Beyond Food Sharing: Supporting Food Waste Reduction with ICTs

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Abstract—Guaranteeing food security is key in improving the quality of life of citizens at all levels of society. The recent economic crisis has increased the number of people living in conditions of food poverty, especially in developed regions. Consequently, the reduction of food waste has become an international trending topic. Despite a growing awareness of the importance of reducing waste and managing food surplus, the role of ICTs in this domain is still unclear and rarely documented. In this paper, we describe our almost 5-year experience in developing and experimenting ICT tools to recover food surplus at different stages of the supply chain and we outline the way forward for an integrated set of ICT tools to reduce waste from producers to households.

I. Introduction

The economic crisis of the last decade has caused an increase of the number of people in developed countries living in a condition of "food poverty". Despite a growing number of charity organizations such as food banks, and public interventions to limit the problem, it is still difficult to guarantee food security to all [1]. At the same time, an enormous and hardly quantifiable amount of food is wasted every day.

Substantial food losses and waste occur along the whole production chain. However, our understanding of the real magnitude of the problem is still very limited [2]. Various studies such as [3], [4], [5], [6] estimated a higher amount of food waste per capita in developed countries (as high as 280-300 kg per person per year in Europe and North America according to [4]).

Food waste is defined by [3] as "the surplus food that is not recovered to feed people, to feed animals, to produce new products, new materials or energy".

Food waste has become a trending topic in the international discourse on food security. Recovery of food surplus has therefore gained much needed attention in the recent years, also giving raise to innovative mechanisms based on Information and Communication Technologies. In particular, several mobile applications to attempt to reduce domestic food waste by introducing a "food sharing" model have emerged [7]. However, an analysis of 8 case studies in Italy (where most of these applications have been developed) [8] highlighted several limitations in this often too simplistic model.

According to [9], [10], a *Smart Sustainable City* is "a city that (a) meets the needs of its present inhabitants (b) without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations." Cities that waste food are less likely to be sustainable and, certainly, demonstrate a considerable lack of *smartness*. This paper presents our experience in introducing innovative processes and technologies to rethink the current practices of food surplus management, with the goal of making food available where and when it is actually needed.

Using our tools, charities in Italy managed to save and redistribute about 720 tons of food in the last 1.5 years. Different from other experiences, we managed to achieve these results by providing solutions customized according to the *Degree or Recoverability (DoR* of the food that has to be recovered and by recognizing the fundamental role of charities in reaching donors and people in need. As a "side" effect, we started collecting systematic data about food waste from canteens and restaurants. This data is helping us to better understand the food waste phenomenon, supports canteens in reducing the amount of food wasted, and helps improving the quality and degree of recoverability of food being donated. Where food surplus cannot be recovered, we also introduced actions to raise awareness of the problem and, thus, prevent waste. This is, however, outside the scope of the paper.

This paper is structured as follows. Section II discusses key concepts related to the recoverability of food surplus at each phase of the supply chain using the Availability-Surplus-Recoverability-Waste (ASRW) framework [3]. Section III presents different mechanisms to reduce food waste using ICTs. Section IV describes the tools we developed and how they fit in the food supply chain. Section V presents our observations from experimenting our tools and VI discusses future work and our vision of how the integration of these tools could contribute to improving food security.

II. The Food Waste Supply Chain

Every stage of the food supply chain produces surplus [2], [3] and therefore waste.

The reduction of this surplus is acknowledged as a mitigating factor for food insecurity, especially in developed countries [3]. However, not all the surplus can be equally recovered and not all surplus is suitable for human consumption.

Table I
VOLUME AND DEGREE OF RECOVERABILITY OF FOOD DONATIONS AT
DIFFERENT STAGES OF THE FOOD SUPPLY CHAIN

Stage	Volume	Degree of Recoverability
Agriculture and Fishing		Medium-Low
Manufacturing	High	Medium-High
Retail Trade		Medium-High
Food Service	Medium	Medium-Low
Household Consumption	Low	Low

Garrone et al. [3] conceptualized the Availability-Surplus-Recoverability-Waste (ASRW) framework to assign a *Degree of Recoverability (DoR)* index to food surplus at different stages of the supply chain. *DoR* is a function of the *Intrinsic Recoverability* and *Managment Intensity* of surplus food. The former depends on factors such as shelf life, need for refrigeration, etc., the latter refers to the commitment required by producers, retailers and intermediaries to make the surplus food available and usable to a beneficiary.

