



GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

“REFORMULACIÓN LOGÍSTICA DEL BANCO DE ALIMENTOS DE
MADRID: BENEFICIOS DE UN MODELO DESCENTRALIZADO”

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Madrid

Julio 2021

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“Reformulación logística del Banco de Alimentos de Madrid: beneficios de un modelo descentralizado”

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Madrid

Julio 2021

REFORMULACIÓN LOGÍSTICA DEL BANCO DE ALIMENTOS DE MADRID: BENEFICIOS DE UN MODELO DESCENTRALIZADO

Autor: Cerezo de Osma, Guillermo.

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Entidad Colaboradora: Banco de Alimentos de Madrid,
ICAI – Universidad Pontificia Comillas

RESUMEN DEL PROYECTO

En un entorno democrático, humano y socialmente responsable, resulta relevante poner especial atención a aquellos colectivos que, durante la posible recesión originada en los próximos años por el COVID-19, puedan llegar a encontrarse en una situación de mayor urgencia o necesidad económica. Estos grupos serán, precisamente, los que, al no disponer de suficientes medios para combatir la recesión por cuenta propia, se encontrarán en una situación de mayor indefensión y exclusión, pudiendo llegar a propiciar cierta desestabilización social que afecte al resto de colectivos, en caso de que no se desplieguen medios para cubrir sus necesidades básicas.

Motivado por esta situación de preocupación e incertidumbre, el objetivo de este trabajo es, precisamente, el de tratar de apoyar la labor de aquellas organizaciones que prestan ayuda a los colectivos más desfavorecidos, con el ánimo de contribuir a satisfacer sus necesidades más básicas y urgentes. En concreto, en este proyecto se pretende realizar un estudio que aborde la problemática relativa a la gestión de los productos provenientes de Fondos Europeos de Ayuda al Desfavorecido (FEAD, de ahora en adelante), persiguiendo realizar una estimación de los costes asociados a cada una de las fases de dichos productos y un estudio comparativo, desde el punto de vista económico, entre el modelo logístico actual empleado (modelo centralizado) por el Banco de Alimentos de Madrid (BAM, de ahora en adelante) para la gestión de los productos FEAD y un modelo alternativo descentralizado.

Para realizar un análisis de costes de los dos modelos propuestos, el proyecto se apoyará en un modelo de simulación que modela los procesos internos a los que se someten los productos FEAD en el BAM (Recepción-Almacenaje-Preparación y entrega). Dicho modelo cuenta con parámetros de entrada como 1) el número de voluntarios que trabajan en cada proceso, 2) los tiempos que se emplean en cada una de las etapas, 3) el número de kg que se reciben de productos FEAD, 4) los costes asociados a cada proceso. A partir de estos parámetros, es posible computar, de manera aproximada, cuál es el coste asociado a la línea de productos FEAD. Además, se realiza de forma exógena al modelo un análisis de costes asociados a las fases de distribución inicial (Empresas proveedoras-BAM) y distribución final (BAM-Entidades Benéficas) para realizar una estimación más precisa de los costes de los productos estudiados.

A fin de determinar qué tipo de cadena de valor es más eficiente (modelo centralizado frente a modelo descentralizado) uno de los objetivos intermedios del trabajo es el de comprobar la validez del modelo desarrollado. Para ello, se plantean dos casos de estudio:

- El primer caso de estudio trata de evaluar la sensibilidad del modelo ante variaciones en parámetros como: 1) el número de voluntarios en distintas fases del proceso logístico o 2) variaciones del perfil cronológico de las salidas.
- Un segundo caso de estudio centrado en la operación real del BAM relativa a la gestión de los productos FEAD durante los meses de mayo-junio-julio del año 2019. Consiste en usar como datos de entrada: 1) la cantidad en kg de productos FEAD que entran y salen de BAM durante los meses mencionados 2) el número de voluntarios que colaboran, además de los tiempos empleados en los diferentes procesos logísticos. Así, por un lado, se podrá comprobar la respuesta del modelo ante un caso realista de operación y por otro, el caso de estudio permitirá realizar una estimación de los costes asociados a cada uno de los procesos internos del BAM: una variable fundamental de cara a posibles procesos de reformulación logística de la organización.

