# MASTER IN INDUSTRIAL ENGINEERING

ANALYSIS OF SUSTAINABLE OPERATION AND MANAGEMENT IN FOOD SUPPLY CHAIN AND CASE STUDY OF ILLINOIS INSTITUTE OF TECHNOLOGY CAFETERIAS

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Chicago, Illinois

August 2020

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August 2020

ANÁLISIS DE OPERACIÓN Y ADMINISTRACIÓN SOSTENIBLE EN LA CADENA DE SUMINISTRO DE COMIDA Y ESTUDIO DE LAS CAFETERÍAS DE ILLINOIS INSTITUTE OF TECHNOLOGY

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## RESUMEN DEL PROYECTO

El presente proyecto se desarrolla dentro del ámbito de la cadena de suministro de la comida, que es la industria que transforma la materia prima en comida que es vendida al consumidor y desechada tras su consumo. El alineamiento y la sincronización de las etapas que conectan la etapa inicial de la red de suministro con la final son cruciales para lograr una cadena de suministro de comida eficiente y sostenible. Este proyecto trata de analizar las ineficiencias y los problemas en las operaciones de la cadena de suministro de la comida y sugerir mejoras centradas en la reducción de las emisiones de dióxido de carbono y en el desperdicio de comida.

La revisión del estado de la técnica en la cadena de suministro de la comida (sus características, relaciones entre entidades y tendencias actuales) llevada a cabo ha proporcionado suficiente base pasa comprender la industria de la comida como conjunto, y las operaciones de restaurantes en particular. Además, el gasto de comida ha constituido un punto fuerte de la investigación, ya que es uno de los problemas principales que hacen que la industrial de la comida actual no sea suficientemente sostenible.

El corazón de este proyecto es un estudio que se centra en dos cafeterías de Illinois Institute of Technology, ubicadas en el campus principal y en el del centro de la ciudad. Este estudio proporciona información de las operaciones en cada cafetería, seguidas del análisis de

su estrategia para la administración y el control de inventario, gasto energético y desperdicio de comida.

Varios aspectos de las operaciones de los restaurantes han sido estudiados. En primer lugar, se han analizado las emisiones de dióxido de carbono generadas en la distribución del inventario, teniendo en cuenta los proveedores, cafeterías, ratios de emisión y tipo de vehículo, entre otros atributos. Los siguientes datos han sido determinados para obtener una buena estimación de las emisiones de dióxido de carbono: (I) factor de emisión constante, (II) distancia, (III) consumo de combustible con el vehículo vacío, (IV) consumo de combustible con el vehículo totalmente cargado y (V) factor de carga. Después de obtener los resultados de la contribución anual de emisiones de dióxido de carbono de cada restaurante, numerosas estrategias han sido sugeridas para reducir dichas emisiones y optimizar las operaciones de las cafeterías, las cuales incluyen reducir el número de proveedores, reducir la frecuencia de pedido de inventario, selecciones proveedores más convenientes y cambiar a modos de transporte eléctrico o híbrido.

En segundo lugar, se midió el gasto energético del equipamiento y electrodomésticos de las cocinas para determinar el coste incurrido y la huella de carbono del consumo energético en la cocina. Para mayor clarificación, los kilovatios-hora anuales de cada restaurante fueron traducidos a numerosos parámetros que resultan más familiares, como kilogramos de dióxido de carbono, o las emisiones de efecto invernadero de las millas recorridas por un vehículo estándar de pasajeros, galones de gasolina consumidos o libras de carbón quemadas. Esta sección muestra una noción de la magnitud de las emisiones de dióxido de carbono generadas en el proceso de cocinar.

Por último, se ha realizado un profundo análisis de la administración del desperdicio de comida de la cafetería del campus principal. Se observó que grandes cantidades de comida preparada no se vendía al final del día. El diseño de la estrategia propuesta para solucionar este problema consiste en distribuir la comida que no ha sido vendida a familias con bajos ingresos a precios más económicos. La comida es empaquetada, almacenada y transportada a un edificio donde se almacena, en buenas condiciones, hasta que una ONG la distribuye a los destinatarios correspondientes. La siguiente imagen muestra el diagrama de procesos de esta estrategia.

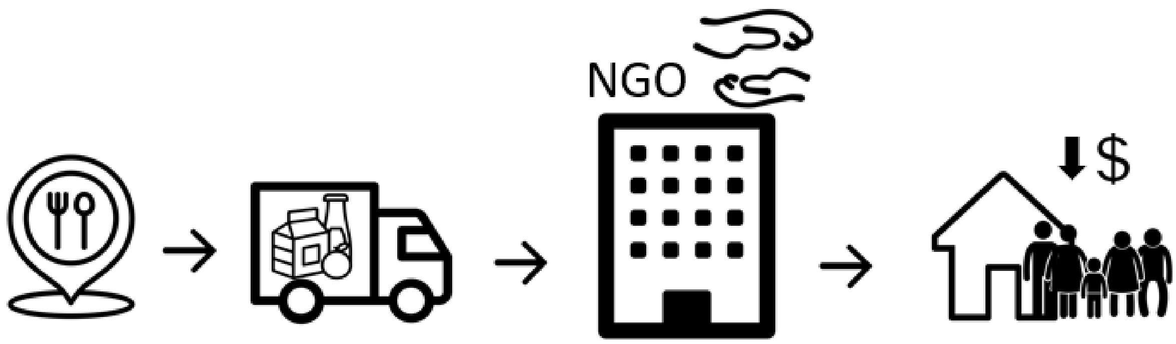


Figura 1. Diagram of the food waste proposed solution (own source)

Se han desarrollado numerosos cálculos para cuantificar la cantidad de comida que se desperdicia diariamente. Posteriormente, se ha determinado el número de envases que almacenan la comida y sus dimensiones, basándose en los cálculos mencionados previamente. Por último, tras seleccionar un edificio concreto donde la ONG pueda operar, se han calculado las emisiones de dióxido de carbono procedentes del transporte de la comida entre la cafetería y el edificio seleccionado, considerando el peso de la carga y el tipo de vehículo utilizado.

Este proyecto se relaciona con los Objetivos de Desarrollo Sostenible en muchos aspectos: (I) fin de la pobreza, (II) hambre cero, (III) salud y bienestar, (IV) energía asequible y no contaminante, (V) industria e innovación, (VI) reducción de las desigualdades y (VII) producción y consumo responsables.

Este estudio tiene como objetivo comprender las operaciones y los problemas de la cadena de suministro de restaurantes de pequeño y mediano tamaño. El análisis de las operaciones y administración de los diferentes aspectos de la cadena de suministro resaltó la importancia de: (I) comprender el patrón del consumo energético y la huella de carbono asociada, (II) optimizar la gestión del inventario utilizando datos de ventas, y (III) la criticidad de la administración del desperdicio de comida con un enfoque en el empoderamiento social.

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## ABSTRACT

The present study is developed within the food supply chain field, which is the industry that transforms raw material into edible food, sold to the end user and disposed upon consumption. The alignment and synchronization of the stages that connect the initial to the final stage of the network are crucial to an efficient and sustainable food supply chain. This project aims to analyze the inefficiencies and issues in the food supply chain's operations and suggest improvements that focus on the reduction of carbon dioxide emissions and food waste.

A review of the state of the art in the food supply chain (its characteristics, relationships between entities and current trends) was developed in order to provide sufficient background to understand food industry as a whole, and restaurants operations in particular. In addition, food waste was a great researched subject, as it is one of the core issues that makes today's food supply chain not as sustainable as it should.

The heart of this project is a case study consisting of two of Illinois Institute of Technology cafeterias, located at Main and Downtown campuses. This case study demonstrates operation information provided by each cafe, followed by the analysis of their strategic approach towards managing their inventory, energy use and food waste.

Upon completion of the study, various aspects of the restaurants' operations are studied. Firstly, carbon dioxide emissions generated in the distribution of inventory are analyzed, taking into account the suppliers, cafés, emission rates and type of vehicle, among other attributes. In order to obtain a good estimation of the carbon emissions, the following input data was determined: (I) constant emission factor, (II) distance, (III) fuel consumption of the empty vehicle, (IV) fuel consumption of the vehicle at full load and (V) load factor. After obtaining results on the annual contribution of carbon dioxide emissions per restaurant, several strategies are suggested for its reduction and the optimization of the cafeterias' operations, which include reducing the number of providers, reducing the order frequency of inventory, selecting more convenient providers and switching to electric or hybrid modes of transportation.

Secondly, the energy use of the kitchens' equipment and appliances was measured aiming to determine the incurred costs and the carbon footprint of the electricity usage in the kitchen. For further clarification, the annual kilowatt-hour per restaurant was traduced into numerous measures that sound more familiar, such as kilograms of carbon dioxide, or the greenhouse emissions from the miles driven by an average passenger vehicle, gallons of gasoline consumed or pounds of coal burned. This section provides a notion of the magnitude of carbon dioxide emissions generated in the cooking process.

Lastly, a deep analysis on Main campus cafeteria food waste management was made. It was observed that large quantities of prepared food weren't sold at the end of the day. The design of the strategy proposed to solve this issue consists of distributing the unused good food among low income families at affordable prices. The main idea is that the unsold food is boxed, stored and transported to a facility in which it is appropriately stored until being distributed to the recipients by a non-profit organization. The next image shows the process diagram of this strategy.

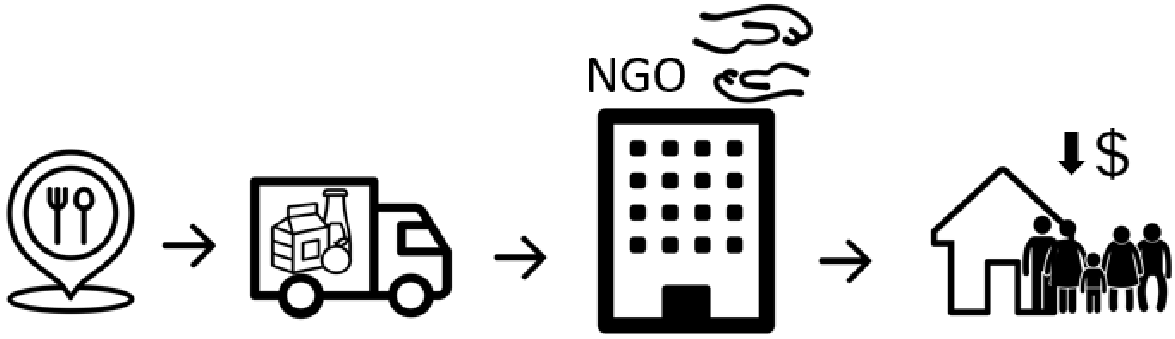


Figure 1. Diagram of the food waste proposed solution (own source)

Several calculations were developed to quantify the amount of food that was wasted daily. Subsequently, the number of containers that store the food and their dimensions were determined based on the previous calculations. Lastly, after selecting a specific facility in which the non-profit organism could operate, the carbon dioxide emissions of the transportation of the food between the cafeteria and the selected building were calculated, considering the weight of the load and the type of vehicle used.

This project strongly relates to the Sustainable Development Goals, specifically with: (I) end of poverty, (II) zero hunger, (III) health and wellness, (IV) clean energy, (V) industry and innovation, (VI) decrease of social inequality and (VII) responsible production and consumption.

This study aimed at understanding operation and supply chain issues in small and medium size food cafes. Analysis of the operation and supply chain management issues highlighted the importance of: (I) understanding energy use pattern and related carbon footprints, (II) optimizing inventory using sales data, and (III) criticality of managing food waste while focusing on social empowerment.

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# CHAPTER 1

# INTRODUCTION

This study was designed in order to understand how operation and supply chain can be designed or optimized with the goal of reducing carbon emissions associated with business operations. This topic is of concern in both Electromechanical and Industrial Engineering field, which I am pursuing. The selected topic is relevant to Industrial Technology and Operations management, which my Master's Thesis is concentrated on. The employed methodological approach in this study was designed to understand operation and supply chain issues in small and medium size enterprises, namely food cafes, with special emphasis on managing energy and food waste resulting from improper design of operation.

Chapters presented in this report begin by exploring food industry operations, supply chain characteristics and new emerging OSC models. Report provides an overview of the existing literature in this field, as presented in CHAPTER 2. Literature reviewed and presented in CHAPTER 2 provided sufficient information and background data needed to understand the food supply chain in SME in food industry. Additionally, food waste management was covered in the literature review, aiming to explain how said issue is originated, how it persists and how it can be mitigated.

CHAPTER 3 introduces two of Illinois Institute of Technology cafeterias (Center Court and Conviser Law Center cafes), maps their strategic approach regarding inventory management and energy use (energy use indicator was used to evaluate carbon footprints of operations in two selected cafes). We basically focused on the carbon dioxide emissions originated in the transportation of inventory from the suppliers to their respective restaurants, the energy use within the cafeterias' kitchens and processing and management of the food waste. Moreover, several suggestions are presented upon completion of our analysis with a view to improve the restaurants' inventory management strategies, reduce their carbon dioxide emissions associated with operations, and manage food waste in OSC.

Lastly, CHAPTER 4 gathers the most important aspects of the project, the conclusions extracted and several suggestions are provided for improving the cafeterias' strategic operations. The analysis of the operation and supply chain management issues highlighted the importance of: (I) understanding energy use pattern and related carbon footprints, (II) optimizing inventory using sales data, and (III) criticality of managing food waste while focusing on social empowerment.

CHAPTER 2

# LITERATURE REVIEW ON FOOD INDUSTRY OPERATION, SUPPLY CHAIN CHARACTERISTICS AND NEW EMERGING OSC MODELS

## 2.1 Introduction

A food supply chain is the alignment and synchronization of stages that allow a specific quantity of raw material to be transformed into edible food, sold to the end user and disposed upon consumption. The elements of the supply chain of food (which includes uncooked ingredients and/or cooked products) are purchasing, delivery of raw material, storage, production and processing, direct or indirect distribution, consumption and, finally, disposal.

The difference between direct and indirect distribution is the presence of an intermediary between the manufacturer and the consumer; with direct distribution, the customers purchases the goods directly from the manufacturer, whilst with indirect distribution the intermediary company receives the food from the manufacturer and sells it to the customer (Ross, 2019). Regarding the retail step, it can be divided into two categories: supermarkets and restaurants. These stages are interconnected as such change in one could affect the whole food supply chain, which frequently leads to cost variations (HPWI Harvard, 2016, p. 1). For further clarification, the block diagram of the food supply chain has been represented in **Error! Reference source not found.** after reviewing Sidra Malik et al.'s work (Sidra Malik et al., 2018, pp. 1–10).