According to the ASRW framework [3], the highest *DoR* is found at the manufacturing and retail stages, which can also offer larger donations. The lowest *DoR* and volume is found at the household consumption stage where donations can be very small amounts of (often unpackaged) food. While this could be suitable for human consumption, it often does not meet the economic and moral requirements set by charities. Not surprisingly, the two categories of products with a higher *DoR* are packaged goods from retail distribution centers and products that do not require storage and transport at a controlled temperature and within a short time span.

Another metric to take into consideration is the amount of food that can be donated by potential givers at the different stages of the supply chain. As products move from producers to end consumers, the volume of a potential food donation decreases. For example, a manufacturer or a retailer is likely to donate a whole production lot of products, while a consumer is only able to donate one or a few packages. Table I summarizes the *DoR* and volume of donations from actors at the different stages of the supply chain. It is clear from the table that it is more convenient to recover large donations from retailers than small donations from single consumers.

III. ICT AND FOOD WASTE: AN EMERGING TREND

There is limited scientific literature on innovative ICT-based tools to reduce food waste. In this paper we focus on tools that connect demand and offer of food products and that allow users to measure their food waste. Large businesses already use advanced business intelligence tools for inventory optimization that are usually stand-alone and not available as Web applications.

Various mechanisms are implemented by Web-based tools to reduce food waste at different stages of the supply chain. We analyzed 13 applications in Italy, Ireland, United States and Germany to identify actors and mechanisms, starting from the framework outlined by [8].

Table II summarizes the food waste reduction mechanisms identified in our analysis:

- Inventory optimization, used by large companies, e.g. to prevent overstocking.
- Donation of food to charities and managing the collection and delivery of donations.
- Advertising sales of products near the end of their shelf-life to households.
- Food sharing among households.
- Measurement of waste to raise awareness and promote behaviors that reduce waste.

The examples mentioned in Table II have varying degrees of human intervention and mediation. The authors of [8] recommended a mediated approach (for example one that includes a food bank as donations broker) to yield better results, especially concerning food security. This was confirmed in our experience, in which these tools offer support to an activity that already exists "offline". An exception are the applications that advertise sales of products near the end of their shelf-life that do not implement communication between two actors but only broadcasting of messages.

We found no web applications addressing the recovery of food from catering services and restaurants. EquoEvento, the only example mentioned at this stage, implements a basic web form to activate the volunteers of a charity organization. According to the Availability-Surplus-Recoverability-Waste (ASRW) framework [3], this is a segment with a limited recoverability. Collective catering is mainly addressed by customized research projects and intervention such as [11] and [12].

Food sharing has become very popular in the last years and all its implementation received a significant media coverage. However, this mechanism allows for the recovery of small amounts of food that are shared among peers and do not necessarily benefit the poor. The quantity of recoverable food is thus negligible as shown in table I. There is however lack of data about the effectiveness of all the examples cited in Table II with the exception of FoodSharing.de [7], which reported over 3,000 tons of food recovered as of April 2016. This exceptional result is due to the fact that the organization behind the platform also recovered significant amounts of food from supermarkets.

Farr-Wharton et al. [13] experimented different application prototypes to reduce household food waste. They observed that food sharing requires a close community of trusted individuals and thus using an ICT application in this context seems superfluous. However, they also observed that informing the user about their food supply (e.g. quantity and expiration of products) helped reducing food waste more than sharing

Table II
FOOD SUPPLY CHAIN AND ICT TOOLS WITH THE MECHANISMS THEY IMPLEMENT

Stage	Giver(s)	Receiver(s)	Mechanisms	Examples
Agriculture and Fishing Manufacturing	Producer	Charities	Inventory Optimization Donation	Business Intelligence Tools Food Cowboy[1]
Retail Trade	Retailers (e.g. supermarkets)	Charities Households	Donation Advertisement of discounts Discounted sale	LastMinuteSottoCasa[2] MyFoody[3] FoodCloud[4]
Food Service	Catering services Restaurants	Charities	Donation Measurement of Waste	EquoEvento[5]
Household Consumption	Households	Households (Charities)	Food Sharing Measurement of Waste	FoodSharing.de[6] IFoodShare[7] S-Cambia Cibo[8]

surplus.

IV. DIFFERENT INTERVENTIONS AT DIFFERENT STAGES

In 2011 we started developing *BringTheFood*[9], a web application to connect potential food donors with charities. The application was the first of its kind in Italy and, at the time of writing, it helped collecting more than 720 tons of food.