El objetivo fundamental es el de comparar si un modelo descentralizado aporta beneficios sociales adicionales frente al modelo centralizado actual. Para realizar este análisis, se han desarrollado dos tipos de modelo. Por un lado, un primer modelo de simulación para emular los procesos de Recepción-Almacenaje- Preparación y entrega de la cadena de valor del BAM y, por otro lado, un modelo financiero que captura los procesos de distribución inicial y final. Mediante la combinación de ambos modelos, se logra obtener una visión tanto holística como granular de los costes asociados a la cadena de valor de los productos provenientes de FEAD. De los resultados obtenidos se ha podido desprender las siguientes conclusiones:

- La incorporación de tan sólo un voluntario (incremento de un 10%) en los procesos internos del BAM puede suponer una reducción en los tiempos de cola superiores al 40%.
- Homogenizar la distribución de alimentos repartidos diariamente (repartir cada día la misma cantidad de comida) se podría traducir en una reducción sustancial de los tiempos de cola en alguno de los procesos del BAM (30 horas agregadas).
- El modelo planteado estima un coste logístico contable de 61218,3€ valor que se aproxima a los resultados ofrecidos por el BAM, señalando la validez del modelo. De dichos costes, aproximadamente el 35% se debe a los costes de distribución inicial, el 30% a los costes relativos al BAM (procesos de Recepción-Almacenaje-Preparación y entrega) y el 35% restante a la distribución final.
- La comparativa de costes entre los modelos planteados sugiere que la transición de un modelo centralizado (modelo actual) a un modelo descentralizado acarrearía una reducción del 30% en el coste social total de la cadena de valor de los productos provenientes del FEAD.

En definitiva, este proyecto realiza una primera estimación de los costes asociados a la cadena de valor de los productos FEAD del modelo centralizado actual y plantea la transición a un modelo descentralizado alternativo con posibles mejoras en términos de beneficio social.

LOGISTICAL REFORMULATION OF THE MADRID FOOD BANK: BENEFITS OF A DECENTRALIZED MODEL

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Collaborating Entity: BAM,
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ABSTRACT

In a democratic, humane and socially responsible environment, it is important to pay special attention to those groups that, during the possible recession caused by covid-19 in the coming years, may find themselves in a situation of greater urgency or economic need. These groups will be precisely those who, not having sufficient means to combat the recession on their own, will find themselves in a situation of greater defenselessness and exclusion, which could lead to a certain social destabilization affecting the rest of the groups, in the event that the means are not deployed to cover their basic needs.

Motivated by this situation of concern and uncertainty, the aim of this work is, precisely, to try to support the work of those organizations that provide help to the most disadvantaged groups, with the aim of contributing to meet their most basic and urgent needs. Specifically, this project aims to conduct a study that addresses the problems related to the management of products from European funds for aid to the disadvantaged (Fead, hereinafter), pursuing an estimate of the costs associated with each of the phases of these products and a comparative study, from an economic point of view, between the current logistics model used (centralized model) by the Banco de Alimentos de Madrid (BAM, hereinafter) for the management of Fead products and an alternative decentralized model.

In order to perform a cost analysis of the two proposed models, the project will rely on a simulation model that models the internal processes to which Fead products are subjected at BAM (receipt-storage-preparation and delivery). This model has input parameters such as 1) the number of volunteers working in each process, 2) the time spent in each of the stages, 3) the number of kg of Fead products received, 4) the costs associated with each process. From these parameters, it is possible to compute, in an approximate way, which is the cost associated to the Fead product line. In addition, an analysis of the costs associated with the initial distribution (supplier companies-BAM) and final distribution (BAM-charitable entities) phases is carried out exogenously to the model in order to make a more accurate estimate of the costs of the products studied.

In order to determine which type of value chain is more efficient (centralized versus decentralized model), one of the intermediate objectives of the work is to test the validity of the model developed. To this end, two case studies are proposed:

- The first case study tries to evaluate the sensitivity of the model to variations in parameters such as 1) the number of volunteers in different phases of the logistic process or 2) variations in the chronological profile of the outputs.
- A second case study of the actual BAM operation concerning the management of Fead products during the months of May-June-July 2019. It consists in using as input

data: 1) the quantity in kg of Fead products entering and leaving BAM during the mentioned months 2) the number of volunteers collaborating, in addition to the times used in the different logistic processes. Thus, on the one hand, it will be possible to check the response of the model to a realistic case of operation and, on the other hand, the case study will allow an estimation of the costs associated with each of the internal processes of the BAM: a fundamental variable for possible logistic reformulation processes of the BAM.