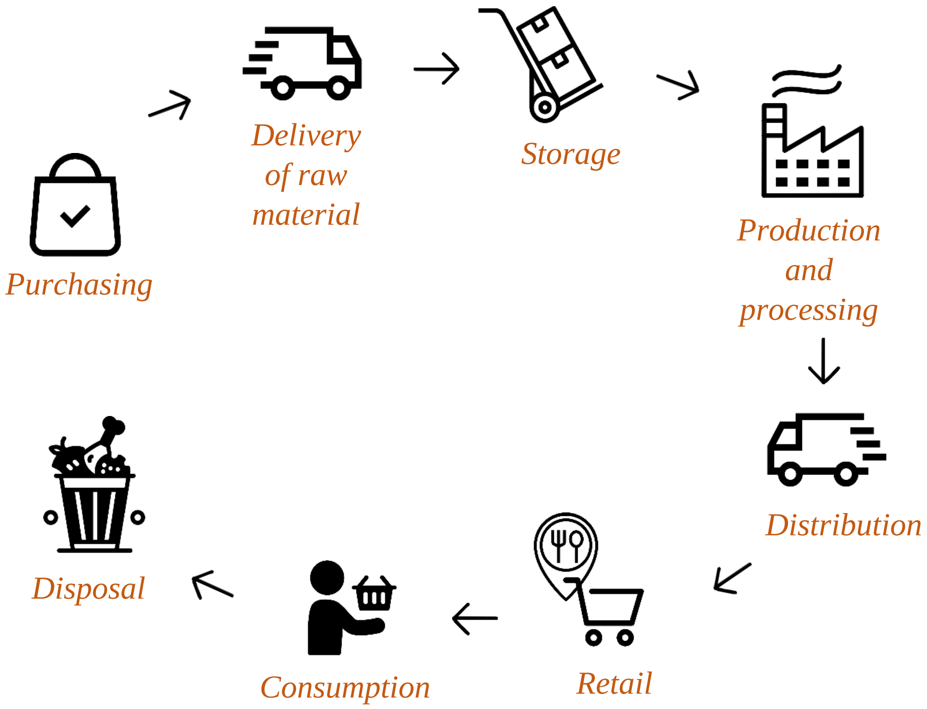


Figure 2. The process of food supply chain (own source)

Additionally, the concepts "pull" and "push" play a distinguished role within the of this industry. In a food supply chain, producers and processors push food, while consumers pull food. Similarly, producers and processors pull money, whereas consumers push money; these pulls and pushes facilitate the movement of food and money along the chain (HPWI Harvard, 2016, para. 2). In the following image, the pull and push directions for flow of money and material in a general supply chain can be observed:

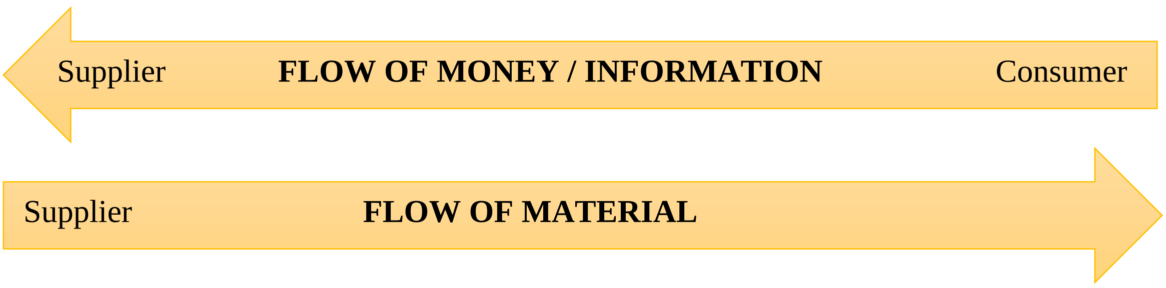


Figure 3. Pull and push directions for flow of money, information and material in a general supply chain (own source)

The agents, the money and material flow in the pull-push model and the connectivity between them in the U.S. food industry are presented in Figure 4. As shown, relational blocks are used to illustrate the direction of food and money within the supply chain. The arrows pointing to the right of the diagram (from the production to the consumer) indicate the flow of material, services and information, whereas the arrows pointing to the left of the diagram (from the consumer to the production) highlight the flow of money, information generated by the consumer and the characteristics of the market's demand (Nesheim et al., 2015, para. 9).

The origins of the raw material are the farm supply and production, which sell food to first line handlers or primary processors (manufacturers); the former prepare the products by carrying out tasks such as washing, waxing, wrapping and packaging of fruits and vegetables, or preparation of raw materials that are sent to the manufacturing stage, whereas the latter process the goods received and transform them into finished products (Nesheim et al., 2015, para. 4). The manufacturing, processing and preserving techniques and storage requirements broadly vary depending upon the type of food industry; some types of products, like fruit and vegetables, require immediate processing, whereas others such as meat can be stored in a cool ambient for a period of time; dairy products normally require pasteurization and sterilization as preserving methodologies, whilst pasta needs to be dried to be preserved. This and many other data about the food industries, their raw materials and processes are explained in detail by M. Malagié et al (M. Malagié et al., n.d., sec. Food Industry Processes).

Additionally, there is a small market directly between farmers and consumers —represented in the image related to this paragraph in dashed arrows—, mostly encouraged by the rising concern on green economy and sustainable food sourcing.

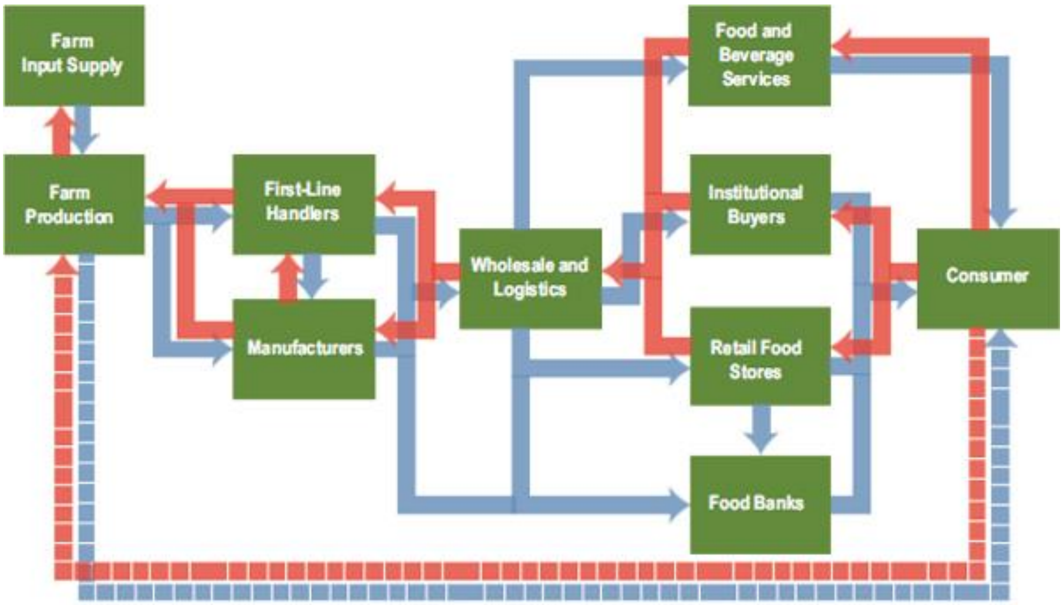


Figure 4. Conceptual model of a food supply chain *(Nesheim et al., 2015, para. 3)*

The next stage of the food pathway in the food supply chain is the wholesale and logistics sector. The wholesale function is to buy goods from manufacturers and first-line handlers and store them in warehouse facilities until they are bought by retail stores. Then, they distribute the products to their new owners through a wide transportation system. A logistics company focuses on distributing the products and organizing the inventory without assuming ownership of the goods (Nesheim et al., 2015, para. 5). The sector of the food supply chain that comprises all the agents between the production of raw material and the distribution of the products is commonly called *agri-food supply chain (ASC)* (Ait Si Larbi El Yasmine et al., 2014, Chapter 2.1).

Wholesale and logistics firms distribute the food products to the retail food and food service sectors. The former refers to facilities that sell products for the customer to buy, take home and consume (supermarkets, convenience stores and vending machines, for instance); the latter, on the other hand, comprises facilities within which food is served to and consumed by the customers, like restaurants and other eating and eating establishments (Nesheim et al., 2015, para. 6). Food banks constitute a considerable receiver of food, as society is becoming increasingly concerned about sustainability and committed to charity.

Finally, as can be observed in Figure 4, consumers attend retail stores and food service facilities to purchase food for their homes or to eat at that moment. Some consumers receive food assistance through governmental programs when their economic situation is challenging. Consumers are the final actors of the food supply chain and the reason that gives the food supply chain meaning.

Each agent of the food supply chain is part of several supply chains at the same time (Jack G.A.J. van der Vorst et al., 2007, Chapter 3.1). As can be easily understood, production, manufacturing, distribution and retailer firms rely on numerous clients and suppliers to be financially solvent. For instance, a distributor will have various manufacturers to collect the products from and several retailers to distribute the products to. That way, it not only covers the costs required to run the company, but also assures an income source in case of insolvency from any of the clients and a material source in case of insolvency from any of the suppliers.

A traditional conception of a supply chain is the “cycle view”. It implies that the core flow of information exists primarily between consecutive stages of the chain, losing its clearness and transparency along the chain. For instance, the real consumer demand will only be known by the retailers, and the inventory levels of the retailer will only be known by the direct distributors or processors. With the cycle view, the supply chain counts with various cycles that operate individually through own inventories, allowing self-problem solving of the cycles (Jack G.A.J. van der Vorst et al., 2007, Chapter 3.1). An image is displayed below for further understanding:

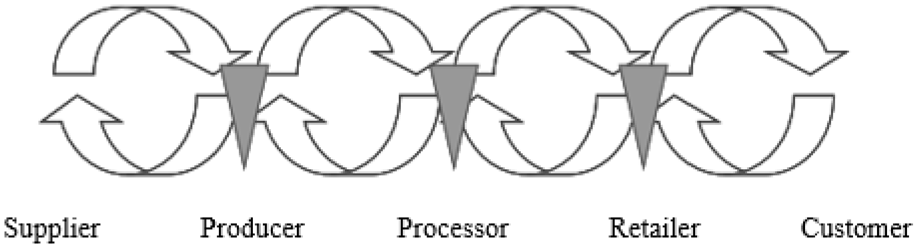


Figure 5. Supply chain with "cycle view" *(Jack G.A.J. van der Vorst et al., 2007, Chapter 3.1)*

Figure 5 represents the cycle structure of the supply chain with the traditional view “cycle view”. As can be observed, suppliers and producers work independently from the processors, retailers and customers; the information they share is not shared with the rest of the stages. The triangles represent inventories that allow independent functioning and operation of the corresponding cycle. The producer’s inventory is refilled by the supplier through the shared loop or cycle, the processor’s inventory level is maintained by the producer through their common cycle, and so on. However, this approach has numerous drawbacks, as explained by Jack G.A.J. van der Vorst et al (Jack G.A.J. van der Vorst et al., 2007, Chapter 3.2). After conducting a simulation of 50 weeks of a beer supply chain that followed the cycle view, the results showed that there were considerable unpredictable fluctuations in the demand when comparing the order volumes to those observed for linear systems (between the consumers and the producers). This leads to less reaction time –as the flow of information from the end user point takes time to arrive to the start point of the chain– and, consequently, rising costs and bad delivery performances.

This effect, commonly known as “Bullwhip effect”, forces the entities of the supply chain to maintain a high level of safety stock to fulfill the peak-demand fluctuations, which leads to high costs of overstocking and to an inefficient use of the resources. All in all, Jack G.A.J. van der Vorst et al have proven the inefficiency the cycle view generates in the supply chain operations and have highlighted the importance of coordination and transparency between the agents in a supply chain.

Therefore, it can be inferred that the actors of the food supply chain need to be correlated to each other to reduce the problems of coordination, cooperation and transparency, understanding defects and properly fixing possible arising problems in order to achieve fluency and efficiency of the overall system. The relationships among supply chain elements and attributes that characterize an effective supply chain are listed and explained by Sufiyan et al.'s work (Mohd Sufiyan et al., 2019, p. 3):

I. *Relationship and governance*

   The supply chain actors need to behave following specific relationships and within a governance structure. Food industry commonly presents long-term relations between the chain partners and captive or hierarchical governance; captive governance refers to the situation in which most firms are controlled by local firms, whilst in hierarchic governance —typical of short food chains—, managers or headquarters have full power over the other chain agents.

II. *Coordination and integration*

   Coordination between the agents in the supply chain imply interactive, joint decision-making processes, where the decisions and actions of the agents of the chain have direct or indirect impact on the rest of the partners. This attribute can be achieved by standardization, mutual adjustment and hierarchies. Regarding integration, we can find two types: horizontal and vertical. The former occurs when, for example, there are different farmers to form the corporation, and the latter refers to a more hierarchical structure. It can be said that vertical integration in the food industry results in a greater coordination among food processors and farmers, leading to an improved economic performance.

*III.* *Collaboration among stakeholders*

This attribute derives from the coordination and integration characteristics. Active collaboration among stakeholders imply having common goals such as high product's value, flexible food production and compliance of the environmental policy.

*IV.* *Supply chain agility*

Natural disasters, technological unexpected events or infectious diseases greatly affect the performance of the food supply chain. The ability of the agents of the chain to notice and react as fast as possible to changes in the network by reconfiguring their resources and operations is called Supply Chain Agility.

*V.* *Logistic management*

Logistics is a core element of the food supply chain: it seeks the efficient flow and storage of the food, the correct performance and alignment of the services and related information from the origin to the user point to meet customer's requirements. Quality in the food industry heavily relies on this step, as temperature, humidity, time and presence of contaminants are factors that directly and strongly affect the food's condition; the worse the logistics is managed, the more the item's condition will differ from the ideal. Vehicles should be temperature-controlled and warehouses should have good refrigeration strategies.

*VI.* *Traceability*

Traceability refers to the requirement to precisely monitor the composition and location of the goods throughout the chain. This technique provides useful information to maintain control and quality of the products.

*VII.* *Packaging*

Proper packaging is key to the food industry, as the food quality is directly affected by the time that passes and the environment conditions. Nowadays, advanced ideas are being developed and implemented, such as active packaging (moisture absorbers, antimicrobial packaging, carbon dioxide emitters, etc.) and intelligent packaging (monitoring of the condition of the packed goods with sensors, detectors and records).

VIII. *Waste management*

Waste comes from mismanagement of temperature during storage and harvesting, inefficient processing or disposal of edible food by consumers. Local governments could be an important agent in reducing food waste by the implementation of new regulations and measures, the publication of advertisements and speeches regarding this aspect.

Waste management is a crucial element of the food industry; therefore, Section 2.3 will intend to present the available data on food waste and loss, and explore its causes, proportions, quantities and characteristics, as well as to learn about the agencies' promoters of food waste and loss reduction and the projects that support the cause.

## 2.2 Food Industry by Type and Characteristics

The food industry has become considerably larger with globalization, making possible to connect food to consumers that are thousands of miles away. This growth increases the complexity of the food industry network. As defined by Wikipedia, the food industry is "a complex, global collective of diverse businesses that supplies most of the food consumed by the world's population" ('Food Industry', 2020, para. 1).

As described in Figure 4, the food supply chain is composed of the following agents: farmers, first-line handlers, manufacturers and processers, wholesale and logistics firms, food and beverage services (restaurants, catering and similar businesses), retail food stores and, lastly but not least importantly, consumers (Nesheim et al., 2015, para. 3). Furthermore, Wikipedia mentions additional agents that are key actors in the food industry ('Food Industry', 2020, para. 2), listed below:

- *Marketing:* it is a key factor to promote the different products and brands, and to make them popular amongst the consumers through advertising.
- *Regulations:* they are the glue that hold the food industry system together, and include local, regional, national and international guidelines for food production and sale, most commonly regarding food quality and safety.
- *Education:* it is crucial in order to have an efficient food industry with capable professionals and informed consumers.
- *Research and development:* they allow the transition into a more technological mode of operation.
- *Financial services:* they are needed to finance processes in the form of credit and to protect them as well in the form of insurance.

### 2.2.1 Food Processing and Manufacturing Food Products

As indicated above, one of the main components of food industry is the food processing, which includes, among others, preparation of fresh products for market and manufacture of prepared food products. It is interesting to review the most important moments that marked the evolution of cuisine to what it is today. In the $19^{th}$ century the sterilization and pasteurization methods were invented, which allowed to remove pathogens such as bacteria and fungi, avoided the appearance of diseases in humans caused by the consumption of food in poor state and extended the products' shelf life. The $20^{th}$ century, apart from introducing the preserving technique of freezing the food in the 1940s, opened a pathway for several cooking methods: pressure cooking in the 60's, the microwave in the 80's and the induction stove in the 90's (Economywatch, 2010, sec. History of Food Trade).

The food industry can present significant contrasts among countries and regions. Depending on the history, climate, culture, agricultural practices and level of development, the type of food produced, processed and consumed varies (A. Gordon, 2017, Chapter Introduction: effective implementation of food safety and quality systems). Countries in the Mediterranean area and Japan are loyal consumers of seafood, Argentina stands out by its steaks and its "empanadas", Central and South America, as well as China, include rice in roughly all of their recipes, French people are the greatest cheese consumers in the world, Italy is an expert in pasta, olive oil is a must in Spanish cuisine… and so on.

