Developing an Artificial Intelligence Powered Application to Connect Grocery Store Inventory and Supply Chains with Local Nonprofits
Technical Topic

Using Problem Definition to Adopt Technology That Helps Reduce Food Waste and Efficiently Allocate Wasted Food
STS Topic

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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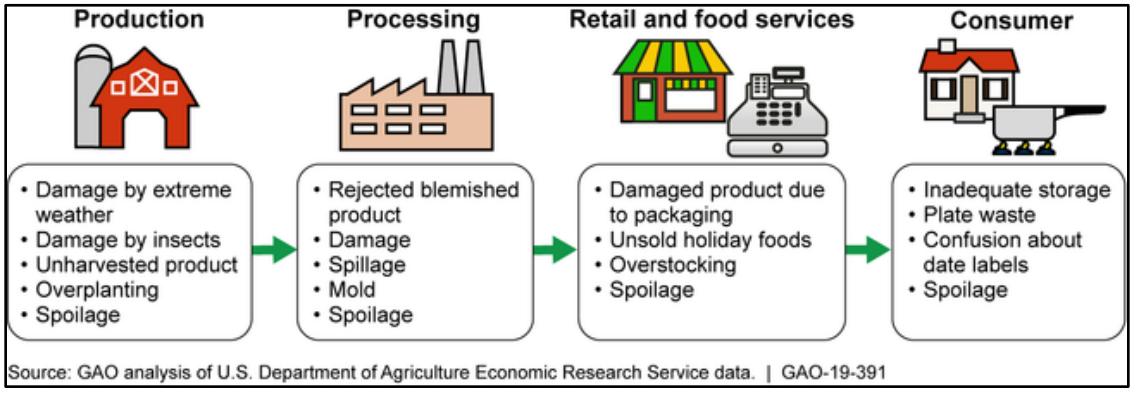
Introduction

The rise of food waste has become as much of a technical issue as it is a social issue in today's society, resulting in about 1.3 billion tons of food being wasted every year through the supply chain (Ishangulyyev et al., 2019, p.297). As shown in Figure 1 below, food can be spoiled in each part of the supply chain including through poor harvests and packaging issues. Furthermore, poor supply chain management can lead to grocers ordering too many items, leading to food being spoiled due to a lack of consumption. This is not only a significant financial burden on retailers, but is underscored by the problem of food insecurity, impacting 815 million people worldwide in 2016, and about 12.8% of households in the United States in 2022 (Onyeaka et al. 2023, p.10482; EPA 2024, EPA's Wasted Food Scale). Recent advancements in Artificial Intelligence (AI), can help combat this problem by helping businesses understand consumer behavior to order the proper amount of food, but there are still issues in redistribution



of the food.

Figure 1: Causes of Food Loss in Supply Chain. The diagram depicts the stages of the supply chain of food and how food is wasted at each stage (U.S. Government Accountability Office, 2019, What GAO Found)

The need for technology to help reduce food waste originates from society's demand for more sustainable and responsible industrial practices. Nonprofit organizations are called upon to help implement these practices, but their desire to incorporate advanced technology in aiding

their mission is overshadowed by their executives' lack of understanding of how the technology works. This includes not knowing how to use technology in a way to make a societal impact similar to how businesses use technology to create financial gain. Moreover, if this issue is not addressed, it could lead to continued food waste, following trends from 2019 where 66 million tons of food were wasted in the United States alone (EPA 2024, EPA's Wasted Food Scale).

Currently, there is no concrete solution that efficiently manages food supply chain and inventory systems while also directly connecting these retailers to local nonprofits to help reduce food waste. In this prospectus, my technical topic proposal is the development of an AI powered application that seamlessly integrates grocery store inventory systems with local nonprofits using existing machine learning algorithms. This will notify store owners at optimal times when to distribute food that is near expiration and is no longer of fiscal value to the company, while also notifying local nonprofits of the food's availability. Furthermore, my STS topic will investigate to what extent holistically understanding problems when adapting technology influences the food waste and hunger issue by using the problem definition process and Actor Network Theory.