The main objective is to compare whether a decentralized model provides additional social benefits compared to the current centralized model. To carry out this analysis, two types of model have been developed. On the one hand, a first simulation model to emulate the receiving-storage-preparation-delivery processes of the BAM value chain and, on the other hand, a financial model that captures the initial and final distribution processes. By combining both types of models, it is possible to obtain a holistic and granular view of the costs associated with the value chain of products from fead. The following conclusions can be drawn from the results obtained:

- The incorporation of just one volunteer (10% increase) in the internal processes of the BAM can lead to a reduction in queuing times of more than 40%.
- Homogenizing the distribution of food distributed daily (distributing the same amount of food every day) could result in a substantial reduction in queuing times in some of the BAM processes (30 hours in total).
- The proposed model estimates total logistics costs of 61218.3€ a value that is close to the results offered by the BAM, thus validating the model. Of the total logistics costs, it is estimated that 35% represent the initial distribution costs, 30% the costs related to the BAM (receiving-storage-preparation and delivery processes) and the remaining 35% to the final distribution.
- The cost comparison between the models proposed concludes that the transition from a centralized model (current model) to a decentralized model would result in potential savings of 30%. This would make it possible to offset the additional costs that the collaborating supermarkets would experience, in addition to promoting the self-management of the products and the dignity of the beneficiaries by not having to go to a charitable entity to receive the food.

In short, this project makes a first estimate of the costs associated with the value chain of Fead products of the current centralized model and proposes the transition to an alternative decentralized model with possible improvements in terms of social benefit.

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Chapter 1. Introduction

The food bank of Madrid (hereinafter referred to as BAM, "Banco de Alimentos de Madrid") is a non-profit charity organization whose goal is to guarantee the human right to adequate food, by aiming, among other duties, at the distribution of food to those who have difficulty to avoid hunger, all over Madrid. Founded in 1994, BAM is a member of the European Federation of Food Banks (FEBA) and since their foundation, they have been fighting to raise awareness within the population and promote a solidary behavior in the face of the problems originated by hunger, unemployment, family abandonment and the lack of resources necessary to ensure human dignity.

In a democratic, humane and socially responsible environment, it is important to pay special attention to those groups that, during the course of the recession, may find themselves in a situation of greater urgency or economic need. These groups will be precisely those who, not having sufficient means to combat the recession on their own, will find themselves in a situation of greater helplessness and exclusion, which could lead to a certain social destabilization affecting the rest of the groups, in the event that the means to cover their basic needs are not deployed.

Motivated by this situation of concern and uncertainty, the aim of this work is, precisely, to try to support the work of those organizations that provide aid to the most disadvantaged groups, with the aim of contributing to meet their most basic and urgent needs. Specifically, this project aims to carry out a study that addresses the problems related to the management of products coming from European Funds for Aid to the Disadvantaged ("Fondo Europeo de Ayuda a Desfavorecidos" - FEAD, from now on), aiming to estimate the costs associated with each of the phases of these products and a comparative study, from an economic point of view, between the current logistical model used for the management of FEAD products and an alternative model.

The food aid program for the underprivileged is a national program that distributes food co-financed 85% by the European Aid Fund for the Most Deprived and 15% by the budget of the General State Administration. The distribution includes the acquisition of food purchased on the market, its supply to the storage and distribution centers of the partner organizations, which distribute it to the Charitable Entities (Source, "Ministry of Agriculture, Fisheries and Food").

The BAM, with the current logistical model, performs the function of a mere distributor. Approximately 6 million kg of food is received every four months of 16 different types of products. The BAM receives these products, stores them in the Corredor del Henares Delegation until an inspector from the ministry checks their condition, and delivers them to the charities, which are then responsible for taking the products to their own organizations.

The alternative proposed model consists in replacing the FEAD product family with coupons with a certain economic value for the beneficiaries themselves to go directly to their nearest supermarket, thus eliminating a high amount of costs associated with the logistical processes of these products. This model will be referred to as the "Decentralized model for BAM" in future occasions.

To perform a social cost analysis of the two proposed models, the project will rely on a simulation model that models the internal processes to which FEAD products are subjected in the BAM (Receipt-Storage-Preparation and Delivery). This model has decision parameters such as 1) the number of volunteers working in each process, 2) the time spent in each of the stages, 3) the number of kg of FEAD products received, 4) the costs associated with each process. From these parameters, it is possible to compute, in an approximate way, which is the cost associated to the FEAD product line. In addition, an analysis of the costs associated with the initial distribution (supplier companies-BAM) and final distribution (BAM-charitable entities) phases is carried out exogenously to the model in order to make a more accurate estimate of the costs of the products studied.