According to Matthew N. O. Sadiku et al., the most lucrative sectors of food industry are meat, fruit and vegetable processing, confectionery, dairy, wine and bakery (Mathew N. O. Sadiku et al., 2019, Chapter Introduction). However, every food industry sector will be covered in this section. The variability of the food characteristics makes necessary a broad range of food industries to process and preserve each type of good. According to M. Malagié et al., the supply chain of the food can be categorized into 13 industries, each of them employing different materials, requiring various storage techniques, employing a specific type of processing method, having different preserving needs and being packaged in certain ways. This information can be observed in the following table, which has been extracted from M. Malagié et al.'s work (M. Malagié et al., n.d., vol. Chapter 67-Food Industry):

Table 1. The food industries, their raw materials and their processes (M. Malagié et al., n.d., vol. Chapter 67-Food Industry)

| **Industry** | **Materials processed** | **Storage requirements** | **Processing techniques** | **Preserving techniques** | **Packaging of finished products** |
|---|---|---|---|---|---|
| **Meat processing and preserving** | Beef, lamb, pork, poultry | Cold stores | Slaughtering, cutting up, boning, comminuting, cooking | Salting, smoking, refrigeration, deep-freezing, sterilization | Loose or in cans, cardboard |
| **Fish processing** | All types of fish | Cold stores or salted loose or in barrels | Heading, gutting, filleting, cooking | Deep-freezing, drying, smoking, sterilization | Loose in refrigerated containers or in cans |
| **Fruit and vegetable preserving** | Fresh fruit and vegetables | Processed immediately; fruits may be stabilized with sulphur dioxide | Blanching or cooking, grinding, vacuum-concentration of juices | Sterilization, pasteurization, drying, dehydration, lyophilization (freeze drying) | Bags, cans or glass or plastic bottles |
| **Milling** | Grains | Silos may be fumigated in storage | Grinding, sifting, milling, rolling | Drying cooking or baking | Silos, sacks or bags to other processes, or boxed for retail trade |
| **Baking** | Flour and other dry goods, water, oils | Silos, super sacks and bags | Kneading, fermentation, laminating surface treatments of seasoning | Baking, cutting surface treatments and packaging | Packaged for wholesale trades, restaurants and retail markets |
| **Biscuit making** | Flour, cream, butter, sugar, fruit, seasoning | Silos, super sacks and bags | Mixing, kneading, laminating moulding | Baking, cutting surface treatments and packaging | Bags, boxes for institutional and retail trades |

| | | | | | |
|---|---|---|---|---|---|
| **Pasta manufacture** | Flour, eggs | Silos | Kneading, grinding, cutting, extrusion or moulding | Drying | Bags, packets |
| **Sugar processing and refining** | Sugar beet, sugar cane | Silos | Crushing, maceration, vacuum concentration, centrifuging, drying | Vacuum cooking | Bags, packets |
| **Chocolate making and confectionery** | Cocoa bean sugar, fats | Silos, sacks, conditioned chambers | Roasting, grinding, mixing, conching, moulding | - | Packets |
| **Brewing** | Barley, hops | Silos, tanks, conditioned cellars | Grain milling, malting, brewing, filter pressing, fermentation | Pasteurization | Bottles, cans, barrels |
| **Distilling and manufacture of other beverages** | Fruit, grain, carbonated water | Silos, tanks, vats | Distillation, blending, aeration | Pasteurization | Barrels, bottles, cans |
| **Milk and milk products processing** | Milk, sugar, other constituents | Immediate processing; subsequently in ripening vats, conditioned vats, cold store | Skimming, churning (butter), coagulation (cheese), ripening | Pasteurization, sterilization or concentration, desiccation | Bottles, plastic wrapping, boxes (cheese) or unpacked |
| **Processing of oils and fats** | Groundnuts, olives, dates, other fruit and grain | Silos, tanks, cold stores | Milling, solvent or steam extraction, filter pressing | Pasteurization where necessary | Bottles, packets, cans |

The table presented above provides specific information about the processing and preserving techniques, the raw material, the storage requirements of said raw material and, finally, the packaging procedure of finished products. Additionally, the processing and storage conditions of the different goods differ broadly among one another depending on the product's final processing level in store. This marks the operations within the supply chain, allowing to distinguish various versions of food supply chain. In this regard, Jack G.A.J. van der Vorst classifies food supply chains into two main groups *(Jack G.A.J. van der Vorst, 2000, p. 26)*:

i. Supply chain for fresh agricultural products

   It is referred to items that do not change their state nor their appearance from their harvesting to the retailing stage. The manufacturing and processing steps of the chain do not have great impact on the product: the stages that give value to this part of food industry is the handling, storing, packing and transportation of the goods, as well as the trading of the food. This last step is quite important, as in most cases it determines the quality of the product. Fruit, vegetables and flowers, for instance, belong to this category.

ii. Supply chain for processed food products

   These types of food chains include the processing and combination of fresh agricultural products as ingredients of a specific final product. As can be inferred, the manufacturing and processing steps are the stages that give value to the product because they transform the raw materials into something new. Snacks, desserts, ready-to-go meals and canned food, among others, are examples of this type of food SC.

M. Malagié et al.'s and van der Vorst's classifications serve to demonstrate the great variability of the processing methodologies depending on the food requirements and the product's final processing level in store. As can be inferred, such broad techniques and procedures make the presence of several specialized food supply chains a necessity.

### 2.2.2 Operation and Supply Chain in Food Industry: Restaurant Sectors

According to Neil Kokemuller (Neil Kokemuller, 2018), small and medium-sized restaurants (food SME) differ from large restaurants in terms of:

- Bargaining power: as small companies order smaller food lots to the wholesaler firms than big businesses, the prices they pay are higher. A solution Kokemuller suggests is to stablish a long-term relationship between the restaurant and the supplier and ensure a minimum purchase of goods.
- Employees roles: small restaurants frequently cannot afford having numerous departments and employees to cover all the necessary tasks, so either employees have to carry out several tasks at the same time or the company has to outsource part of their supply chain such as logistics or distribution.
- Scope of distribution: the supply chain network of small businesses is normally simpler than that of big companies. The number of intermediaries is lower and the distance among them is shorter.
- Costs: as has been mentioned above when talking about the employees roles, the budget is usually scarcer in small restaurants, therefore their investment in supply chain management processes (SCM) and software is reduced as well. According a survey from Software Advice, only 6% of small restaurants are currently using supply chain management software (spending an average of $30,000 on new SCM software and considering restaurants with income below $50 million), whereas the proportion of medium-sized and large restaurants that include them in their business strategy is 21% (with an average annual budget of $171,000 for new SCM software) (Kabbage Resource Center, n.d., para. 6).

Arun Jose et al. developed a study that made a review of the most popular issues in the SME food industry. They discovered that the four major subjects in SME food industry regarding production and distribution are (1) the relationships among the partners, (2) safety and norms in the food supply chain, (3) greenhouse gas emission impact in the farm operations, and (4) traceability and product quality. Additionally, the mentioned study showed that dairy is the most named food sector, followed by fruits and vegetables, meat, seafood and grain and oil seeds (Arun Jose & Prasanna Venkatesan Shanmugam, 2020, sec. 4).

A characteristic of small and mid-size restaurants is that they face challenges when there is growth. They have difficulties adapting to bigger volumes of demand, for instance in holidays such as Thanksgiving, Christmas and Easter (Wu et al., 2006, p. 5), and to the spread of the geographical area of supply and sales (Susanne Von Münchhausen et al., 2017).

A concept that is frequently associated with small restaurant businesses is value supply chain, defined by Stevenson et al. as the supply chain that focuses on both the values associated with the food and with the business relationships within the supply chain (Stevenson et al., 2011, p. 4). According to Stevenson et al., efficient mid-scale food value chains are based on (1) proper balance between volume, quality and originality, (2) trustworthy business relationships and practices with added value –that is, businesses that include fair trade, organic, local production, or animal-friendly practices in their operations (Susanne Von Münchhausen et al., 2017, p. 2)–, and (3) effective supply chain management (Susanne Von Münchhausen et al., 2017, p. 5). Point 2 (the added value in the restaurant supply chain practices), is a very popular aspect today that managers seek and consumers like. Ethic sourcing of goods and efficient operations within the restaurant is frequently included in SMEs business strategy. The management of waste, in the form of food, energy, resources or time, is an aspect that is increasingly gaining interest not only along the production line, but within the restaurant operations as well. This topic will be further discussed in chapter 3.

SME food businesses' success also relies on customer service: the customer must have good reasons to go to an unpopular small restaurant, and that reason can be outstanding customer treatment, fast service or clean establishment. Common examples of small and mid-sized food businesses are restaurants and cafeterias of public and private institutions such as health care facilities, schools and large offices, as well as regional grocery stores (Stevenson et al., 2011, p. 3).

### 2.3 Food Waste: Sources and Management Strategies

The food industry is highly inefficient due to waste and losses in several parts of the supply chain. This is an issue that has been gaining audience over the past decade, causing numerous organisms to take action and confront the situation. Data reported in 2010 indicated that, in the United States, food waste was estimated to be between 30% and 40% of the food supply, which corresponds to approximately 133 billion pounds of food with market values close to $161 billion (U. S. Department of Agriculture, n.d., sec. 1). The U.S. Environmental Protection Agency reported the types of food waste identified in municipal solid waste (MSW) and their management pathways between 1960 and 2015 (as shown in Table 2). As shown, composting started in 2000, combustion has been a method used since the 1970s, and landfilling indicated to be the method of choice throughout this period of time (1960-2015).

Food loss and waste lead to the inefficient use of resources such as water, land, energy, labor and capital, as well as to the generation of greenhouse gas emissions that, together with the implementation of unsustainable and improper treatment methods of waste, boost global warming (Food and Agriculture Organization of the United Nations, n.d.-b, para. 12). EPA estimates that more food reaches landfills and combustion facilities than any other material in everyday trash —as can be inferred from Table *2.* Data on food in MSW by weight (in thousands of U.S. tons) (‘Food Waste in America’, 2019)Table 2— (U.S. Environmental Protection Agency, 2019, para. 1).

Table 2. Data on food in MSW by weight (in thousands of U.S. tons) *(‘Food Waste in America’, 2019)*

| **Management Pathway** | **1960** | **1970** | **1980** | **1990** | **2000** | **2005** | **2010** | **2014** | **2015** |
|---|---|---|---|---|---|---|---|---|---|
| Generation | 12,200 | 12,800 | 13,000 | 23,860 | 30,700 | 32,930 | 35,740 | 38,670 | 39,730 |
| Recycled | - | - | - | - | - | - | - | - | - |
| Composted | - | - | - | - | 680 | 690 | 970 | 1,940 | 2,100 |
| Combustion with Energy Recovery | - | 50 | 260 | 4,060 | 5,820 | 5,870 | 6,150 | 7,200 | 7,380 |
| Landfilled | 12,200 | 12,750 | 12,740 | 19,800 | 24,200 | 26,370 | 28,620 | 29,530 | 30,250 |

Regarding emissions, it has been measured that landfills are the third largest source of human-related methane emissions in the United States, and that food loss and waste together have a carbon footprint of 4.4 billion metric tons of carbon dioxide equivalent according to the United Nations Food and Agriculture Organization (U.S. Environmental Protection Agency, 2019, sec. 1). The following graph displays the distribution of the different final stages of the food waste, expressed in tons, between the years 1960 and 2015.

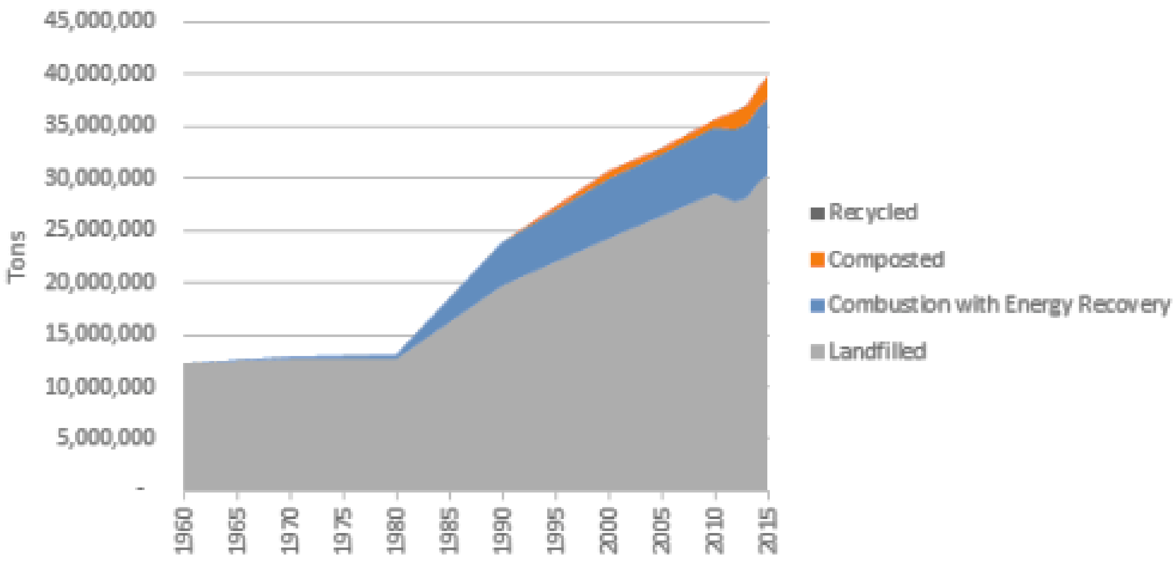


Figure 6. Food waste management *('Food Waste in America', 2019)*

As in Figure 6, the vast majority of the food waste ends up in landfills. Combustion with energy recovery takes the second place, while composting and recycling are techniques that seem scarcely performed. When composting food, their nutrients filtrate to the soil, which improves its health and helps other plants to grow ('Food Waste in America', 2019). The preferred methods of food disposal, in terms of efficiency and ecofriendship, are hierarchically ordered by USDA and EPA as it follows:

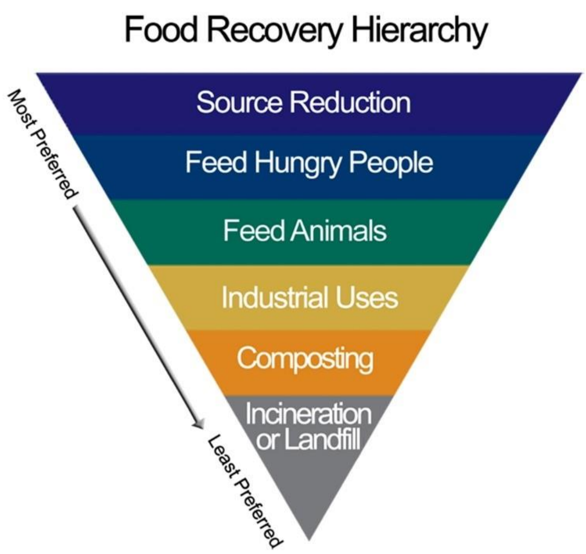


Figure 7. Food Recovery Hierarchy *(U. S. Department of Agriculture, n.d., sec. 6)*

Before continuing with the exploration of food waste management, the difference between food waste and food loss needs to be clarified. According to the FAO (Food and Agriculture Organization of the United Nations, n.d.-a, paras 6–10):

- Food loss refers to the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the supply chain, excluding retailers, food service providers and consumers.
- Food waste, however, is the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers.

What causes food loss and waste? The answer to this question applies to basically all stages of the food supply chain, from farming to consumption and retail. Complications during the processes within the chain can that take place not only between the farm and the retail spots (such as the deterioration of the food due to insects, rodents, birds, molds or bacteria), but also at the retail stage because of equipment malfunction that fail to keep the goods properly refrigerated (U. S. Department of Agriculture, n.d., sec. 2). In addition, fresh produce that deviates from what is considered to be optimal, for example in terms of shape, size and color, is often removed from the supply chain during sorting operations (Food and Agriculture Organization of the United Nations, n.d.-a, para. 10). Consumers contribute to food waste as well by not planning their meals and cooking more than they need, and by leaving leftovers on their plates when they eat at restaurants. Another cause that affects both retailers and consumers is the confusion with the meaning of the labels: more often than not, the meaning of "best-before" date and "expiration" date are misunderstood, leading them to discard aliments that have not yet expired.

