Transforming Surplus into Solidarity: Systems Dynamics modelling in support of food redistribution

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Abstract

Food loss and waste (FLW) in the EU remains a critical challenge, with 59 million tonnes wasted annually, exacerbating resource inefficiencies and greenhouse gas emissions. The objective of the study is to design a data tool that will allow policymakers and social entrepreneurs to assess the feasibility and funding needs of new initiatives addressing the problem of food surplus through redistribution. Using a Living Lab approach within the Horizon Europe RUSTIK project, we analyse data from Etri, a social cooperative that redistributes food to marginalised peoples. Through system dynamics modelling, we integrate logistics data, survey responses, and expert assessments to quantify the social and environmental benefits of redistribution. The robustness of model parameters was preliminarily confirmed by iterative validation against historical accounting data. Future work focuses on procuring additional data sources to enhance both validation and the model's applicability for diverse regional contexts.

GLOSSARY

Term	Definition
Food Loss	The decrease in edible food mass throughout the production, post-harvest, and processing stages of the food supply chain, excluding retail and consumption. Common in agricultural and logistics phases.
Food Waste	Edible food discarded at the retail or consumer level, often due to spoilage, overproduction, or aesthetic standards. Occurs at supermarkets, restaurants, and households.
Food Surplus	Food that is still safe and edible but exceeds market demand.
Food Redistribution	The process of collecting surplus food and reallocating it to people in need, often via food banks, social cooperatives, or charitable organizations.
Causal Loop Diagram (CLD)	A systems-thinking tool used to visualize the interdependencies and feedback loops in food redistribution processes.
Living Lab (LL)	A user-centered, open innovation ecosystem where researchers, stakeholders, and users co-develop and test solutions in real-life environments.

PROBLEM STATEMENT

Every year, around 59 million tonnes of food are wasted in the EU, which represents a significant inefficiency in the use of limited resources such as land, fertilisers and energy, while contributing to greenhouse gas emissions (Cattaneo et al., 2021). Simultaneously, more than 42 million people in the EU cannot afford a good quality meal every second day (Eurostat, 2023), the affected often belonging to groups of marginalised people (Poczta-Wajda and Guth, 2024). In contrast to food waste, there is no periodical monitoring established on the amounts of food loss in Slovenia and the EU, and consequently on the feasibility of food redistribution. A World Wide Fund for Nature report estimates however, that 15,3% of food produced globally is lost at farm stage, amounting to 1,2 billion tonnes per year (*Driven to Waste…*, 2021).

RESEARCH QUESTION AND OBJECTIVES

The research aims to answer how different approaches to food redistribution and donation impact subjective well-being, assess the costs and benefits of redistribution, and explore the integration of quantitative and qualitative data for evidence-based policymaking. The objective is to design a data tool that will allow policymakers and social entrepreneurs to assess the feasibility and funding needs of new initiatives addressing the problem of food surplus through redistribution. In this process, we seek to provide data driven insights to support initiatives aiming to reduce FLW while enhancing social inclusion.

METHODS

The research is based on our work in a Living Lab (LL) of a Horizon Europe project (RUSTIK, 2025). In the LL we apply a heuristic approach, aiming to address the issue of FLW while simultaneously addressing the lack of social inclusion among marginalised individuals. The main guiding principle is the conceptual framework of Theory of Change, which is the formulation of an explicit theory of how and why the activities of a policy or programme should lead to impacts (Mayne, 2017). Through this approach, we draw on insights gained through our project partner Etri – a local social cooperative that engages in food redistribution and donation through social entrepreneurship. By analysing their logistics and accounting data, we obtained a detailed understanding of the operations of this type of

organisation. Additional data has been gathered on the impact of food donation on the well-being of beneficiaries through Likert scale surveys.
Based on the data collected, we are designing an economic model using a system dynamics (SD) methodology (Coyle, 1997). The model combines quantitative data on surplus food and processing logistics with insights gathered through surveys. In this way, the model will serve as a link between the flow of food items, the social and environmental impacts, and the costs incurred.
The initial stage of SD modelling is based on devising a causal loop diagram (CLD), that describes the process in a non-linear fashion, focusing on key elements and the relationships between them (Figure 1.). Considering our overarching goal of dispersing the model by using it in support of small-scale projects, we adapted the CLD accordingly. To construct it parsimoniously, we established a standard meal unit (SMU) based on the assumption, that the meals provided are nutritionally balanced and within the recommended caloric intake for the average beneficiaries' age. Additionally, we calculated coefficients for converting foodstuffs into SMUs using categories that are internally consistent in caloric density and type of use in meal preparation. The robustness of these coefficients was preliminarily confirmed by iterative validation against historical accounting data (comparing calculated outputs with actual outputs).

DATA

The living lab' heuristic approach integrates social metrics research and data-driven innovation. Through surveys, direct observations, and the analysis of logistics data, we gathered comprehensive insights into the operational dynamics and societal impact of this type of initiative and its niche. The primary source of data and demonstration case is Etri. Their operations consist of redistributing surplus food to vulnerable groups of people in a canteen, while providing employment opportunities for marginalised individuals. They made available to us detailed records of food donations, including type, quantity, and distribution patterns, which serves as the basis for the quantitative part of the modelling process.
Expert assessments are used to fill gaps where quantitative data is unavailable, particularly regarding volunteer work contributions, supply fluctuations and its' characteristics. Expert knowledge was utilised in the first stage of the system dynamics modelling process, namely in developing the CLD. To assess the impact of food redistribution on well-being, financial security, and social inclusion, we also collected data through structured Likert-scale questionnaires. Lastly, we conducted several interviews with LAGs to understand data needs and potential applications for small scale project support.