The work presented here is structured as follows: the first chapter focuses on the

introduction of the problem to be addressed, the motivation and objectives of the project, as well as the tools and methodologies employed. In the second chapter, a review of the relevant literature on the subject is presented.

The third chapter describes the details of the proposed model: it explains the assumptions assumed in the modeling, the structure of the simulation model and the explanation of the different blocks that constitute it. The fourth chapter details the collection and adjustment of the input data for the model. The fifth chapter presents the case studies analyzed and explains the results obtained. A study of the costs relative to the alternative model mentioned above and a comparison between the two scenarios is presented in the sixth chapter. Finally, the main conclusions of the work are drawn in the last chapter.

1. Origin and motivation of the project

The idea of carrying out a collaborative project with the Food Bank arises from an effort to give continuity to the project developed by the directors of this senior thesis. In said project, a strategic study is carried out to address the food provisioning problem of the Food Bank of Madrid by means of a mathematical model (NUTROPT), seeking to determine how to maximize the social and nutritional utility of the economic resources available in the organization. However, NUTROPT lacks a detailed characterization of the logistic costs along the value chain that could make this model an important social tool to analyze costs in a holistic and comprehensive manner, as well as a chronological representation that captured time-dependent costs associated to resource management.

Initially, a simulation model was developed using stochastic variables corresponding to the different processes of the BAM in order to carry out a detailed study of the internal processes of the organization's warehouses, and thus provide NUTROPT with an adequate chronology for the benefit of the BAM.

However, during the creation of the model using the Arena software, a series of computational limits appeared that hindered the development of the model. These computational limits are directly related to the student license with which one has to work and restrict the number of entities (study element) that can be generated in the model, as well as the number of blocks available for modeling. Therefore, the idea of continuing with the development of the model created is discarded, leaving it as a proposal for future developments, to give further continuity to the line of research initiated with NUTROPT. At the point of discovery of these computational limitations, a new period of reflection began, pursuing the development of simulation projects that could deliver value, while being constrained by the computational limitations of the student license.

During the months of March, April and May, a very close collaboration with the logistics department of the BAM was initiated in order to know in detail the operation of the same and thus be able to have a real perspective of the existing logistic problems and the development of a project that really brings added value to the organization.

As a result of this process, and under the experience gained in the development of the initial model and the knowledge of the computational constraints, this project arises, which addresses the real need of BAM to carry out a study of the FEAD product line. Specifically, it aims to support, through a model developed in Arena by means of simplifications adopted in order to avoid the computational limitations, the proposal for change made by the European Funds to modify the organization of these products and redefine a new logistic model that implies a greater benefit for the beneficiaries, both for the Entities and for the BAM.

2. Objectives

As stated in the previous section, the main objective of the project is to develop a model that, being able to satisfactorily represent the internal processes of the Food Bank of Madrid, allows to reflect the cost associated with said processes, and thus, together with a cost study of the other phases of the value chain (exogenously to the simulation model), serve as a useful tool to represent the operational costs of supplying FEAD products with the current paradigm.

Said objective pursues a larger one: to understand whether other value chain models, such as the decentralized model mentioned in the Introduction could provide a more cost-efficient solution to the food provisioning problem of BAM. To undertake such analysis, and validate the developed model in the process, two case studies have been analyzed:

- 1) Study of the sensitivity of the model to i) variations in the number of volunteers working in the last phase of preparation and delivery of FEAD products to charities and ii) variations in the chronological profile of food outlets. More specifically, an analysis is made of the queuing times generated by the orders in the afore mentioned process and their variation when faced with i) the modification of the number of volunteers during the periods established for the outputs and ii) a uniform FEAD food output profile, i.e., the same amount of food is delivered every day.
- 2) The study of the actual operation of the Madrid Food Bank of FEAD products during the months of May, June and July 2019, for a posteriori estimation of the costs linked to internal processes.

In the line of developing a work aligned with the Sustainable Development Goals [2], we seek to contribute significantly to Goal 2 "Zero Hunger" and collaterally, also to Goals 1 "End Poverty" and 3 "Health and Well-being".

Finally, this work can also serve as a launching pad for the transmission of knowledge from the Universidad Pontificia de Comillas to the Food Banks of

Spain, which could lead to the creation of associations of ICAI students for active collaboration with food banks. In fact, meetings are currently being held with the general director of the Food Bank of Madrid, Gema Escrivá, in which ways of collaboration between the School and the Organization are being studied.