Food waste and loss data differ among countries and types of food. The Food and Agriculture Organization of the United Nations has estimated global quantitative food losses and waste per year in 30% for cereals, 40-50% for root crops, fruits and vegetables, 20% for oil seeds, meat and dairy, and 35% for fish (Food and Agriculture Organization of the United Nations, n.d.-b, para. 5). However, when each region is analyzed, factors such as environmental characteristics, technological development and culture arise, affecting the proportions of where within the supply chain the food is lost. The FAO has explained what the situation is and what strategy is needed to cope with food waste in developed and developing countries (Food and Agriculture Organization of the United Nations, n.d.-b, paras 13, 14), which results very intuitive:

- In under-developed countries, food waste and losses take place primarily at early stages of the food chain due to financial, managerial and technical restrictions in harvesting techniques and storage. The core of the solution in this situation is to invest in infrastructure and transportation to strengthen the supply chain.
- On the other hand, in medium and high-income countries, most of the wasted and lost food occurs at later stages in the supply chain such as retail and consumption. In order to reduce the amount of waste and losses, good practices include pacts between farmers and buyers that allow more coordination between actors in the supply chain, boosting awareness among industries, retailers and consumers, and using the food that has been thrown away to serve other purposes.

This differentiation among countries' food waste generation, studied by FAO, is presented in the following diagram (Figure 8):

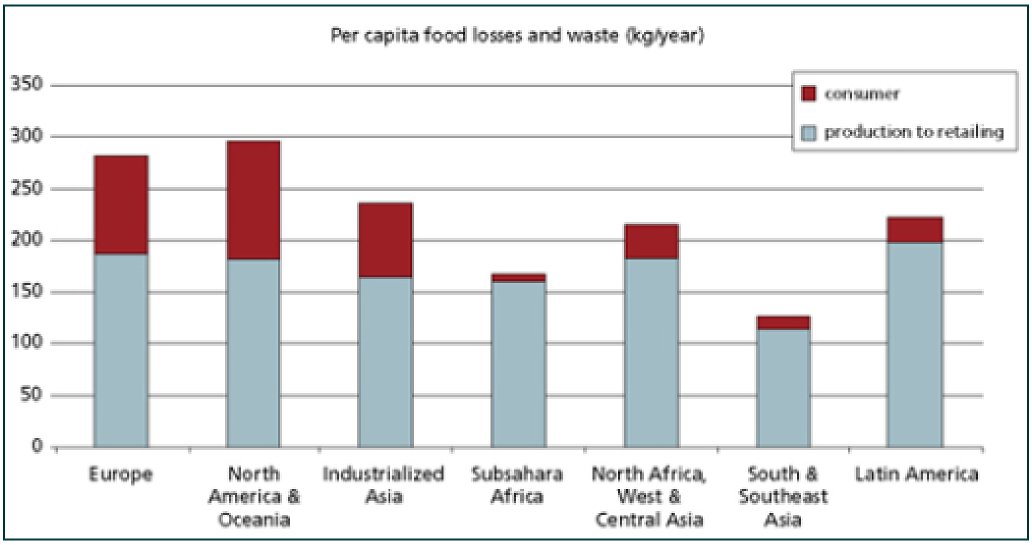


Figure 8. Per capita food losses and waste, at consumption and pre-consumption stages, in different regions *(Food and Agriculture Organization of the United Nations, n.d.-b, para. 8)*

The bar diagram presented above clearly reflects the facts stated by FAO that developed areas such as Europa and North America have about 40% of food waste and loss in the consumption stage, whereas underdeveloped regions like Subsahara Africa, South Asia and Latin America present 10% or less of food waste in consumption.

The main state organizations that contribute to reduce food loss and waste in the United States are EPA (The U.S. Environmental Protection Agency), FDA (the U.S. Food and Drug Administration) and USDA (U.S. Department of Agriculture). Each of them is fully compromised with the cause by joining and starting initiatives to decrease the food wasted in the country. The three mentioned organisms signed in October 2018 a joint agency formal agreement under the *Winning on Reducing Food Waste Initiative*, which focuses on better coordinating federal agencies and increasing their communication to inform the American population about the importance and impact of reducing food waste and loss (U.S. Food & Drug Administration, 2019, para. 2). Furthermore, in April 2019, the three agencies released a federal strategy prioritizing six main areas of action: (1) enhance interagency coordination, (2) increase consumer education and outreach efforts, (3) improve coordination and guidance on food loss and waste measurement, (4) clarify and communicate information on food safety, food date labels and food donations, (5) collaborate with private industry to reduce food loss and waste across the supply chain, and (6) encourage food waste reduction by federal agencies in their respective facilities (U.S. Environmental Protection Agency, 2019, para. 3).

On April 2019, USDA, EPA and FDA signed a formal agreement with ReFED, Inc. that includes monitoring the performance of the food waste methodologies, the recollection of data and becoming part of the *Further with Food: Center for Food Loss and Waste* partnership, among other activities (U.S. Food & Drug Administration, 2019, para. 4). However, these entities not only form partnerships, but also develop projects on their own. EPA has taken numerous actions to reduce food waste and loss, which can be found in the document *Food Loss and Waste Factsheet (September 2019)* on their website. A distinguished project is the one called *Food Recovery Challenge*, a system by which help is given to the applicants so as to measure and improve their sustainable food management performance through data management software and technical assistance. Additionally, useful information is provided such as an annual climate report that converts their food data results into greenhouse gas reductions, or the measure “cars off the road” to help them communicate the benefits of the modifications implemented (U. S. Department of Agriculture, n.d., sec. 10).

FAO divides its scope of work into three categories: the macro level, the meso-level and the micro level. At the macro level, FAO collaborates with governments and state organizations to boost awareness and carry out guidelines to decrease food waste and loss; at the meso-level, FAO focuses on coordinating the public and private sectors and citizens; lastly, at the micro level, the focus is set on educating the population and instilling in them responsible food shopping and consuming habits (Food and Agriculture Organization of the United Nations, n.d.-a, sec. 2).

This chapter intends to navigate through all the available data on food waste and loss and explore its causes, proportions, quantities and characteristics, as well as to learn about the agencies' promoters of food waste and loss reduction and the projects that support the cause. It can be deduced from the information presented that food loss and waste is a problem that has been gaining concern over the past decade among countries and cultures due to the negative effects it has on the environment and health. The root of the problem resides within the inefficiency in the supply chain and the lack of appropriate education of retailers and consumers. Fortunately, organisms such as USDA, FAO and EPA are constantly seeking to tackle this problem and reduce food loss and waste; us, either as a governor, a producer, a retailer or a consumer, only need to listen and act accordingly.

## 2.4 New Approaches and Optimization in Food Supply Chain

### 2.4.1 Blockchain technology and Industrial Internet of Things (IIoT)

Supply chain can be seen not only as interconnected agents (aligned to create a product), but as a community that publishes and shares the agents' identities, the daily activities within the chain, the certifications obtained and the agreements reached. This platform that interconnects everything that occurs within the supply chain is called "blockchain". Sara Saberi et al. distinguish four main elements in blockchain-based supply chains (Sara Saberi et al., 2018, Chapter 3):

1. *Registrars:* their function is to create profiles of all the actors in the chain.
2. *Standards organizations:* they determine the standards baselines and requirements, such as Fairtrade for sustainable supply chains, blockchain policies and minimum technological level.
3. *Certifiers:* they are in charge of providing certifications to the agents that comply with the requirements.

4. *Actors:* these elements refer to the basic agents that make the supply chain possible, that is, the producers, manufacturers, distributors, retailers and consumers. They need to be certified by a registered auditor to make the network reliable.

Blockchain provides a network with available information about the products based on an identity number that is physically attached to the product that corresponds to its profile in the net. That way, the platform displays up-to-date data such as type of product, its status and location, the producers, manufacturers and distributors that contributed to create and transport the product (with their respective certifications), and the product's quality, quantity and ownership.

A key element of the blockchain concept is the smart contracts. These are pieces of code that determine any action related to the relationship between supply chain parties, including, for instance, cost of manufacturing products, delivery schedules and payment terms (*A Quick Guide to Smart Contracts, Blockchain and the Supply Chain*, n.d., para. 3). They do not substitute traditional paper contracts, as these are needed to assure the transaction or trade is reliable, but they make the routine easier and more efficient by reducing the waiting time to send and sign regular contracts. Additionally, smart contracts and any activity is digitally stored in the cloud without alterations, making blockchain a highly secure system.

Figure 9 presents the blockchain-based supply chain model, which integrates all the elements discussed: the major four components of the model (registrars, standards organizations, certifiers and actors) and smart contracts.

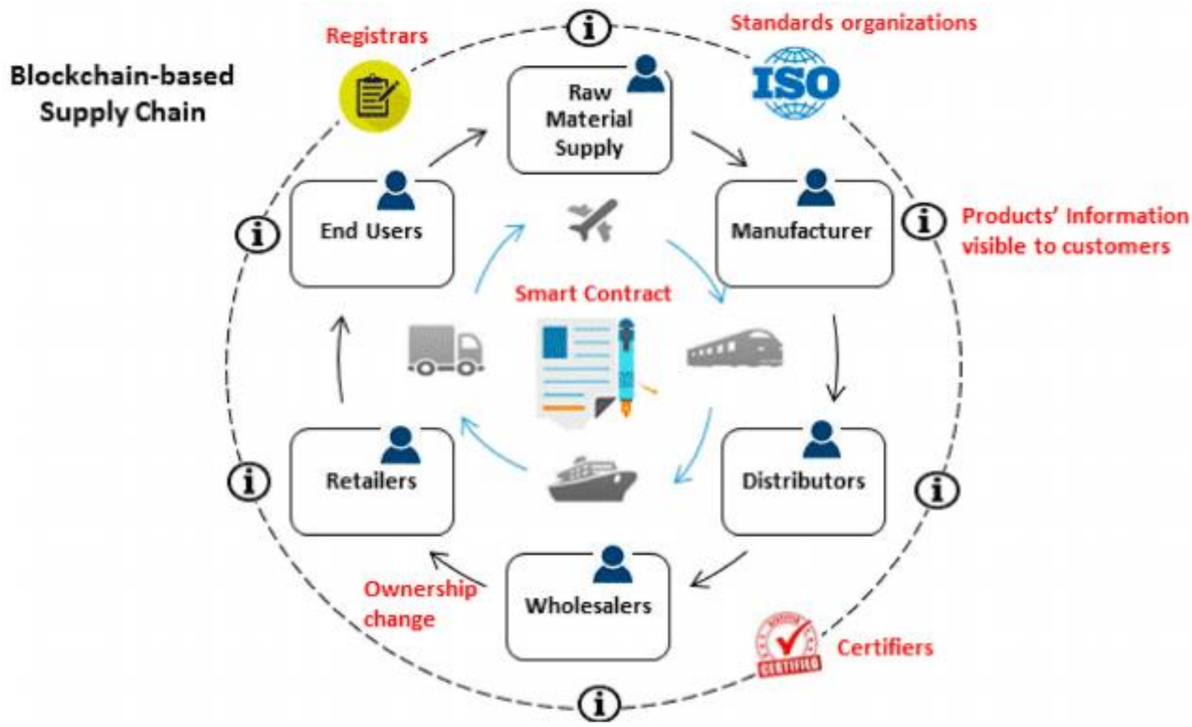


Figure 9. Blockchain-based supply chain *(Sara Saberi et al., 2018, p. 2121)*

Therefore, the concept of blockchain technology can be summarized as a secure, decentralized database of records of all the actions that occur between agents of a supply chain, which includes audits of the chain processes, certification concessions and agreements in the form of smart documents –that is, available for all the participant agents in the cloud.

Blockchain technology can be conceived as part of Internet of Things (IoT), which is defined by Ernst and Young (EY) as "the connection of devices to the internet through software and sensors that collect and exchange data with one another" (Chrisjan Pauw, 2018, para. 4). Blockchain is a useful complement to IoT because it assures confidentiality and security of the information of the chain by the use of cryptographic algorithms (LeewayHertz, 2019, sec. 5). Industrial Internet of Things (IIoT) is the application of IoT to industry, also referred to as Industry 4.0. The main idea of IIoT is to connect all the processes involved in the chain, from raw material extraction to the end user point–in the case of FSCs, from the farms to the consumers. As can be observed in Figure 10, all the processes (farming on the left, manufacturing on the top right and bottom left, and transportation on the bottom right) generate and share data to the cloud (in the center of the image), such as times, statistics and data. Any agent participant in the process can read said information and send orders and information back to the cloud and to the desired part of the process.

The main idea is to set a platform that allows participants to act based on real-time data. This allows to increase the manufacturing productivity (by reducing parameters such as energy consumption and setup and changeover times, and by improving the product or process quality) and to reduce the inventory and waste. All in all, IIoT generates value and makes companies more competitive ('What Value Does IIoT Offer Manufacturers?', 2018, fig. 1).

Figure 10. Industrial Internet of Things Diagram *(WildNetTechnologies, 2018)*

Noor Zafira et al. explore various characteristics of Industry 4.0 (Noor Zafira Noor Hasnan & Yuzainee Md. Yusoff, 2018, sec. 3), among which I found most relevant intelligent manufacturing, quality control, traceability and simulation:

- *Intelligent Manufacturing*

  Intelligent manufacturing refers to plants in which the production lines are automated and the machinery has the ability to exchange information with one another, analyze and respond to production issues with minimal human involvement. Industrial robots record data that has been experienced in past situations and learn from it, taking the necessary corrective steps to optimize the new operation strategy with the minimum deviation possible from the optimum.

- *Quality Control*

  Visual tracking in production lines contribute to elevate the quality level of the products. The technology is based on the comparison of the product parameters extracted from the image that is captured by the camera and the predefined parameters that make that product "acceptable". For instance, the diameter of a tomato can be measured from an image and compared to the diameter considered as valid (previously registered in the system). If the measured diameter is outside the acceptable tolerance, let's say considerably smaller, it might mean that a piece of the tomato has been chopped off in the process, making it no longer valid. These observations and the determination of the validity of each product is made real-time, discarding from the production line the "bad" elements in a matter of milliseconds. The technology that supports this procedure is automated, which allows to increase productivity and minimize errors that lead to inefficiencies (Mike Koeris, 2017, para. 7).

- *Traceability*

  Traceability mainly consists of tracking the path of each product along the supply chain, from its origin to the retailer stage. Technologies such as the Quick Response (QR) square code-system and Radio Frequency Identification (RFID) permit to differentiate products by unique identification codes that register in the cloud their characteristics, location, route itinerary and so on. This traceability system leads to intelligent labelling, whereby customers can scan an item's reference code to visualize in their smartphones the data related to the origins of the product and its route from the harvesting stage to the retail store ('How Industry 4.0 Is Changing the Food Industry', 2018, sec. 2.2).

Intelligent automated systems that connect all the different stages of the food supply chain in an attempt to increase efficiency have been studied and developed for many years and are now beginning to make their way into the market. Jung et al. published in 2014 a patent of an intelligent traceability system (Edward K.Y. Jung et al., 2014) that explains the concepts presented in this section.

