the *Effect on leftovers.*	$IF\ THEN\ ELSE(\ Amount\ of\ leftovers\ stored >= 0,(Amount\ of\ leftovers\ stored*Desire\ to\ consume\ leftovers*Leftover\ knowledge)+((Amount\ of\ leftovers\ stored*Desire\ to\ consume\ leftovers*Leftover\ knowledge)*Effect\ on\ leftovers),0)$ [kg/week]
Effect on leftovers	Is influenced by the variable *Fraction of leftovers stored needed for one person*. It is assumed that leftovers tend to be eaten faster when bigger portions are available. The x-axis represents the *Fraction of leftovers stored needed for one person*. The effect will be on the fraction of the food leftover that will be eaten extra, based on the original amount.	
Fraction of leftovers stored of needed for one person	The fraction can be calculated by dividing the *Amount of leftovers stored* by the *"Average kg/person"*.	$Amount\ of\ leftovers\ stored\ /$ "$Average\ Kg/person$" [person*day]

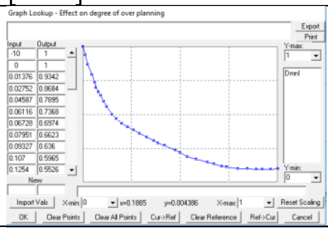
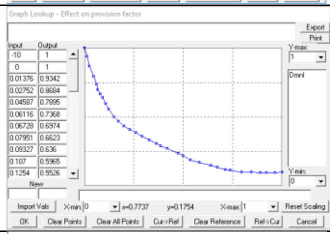
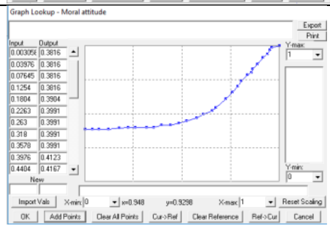
General variables

The following variables/constants do not belong to a specific phase, or they are variables that are needed to connect the submodels with each other. Figure A7 (at the end of this appendix) provides a complete overview of the stock-flow diagram of the household food waste model with colours representing the different phases.

The *Household size* affects the *Average amount of food needed for a household. Knowledge on consequences food waste* affects the *Moral attitude,* which in turn affects the *Perceived amount of food waste*. The *Perceived amount of food waste* is the waste perceived by the household. Having a higher *Moral attitude* leads to a higher *Perceived amount of food waste*. *Total food waste* is the sum of all the food waste variables.

The re-using leftovers phase is connected with the preparing phase. If the *Amount of leftovers consumed* increases, a lower *Amount of food prepared* results; less food is prepared to compensate for the *Amount of leftovers consumed.* A similar relation is present regarding the consuming phase. If the *Amount of leftovers* increases, the *Amount of consumed food* decreases. The storing phase (via the *Amount of stored food*) and the re-using phase (via the *Amount of stored leftovers)* are directly connected with the planning phase via the *Perceived amount of food inventory*. In both cases, more stored food or leftovers leads to a higher *Perceived amount of food inventory*.

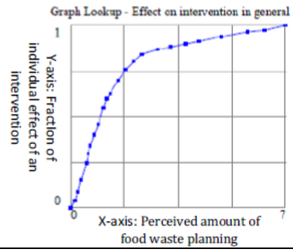
Variable/parameter	Description	Value/equation
"Average Kg/person"	Average food and drink consumption in Netherlands is 3.1 kg per day, of which 1/3 consists of food (RIVM, voedselconsumptie in Nederland 2012-2016)	7 [kg/(person*week)]
Household size	In the Netherlands, the average household size is 2.17 people.	2.17 [person]
Knowledge on consequences food waste	A value of 0 represents no knowledge at all and a value of 1 represents a total knowledge. In the Netherlands, it is assumed that the average household has a knowledge level of 0.7.	0.7 [dmnl]
Average amount of food needed for a household	Is determined by the variables *Average Kg/person* and the *Average members household*.	$"Average\ Kg/person" *Average\ members\ household$ [kg/week]
Total discarded stored food	Is determined by the variables *Amount of edible stored food discarded* and *Amount of inedible stored food discarded*.	$Amount\ of\ edible\ stored\ food\ discarded + Amount\ of\ inedible\ stored\ food\ discarded$ [kg/week]
The perceived amount of food waste planning	Is influenced by the variables *Moral attitude* and the *Total food waste regarding the planning loops*.	$(SMOOTHI(\ Moral\ attitude*Total\ food\ waste\ regarding\ the\ planning\ loops, Perceived\ time, Initial\ perceived\ amount\ of\ food\ waste\ planning))$ [kg/week]
The perceived amount of food waste preparing	Is influenced by the variables *Moral attitude* and *Total food waste regarding the preparing loops*.	$(SMOOTHI(\ Moral\ attitude*Total\ food\ waste\ regarding\ the$ preparing $loops, Perceived\ time, Initial\ perceived\ amount\ of\ food\ waste$ prepared)) [kg/week]
Perceived time	Is used in *Perceived amount of food waste planning* and *Perceived amount of food waste preparing* as smoothing time	2 [week]
Initial perceived amount of food waste planning	Is used as initial value of *Perceived amount of food waste planning*, initialised close to equilibrium	1.02 [kg/week]
Initial perceived amount of food waste prepared	Is used as initial value of *Perceived amount of food waste preparing*, initialised close to equilibrium	0.3971 [kg/week]