The idea behind BringTheFood is the output of a RHoK hackathon[10] held in Trento in 2011 and the significant implementation work by the authors, colleagues and students. At its core, the application allows anyone registered in the platform to publish donations of surplus food, indicating:

- Category of food (one of dried/packaged, fresh, frozen and cooked), which determines the *Intrinsic Recoverability* of the donation.
- Short description.
- Quantity and packaging.
- Expiration date in case of uncooked products and preparation date in case of cooked products.
- Availability of the donation, i.e. date and time by which it must be collected.

Donations can be collected by people who have a use for it. For example, because they will directly consume it or because they will make it available to people in need. One of the most innovative aspects remains the possibility of drastically changing the logistics of donations, moving from traditional recovery-stocking-distribution by few actors to a more flexible approach in which many actors would recover smaller quantities.

In early versions, a reputation mechanism allowed users to verify the reputation of both donors and receivers. This was removed after the first trial showed that it might have

[1]http://www.foodcowboy.com
[2]http://www.lastminutesottocasa.it
[3]https://www.myfoody.it
[4]http://food.cloud
[5]http://www.equoevento.org
[6]http://www.foodsharing.de
[7]https://www.ifoodshare.org
[8]https://www.scambiacibo.it
[9]http://www.bringfood.org
[10]RHoK stands for Random Hacks of Kindness and it was a series of global hackathons held between 2009 and 2013.

negatively influenced the willingness of donors to use the application.

The application has been experimented in different settings over the last five years and it is available to the general public since 2012. This allowed us to observe and match the needs of the stakeholders who operate at all the stages of the supply chain.

In this section we report the various stakeholders and the interaction models that we implemented to suit their needs. The discussion follows the same terms of Table II for the stages of the supply chain, grouping "Agriculture and Fishing" and "Manufacturing" into a single "Production" stage.

A. Production

Food surplus at the Production stage is mostly characterized by large volumes (in our experience the average donation is of around 20-25 tons of produce) and medium to high *DoR*. In 2014, we partnered with ACLI, one of the largest charities in Italy, to adapt BringTheFood to manage the recovery of food surplus from organization of agricultural producers. These organizations can access subsidies and tax deductions by donating products that would not be convenient to sell to organizations that distribute them for free to the poor. However, it is possible to match this offer with the aggregated demand of multiple small charities.

The need of ACLI was thus to simplify the distribution of these large donations to a group of 50 affiliated charities, in accordance with the relevant regulations. This is achieved as follows:

- The producers notify a representative of ACLI that a new load is being shipped.
- The representative of ACLI publishes the donation.
- Charities book their share using BringTheFood and immediately receive the necessary documents for receiving the delivery and transporting their part of the donation.
- On the day of the delivery, the charities have their documents signed by the transporter who can hand over the load.

At the end of the process, BringTheFood generates the necessary documentation for the producers organization to access the relevant tax deductions and for ACLI to report on the quantity of food received.

At the time of writing (April 2016), the charities affiliated with ACLI in the area of Padova have received more than 720 tons of food that has helped more than 19,000 people.

B. Retail Trade

Our impact on retail with BringTheFood has been limited by the fact that most large retailers (e.g. supermarkets) in Italy have already implemented procedures to donate their surplus.

We experimented BringTheFood with a group of small retailers and the local Food Bank in the area of Trento in 2013.

The key change to the original implementation of BringThe-Food was the introduction of a "mediator" to ensure the quality of donations and the adherence of donors to the guidelines set by the Food Bank. This guaranteed that only pre-approved donors could join a "private network" of entities already trusted by the Food Bank.

Although the results were limited (only small quantities of food were exchanged), this experience highlighted the importance of building trust "offline". Supporting the creation of the network and conducting training meetings later allowed us to achieve the results described above with ACLI.

C. Food Service

Food Service is a stage that produces surplus that must be consumed within 24 hours of its preparation (according to the Italian law on food security). Therefore, it is one area where only some very well organized charities can recover and redistribute food in a timely manner.

In this area we developed two new applications based on BringTheFood: one associated to an educational initiative called "ZeroAScuola" and "BringTheFood per la ristorazione" (BringTheFood for food service).

ZeroAScuola is a project we are currently running in collaboration with a local administration and the middle schools in Valagarina, Italy. The project is the follow up of a research that highlighted that between 9% and 30% of the food prepared in school canteens is wasted. Our goal is to reduce the amount of food served but not consumed ideally to zero, thus increasing the *DoR* of prepared and unconsumed food.