- *Simulation*

  Simulation allows to test strategies on specific supply chain settings before implementing it in real life. The great advantage of this is that the virtual results of the simulation can be analyzed and, if they turn out to be ineffective and unprofitable, no real money nor resources are wasted, permitting to define a different strategy to test. Current existing software provides highly accurate results thanks to the broad range of inputs to insert and the precise forecast models programmed. An example of the type of inputs that can be selected is provided by Riccardo Accorsi et al. (Riccardo Accorsi et al., 2017, Chapter 3):

Table 3. Inputs for modeling FSC systems *(Riccardo Accorsi et al., 2017, Chapter 3)*

| | **Stages** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Crop** | **Processing** | **Transport** | **Storage** | **Market** | **Waste Processing** | **Power Supply** |
| **Entity** | Soil<br>Seeds<br>Fertilizer<br>Water<br>Energy<br>Harvest equipment | Package<br>Product<br>Package lines<br>Working station | Vehicle<br>Unit load<br>Route | Unit load<br>Racks<br>Handling equip. | Shelf store<br>Order<br>Consumer | Waste<br>Facility<br>Recycling lines | Power<br>Energy plant<br>Demand<br>Distribution grid |
| **Resource** | Soil<br>Seeds<br>Fertilizer<br>Water<br>Energy<br>Labor | Water<br>Energy<br>Labor<br>Time | Energy<br>Fuel<br>Labor<br>Time | Energy<br>Labor<br>Time<br>Shelf life | Energy<br>Labor<br>Shelf life | Energy<br>Labor | Energy |

| **Supply** | Unpacked food Waste | Packed processed food Waste | Delivered food | Repacked food Waste | Consumable food Waste | Energy fertilizer | Energy |
|---|---|---|---|---|---|---|---|
| **Parameter** | Soil moisture Soil texture Rainfall Temperature Wind speed | Throughput Labor cost Energy cost Processing Capacity Working shifts Layout | Transport mode Shipping capacity Distribution speed Transport costs Transport GHGs Loading capacity | Storage mode Storage capacity Handling Labor costs | Demand Order frequency Retailer network | Collection capacity Recycling capacity Recyclable, reusable, recoverable fractions Reverse network | Solar irradiance Temperature Sundays Sun-hours Wind speed Geothermal sources Hydropower sources |
| **Decision** | Crop allocation Crop turnover Harvest scheduling Irrigation planning | Batch scheduling Pckg. design Processing station design Layout planning Facility allocation | Vehicle routing Vehicle loading | Inventory management Storage Allocation and assignment Loss prevention Facility deisgn Network design | Shelves planography Grocery network design | Processing station design Layout Planning Facility location | Grid management Infrastructure design Grid design Power assignment |

### 2.4.2 IIoT for Managing Restaurant Supply Chain

Regarding restaurant businesses, IIoT constitutes a powerful resource to increase effectiveness and profitability. The performance of the kitchen appliances can be monitored by this technology and notify the manager or designated workers when a fault occurs or strange data is registered. This will optimize the time workers spend on tasks, eliminating the time devoted in checking the correct functioning of the devices. Additionally, the appliances can be remotely controlled via smartphone, making possible to turn them on to have something ready ahead of time or to turn them off when it was forgotten to do so. Another example is the systematic control of the inventory: each item is registered, along with its expiration characteristics and its frequent quantity available. This not only saves time in the shopping list preparation time, but also allows to buy goods only in the amount that is needed, which in turn helps to reduce waste (‘10 Ways IoT Can Benefits Restaurants & Food Industry’, 2019). A practice that is becoming more popular among restaurants is the ordering and billing from the table through a device that notifies the central restaurant system and assigns a waiter to attend to the customer.

Kerem Aytaç and Ömer Korçak developed the software and hardware for a system based in IoT that attempts to increase quick service restaurants efficiency (Kerem Aytaç & Ömer Korçac, 2018). It includes an intelligent weight-meter that aims to reduce waste by collecting data on usual weight and capacity of the dumpsters within the restaurant and by detecting anomalies and tendencies; a production service level estimator module that measures the queue and waiting time and informs the workers of their level of commitment speed-wise; and a smart staff allocator that assigns tasks to the most appropriate worker depending on his/her abilities and knowledge.

The implementation of modern technology and new procedures can optimize the food supply chain through the prediction of demand and availability of raw material. For instance, the weather is a factor that strongly affects the farmers and producers’ activity, and economic recessions impact the customer demand; these and more factors are predicted and analyzed in order to form a complete, precise overview of the product demand and offer situation. Big data is a key factor to this approach (Md. Muminur Rahman, n.d., sec. 1.1) because it allows the gathering of numerous data, its analysis and the development of a series of algorithms and prediction models that shape the decision making process.

The consulting firm CrunchTime assists restaurants with a management software aimed at reducing food and labor costs, improving the guest experience and increasing profits. The technologies developed by this firm include powerful forecasting tools that allow the delivery of the exact needed quantity of inventory at the right time, vendor bid analysis strategies for comparison of prices for a specific product among numerous sellers in a variety of markets, and auto suggested orders generated by the gathering of data within the restaurant (typical items ordered in time, frequency of ordering, etc.) that enables time savings.

These technologies are based on real-time software and platforms, allowing visibility among the chain agents, eliminating delays and cutting costs through waste reduction, smaller inventory levels and a reduced workforce (One Network Enterprises, n.d., sec. 2). A real-time network allows the trading partners to be synchronized and working aligned and towards the same objectives and by the same rules. Moreover, it provides a "single version of the truth" (SVOT) that clarifies the real customer demand and is used to auto-generate a list of ingredients and supplies that is later shared over the delivery network (Nigel Duckworth, 2018, para. 33).

The technologies and procedures presented above (forecasting tools, vendor bid analysis strategies and auto suggested orders), when properly implemented, can give spectacular results. Nigel Duckworth gathers some of the typical results obtained in different restaurants after incorporating these forecasting and optimization strategies (Nigel Duckworth, 2018, para. 40):

- Forecast accuracy increase to 85-90%
- Cost of Goods Sold (COGS) decrease of 5-10%
- Radical decrease of inventory levels throughout the network, including by up to 50% at the restaurant stage
- Food waste decrease of up to 75%
- Roughly ideal fill rates, that is, very high percentage of customer demand that can be fulfilled immediately by the available stock in the inventory (TradeGecko, 2017, para. 1)
- Less time needed for ordering, replenishment and delivery

- Increased sales for LTOs (Limited-Time Offers) and new menu item launches

The forecast accuracy increase inevitably leads to reduced COGS, inventory levels and food waste, as the demand adjusts better to the ingredients and supplies purchased. These numbers demonstrate that the explained technology, which provides transparency of data among the participant agents, real-time information available across the chain and strong demand forecasting tools, can greatly and positively impact the performance and operations of the restaurants that integrate it in their business operations.

In conclusion, it can be said that modern technology has opened a new gate into increasing efficiency and time savings. Industrial Internet of Things permits the optimization of the supply chains, and therefore of the restaurants, by the connection of all the agents and devices involved and the real-time data collection and sharing. Blockchain technology assures a secure management of information regarding agreements, certifications and contracts. Forecasting tools accurately estimate the demand that, in turn, allow a more efficient use of resources and waste management strategy.

## 2.5 Conclusion

This chapter provided a review of the basic concepts of the food supply chain in order to provide sufficient background to understand food industry as a whole, and restaurants operations in particular. An example for a conceptual model of food supply chain has been presented and explained. Furthermore, the core attributes that make a food supply chain fluent and efficient have been explored (relationship and governance, coordination and integration, collaboration among stakeholders, supply chain agility, logistic management, traceability, packaging and waste management), in section 2.1. Additionally, the numerous types of food industry have been identified, including food industry specific to restaurants and food cafes, as well as the processing of food products.

Moreover, new approaches and optimization methodologies in food supply chain were explored. More specifically, research focused on blockchain technology, industrial internet of things or industry 4.0 and several forecasting techniques that increase accuracy of the chain's operations. These current, trendy technologies and procedures push this type of supply chain (or any kind, really) towards a more connected, aligned set of partners that collaborate to produce the best product possible. In addition, broad background on food waste management was given in section 2.3, as it is one of the key issues that makes today's food supply chain not as sustainable as it should, with the intention of emphasizing the importance of this problem and to create awareness.

Lastly, it needs to be highlighted that the main goal and objective of this study is defined upon completion of literature review to be:

- Providing detailed analysis of the existing operation and supply chain in small and medium size restaurants and food cafes, focusing specifically on management of food waste.
- Design best practices/approaches for optimization of operation and supply chain in (I) medium size restaurants and (II) small food cafes operating independently or within larger business entities.
- Identifying and comparing common food waste management strategies at selected restaurant types.

CHAPTER 3

# ANALYSIS OF THE OPERATION AND SUPPLY CHAIN IN MEDIUM AND SMALL SIZE RESTAURANTS: CASE STUDY OF ILLINOIS INSTITUTE OF TECHNOLOGY CAFETERIAS

## 3.1 Illinois Institute of Technology Campus Food Services

The university Illinois Institute of Technology was originated in Chicago by the merger of Armour Institute and Lewis Institute in 1940, and currently has a broad spectrum of degrees in engineering, science, design, architecture, applied technology, business, law and human sciences (Illinois Tech, n.d.-c, sec. About). The university is divided into four different campuses (Illinois Tech, n.d.-a, sec. Campus Information):

- *Mies Campus:* it is located in Bronzeville, a district in the southside of Chicago that is about 3 miles from downtown. It counts with roughly 50 buildings, which include academic buildings, facilities services, residence halls and student services, among others (Illinois Tech, n.d.-d, sec. Mies Campus Buildings). This campus harbors the Armour College of Engineering, the College of Architecture, the College of Computing, the Institute of Design and the Lewis College of Science and Letters. As can be inferred, the area of education in this campus belongs to the technical field.
- *Conviser Law Center:* also referred to as Downtown Campus, it is located in Chicago's loop. It consists of two colleges, which are Chicago-Kent College of Law and Stuart School of Business.
- *Daniel F. and Ada L. Rice Campus:* situated in Wheaton (a city 30 miles west of Chicago), it is a 54,000 square foot satellite center of Mies Campus that focuses on technological education and training for students more experienced in industry (Illinois Tech, n.d.-e, sec. Rice Campus).

- *Moffett Campus:* it is ubicated in Bedford Park, a village to the southwest of Chicago, and consists of the Institute for Food Safety and Health (an association of Illinois Tech, the FDA Center for Food Safety and Applied Nutrition and the food industry aimed at research) and the National Center for Food Safety and Technology (Illinois Tech, n.d.-a, sec. Campus Information-Moffett Campus).

The scope of this project is limited to the two main campuses, which are Mies Campus and Conviser Law Center. This decision has been made considering that the bigger dimensions and the higher number of students of said campuses would most probably give the study greater impact. Additionally, as the author of this project completed her studies at Mies Campus and her residence was close to downtown Chicago, the locations of these campuses were very convenient. The aim of this chapter is to provide a detailed analysis of the operation and supply chain management in the Center Court cafeteria in Mies Campus and the cafeteria in Conviser Law Center. In order to do so, it is important that these cafeterias are adequately described to better understand the analyses of their operations and supply chain management strategies. These descriptions are presented in the following sections.

### 3.1.1 Mies Campus Center Court Cafeteria

Mies campus counts with a few food establishments owned by different food companies: The Commons, 10 West, Center Court, Global Grounds, The Bog and John + Pat Anderson’s Cafe (Illinois Tech, n.d.-b, sec. Dine On Campus). The Commons was not considered for this project because it fell out of the small cafeteria category due to its large dimensions; 10 West, Global Grounds, The Bog and John + Pat Anderson’s Cafe, on the other hand, were too small to be considered small or midsize cafes, which would impede this project from constituting a significant contribution. Therefore, the chosen cafeteria was Center Court, which has a reasonable size to be considered a midsize restaurant, as observed in Figure 11. It is located in McCormick Tribune Campus Center, as indicated by a red circle in the campus map in Figure 12. The red and green lines represent the red and green CTA train lines respectively, making the campus very well connected to the rest of the city.

McCormick place harbors numerous spaces devoted to office activities and student services, among which can be included retail shops, leisure activities and food courts (Illinois Institute of Technology, n.d.-b, sec. McCormick Tribune Campus Center). The food services available at McCormick Tribune Campus Center are Global Grounds, The Commons and Center Court (Illinois Tech, n.d.-b, sec. Dine On Campus).

Central Court cafe offers various types of food: ramen, sushi, beef, chicken, rice, vegetables, etc (lllinois Tech, n.d., sec. Center Court). Additionally, individual beverages and snacks can be purchased. The cafe is operated by a third party called Chartwells, member of the large food service chain Compass Group that works in restaurants, hospitals, schools, museums and more throughout North America (Compass Group USA, n.d., sec. Our Story).

Figure 11. Center Court cafeteria *(Architettura & Viaggi, n.d.)*

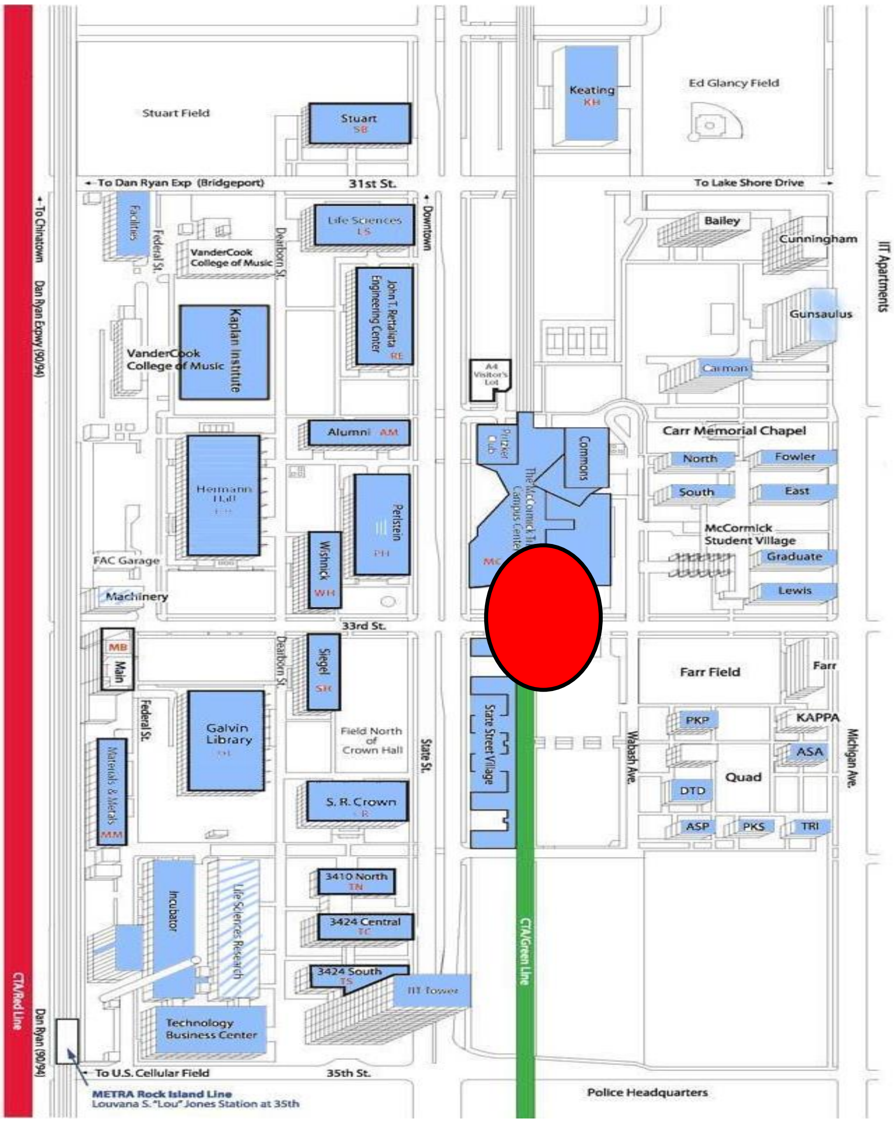


Figure 12. Location of Center Court cafeteria in Mies campus *(Illinois Institute of Technology, n.d.-a, sec. Information and Coverage)*

### 3.1.2 Conviser Law Center cafeteria

The cafeteria in this facility is the primary food service establishment in Conviser Law Center. The cafe offers not only made-to-order food, but a self-service bar with a broad variety of goods: salads, meat, fruit and refreshments, among others.

## 3.2 Analysis of the Center Court and Conviser Law Center Cafeterias (Operations and Supply Chain)

Both cafes were analyzed in terms of carbon dioxide emissions, electricity use and food waste, with the goal of reducing these factors by optimizing the restaurants' operations and supply chain management strategies currently in place. In the following sections, these aspects will be described and possible solutions or improvements will be proposed.

### 3.2.1 Carbon dioxide emissions analysis

The miles traveled by the suppliers' distribution trucks to deliver their products to their customers can sum considerably large quantities of toxic emissions. $CO_2$ emissions are specially harmful to the environment, as they are major contributors to greenhouse gases –which are responsible for global warming. It is crucial that this aspect is considered when aiming at making the cafeterias' operations and supply chain more efficient and sustainable.