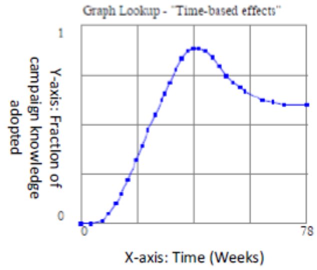
Correctness factor planning	Is influenced by the variables *Perceived amount of food waste planning* and *Average amount of food needed for a household*.	*Perceived amount of food waste planning/Average amount of food needed for a household* [dmnl]
Correctness factor preparing	Is influenced by the variables *Perceived amount of food waste preparing* and *Average amount of food needed for a household*.	*Perceived amount of food waste prepared/Average amount of food needed for a household* [dmnl]
Effect on the degree of over planning	Is dependent on the *Correctness factor planning*. This factor will be used in order to affect the degree of over planning. Having a higher *Correctness factor planning* will result in a lower *Degree of over planning*.	
Effect on provision factor	Is dependent on the variable *Correctness factor prepared*. Having a larger *Correctness factor prepared* will result in a lower *Provision factor*	
Moral attitude	The moral attitude is dependent on *Knowledge of the consequences of food waste*. Attitude is expressed in a number between 0 and 1. A higher *Knowledge of the consequences of food waste* results in a higher *Moral attitude*. However, knowledge is not the only factor explaining the *Moral attitude*. Therefore a baseline will be chosen, which represents the normal level of *Moral attitude*. For a normal person, it is assumed that a base-level of 0.4 moral attitude on average is applicable. This attitude increases when the *Knowledge on consequences food waste* increases. The x-axis represents the *Knowledge of the consequences of food waste*	
Total food waste regarding the planning loops	Is influenced by the variables *Total discarded leftovers* and *Total discarded stored food.* These types of wastes will be taken into account for coping with the variable *Degree of overbuying*.	*Total discarded leftovers + Total discarded stored food* [kg/week]
Total food waste regarding the preparing loop	Given the preparing loops, the only kinds of food waste that will be taken into account are these dependent on the leftovers.	*Total discarded leftovers* [kg/week]
Total food waste	Is determined by the variables *Total discarded stored food, Total discarded leftovers,* and *Amount of inedible prepared food discarded.* Adding these values will result in *Total waste food*. This variable can be summarized by adding the *Total food waste regarding the*	*Total food waste regarding the planning loops + Amount of inedible prepared food discarded* [kg/week]

	planning loops and the *Amount of inedible prepared food discarded*.	
Total discarded leftovers	Is the sum of the variables *Amount of Leftovers discarded directly* and the *Amount of inedible leftovers discarded*.	$Leftovers\ discarded\ directly + the\ Amount\ of\ inedible\ leftovers\ discarded$ [dmnl]
Fraction of food thrown away	Is the fraction of the *Total food waste* with respect to the *Amount of bought food*.	$Total\ food\ waste/amount\ of\ bought\ food$ [dmnl]

Setup of interventions

The interventions are assumed to change the following parameters or variables.

FridgeCam		
Degree of using a shopping list	The base value for the degree of using a shopping list is 70%. Using a FridgeCam is assumed to increase the use of a shopping list. However, it is not known to what degree. To consider the effect on the *Degree of using a shopping list,* we assume a maximum increase of 15%, resulting in a base-run input of 70% and a maximal intervention input of 85%.	$Degree\ of\ using\ a\ shopping\ list = 0.7 + (0.15 * Effect\ on\ intervention\ general * FridgeCam)$ [dmnl]
Degree of the inventory checking	To consider the effect on the *Degree of the inventory checking* a maximum increase of 50% is assumed, going from 50 to 100%.	$0.5 + ((0.5 * Effect\ on\ intervention\ general) * FridgeCam)$ [dmnl]
Effect on intervention general	Households with a higher *Perceived amount of food waste* are more willing to reduce food waste in their household. There is an assumed relation between the *Perceived amount of food waste planning* and the effect of an intervention.	
No discounts		
Effect of economies of scale and discounts	The full effect of this intervention removes the *Effect of economies of scale and discounts*.	$0.1 - (0.1 * No\ discounts\ and\ economies\ of\ scale * Effect\ on\ intervention\ general)$ [dmnl]
Spoilage knowledge campaign		
Spoilage knowledge	With the *Awareness campaign on the use by and best before date*, the level of knowledge is assumed to increase, but over time people adopt this knowledge and people forget it on the longer term. It is assumed that level of spoilage knowledge increases with a maximum of 20%.	*0.5+("Time-based effects"*((0.2*Awareness campaign on Best before Best used by dates*Effect on intervention in general)))* [dmnl]