Technical Topic: Developing an Artificial Intelligence Powered Application to Connect Grocery Store Inventory and Supply Chains with Local Nonprofits

Most grocery stores rely on inventory supply software to manage the food they sell at stores. Current systems tend to include the amount of food in storage, the amount of goods sold, and consumer patterns (Jimoh et al., 2015). While not all systems have used AI in their implementation, algorithms have been made for predictive purposes and are becoming more prevalent with the expansion of data collection. In this project, I plan to use existing data and input it into various existing predictive AI models to make concrete predictions and analysis for consumer trends, helping grocers more accurately manage inventory. Furthermore, this project

will require a process to connect nonprofit organizations to the grocers to deliver the extra food, thus requiring a mapping service to be implemented in the application to ensure it will find the closest nonprofit grocery stores can deliver their products to whenever an item is available for redistribution.

To create accurate inventory prediction models for the project, I will need access to the retailer's current inventory supply and sales data because all artificial intelligence models have a foundation built on data, and having more data available to the model ensures less bias in the algorithm's prediction (Belenguer, 2022). Next, it is important to clean the data, or ensure there are egregious outliers or inconsistencies that would cause any specific bias in the result, thus an inaccurate output when conducting supply chain and inventory model analysis. This can be accomplished by using python libraries built by SAP such as sapnrfc and pyrfc. This will allow the data to be ready to be processed by models such as time series analysis and inventory models, as well as machine learning algorithms such as the Random Forest algorithm. The former two models will leverage the data to forecast future consumer demands for food products based on past trends as well determine the optimal amount of supplies to order (Shaik et. al, 2023, p.3-4). The Random Forest algorithm classifies sample data into groups, trains the data using unique features, generating a predictive model for navigating and understanding consumer demands using the Skicit-learn python library (Koehrsen, 2018). This can also be applied to understanding the lifespan of certain foods as well.

Having the backend of the application understand the consumer behavior and food lifespans is crucial for the development of this technological use case as it allows the AI algorithm to accurately classify trends for retailers to use when understanding how to efficiently make supply orders. This will allow the inventory management system to make notifications to

let the retailer know when it is time to donate the current supply of food that is no longer of financial value to the business and reorder new supplies, and of what quantity. This is very important because as shown in Figure 2, understanding product quality when ordering new inventory is a large challenge businesses face.

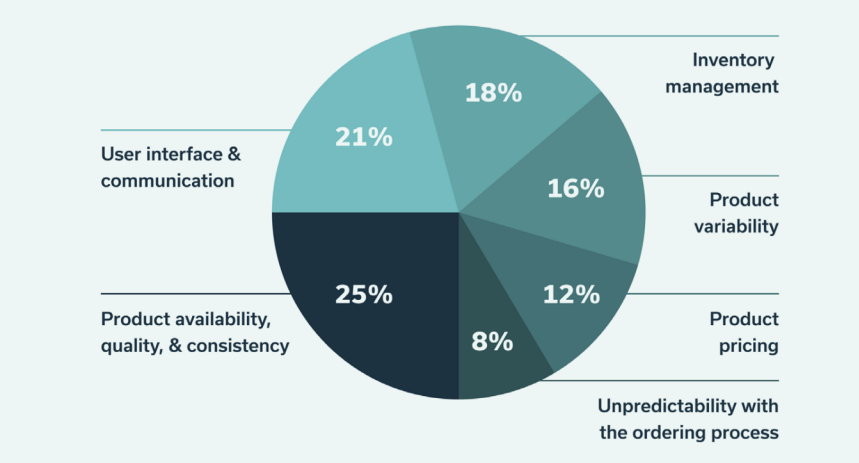


Figure 2: Biggest Ordering Challenges Retailers Face. This pie chart illustrates the largest challenges businesses face when attempting to reorder inventory (Pacific Coast Collaborative, 2022, p.5)

Furthermore, by integrating this system with nonprofit organizations, both parties in this system will be aware of what products are available and when. To seamlessly transition the food from the stores to the nonprofits, the Google Maps API will be used to determine the closest nonprofits to the store, and then calculate the most efficient route to get there.