Figure 13 shows the location of the Conviser Law Center, its cafeteria's suppliers and the best route between them as suggested by Google Maps (considering automotive methods of transportation). As can be observed, Conviser Law Center cafeteria's supplier list consists of five firms: Vistar, Midwest Industries, Farmer Brothers, Sysco, Pepsi and Coca-Cola. Figure 14, on the other hand, presents the same information for Center Court cafeteria. In this case, the cafe's suppliers are reduced to four: Midwest Industries, Sysco, Pepsi and Coca-Cola.

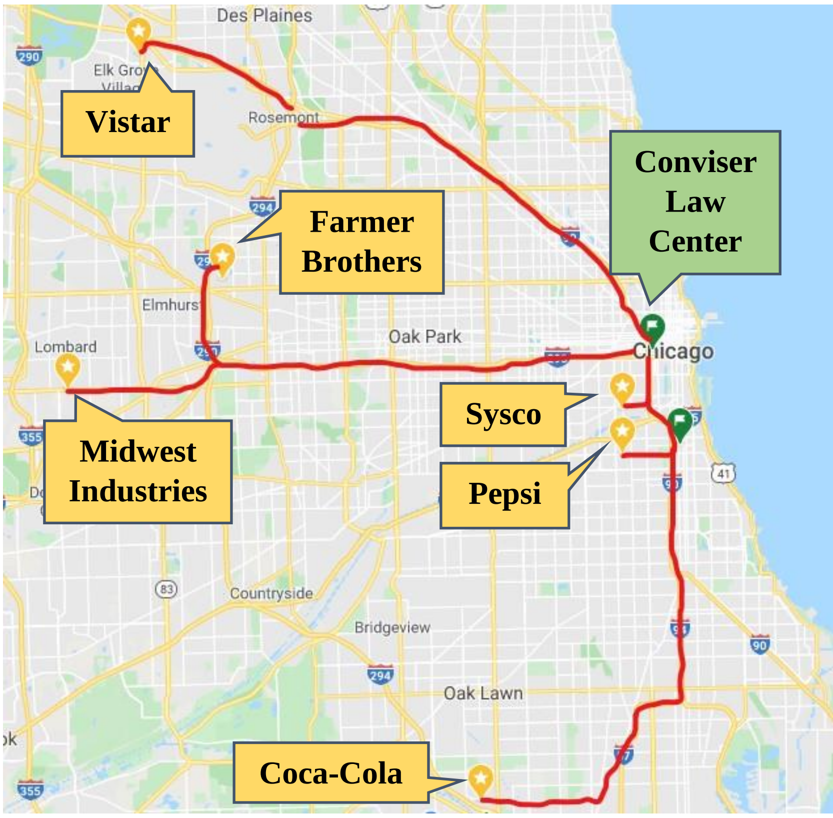


Figure 13. Location map of Conviser Law Center cafe and its suppliers (own source)

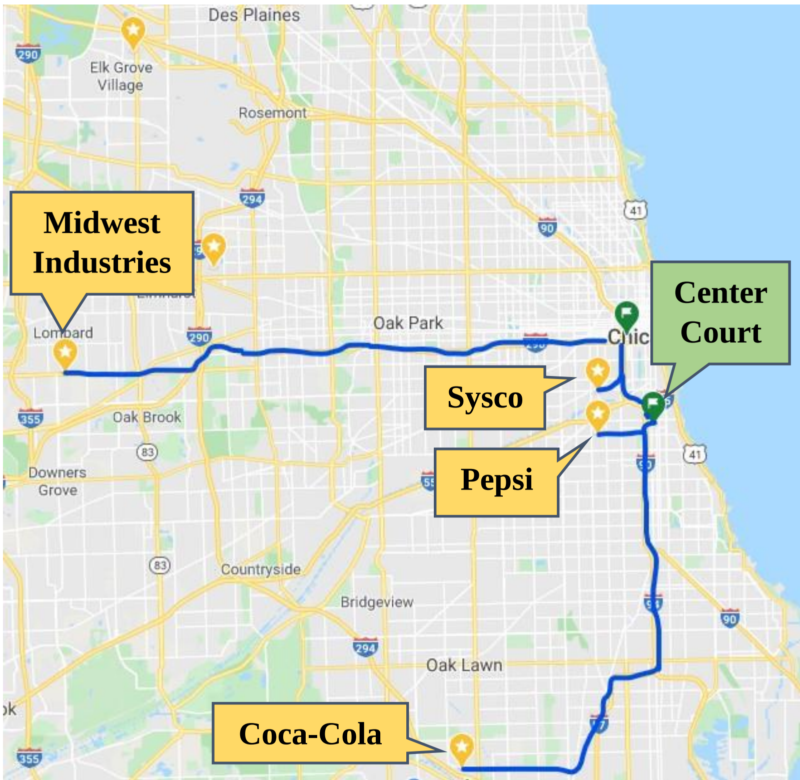


Figure 14. Location map of Center Court cafe and its suppliers (own source)

Velázquez-Martínez et al.'s work (Josué C. Velázquez-Martínez et al., 2013, Chapter 2) has been referenced in this study, particularly the formula used to calculate the total annual emissions of carbon dioxide per restaurant, expressed by the following equation:

$$TE = CE \times D \times \left[FC_{empty} + \left(FC_{full} - FC_{empty}\right) \times LF\right] \qquad [1]$$

This equation was modelled by the Network for Transport Measures (NTM, n.d., sec. Calculation of fuel CO2 emissions), and includes the parameters explained below:

- *TE:* total $CO_2$ emissions ($g_{CO2}$)
- *CE:* constant emission factor ($g_{CO2}/L$)
- *D:* distance ($km$)
- $FC_{empty}$: fuel consumption of the empty vehicle ($L/km$)
- $FC_{full}$: fuel consumption of the vehicle at full load ($L/km$)
- *LF:* load factor, where

$$LF = \frac{cargo\ weight}{truck\ weight} = \frac{w}{W} \qquad [2]$$

Data presenting anticipated distance *D* in miles between the establishments and their respective suppliers are presented in Table 4. This information was obtained from Google Maps and is specific to the best routes (see images 12 and 13). Distance data is also presented in kilometers.

Table 4. Distances between the cafeterias and their respective suppliers (own source)

| Cafeteria | Supplier | Distance (miles) | Distance (km) |
|---|---|---|---|
| **Conviser Law Center** | Sysco | 3.1 | 5.0 |
| | Midwest Industries | 19.6 | 31.5 |
| | Vistar | 21.2 | 34.1 |
| | Coca-Cola | 25.8 | 41.5 |
| | Pepsi | 5.8 | 9.3 |
| | Farmer Brothers | 18.4 | 29.6 |
| **Center Court** | Sysco | 3.1 | 5.0 |
| | Midwest Industries | 23.8 | 38.3 |
| | Coca-Cola | 22.6 | 36.4 |
| | Pepsi | 2.5 | 4.0 |

In order to find the values of $FC_{empty}$, $FC_{full}$ and $LF$, the type of truck used in the transportation of the products needs to be determined. Following the Federal Highway Administration's classification of trucks by their weight, class 4 was selected as the average type of distribution truck for these cafeterias (refer to Figure 15 for further clarification).

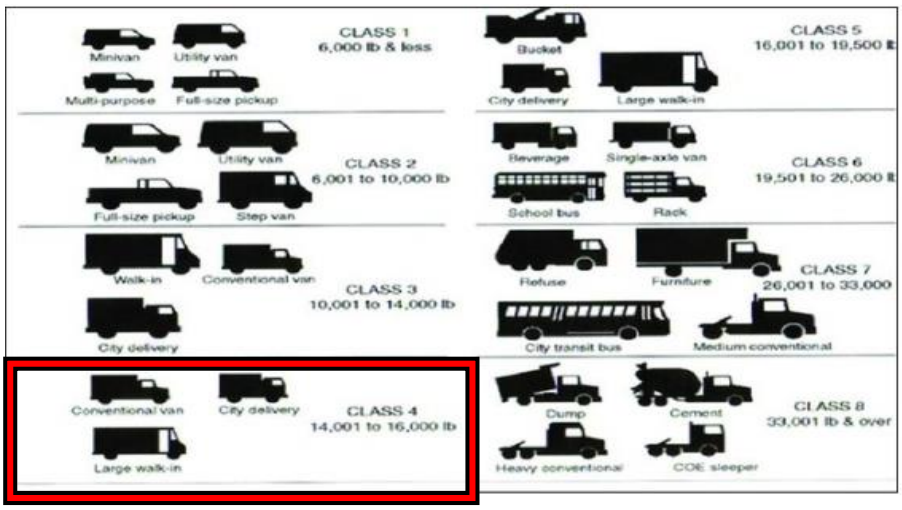


Figure 15. Classification of trucks by weight *(Matthew C. Camden et al., 2017, fig. 2)*

Trucks that belong to class 4 (conventional vans, city delivery trucks and large walk-in vehicles, for instance) approximately weight between 14,000 and 16,000 pounds, which is equal to 7-8 tons. Table 5 presents the classification of trailers per type and their respective fuel consumption *(FC)* and maximum truck weight *(W)*. For the previously selected class of truck (class 4), the correspondent type of trailer in Table 5 would be type 1, as the truck capacity is 7.5 tons. Considering that the routes the trucks travel are through urban areas, the Urban values of $FC_{empty}$ and $FC_{full}$ have been chosen.

Table 5. Fuel consumption and maximum truck capacity per type of trailer *(Josué C. Velázquez-Martínez et al., 2013, p. 201)*

| Type of trailer | W (tons) | Motorway | | Rural | | Urban | |
|---|---|---|---|---|---|---|---|
| | | $FC_{empty}$ | $FC_{full}$ | $FC_{empty}$ | $FC_{full}$ | $FC_{empty}$ | $FC_{full}$ |
| 1 | 7.5 | 0.122 | 0.137 | 0.107 | 0.126 | 0.11 | 0.134 |
| 2 | 14 | 0.165 | 0.201 | 0.152 | 0.197 | 0.171 | 0.228 |
| 3 | 26 | 0.204 | 0.273 | 0.199 | 0.284 | 0.244 | 0.352 |
| 4 | 28 | 0.201 | 0.294 | 0.205 | 0.318 | 0.255 | 0.402 |
| 5 | 40 | 0.226 | 0.36 | 0.23 | 0.396 | 0.288 | 0.504 |
| 6 | 50 | 0.246 | 0.445 | 0.251 | 0.495 | 0.317 | 0.634 |

Lastly, the cargo weight *w* needs to be determined. In order to do so, the rule of three has been applied as follows:

$$FC_{empty} \quad \text{———————} \quad W$$

$$FC_{full} \quad \text{———————} \quad W + w$$

obtaining the calculation of *w* by the following expression:

$$w = \frac{W \times (FC_{full} - FC_{empty})}{FC_{empty}} = \frac{7.5 \times (0.134 - 0.11)}{0.11} = 1.636\ tons \qquad [3]$$

Finally, considering that the constant emission factor for road diesel transport is $CE = 2{,}621\ g/L$ (K.M.R. Hoen et al., 2010, p. 18), the total emissions of $CO_2$ can be calculated using equation 1. The carbon dioxide emissions per trip from the cafeterias to their respective suppliers have been calculated and presented in Table 6.

Table 6. Carbon dioxide emissions per trip from the cafeterias to their respective suppliers (own source)

| Cafeteria | Supplier | $CO_2$ emissions (g) |
|---|---|---|
| **Conviser Law Center** | Sysco | 1,506.8 |
| | Midwest Industries | 9,527.1 |
| | Vistar | 10,304.8 |
| | Coca-Cola | 12,540.7 |
| | Pepsi | 2,819.2 |
| | Farmer Brothers | 8,943.8 |
| **Center Court** | Sysco | 1,506.8 |
| | Midwest Industries | 11,568.6 |
| | Coca-Cola | 10,985.3 |
| | Pepsi | 1,215.2 |

The goal of this section is to determine the total annual carbon dioxide emissions per restaurant. It is key to highlight that Conviser Law Center cafe inventory purchases is twice a week, whereas Center Court cafe only purchases inventory once a week. The reason for this difference might be that Conviser Law Center is located within the city, which reduces significantly the available storage area for making inventory; Center Court, on the other hand, is located in a large campus in the outskirts of the city center, which makes easier the availability of more spacious facilities for larger inventories. Hence, carbon dioxide emissions double for the case of Conviser Law Center cafeteria (as the distribution trips double as well) compared to Mies campus. Of course, we state this cautiously, since other factors such as the food types, demand pater and possibility for storage (i.e. in the case of perishable food items) can also impact inventory models practices in these two cafeterias. Table 7 shows the results of our analysis performed to estimate the $CO_2$ emissions from each location on weekly and annual basis, and the sum of annual $CO_2$ emissions per cafeteria, assuming:

- It was considered that each supplier would contribute twice to the weekly emissions (assuming each trip is conformed of the route from the distributor to the restaurant and the way back from the restaurant to the distributor).
- It was taken into account that Center Court ordered inventory once a week, whilst Conviser Law Center cafeteria ordered twice a week, therefore doubling its weekly carbon emissions.
- It was estimated that each establishment closed for vacation 6 weeks per year, period in which no carbon dioxide emissions would be produced.

Table 7. Weekly and yearly carbon dioxide emissions per cafeteria (own source)

| **Cafeteria** | **Supplier** | **$CO_2$ emissions (g)** | **$CO_2$/week (g)** | **$CO_2$/year (g)** | **Total annual $CO_2$ emissions (g)** |
|---|---|---|---|---|---|
| **Conviser Law Center** | Sysco | 1,506.8 | 6,027.3 | 277,257.4 | 8,398,215.6 |
| | Midwest Industries | 9,527.1 | 38,108.3 | 1,752,982.2 | |
| | Vistar | 10,304.8 | 41,219.2 | 1,896,082.8 | |
| | Coca-Cola | 12,540.7 | 50,163.0 | 2,307,496.9 | |
| | Pepsi | 2,819.2 | 11,276.9 | 518,739.6 | |
| | Farmer Brothers | 8,943.8 | 35,775.1 | 1,645,656.7 | |
| **Center Court** | Sysco | 1,506.8 | 3,013.7 | 138,628.7 | 2,325,384.5 |
| | Midwest Industries | 11,568.6 | 23,137.2 | 1,064,310.6 | |
| | Coca-Cola | 10,985.3 | 21,970.6 | 1,010,647.9 | |
| | Pepsi | 1,215.2 | 2,430.4 | 111,797.3 | |

As observed in Table 7, the total annual $CO_2$ emissions of Conviser Law Center and Center Court cafes are 8,398,215.6 g and 2,325,384.5 g, respectively. This indicates that **Conviser Law Center cafeteria pollutes 3.61 times more than Center Court** in terms of carbon dioxide emissions from inventory orders per year.

In the intent of explaining the contrast of these numbers, more aspects have been considered in our analysis. For instance, the $CO_2$ emission per unit of distance ratio is constant at 576.62 g/km. The average distance between Conviser Law Center and its suppliers is 25.19 km, whereas that for Center Court is 20.92 km. The larger average distance does not seem like a big difference. However, when adding all the trips made from the suppliers to the restaurants and back in one day of inventory delivery, the contrast in miles traveled when comparing both restaurants greatly increases: 302.23 km for Conviser Law Center versus 167.37 km for Center Court. The origin of this disparity is that Conviser Law Center has two more suppliers than Center Court, which inevitably rises the number of kilometers traveled. Moreover, if we take into account the total distance traveled per week, as Conviser Law Center cafe purchases inventory twice a week, the disparity grows even more: 604.47 km for Conviser Law Center versus 167.37 km for Center Court. The results of analysis for the two cafeterias are provided in Table 8.