3. Methodology

With the aim of reaching the objectives mentioned previously, the methodology followed is described below:

STAGE	Sept	Oct	Nov	Dec	Jan	Feb	Sea	Apr	May	Jun
Familiarization with ARENA software										
Understanding of warehouse logistics										
Evaluation of possible solutions										
Creation of the simulation model										
Analysis of the costs related to the different logistic processes										
Validation of the model										
Realization of study cases										
Report writing										
Bibliography review and research										

Table 1. Project methodology

The first stage of the project focused on understanding the problem that is being tackled. For this, work [4] is essential to deep into warehouse logistics and get a clear idea of how a warehouse should be structured in order to orient the project properly.

Additionally, a preliminary research was carried out not only to know the different ways a food bank is organized and analyze facts that could be useful in the project but also to start having some ideas about how this type of queuing problems should be modeled with a simulation software. At the same time, once Arena is decided to be the simulator to be used, a process of familiarizing and understanding the tools and the potential of the software began, based on

reference [10]. With a better understanding of the logistics from a food warehouse and a certain skill using Arena, the second stage was oriented to the creation of the model. Through several references mentioned above, specially work [7], a first idea of the required data, different resources, variables, blocks etc. were drawn. This provided a starting point for the development of the simulation model.

A third stage was channeled to a validation process. With the simulation model created an iterative process began, where the possible incorporation of new variables, necessary simplifications or other considerations were analyzed to make the model as accurate as possible and got to a computational solution which happened to be adjusted to reality.

With the model validated, a study of the processes undergone by the FEAD products external to the Food Bank was initiated in order to conceptualize the costs linked to the decentralized model.

Finally, with the final model created, different scenarios or possible study cases were studied to evaluate the different results obtained with the aim of reaching a representative robust solution for the centralized and decentralized model. .

While the project is developed, a constant research was carried out to gain deep know-how in the studied problem and to update the state of the art. This research was mainly based in the different perspectives of the most renowned authors in the topic.

4. Resources

The bibliographic review is the result of reading and analyzing documentation found on the Internet on the pages of official bodies such as the Ministry of Agriculture, Fisheries and Food, in addition to audit reports and official reports presented by the BAM in 2019 and information provided by the logistics department of the BAM. The web pages, technical articles and other books consulted are shown in the "References" section at the end of the document.

The simulation model was developed in ARENA, using a license provided by Comillas Pontifical University. MATLAB and Excel are used to develop additional charts and statistical analyses.

For the writing and presentation of the project, the Microsoft Office pack provided by the university is used.

Chapter 2. State of the Art

This state of the art includes different references that shed light on how a food bank should be organized, what features should a food warehouse simulation model include, and a general overview of the logistics behind a warehouse with the aim to create not only a working logistic model but an implementable one, to handle the operations at BAM.

1. Criteria for logistic processes in food warehousing

Firstly, a cross-cutting research is carried out to understand the general logistic processes that are relevant to understand food warehousing. The purpose of this first review is to develop an intuition of the must-have criteria that have to be taken into account to handle large quantities in an organized and hygienic manner.

Work [1] gives an improvement proposal of storage and dispatch processes to make "Fundación Banco Arquidiocesano de Alimentos" more effective from a logistic standpoint. Unlike BAM, "Fundación Banco Arquidiocesano de Alimentos" already knows what kind of food is going to come in the food trucks and need to be added to their warehouses so it divides the products and carries out different processes depending on whether the type of food received is: "fruver" (vegetables and fruit), "abarrotes" (canned food), "panadería" (bakery), "lácteos" (dairy products) and "artículos de feria" (fair items). Each food group has a different type of reception, selection (in which good food condition is evaluated), and storage. Knowing what kind of food is received and having a first classification by suppliers before arrival allows a better and faster organization within the receivers' warehouses. However, the large heterogeneity and number of resources BAM receives from donations makes this first classification hard to be done.

Work [2] designs strategies to improve warehousing at "Banco de Alimentos de Ciudad León". The reception phase consists in a previous communication from the companies to the food bank a week in advance before the food delivery, to report what kind of food will be arriving, enabling the preparation of the warehouse. Supplies are delivered through direct delivery to the food bank from the suppliers or by collecting all the food in the company itself through a driver. Following, once the food is unloaded, volunteers use a labelling system on the pallets with different colors with the purpose of identifying them. Then, the head of logistics determines where to put the classified food in the warehouse until the delivery of supplies to beneficiaries.