Time-based effects	It is assumed that on average it will take time before households adopt this new knowledge and some of the knowledge is forgotten over time. It is assumed that it peaks at almost 90%, thus at the best almost 90% of the households have adopted the knowledge. However, not every household will remember the knowledge provided in the longer term.	
Knowledge on consequences campaign		
Knowledge on consequences food waste	The average knowledge on the consequences of food waste is assumed to be 70%. Increasing the knowledge with a campaign is assumed to result in an average increase of 20%.	*0.7 + (((0.2 * Awareness campaign on consequences food waste)*"Time-based effects")*Effect on intervention in general)* [dmnl]

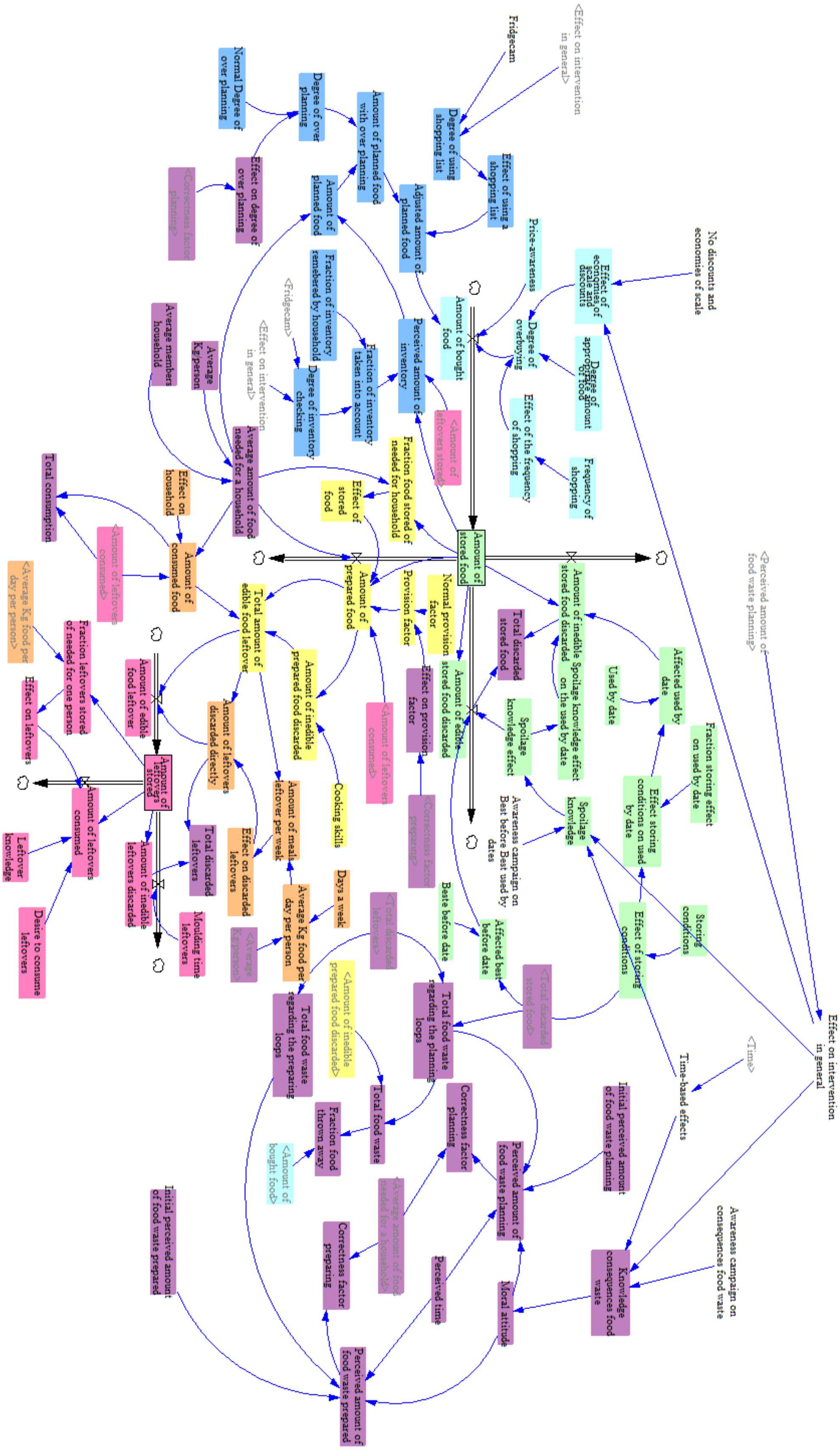


Figure A7. Stock-flow diagram of the household food waste model