Table 8. Comparison of distance traveled between cafeterias and their suppliers (own source)

| **Cafeteria** | **Averaged distance between cafeterias and suppliers** | **Total distance per inventory delivery** | **Total distance per week** | **Emission per unit of distance ratio** |
|---|---|---|---|---|
| **Conviser Law Center** | 25.19 km | 302.23 km | 604.47 km | 576.62 $g_{CO2}$/km |
| **Center Court** | 20.92 km | 167.37 km | 167.37 km | |

Throughout this section, the carbon dioxide emissions originated in the delivery of purchased inventory by the Conviser Law Center cafeteria and the Center Court cafe have been directly affected by their inventory management strategy and supply chain operations. After analyzing the numbers' magnitudes and motives, it has been discovered that Conviser Law Center cafeteria does not succeed at having an efficient inventory management strategy. Hence, the following suggestions are provided for reducing Conviser Law Center cafeteria's carbon dioxide emissions and optimization of their inventory strategy:

i. *Reduce the number of providers:* having less suppliers will incur in less inventory delivery trips, therefore reducing $CO_2$ emissions.
ii. *Reduce the order frequency to once a week:* this measure will reduce the weekly $CO_2$ emissions by a half.
iii. *Select providers closer to Conviser Law Center:* this will imply shorter distances between the cafeteria and its suppliers, which in turn helps reducing $CO_2$ emissions.
iv. *Switch to electric or hybrid transportation vehicles:* although the economic viability of this option needs to be further studied, it would undoubtedly and significantly reduce $CO_2$ emissions in the case of hybrid transportation, and totally eliminate $CO_2$ emissions in the case of electric vehicles (if not considering the battery charge).

### 3.2.2 Energy consumption analysis

The energy use of the kitchens' equipment and appliances of Conviser Law Center cafeteria and Center Court was measured aiming to determine the incurred costs and the carbon footprint of the electricity usage in the kitchen. It is important to note that neither the electricity used for lighting the cafeterias nor the water consumption could be measured due to administration restrictions, therefore these utilities were not included in the present study.

The energy cost per appliance and equipment was, however, calculated for both Center Court and Conviser Law Center cafe based on the current cost of electricity in Illinois of 9.01 cents per kWh (ElectricRate, 2020) and considering that all of the equipment was operating for 10 hours a day (except refrigerators, freezers, coolers and ice makers, which need to be functioning 24 hours a day). We also estimated the greenhouse gas emissions resulting from this energy use employing EPA Greenhouse Gas Equivalencies Calculator (US EPA, 2020). Table 9 presents the results of these estimations for Center Court:

Table 9. Center Court energy use and cost (own source)

**Center Court energy use and cost**

| Equipment | Characteristics | Power (W) | Energy cost per day ($) |
|---|---|---|---|
| Hot container for food #1 | ATLAS, Hot & Cool Well, Model WCM-HP-2 | 2,000 | 1.802 |
| Hot container for food #2 | ATLAS, Hot & Cool Well, Model WCM-HP-2 | 2,000 | 1.802 |
| Hot container for food #3 | ATLAS, Hot & Cool Well, Model WCM-HP-2 | 2,000 | 1.802 |
| Hot container for food #4 | ATLAS, Hot & Cool Well, Model WCM-HP-2 | 2,000 | 1.802 |
| Hot container for food #5 | ATLAS, Hot & Cool Well, Model WCM-HP-2 | 2,000 | 1.802 |
| Hot container for food #6 | ATLAS, Hot & Cool Well, Model WCM-HP-3 | 2,000 | 1.802 |
| Food display case | Federal Industries, Model CRR3628 | 972 | 0.876 |
| Food warmer #1 | Hatco, Model GR3SDS-39 | 1,493 | 1.345 |
| Food warmer #2 | Hatco, Model GR2BW-36 | 1,470 | 1.324 |
| Refrigerator #1 | True, Model T-49 | 367.7 | 0.795 |

| | | | |
|---|---|---|---|
| Bottle Coolers | Beverage-Air, Model DW94HC-B | 186.4 | 0.403 |
| Deep fryer | Pitco, Model SE14-C Electric | 17,000 | 15.317 |
| Flat Top Grill | VULCAN, Model MSA48 | 31,671.50 | 28.536 |
| Oven-Toaster #1 | Tornado TurboChef, Model HHD-9500-14-DL | 21,480 | 19.353 |
| Oven-Toaster #2 | Tornado TurboChef, Model HHD-9500-14-DL | 21,480 | 19.353 |
| Pizza Oven | Lincoln, Model 2501/1346 208V* | 6,000 | 5.406 |
| Refrigerator #2 | McCall, Model 4-4020* | 490 | 1.060 |
| Freezer #1 | True, Model T-49F-HC | 745.7 | 1.613 |
| Freezer #2 | Victory, Model FA-2D-S7 | 372.85 | 0.806 |
| Ice maker | HOSHIZAKI, Model KM-1300SAH-E | 2,050 | 4.433 |
| Refrigerated display case #1 | FEDERAL INDUSTRIES, Model RSSM478SC | 2,198 | 1.980 |
| Refrigerated display case #2 | Beverage-Air, Model SPE48HC-12M | 186.4 | 0.168 |

All this information can be gathered in the following table in the form of total energy use and total cost per day and per year.

All in all, Center Court spends approximately $36,345.98 yearly in its kitchen's electrical operations (not counting the electricity used for lighting). The yearly energy use of 384,523.36 kWh can be traduced into the release of 599,378 pounds or 271,873 kilograms of $CO_2$, which is equivalent to the greenhouse emissions of 674,624 miles driven by an average

* This model has been adapted for this project

passenger vehicle, or the $CO_2$ emissions from either 30,592 gallons of gasoline consumed, 26,707 gallons of diesel consumed, 299,567 pounds of coal burned or 46 homes' electricity use for one year (US EPA, 2020), as shown in Table 10.

Table 10. Center Court total energy use and cost (own source)

| | Center Court | |
|---|---|---|
| | **Per day** | **Per year**[†] |
| **Total energy use (kWh)** | 1,201.64 | 384,523.36 |
| **Total cost ($)** | 113.58 | 36,345.98 |

These estimations show the significance of energy use in a midsize cafe's kitchen.

Conviser Law Center cafeteria's energy use and associated costs are presented in Table 11. It needs to be highlighted that the hot and refrigerated self-service stands located outside the kitchen have not been included in this study.

Table 11. Conviser Law Center cafeteria energy use and cost (own source)

**Conviser Law Center cafeteria energy use and cost**

| Equipment | Characteristics | Power (W) | Energy cost per day ($) |
|---|---|---|---|
| Jelly cooler | Structural Concepts, HARMONY, Model HMG3953R | 1,117 | 2.415 |
| Ice maker | Hoshizaki KM-901MAJ 30" 950 lb | 5 kWh per 100 lb | 3.604 |
| Toaster | Waring CTS1000 | 1,800 | 1.622 |
| Fryer | Pitco 65C+S Natural Gas 65-80 lb | 43,935 | 39.585 |

[†] Considering a 6-week vacation period, that is, 320 working days per year

| | | | |
|---|---|---|---|
| Flat top | KEATING 36" MIRACLEAN Electric Griddle | 8,600 | 7.749 |
| Grill | MagiKitch'n APM-RMBCR-636-H 24" Natural gas | 23,432 | 21.112 |
| Self-contained automated damper and hood | LISTED 516X UL, Model CM100-DM | - | - |
| Hot bar | Wells Mfg Co., Model MOD400DM | 1,200‡ | 1.081 |
| Wine cooler | Tramontina | 103.5§ | 0.224 |
| Conventional oven | Vulcan 36S-6BN Endurance 6 Burner 36" Natural Gas. Item #: 90136S6BN | 62,973.5 | 56.739 |
| Reach in cooler #1 | QBD Cooling Systems Inc., Property of Pepsi Beverages Company, Model CD26HB | 552§ | 1.194 |
| Reach in cooler #2 | True Manufacturing Co., Property of Coca-Cola, Model GDM-35EM, Unit NF11FX.2 | 782§ | 1.691 |
| Convection oven | VULCAN 1-866-688-5226, WOLF 1-866-688-5226, HOBART 1-888-4 | 14,645 | 13.195 |
| Triple reach in freezer | HOSHIZAKI | 2,530§ | 5.471 |

Table 12 presents the total energy cost and usage of the cafeteria per day and per year. It needs to be mentioned that the fridge used in this cafeteria consists in a refrigerated room

‡ 1,200 W was chosen from the range 900/1,200W because the equipment operation mode is permanently set on high temperature

§ Calculated from the voltage and amperage values on the specifications sheet which electricity usage is associated with the whole facility's electricity consumption and, as stated at the beginning of section 3.2.2, overall water and electricity consumption of the facility could not be determined due to administration issues.

Table 12. Conviser Law Center cafeteria total energy use and cost (own source)

| | **Conviser Law Center cafeteria** | |
|---|---|---|
| | **Per day** | **Per year**† |
| **Total energy use (kWh)** | 1,656.70 | 530,144 |
| **Total cost ($)** | 155.68 | 49,818.32 |

All in all, Conviser Law Center cafeteria spends approximately $49,818.32 yearly in its kitchen's electrical operations (not counting the refrigerated room nor the electricity used for lighting). The total annual energy use is 530,144 kWh, which, in terms of carbon dioxide emissions, is equivalent to 826,365 pounds or 374,833 kilograms. These values can be traduced into the greenhouse emissions from 930,107 miles driven by an average passenger vehicle, or the $CO_2$ emissions from either 42,178 gallons of gasoline consumed, 36,821 gallons of diesel consumed, 413,015 pounds of coal burned or 63.5 homes' electricity use for one year (US EPA, 2020). Again, such contamination figures show the strong environmental consequences a midsize cafeteria's operations can provoke.

**3.2.3 Center Court food waste management analysis**

It was observed that food waste (food prepared and not sold) at Conviser Law Center cafeteria was not significant, whilst Center Court presented considerably large quantities of food that was not sold at the end of the day. Another main goal of the project is to also analyze and optimize the food waste management strategies at Center Court. In order to meet this goal, we first analyzed the menu at this location.

Our analysis indicated that they have three different types of food in their menus: Asian food, Indian food and fried chicken. The items within each type and their prices are shown in the following tables (Table 13, Table 14 and Table 15). This variety of cultures in the offered food's origin is a positive aspect, as it gives the consumers flexibility in their lunch choices. Having that said, it was observed that there was considerable food that remained unsold at the end of each day. According to the restaurant's office manager, Asian food was not so popular amongst customers, specifically the sushi. She added that sushi constitutes the majority of the food waste at the end of the day, which is about 50% of the initial food at the beginning of the day. So as to make an estimation of the number of units unsold per day, the following assumptions were made:

- The initial food inventory is equally distributed between the three types of menus: 33.33% Indian food, 33.33% Asian food and 33.33% fried chicken.
- Food waste is 5% for Indian food, 5% for fried chicken and 40% for Asian food (more specifically, sushi).

Table 13. Asian food menu at Center Court (Illinois Tech Culinary and Hospitality Services, n.d., sec. Asiana)

***Asiana Sushi and Poke***

| **RAMEN** | | **SUSHI** | | **SIDES** | |
|---|---|---|---|---|---|
| Mild (Chicken/Tofu) | $6.99 | Vegetarian California Roll | $5.99 | Wakame (Seaweed Salad) | $3.99 |
| Spicy (Chicken/Tofu) | $6.99 | California Roll | $5.99 | Edamame | $3.49 |
| | | Spicy California Roll | $6.99 | Veggie Dumplings | $5.89 |
| | | Crunchy California Roll | $6.99 | Beef Dumplings | $5.89 |
| **POKE BOWLS** | | Inari (Tofu) Roll | $5.99 | | |
| Tuna Poke | $9.99 | Shrimp Tempura Roll | $7.99 | | |
| Salmon Poke | $9.99 | Salmon Avocado Roll | $6.99 | | |
| Veggie Tofu Poke | $9.99 | Spicy Tuna Roll | $6.99 | | |

| | | | |
|---|---|---|---|
| Green Delight | $9.99 | Spicy Salmon Roll | $6.99 |
| | | Kamikaze Roll | $9.99 |
| | | Uncle Roll | $9.99 |
| | | Red Dragon Roll | $9.99 |

Table 14. Indian food menu at Center Court (Illinois Tech Culinary and Hospitality Services, n.d., sec. Saffron)

| ***SAFFRON INDIAN CUISINE*** | | | |
|---|---|---|---|
| ***Indian Combos*** | | | |
| **Combo 1**<br>Choice of vegetable and side of rice | $5.49 | **Combo 4**<br>Choice of 2 meats, vegetable and side of rice | $8.99 |
| **Combo 2**<br>Choice of 2 vegetables and side of rice | $6.49 | **Combo 5**<br>Choice of meat and side of rice | $6.99 |
| **Combo 3**<br>Choice of vegetable, choice of meat and side of rice | $7.99 | | |
| ***Extras*** | | | |
| Veg Samosa | | | $1.49 ea |
| Naan | | | $1.49 ea |
| Rice | | | $1.49 ea |
| *Substitute your combo vegetable for dahi boondi or seasonal salad* | | | |
| 100% Zabiha Halal Certified | | | |

Table 15. Fried chicken food menu at Center Court (Illinois Tech Culinary and Hospitality Services, n.d., sec. Student Choice)

| **Chicken & Biscuits** | | | |
|---|---|---|---|
| **FRIED CHICKEN WITH BISCUIT** | | **SIDES** | |
| 3 piece | $4.99 | Hand cut fries | $2.89 |
| 4 piece | $6.99 | Biscuits (2) | $2.49 |
| 5 piece | $7.49 | | |
| *Add fries and a drink* | $2.99 | **DIPPING SAUCES** | |
| | | Siracha Ranch | |

| | |
|---|---|
| *Your choice of sauce:*<br>*- Original*<br>*- Nashville Hot*<br>*- Honey Buffalo*<br>*- Smokehouse Maple* | Comeback Sauce<br>Honey Mustard<br>Ranch<br>BBQ |
| | **BISCUIT SPREADS** |
| | Apple Butter<br>Pimiento Cheese |

We also learned that their daily income is approximately $3,808, as stated by the office manager. This data, along with the office manager's initial provided information, we were able to estimate the portions of unsold food at the end of the day for this location following the steps below:

1. The percentage of food sold was calculated according to the information provided for initial food inventory for the different types of food and the food waste percentage:

$$\%_{food\ sold} = \%_{initial\ food\ inventory} \times (1 - \%_{food\ waste}) \quad [4]$$

2. The daily income per type of food was determined by multiplying the total daily income of $3,808 by the percentage of each type of food sold:

$$Daily\ income = Total\ daily\ income \times \%_{food\ sold} \quad [5]$$

3. An average price for each menu was estimated taking into account all the correspondent main dishes.
4. The estimated units sold per day were calculated by dividing the daily income by the average menu price:

$$Units\ sold\ per\ day = \frac{Daily\ income}{Average\ menu\ price} \quad [6]$$

5. In order to obtain the initial units per day, the Rule of Three was applied as follows:

$$\%_{initial\ food\ inventory} \quad \text{————} \quad Initial\ daily\ units$$

$$\%_{food\ sold} \quad \text{————} \quad Daily\ units\ sold$$

which equals to:

$$Initial\ daily\ units = \frac{\%_{initial\ food\ inventory} \times Daily\ units\ sold}{\%_{food\ sold}} \qquad [7]$$

6. Finally, the unsold units per day are calculated by subtracting the initial minus the sold units per day:

$$Units\ unsold\ per\ day = Initial\ daily\ units - Daily\ sold\ units \qquad [8]$$

Table 16 presents estimated unsold food for the three different categories. As shown, the majority of food waste is originated in the Asian food, specifically with the sushi items, as the office manager indicated (63 units of Asian food versus 9 units of Indian food and 7 of fried chicken).

Table 16. Daily units unsold at Court Center (own source)

| | **Type of food** | | |
|---|---|---|---|
| | Indian | Fried chicken | Asian |
| **Initial food inventory** | 33.33% | 33.33% | 33.33% |
| **Food waste** | 5% | 5% | 40% |
| **Food sold** | 31.7% | 31.7% | 20.0% |
| **Income per day** | $1,205.75 | $1,205.75 | $761.52 |
| **Average menu price** | $7.19 | $9.48 | $8.05 |
| **Units sold per day** | 168 | 127 | 95 |
| **Initial units per day** | 177 | 134 | 158 |
| **Units unsold per day** | **9** | **7** | **63** |

### 3.2.4 Proposed Strategies for Managing Estimated Food Waste

This section offers suggestions for optimizing in order to provide solutions for the improvement of food waste problem. The proposal specifically aims at better management of the unsold food at the end of the business day. For example, distribute the unused good food among low income families at affordable prices.