On work [3], there is an analysis of "Fundación Casa Hogar de Jesús" food warehouse. It studies what characteristics of space, distribution, and dimension a food warehouse should have, the criterion to be followed to determine if some kind of food should be accepted or not (such as broken packaging in preprocessed foods or lack of labeling in canned food) and finally, the process that the food should follow in the reception phase. The first step is to verify the unitary and total costs and payment fulfillment of the ordered food. Secondly, the manager must establish product standards, inspections of the reception area and verify that the procedure for the reception, storage and dispatch are correctly stated for the incoming food. Thirdly, the receptionist will ensure the quantity and quality of the food matches the expected and checks if it follows fixed specifications (packaging, organoleptic characteristics...). And finally, supplies will be carried to "Fundación Casa Hogar de Jesús" warehouse until delivery.

The last three works mentioned above are going to be used not only as references to get to know other food banks, the organization, and administration of a food bank and analyze possible advantages and disadvantages between "Banco de Alimentos de Ciudad de León", "Fundación Banco Arquidiocesano de Alimentos", "Fundación Casa Hogar de Jesús" and BAM, but also as projects to be based on if there is unknown data that needs to be modeled.

Reference [4] is a book based on the logistics behind a warehouse. Initially, it carries out an introduction where it details the role of warehousing within logistics. It continues with an analysis about the variety of terms, typology and constructive parameters from a warehouse.

This book (reference [4]) proposes a division of the activity in a warehouse in three main phases: reception, storage and dispatch. Inside reception stage, the next steps are followed: unloading the supplies from the transport vehicles and verification and count of the products. This process of verification can be done in a batched fashion (i.e., the check of the supplies is based on cargo units or sealed packages without verifying the units in each of the assortments) or in a more detailed manner consisting of an exhaustive physical count of every package.

At the same time, reception stage happens to be "blind reception", when the receptionist is deprived of the information from the arrival foods, or "conventional reception", when the person in charge of receiving the supplies knows all the information about the goods such as type or quantity of food in every package. In addition to that, the book defines the steps to follow in a "conventional reception" and quality controls to be done in order to minimize times and optimize warehouse management.

Additionally, the work presents a deep analysis of storage procedures and relevant regulation. Regarding the storage procedure, it establishes FIFO (First-In, First-Out) as the main rule to follow in food flows, that is, when the newest incorporated supply is added to the stock, the previous supplies need to be relocated to make sure they are the next ones to be delivered. About storage regulation, it defines several rules according to the type of food that is going to be stored, differentiating: cereals, condiments, and fatty products. Furthermore, this reference provides numerous facts concerning the ideal temperature of a refrigerator used to store dairy products, ideal humidity of each part of the warehouse depending on the food and the numbers of days that each type of supply (dairy, fish, meats...) stands in good conditions.

Ultimately, due to the variety and detail of the references and numerous facts that are discussed in the book, work [4] establishes a starting point to the project that is proposed to be developed here. From this book, numerous facts and relevant references can be pulled out in order to make a more accurate and advantageous project for BAM.

2. Modeling and simulation of food warehousing

Having developed a general understanding of the processes involved in food storage through the last paragraphs, the following paragraphs will present a review of specific modeling and simulation approaches that have been conducted, targeting food warehousing in solidary contexts.

"Simulation of a Food Warehouse for a Hunger Outreach Program" (work [5]) simulates the operations at the Community Hunger Outreach Warehouse (CHOW) (that is distributing foods and supplies to different churches which will use this food to cook for the homeless and for local families in social risk) for evaluation and improvement. The main objective of this work is to improve CHOW's operations by reducing the wait time of the soup kitchen vehicles and CHOW employees without incurring additional cost or incorporating other employees. CHOW's Distribution Center (abbreviated as CHOW DC from here onwards) not only works on collecting and delivering donated food items for those in need but also, it provides supplies for soup kitchen with aim of preparing that food to the most vulnerable people. In order to determine which of the two activities can be optimized, based on previous studies and information collected from employees, two alternative scenario-based case studies were suggested; scenario 1, where it is proposed to "increase the service capacity by sharing the two dedicated garages" (used to load and unload the food) and scenario 2, which targets to reduce "the variation in arrival rate of the trucks by assigning time slots for pick up".