The project has an educational component and a tool-supported monitoring component. The educational component has the goal of raising awareness about food waste and healthy nutrition with the support of the Italian Food Bank and with workshops in class. The tool-supported monitoring component of the project is ongoing at the time of writing and will allow us to collect data over a period of four months. More in detail, at the end of each meal, pupils are asked to compile a short anonymous questionnaire asking for the food eaten (servings and quantities) and the perceived quality. This will allow us to collect data on dietary and waste habits as well as generate awareness in pupils of a small age.

While ZeroAScuola has the goal of reducing the food that cannot be recovered, "BringTheFood per la Ristorazione" allows canteens to the availability of food to the local branch of the Italian Food Bank. The application allows canteen managers to report the amount of servings available organized per type of dish. This improves the collection and redistribution process, informing the volunteers of the Food Bank only when a pick-up is needed. This allows them to reach donors that previously were not considered due to the irregular frequency of their donations.

This differs in small but significant way from the original BringTheFood experience: donations are targeted (there is no need to wait for a charity to book it) and the pickup is guaranteed.

D. Household Consumption

Household consumption is an extremely challenging area for reducing food waste and enabling forms of food donations. Although various studies such as [6] and [5] suggest that the yearly amount of food wasted in households is measured in hundreds of kilograms, the *DoR* of such food is low. The reasons are many, including quantity, required storage conditions and distance to the expiration date.

Previous studies [13] seem to suggest that some of the causes for household waste include food "forgotten" in the fridge (or in the pantry) and scarce planning of meals at shopping time, ending up with ingredients in the pantry which are difficult to make into a meal.

"QuantoSpreco?" is an application for Android Devices that we are currently experimenting to tackle some of the issues mentioned above. It is available on Google Play Store.

At its core, "QuantoSpreco?" allows users to track the content of their pantries and fridges. The user can enter the expiration date of each item they buy or use the average expiration dates made available by the application. Consumed items are marked by the user and are automatically added to a shopping list. Similarly, a user can mark an item as wasted (or partially wasted), reducing its amount or removing it from the shopping list. The application computes over time the average shelf life of products and integrates with recipe services, improving the shopping list over time. Additional services compute the nutrients available in the pantry and allow the user to understand whether the pantry has a content which is compatible with that of an healthy diet.

In this case, food waste is reduced by increasing the awareness of households of expiration dates and of the content of their pantries, similarly to what suggested by [13]. Food sharing is provided as a value added service.

V. RESULTS

Being the first in Italy and among the first in the world, the application raised quite some interest from the media and it was covered both at the local and national level. Despite the interest and the growing number of users brought by the news, the volume of donations remained small for various reasons, among which: *DoR* of donations, little support to the logistical aspects, lack of focus.

Concerning the first point, the donations initially made available through the platform were small quantities of food,

close to the expiration date (e.g., two cups of yogurt) and far from the registered charities. The initial community was in fact composed mainly of very scattered household and few charities in Italy. These donations were thus at the bottom of Table I and the contribution of BringTheFood to reduce the *Management Intensity* of recovering them was low. However, the same happened with large donations (e.g., three hundreds kilos of walnuts) from producers and retailers. The registered charities and households had little use for such large quantities and they did not have the capability to redistribute them.

A second significant obstacle was that the platform provided little support to the logistics of collecting donations. The platform provided little support to organize the transportation of food from one place to the other and the actual feasibility of picking the food was severely limited. This obstacle was partially overcome by partnering with large charity organizations with their own fleet of vans. These organizations generally take care of the logistics on behalf of smaller affiliated charities that do not have the capabilities (e.g. availability of refrigerated vans) to collect donations themselves.

In fact, one of the success factors of FoodSharing.de, which was developed in parallel to BringTheFood, is that it is backed by an volunteering organization that manages the collection and redistribution of food [7].

The third and final obstacle was related to the lack of focus. By supporting multiple types of givers and beneficiaries at the same time, the users did not have a clear perception of the purpose of the application. In fact household users felt "guilty" about collecting food which could be used by charities. Charities, on the other hand, thought of the platform as a "food waste reduction application" (and not a "food surplus recovery" application), which had little use for their purposes.

Additionally, Italy is very developed with respect to volunteering, with more than 15,000 organizations working to reduce food poverty [1]. We observed a significant resistance to change and digital divide when trying to stimulate the adoption of BringTheFood in this environment. The former due to already consolidated food surplus recovery practices, the latter due to a high average age of volunteers and limited computer literacy.