While this system sounds optimistic in theory, there are concerns among grocery stores about data security in AI based supply chains in an integrated system like this. The issue is known as Digital Supply Chain Surveillance (DSCS). The concern is based on the fact that since AI systems have access to an unprecedented amount of data, an AI system that has access to multiple supply chains may mix data, giving unauthorized suppliers access to another supplier's data without their consent, causing financial repercussions in future negotiations (Brintrup et al., 2023, p.3-6).

I plan to combat this issue by creating modular applications of each grocer's supply chain, having a separate model created for each use case to ensure no data is mixed with unauthorized information. This is an important precaution to take because by not having access to data about consumer behaviors and supply chain inventory, there is no efficient way to capture patterns to help reduce food waste. This would then contribute to the ⅓ of food being wasted, even reaching a value of 750 billion dollars being lost in food waste (Onyeaka et. al, 2023, p.10482). By building off current AI algorithms used in supply chains and current mapping APIs, it would allow for a modular, cohesive, and well-integrated system to share information about retail food statuses and efficiently communicate to nonprofit organizations when food is available for redistribution, helping reduce food waste.

STS Topic: Using Problem Definition to Adopt Technology That Helps Reduce Food Waste and Efficiently Allocate Wasted Food

Although significant food waste is generated by households in the United States, as mentioned earlier, a majority of it is created through supply chain cycles in the economy, often due to inefficient and ineffective technology use. As shown in Figure 3 below, this includes roughly 35% of food not being purchased and 1.49 million tons of food being spoiled in grocery stores in 2019 (Pacific Coast Collaborative, 2022, p. 3-4). To combat this issue, there have been many strides in society to encourage using technology such as AI, especially through the "AI For Good" movement to achieve the sustainability goals set forth by the United Nations (Cowls et al., 2021). However, such strides to reduce waste can be useless if technology cannot be properly embraced by the organizations responsible for carrying out such actions if they do not have a clear definition of what the problem entails.

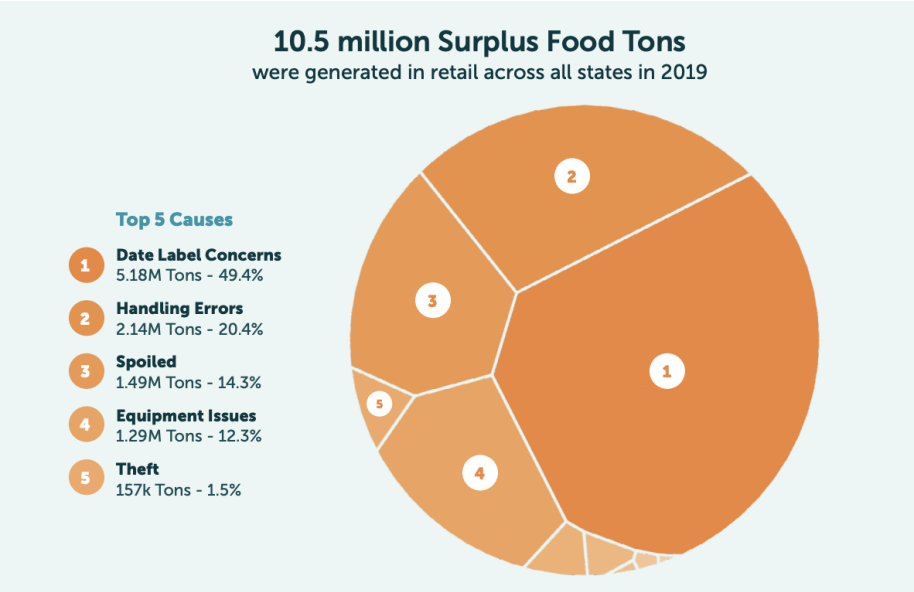


Figure 3: Surplus Food in The US in 2019. This pie chart shows the distribution of how different food was wasted (Pacific Coast Collaborative, 2022, p. 3)

More specifically, it was noted that only 11% of nonprofit organizations believed they used technology effectively (Yale Insights, 2018). Although nonprofit organizations do want to use such means, they are unsure on how to use modern tools such as Artificial Intelligence in a way that helps promote their social cause. They are more focused on finding ways to solve the issue rather than understanding the diverse perspectives and actors involved in their system. This leads to them not recognizing the additional benefits that new technological infrastructures can bring them. Their lack of awareness can also stem from viewing nonprofit organizations as separate entities from businesses, thinking technology used to increase profits is not applicable to charitable organizations.