After a review of the two activities CHOW executed (collecting and delivering

donated food and providing supplies for soup kitchen), "servicing of the soup kitchen vehicles" is selected as the process to optimize since it had a considerable margin of improvement. To do so, three output measures are used to compare the activity and the results between the initial model (which captures the original operation) and the alternative model (which would correspond to the proposed operation): 1) average waiting time of soup vehicles, 2) number of soup vehicles with a queuing time greater than 20 minutes, and 3) average waiting time of the CHOW trucks. The simulation model is created through Rockwell Arena software with three types of entities: soup vehicles (trucks that pick-up food for the soup kitchens), CHOW truck 1 (CHOW vehicles operated by full-time employees) and CHOW truck 2 (CHOW vehicles operated by volunteers). The logistics of the soup vehicles can be understood as a queuing problem (1. vehicles arrive-2. they are serviced-3. they leave the system), however, CHOW trucks logistics are considerably more difficult to model as they leave the CHOW DC to many different destinations (11 static routes) to load the trucks with the supplies and finally carry them to the food bank so that soup tracks can begin their labor.

With a simulation model supported in queuing problems, [5] studies a two-sample t-test using historical data from CHOW DC and simulation results in order to verify or check the reliability of the proposed model. More specifically, the work evaluates the impact of scenario 1 introducing two queues for the "two dedicated garages" and simulates an increase of the service capacity and analyzes the results. Thereupon, scenario 1 is removed (eliminating the two queues mentioned above) from the model and scenario 2 ("reduce the variation in arrival rate of the trucks by assigning time slots for pick up") is implemented. Finally, the synergies between scenarios are considered by studying a model that implements both scenarios simultaneously providing a discussion of the results and a conclusion is suggested. Note that even though the research is based on delivery processes, the work proposes a simulation model and a discussion from its results that could be helpful for a rear analysis of Madrid's food bank.

Work [6] gives a proposal of improvement for the preparation of food orders in Bogota's food bank through techniques of reference location and route-design in order to reduce food-pathlengths. The methodology followed begins with a preliminary analysis of the supplies location and the design of the routes done by the food bank to establish possible parameters of improvement in the warehouse. Then, a second stage targets the identification of a regulatory framework that could strengthen the food banks' operation. Among the candidates to this sort of frameworks, the strongest one relies on the implementation of location methods by ABC, i.e., dividing the products in three big categories being A the category with most relevant products, B less importance products and C with the least important products. COI (Cube-per-order-index) being an assignment warehouse policy frequently used to allocate the inventory. Inventory rotations, which allows to know the delay time and how efficient the distribution of the warehouse is. Saving methods, to minimize the total distance done by the people in charge of placing supplies or TSP method (Travelling Salesman Problem) that can be defined as a problem that looks for the shortest route for a seller that has to cross different cities visiting every city just once and arriving at the place where it started.

To continue, a third stage in which first route system design is proposed, following the regulatory framework mentioned above in order to minimize distances and optimize warehouse's organization. Finally, a last stage of evaluation of the design through mathematical technics (instead of using a simulation model) considering the mentioned problem as an optimization problem with an objective function and certain constraints.

Work [7] research is focused on the warehousing process at a large food distribution center that comprises goods reaching by trucks, unloading of the supplies and location the contents to different aisles. The methodology in the project is based on "lean" philosophy (a way of working which emphasizes the removal of waste within a process, conceptualized as loss of value). Firstly, it creates a Value Stream Map (VSM) that helps identifying all the areas that have null-value activities. Then, to gain more insight in these activities a detailed

process mapping is developed which included processes such as scheduling of the trucks, paper work or the payment process, using these details as information to be added in the simulation model. Additionally, it develops a simulation model using ARENA to analyze the existing warehouse inbound receiving operations. It also defines what information should be obtained through probability distributions (such as the delay experienced by trucks throughout the different times during the day) and required data like the delay observed in intermediate stages, duration for unloading the goods or pallet capacities for different products that will be taken into account when modeling Madrid's food bank. Finally, once the model is created, their results are analyzed to determine which is the most optimal location of the docks based on the distance travelled (baseline scenario) using a wide range of criteria (such as "Dock Allocation based on Aisle", "Dock Allocation based on Distance Travelled" or "Dock allocation based on Schedule).

Work [8] ("A Simulation environment for the redesign of food supply chain networks: modeling quality-controlled logistics") and work [9] not only provide methods and techniques to build a proper simulation model but also requirements for a FSCN ("Food Supply Chain Networks") to be modeled correctly.

After a brief introduction of FSCN in work [8], the rest of the paper is organized with a first section of discussion of essential FSCN characteristics and a second section with a current simulation tools deep review starting from a survey of model capabilities essential for successful simulation.