The initial experience brought to a profound revision of the application, thanks also to the close collaboration and interested by the Italian Food Bank and other organizations. We started with an evaluation of the different areas where BringTheFood could bring an advantage and decided to target Production and Retailing, Food Services, and Household consumption. Rather than a one-size-fits-all solution, we customized and diversified the platform for the different areas as described in the previous section.

This allows us to better address food waste reduction according to the *DoR* of the food surplus at the different stages of the supply chain. Table III outlines the food waste reduction mechanisms implemented for the five stages:

- At the **Production** stage (Agriculture and Fishing, and Manufacturing) we extended the original implementation

Table III
FOOD WASTE REDUCTION MECHANISMS IMPLEMENTED BY THE APPLICATIONS DISCUSSED IN SECTION IV

Stage	DoR	Mechanism
Agriculture and Fishing	Medium-Low	Redistribution of large donations
Manufacturing	Medium-High	
Retail Trade	Medium-High	(Mediated) donation on private networks
Food Service	Medium-Low	Direct donations Food waste monitoring
Household Consumption	Low	Food waste monitoring (Food sharing)

of BringTheFood with features aimed at reducing the *Management Intensity* of recovering large donations from producers. These features include a booking mechanism for charities that want to receive part of the donation (e.g. one lot) and the automatic generation of all the documents required by law to transport large quantities of goods and to document their donation for tax deduction. This allowed us to support the redistribution of more than 720 tons of agricultural produce in 1.5 years.

- At the **Retail** stage we maintained the original implementation of BringTheFood with the addition of a mediator (e.g. the representative of a food bank) who ensures the quality of the donations and verifies the adherence of donors and charities to certain rules.

- At the **Food Service** stage we are partnering with the Italian Food Bank for a trial with a food service company to recover food surplus. The Food Bank has the appropriate procedures and equipment to collect and redistribute daily the food surplus of canteens, provided that the relevant food security regulations are followed. In addition, we started a food waste monitoring process to reduce the food surplus (and therefore waste) produced by canteens.

- At the **Household Consumption** stage, due to the very low *DoR*, we opted for the implementation of a tracking tool that provides relevant suggestions to limit food waste such as recipes and smarter grocery lists. Food sharing is still provided as an added value feature.

VI. CONCLUSION

The quantity of food that is wasted yearly in developed and developing countries alike is staggering. This is even more alarming if we consider how food poverty has increased in the last decade in developed countries [1].

Current practices to recover food surplus are still unable to reach the vast majority of food that is wasted but could still be consumed. We believe that innovative ICT solutions can help further scale up the amount of food which is not wasted, for the benefit of people in need and that of future generations.

As technology helps connecting demand and offer of food surplus, the most common ICT-based approaches have implemented "food sharing" mechanisms that, despite the best intentions, failed to have a significant impact. The volume and *Degree of Recoverability* of donations decreases as food

moves along the supply chain. Different approaches are thus needed to effectively connect potential givers with potential beneficiaries and simultaneous actions must be taken to reduce food waste at the stages where the *Degree of Recoverability* is lower.

In this paper, we have described our experience with technologies to change the logistics of food surplus, at various stages of the supply chain. Technologies, when paired with the activity of volunteers can effectively increase the recoverability of food surplus, reducing the *Management Intensity* of collecting donations. However, where food is available in small quantities and often close to the expiration date it is necessary to work on the reduction of food waste by increasing awareness.

The work presented in this paper is currently limited to the Italian context. However, there is no technical constraint that limits the application of the solutions that we presented. In fact, while Italy is a particularly favorable environment thanks to the fact that 1 out of 8 citizens participate in some form of volunteering, age and culture pose significant barriers to the adoption of innovative and disruptive ICT tools. Thus, as long as the importance of the human factor is adequately taken into account, we believe our experience could and should be replicated in other contexts.

This work allowed us to start collecting systematic data about food waste from canteens and restaurants. This is helping us to better understand the phenomenon and improve our tools. In addition, this is providing useful insights to reduce food waste where food surplus cannot be recovered.

Future work will thus include the study of the data that is being collected to improve the current implementations and adapt them to different geographical and – more importantly – legal contexts. Additionally, we plan to explore how the already validated food waste reduction models described in Section IV can be scaled to a larger context.

It seems to us that there is no "killer app" to reduce food waste. Integration and federation of different solutions at different stages of the chain, for example considering other uses than human consumption, will play a significant role in better understanding the phenomenon and on the future contribution of ICTs to reduce food waste.

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