RESULTS

Using expert assessment we established a causal loop diagram for food redistribution (Figure 1). While the modelling process is still ongoing, preliminary validation tests have shown that the model's estimates for redistributed meals using SMU conversion amounted to 27% less meals than the number of meals donated in the accounting data. This is within the expected margin, as the cooperative needs to buy some food items in order to provide balanced meals. As the use case and validation of the model is limited by data availability, our current efforts include securing additional data sources and adapting the model to different regions and approaches to food redistribution. In addition, we plan to test its applicability in support of a call for proposals and its implementation in a Local Action Group (LAG) project.

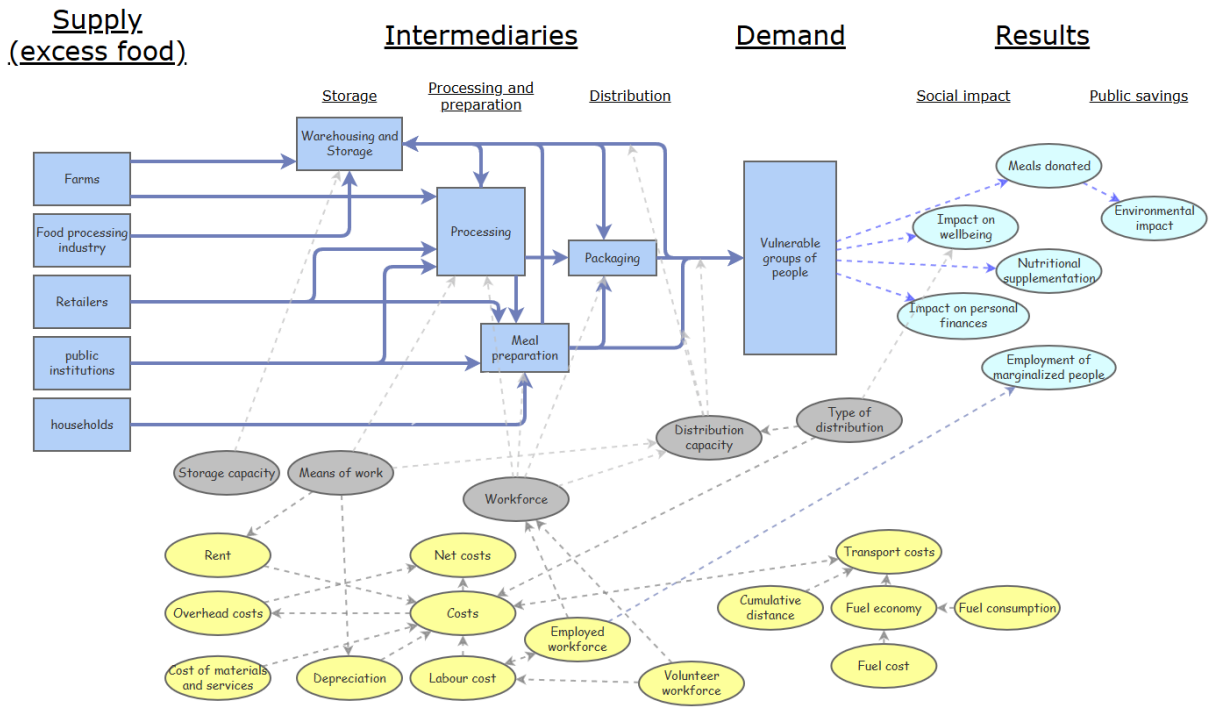

Figure 1: Causal loop diagram of the food redistribution process (Own elaboration)

During the modelling process we gathered several notable insights into food redistribution dynamics:

- The largest portion of surplus food (57% in this case) consists of unsold bread, which poses a challenge in providing nutritionally balanced meals.
- There is a strong seasonal variation in the supply of surplus food, impacting the consistency of redistribution efforts.
- Food redistribution in a canteen setting, as opposed to a packaged donation, appears to provide additional social benefits, including fostering social cohesion and feelings of reciprocity among vulnerable populations. We aim to confirm this by surveying of beneficiaries of several different donation types.
- Discussions with Etri employees revealed regulatory limitations, such as contractual clauses limiting food donation among competitors.

We also consulted with Local Action Groups (LAGs), interviewing them on the following:

- Similar enterprises that could serve as additional data sources. We found that there is a lack of food redistribution enterprises utilising the same donation approach, however there are several that could serve as a control for establishing the impact on beneficiaries' well-being.
- The existence of projects with similar infrastructure requirements (food-safety certified kitchens and canteens). Our findings indicate that there were some projects including cooking classes for FLW reduction that utilised public infrastructure (i.e. local school's kitchen facilities).
- Their interest and need for the data support we are aiming to provide. They expressed interest in using the model for small-scale projects. We are currently in discussions with one such LAG for implementing the model in a call for proposals.

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