Furthermore, the most critical reason why such nonprofit establishments and even businesses are reluctant to adopt or learn about new tools are preconceived notions about barriers that exist including that the technology is not advanced enough to be used due to a "lack of infrastructure" or because there are high risks involved (K, et al., 2023, 1544-1547). However,

these reasons noted above contribute to the lack of adopting innovation because unlike business entities, nonprofit organizations are disregarding the importance of conducting research to assess the true value technology can bring to their cause. The preconceived notions and systematic beliefs of these organizations are rooted from their narrow perspective, but they have not weighed the positive and negative consequences of using innovative and modern solutions.

My investigation into how the limited use of technology by nonprofits and businesses contributes to food waste will be carried out through a thought provoking discussion and analysis through interviews between selected organizations to develop a robust case study to understand the diverse practices of each entity. The investigation can build on the Problem Definition Solution Process outlined by Downey because it can apply to leaders who are weary of using technology before doing their research on it.

In his journal article, Downey mentions four ways to approach problem definition and solution, including but not limited to defining the problem, collaborating with others, and assessing the implications of the approach. For both businesses and nonprofits, by clearly outlining the problem that needs to be addressed, you are creating an opportunity to focus on a specific solution rather than solving the wrong problem (Downey, 2005, p. 589-592). Moreover, when collaborating with others, including different members of your organization and other establishments, including businesses working with nonprofits, these entities will better understand diverse perspectives of the same issue, allowing for a wider knowledge base when looking for a solution.

This is important as it segways to the most important factor: assessing the implications of different approaches. In this situation, after gathering all of the information, you can more accurately analyze how applying technology will be beneficial or detrimental to your

organization's goals. For example, if AI solutions were to be adopted, "an estimated 1.1 million tons of food waste and 2.8 million tons of CO2 emissions could be avoided," (Pacific Coast Collaborative, 2022, p.12). However, there are concerns that justify the preconceived attitude towards the negative impacts of applying new AI technologies including high initial investment costs and possible security vulnerabilities when using shared systems (K, et al., 2023, 1544-1547; Brintrup et al. 2023).

To further underscore the importance of understanding a system holistically, the investigation would also use Actor Network Theory (ANT) to help organizations map how current actors in the sociotechnical system impact food loss. This includes connecting current technology and supplier actors to see if there are any current gaps in the food supply process. By outlining this procedure, it can help entities determine if a new technological actor can indeed make a vast improvement as it allows for open dialogue and controversy to occur, helping them see if there are seemingly unrelated actors that play a large role in the issue (Venturini, 2009, p. 261-267). By identifying the problem and entities involved, organizations striving to address this humanitarian issue can fully understand the challenges they face. This enables them to make more analytical and thoughtful decisions, assessing whether the advantages of proposed technology-driven solutions surpass the potential drawbacks.

Conclusion

Because of society's high demand for a sustainable and economical future, my project deliverable serves to address those desires by building an integrated platform using artificial intelligence algorithms and the Google Maps API to streamline communication and analytics about grocery store supply chain and inventory directly to nonprofit organizations. If successfully implemented, it will provide important information about what foods are on the

verge of being wasted and are no longer of financial value to businesses, allowing them to be donated. This would help reduce food waste and create an efficient method of redistribution, solving a connectivity issue between two entities with a solution that does not currently exist. Furthermore, my STS topic dives into the implications of both businesses and nonprofits not adopting new technologies. It investigates to what extent using the Problem Definition and Solution process and Actor Network Theory can help them make better decisions about weighing the pros and cons of deciding to use technology, all in hopes of finding a way to reduce food waste in society.

(Approximate Word Count ~ 2100 words)

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