Bronzeville, the neighborhood where Mies Campus (and Center Court) is located, is a humble district that adjoins areas of low income and social level, therefore making this idea very suitable for the case. The main idea is that the unsold food is boxed, stored and transported to a facility in which it is appropriately stored until being distributed to the recipients. A non-profit organization would be in charge of receiving the goods in the facility and correctly assign them and facilitate their pickup and distribution to the receivers. Figure 16 shows the process diagram of this strategy.

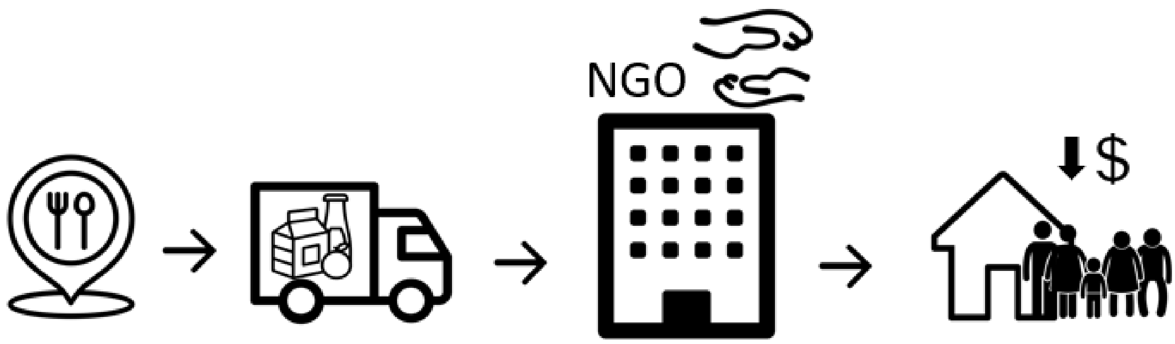


Figure 16. Diagram of the food waste proposed solution (own source)

The major players include but are not limited to (I) Chartwells management (this firm being the third-party company hired by Illinois Institute of Technology to run the cafeteria), (II) student organizations on campus (can be created to promote social entrepreneurship programs via Illinois Institute of Technology campus), (III) the City of Chicago government offices, that have programs through which distribution can be materialized, (IV) nonprofit organizations such as food banks and NGOs, and (V) low-income families and social housing occupants. The business plan and each stakeholder's requested actions are described below:

1. Chartwells management

   His or her role is to assure that the unsold food is correctly packaged and stored, and to hire a truck delivery company to transport the goods to the designated facility.

Additionally, the government would provide an incentive of 7% Center Court's annual income when including this service in its business strategy, as well as an officialized certificate that recognizes the restaurant's social awareness.

2. Illinois Institute of Technology Student Association Aiming at Social Empowerment

   This association can be created or housed in Illinois Institute of Technology Sustainability Student Association.

3. Government

   The government would give the restaurant's manager an incentive of 7% of Center Court's annual income (so he or she could invest it in the business), as well as an officialized certificate recognizing the cafeteria's social awareness, as mentioned in the previous paragraph. Moreover, it would provide a suitable facility to the nonprofit organization in order to store the goods from Center Court until they are distributed to the recipients. Contributing to develop this initiative by funding the restaurants (not only Center Court, but other restaurants that want to join this project as well) would rise their image as a government concerned about its inhabitants' welfare.

4. Nonprofit organization

   Its role would be to connect the truck company to the recipients of Center Court's food. The people within the organization would receive the truck loads and coordinate the pickup and distribution to the registered low income families and social housing occupants, and create a platform that records all the recipients' information such as name, address, annual income and number of family members. In order to develop these tasks, the funding would come from the following sources:

   i. The government would provide an appropriate facility, inside which the food would be conserved until it is distributed.

ii. Additional money the non-profit organism would need for transportation of goods to the recipients that cannot walk in personally (the elderly and physically or mentally disabled people) could be earned from donations through social media:

  a. Develop a website with the information about the project and a platform available for donating.
  b. Post on petition websites such as change.org so as to receive funding from donations.
  c. Employ social media (Instagram, Facebook, Twitter, etc.) to spread the word.

5. Low income families and social housing occupants

   They would need to prove their income is equal or lower than a certain quantity and register in order to be a part of this new system. They would personally pick up the food, unless they are not able to due to disabilities, in which case the NGO workers would distribute it to their home.

Other agents could be involved, such as truck companies that could be hired by Chartwell Center Court's owner to transport the food boxes to the facility designated to the nonprofit organism, or Center Court customers who could inform Illinois Institute of Technology campus' neighborhoods about the restaurant's initiative and help with the growth of the project.

There could be plans to motivate the government to provide the NGO with a suitable facility in which conveniently store the food. After making a review of the vacant and abandoned buildings in Chicago (Chicago Department of Buildings, 2018), the most convenient facility was identified for food storage. This facility was chosen based on its proximity to Mies Campus, and is located in 3329 S Morgan Street, Chicago IL, 60608. Figure 17 shows its distance to Mies Campus on a map (based on Google Maps).


Figure 17. Location map of Center Court cafe and vacant building (own source)

In the following subsections, we propose examples for the type, dimensions and materials of the containers needed to properly store and distribute excess food on a daily basis. We also calculate carbon dioxide emissions originated from the transportation of said goods in order to evaluate operation carbon footprints, which is important, as we must design plans that are capable of meeting sustainability criteria as well.

*a. Food containers*

As the results indicate in Table 16, the unsold units of food at the end of the day at center Court are, approximately, 63 sushi roll servings, 7 fried chicken menus and 9 Indian combos.

- Each typical sushi roll serving consists of a roll made of rice, raw fish and a seaweed sheet of approximately 20x18 centimeters (MakeSushi, 2012). The rice and raw fish are positioned on the algae sheet, and the sheet is then rolled from the longer side until obtaining a tube shape. Once this is done, the tube is transversally cut into several pieces, obtaining the so-called sushi rolls. The dimensions of each sushi roll can be calculated from the length and width of the algae sheet. Based on the circumference perimeter equation:

$$perimeter = 2 \times \pi \times R = 18\ cm$$

the roll diameter can be expressed as:

$$D = \frac{perimeter \times 2}{2 \times \pi} = \frac{18\ cm}{\pi} = 5.73\ cm \qquad [10]$$

Therefore, the dimensions of a sushi roll are the ones represented in the drawing below:

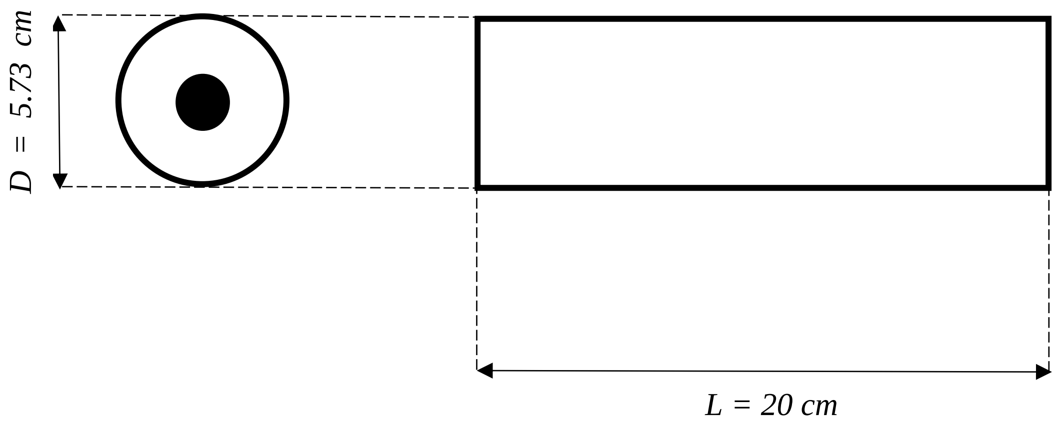


Figure 18. Dimensions of sushi roll (not to scale) (own source)

It can be concluded that the volume that a sushi roll takes up is 5.73x5.73x20 centimeters. As there are 63 sushi rolls that need to be stored, it has been considered that each container will hold 9 rolls, hence requiring 7 rectangular containers of 18 cm wide, 18 cm high and 22 cm long.

- For the case of fried chicken, it has been estimated that each chicken tender is of about 3.5 cm wide, 1.5 cm high and 12 cm long, based on comparison with common chicken tenders from other restaurants and on the price. Considering that each batch of fried chicken is composed of 4 pieces, and that there are 7 unsold batches, the total number of unsold fried chicken tenders at the end of the day is 24. As a result, it has been decided that only one rectangular container will be required with dimensions of 19 cm wide, 10 cm high and 5 cm long.

- Lastly, there are 9 Indian food combos that remain unsold at the end of the day. These meals will be packed individually in rectangular containers of 20 cm wide, 7 cm high and 15 cm long.

All the containers will be made of recycled plastic and will serve to store the food from Center Court to the designated facility. Once the food arrives at the facility, it will be distributed to the final consumers in individual containers made of recycled cardboard. The recycled plastic containers will be reutilized.

*b. Carbon dioxide emissions*

In order to determine the emissions of $CO_2$ to the atmosphere from the transportation of the goods from Center Court to the facility where the NGO operates, it is first needed to calculate the weight of the transporting load.

- According to John D. Ayer, each sushi roll weighs between 168 and 224 grams (Ayer, 2011). Considering the average of these quantities, and that the number of rolls in this specific case is 63, the total weight of the unsold sushi is 12,348 grams.
- A recommended weight of a fried chicken tender is about 50 grams (Emily Bites, 2017). Considering that each serving (on average) consists of 4 pieces of this item, each serving weights 200 grams. Additionally, there are 7 servings that are not sold at the end of the day, which all together weight 1,400 grams.
- Lastly, for the case of Indian cuisine, it can be estimated that the weight of a common combo can consist of the sum of 200 grams from a cup of rice

(Cooksinfo, 2020), about 75 grams from a standard vegetable serve (Cox, 2012) and 155 grams of meat (Kristen Stewart, 2009), which in total is 430 grams per meal. This number times 9 (the number of unsold Indian combo meals) makes 3,870 grams of total weight.

As a result, the sum of the total unsold Asian, Indian and fried chicken food's weight is 17.62 kilograms:

$$12{,}348\ g + 1{,}400\ g + 3{,}870\ g = 17{,}618\ g = 17.62\ kg \qquad [11]$$

Luckily, this weight is light enough to allow to utilize a small ***electric car*** as the transportation method, achieving net zero emissions, or a hybrid car. However, if the ownership of an electric or hybrid vehicle is not possible, another possibility is to use a sedan-type car, which has a $CO_2$ emission rate of 176 grams per kilometer (I. Wagner, 2020). The route between Center Court and the designated facility presented in Figure 17 has a length of 3.54 kilometers; hence, the carbon dioxide emissions generated from the transportation of the food from Center Court to the NGO building and the way back to the restaurant would be:

$$176\ \frac{g_{CO2}}{km} \times 3.54\ km \times 2\ trips = 1{,}246.08\ g_{CO2} = 1.25\ kg_{CO2} \qquad [12]$$

It needs to be highlighted that not only the prepared food, but also inventory leftovers can be included in this new system, so as to contribute to reducing food waste. The quantities and packaging procedure in this case do not belong to the scope of this project and would have to be further analyzed. Additionally, as this strategy might be costly and difficult to achieve, another more feasible and economical alternative is to transport the food directly to food banks and let said organisms handle the storage and distribution. In this case, the only difference with the previous calculations would be the change in distance between Center Court and the food bank.

# CHAPTER 4

# CONCLUSIONS AND RECOMMENDATIONS

This study aimed at understanding operation and supply chain issues in small and medium size food cafes. Analysis of the operation and supply chain management issues highlighted the importance of: (I) understanding energy use pattern and related carbon footprints, (II) optimizing inventory using sales data, and (III) criticality of managing food waste while focusing on social empowerment.

The case study presented in Chapter 3, while focusing on two food cafes at Illinois Institute of Technology downtown and Mies Campuses, began by introducing Illinois Institute of Technology and its food services. After focusing on Center Court and Conviser Law Center cafeterias, their strategic approach regarding inventory management and energy use was studied: the carbon dioxide emissions originated in the transportation of inventory from the suppliers to their respective restaurants, the energy use within the cafeterias' kitchens and the food waste management.

The analysis of the two cases resulted in the development of sustainable solutions for operation of small food cafes:

I. We provided several suggestions aiming to improve the current operations strategies at the Conviser Law Center Cafe by reducing the carbon dioxide emissions in the inventory distribution. These suggestions include reducing the number of providers of the restaurant, reducing the order frequency of inventory from twice to once a week and selecting providers closer to the facility, which all help reduce the carbon dioxide emissions by cutting the distance traveled by the distributors. Additionally, it is proposed to switch to electric or hybrid transportation vehicles in order to drastically reduce said emissions.

II. We calculated both cafeterias' energy consumption within the kitchen and the associated cost, obtaining the result of more energy use in Conviser Law Center restaurant's kitchen, thus greater contribution to carbon dioxide emissions.

III. We quantified food waste in Center Court cafe and proposed an alternative that consists in the storage and packaging of the food that has not been sold at the end of the day, primarily Asian food, and the delivery and sale (at more affordable prices) of the unsold cooked items to low income families or social housing occupants by means of the collaboration of non-profit organisms and the local government. Considering the government's solvency, it would provide a suitable facility near the Campus where the NGO would operate, and give the owner an incentive of 7% the cafeteria's annual income to invest in this initiative. The NGO's role would be to assign and facilitate the pick-up of the food items to the receivers, and to develop a database that records each member's personal situation: address, number of family members, salary, etc. It needs to be mentioned that, in order to take advantage of this initiative as a consumer, he or she needs to earn a maximum wage.

This project opens a path for further study on the following subjects:

- Analysis of the efficacy of the cafes' kitchen equipment and appliances compared to their equivalents available in the market.
- Determination of the total energy use within Main and Downtown campuses by including the lighting and water use within the kitchens.
- Viability study of the incorporation of electric and hybrid vehicles as means of inventory transportation between suppliers and the cafes.
- Assessment of the installation of a dishwasher in Main campus cafe and the substitution of disposable plates and cutlery for ceramic, metal or similar materials.
- Study of using the remaining used vegetable oil from the cooking operations as biofuel.

- Further analysis of the viability of the proposal for food waste management in Main campus cafe, regarding aspects such as (I) type of vehicle used to distribute the food items, (II) cost of packaging the goods and transportation, (III) lighting and refrigeration expenses in the facility operated by the correspondent NGO, (IV) validation of the chosen facility as appropriate, and (V) profitability study of distributing the food items directly to a food bank, among others.

# ANNEX: SUSTAINABLE DEVELOPMENT GOALS

This project seeks to improve the world we live in by proposing several strategies that include more sustainable aspects of operation. The importance of efficiency and sustainability must be present in any contribution to the state of the art, as we are the generation that will make the big push into a greener industry and society.

The Sustainable Development Goals are a great measure to quantify one's contribution to sustainable development. The following goals can be identified with the present project:

I. *End of poverty:* this project encourages to make the purchase of food more affordable for people with low income.

II. *Zero hunger:* as mentioned above, one of the main goals of the project is to offer food at reduced prices for low income individuals and families, therefore aiming at reducing hunger amongst people.

III. *Health and wellness:* by reducing the number of people that cannot afford buying enough food, their health and wellness will improve.

IV. *Clean energy:* this project proposes some alternatives regarding electric transportation for inventory distribution and for innovative food waste management strategies.

V. *Industry and innovation:* the present project aims to make food industry more sustainable and efficient by proposing and innovative approach to improve food waste management strategies, among other techniques.

VI. *Decrease of social inequality:* by helping communities with lower income, the social gap is being reduced.

VII. *Responsible production and consumption:* this project encourages to reduce waste by finding a better use to the inventory that is not and will not be sold to regular customers.

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