Household Simulation Model: Methodological Summary

Introduction

This document provides a summary of the methodology for the Household Simulation Model (HHSim).

Background to household food waste

The generation of waste food in the home is a complex issue. There are many, interrelated reasons for waste being created and many different actions that can prevent this waste from arising. These drivers for waste generation and prevention cover several different areas: how the food is sold and its pricing structure, its shelf life, how the food is stored in the home, and ways in which it is prepared and served.

As most of the drivers occur well in advance of the food being discarded, it is necessary to understand how these drivers influence the passage of food through the home over a relative long period of time. Furthermore, the various drivers of food-waste generation interact with each other: for example, whether an item gets thrown away because its passed its use-by date depends on – amongst other things – the frequency with which people go shopping, how much of that item they buy on a shop, the size of the packs, the shelf life and how much they consume in a relevant period. Given this complexity, it is useful to deploy methods that can model these interactions.

The HHSim described below is currently being used to investigate how various changes to a product or to decisions / behaviours within a household influence the amount of food waste. In many cases, it would not be practical to empirically measure the effects of these changes in real households as the scale of primary research required would be prohibitively expensive.

The Household Simulation Model Methodology

Discrete event simulation

The Household Simulation Model (HHSim) uses an approach called Discrete Event Simulation (DES) – which models a system as a sequence of events over time. The 'system' in this case is a household, focusing on the journey of a type of food (e.g. milk) through the household from purchasing to either consumption or being thrown away. The HHSim models a long period of time (years or decades) to simulate multiple decisions made by a householder related to when they go shopping, how much they buy, where they store the product, when and how much to use and under what circumstances it gets thrown away.

Because the HHSim focuses on how the characteristics of the item (e.g. shelf life) and decisions by the householder influence the journey of items of food through the home (e.g where to store such as in fridge, freezer or ambient temperatures), the method can be used to explore the interaction between these phenomenon.

A key element of DES is its probabilistic nature. For instance, the shelf-life of a bottle of milk is not always the same; it varies over a distribution of likely values. Similarly, the decisions made by householders will not always be the same, e.g. the amount of milk used each day will vary.

Therefore, in the simulation, the amount of milk drunk eaten each day is determined by taking values at random from a distribution of likely values determined from consumption data.

This helps the model to recreate the observation that many instances of food wastage are related to 'unexpected' and 'unusual' events: buying a product with an unusually short shelf life, an unplanned social engagement, or a work commitment leading to dinner being bought and eaten on the way home, rather than in the home. The variability inherent in the model helps to capture these phenomenon. Many other methods for modelling systems (e.g. system dynamics) cannot consider these variations over time and, for this reason, are relatively poor in describing – and aiding the understanding of – household food waste.

The use of DES for modelling food waste in the home was first developed by WRAP as part of the Milk Model[1] and has been replicated for households in the USA[2].

Model Structure

The basic model of the HHSim has 4 modules:

- **Shopping Module**: Purchase of an item can occur in 'main' and 'top-up 'shops. The shopping module uses input data from the model user to specify the frequency of main shops and the triggers that lead to top-up shops, i.e. running low or running out of that food stuff. The user can specify how much is bought in each type of shop. Furthermore, the user can specify whether the amount purchased is influenced by the amount of that food already in the home. The shopping module also assigns the shelf-life to each food item, using data derived from WRAP's Retailer Survey[3].

- **Storage Module:** Food items can be stored in the fridge, freezer or at ambient temperatures depending on the food item and the set-up specified by the user. Items suitable for freezing can be frozen when purchased or as they approach their expiry date. If frozen, the shelf life of the item is adjusted accordingly. This module also checks items daily to see – depending on the options selected by the user – whether any get frozen or thrown away.

- **Demand Module:** This module determines how much of that food item is demanded by the household members that day. This is built up by the number of people (and their ages) in the household, using distributions derived from National Diet and Nutrition Survey[4] (diary-based consumption study).

- **Consumption Module:** Once information is received from the demand module on the amount of that food item required for a day, the consumption module works out whether this amount of food is present in the home. If so, food in the fridge and ambient conditions is usually used before using food in the freezer. In some cases, demand not met by the amount of food in the home can trigger a top-up shop.

Data recorded

The HHSim records a range of information about each run of the model:

- All input data relating to a run, to allow the model to be rerun if necessary
- The amount of the food item wasted, split by why it was wasted, i.e. due to length of time:
    - Since purchase

[1] http://www.wrap.org.uk/sites/files/wrap/Milk%20Model%20report.pdf
[2] https://www.mdpi.com/2071-1050/11/7/2152
[3] E.g. http://www.wrap.org.uk/sites/files/wrap/Retail_Survey_2015_Summary_Report_0.pdf
[4] https://www.gov.uk/government/collections/national-diet-and-nutrition-survey#archive-of-ndns-reports

    - Since opening
    - In the freezer
    - Since thawing
- Instances where demand for an item was not met (due to lack of that food item in the home)
- Amount of food purchased
- Amount consumed
- Amount / number of items frozen
- Amount of food item in the household at the end of the simulation
- Amounts of waste in each of the first 5 weeks (to investigate start-up effects in the model)

Household archetypes

One of the challenges for the HHSim is obtaining information relevant to a wider (UK) population from simulation runs, each of which is for an individual household. Therefore, the simulation needs to be run for a series of different household types (or 'archetypes') designed to represent a wide range of households within the UK.

Seven archetypes have been developed for the UK, based on previous food-waste segments developed for WRAP. These archetypes are diverse, differing with respect to: number of occupants in the household, shopping patterns; quantities purchased; attitude to food safety; degree of engagement with food-waste-prevention practices / behaviours.

When results from the archetypes are combined, they are weighted to ensure that the profile of household size (number of occupants) is in line with the UK population. It is also useful to observe how results vary between the archetypes: e.g. for instance, the effect of freezing bread in different types of household. This helps identify which groups are most (or least) affected by a given change to a household.

Limitation

The model is only well suited to predict estimates of changes in the amount of food that is wasted because it is not used in time (e.g. gone mouldy, thrown away because it has gone past a date label). It is not designed to predicted other causes of waste (e.g. cooked too much, personal preference).

The HHSim is run for a given type of food at any one time (e.g. milk, bread, cheese). Currently the interaction between different types of food (e.g. a temporary lack of milk in the household reducing breakfast cereal consumption) cannot be modelled explicitly, but will be captured implicitly by the variation in demand within a household.

Finally, the HHSim is an approximation of real, complex households. Although the HHSim attempts to include all important decisions and behaviours, real households will have complexities not fully captured in the HHSim. These omissions have the potential to influence food waste, and for this reason the HHSim only provides approximate estimates of the impact on household food waste of a given change to a product or to decisions in the household.