On the other hand, work [9] begins with an introduction in which it reflects on the relevance of "Logistics Informatic Systems" (LIS) and determines the importance of knowing the characterization of food marketers and process analysis. In terms of "Methods and techniques" it establishes several stages in which the procedure of modeling should be based on a first phase of research that has as the main purpose to identify and characterize their logistical processes: followed by the creation of the model itself, definition of the inputs,

analysis of internal activities and output definitions, a final stage of "control" should be conducted, with the aim of considering other possible activities that are needed to make the model more accurate and dismiss other activities irrelevant for the model.

Having done a somewhat extensive research on the different stages a food bank should have, logistics behind a food warehouse, advices and requirements for a proper simulation model and the analysis of different simulation modeling papers, a last research about modeling systems is carried through.

In this regard, work [10] gives a comparison of structured modeling and simulation modeling of queueing systems. It provides the description of 13 structured modeling systems such as AnyLogic, Arena, GPSS W or Plant Simulation which allows to create structured and simulated model without programming and solves a queueing system to add the results obtained in each and every modeling system and, subsequently, compare them. This last reference will be used to drive the decision of what kind of system can come closer to Madrid's food bank simulation.

3. Tableau basic summary

The following table classifies the different stages mentioned in the food banks studied:

	Reception		Administration		Classification		Storage	
	Direct reception	Previous collection of food ¹	Registration of the food received	Registration of the pallets	Before the reception ²	After the reception	Based on a labelling system	Based on the classification in reception
[1]- "Fundación Banco Arquidiocesano de Alimentos".								
[2]- "Banco de alimentos de ciudad de León".								
[3]- "Fundación casa hogar de Jesús".								
BAM								

Table 2. Comparison of the logistical organization of the Food Banks referenced.

¹ Process where the food bank itself goes to a food distributor to collect the food.

² The supplies the food bank is receiving are already classified.

The following table shows a brief summary of references [5], [6] and [7]:

	Flowchart of the different processes		Simplifications made for the modeling	Statistics analysis of the simulation results	Stages simulated	Software used
	YES	NO				
[5]- "Simulation of a Food Warehouse for a Hunger Outreach Program".			Studies only one of the three possible routes the supplies have	Boxplot analysis	Reception-delivery	ARENA
[6]- "Proposal for the improvement of the order enlistment system at the Bogota food bank."			*ABC-COI- IR-TSP ³	ANOVA	-	Mathematical formulation
[7]- "A simulation-based approach for dock allocation in a food distribution center".			Lean philosophy	Hypothesis Contrast	Reception- Classification-Storage process	ARENA

Table 3. Summary of references [5], [6] and [7].

³ Initials of several simplification models frequently used in logistics (described above, State of Art pp.8)

Chapter 3. Modeling the logistics of Fead products

1. Problem statement

The simulation model proposed in the proposed project represents the different processes to which FEAD products are subject within the BAM (BAM) with the aim of estimating the costs associated to the BAM's value chain, with a focus on the storage and management of food in the organization. Thus, the simulation model developed does not intend to address the initial distribution phase (logistics from suppliers to the BAM) or the final distribution phase (from the BAM to the Charities), although the costs associated to these stages will be characterized exogenously to the model, in section 2 of Chapter 5 of this work.

The approach or conceptual framework of the model is simple and the steps followed in its development are shown below:

1. Analysis of the FEAD product line, i.e., study of the food logistic route separation of the modeling processes into the following phases: Receiving-Storage-Preparation and Delivery.
2. Conceptual characterization of the processes within the value chain described in aforementioned point (1) and sizing of the number of workers and volunteers involved in each of the phases.
3. Characterization of the costs (accounting and non-accounting⁴) associated with the development of these processes.
4. Reconceptualization at the computational level of the processes of point (2) and subsequent mapping to logical processes of the Arena software, capturing the food storage and management costs established in point (3).

⁴ Non-accounting costs are those that do not appear in BAM's audit reports, such as the cost of a volunteer's working hours.

Apart from the simulation model itself, this project aims to characterize the total cost of the BAM operation, i.e. including the costs associated with the initial and final distributions, although this will be done exogenously (outside of the simulation model). The objective of this analysis is to compare the efficiency of the current configuration of the BAM with respect to FEAD products, in which a large number of products of different characteristics are received, stored and distributed on a quarterly basis, against a scenario in which the distribution of FEAD products is decentralized through the incorporation of cards with a certain economic value, redeemable in supermarkets, for the neediest families. This efficiency is measured in economic terms, so that the lowest cost solution will be the most efficient. In both cases, it will be considered that the same social value is being provided.

The resulting model can be explained visually by the following conceptual scheme:

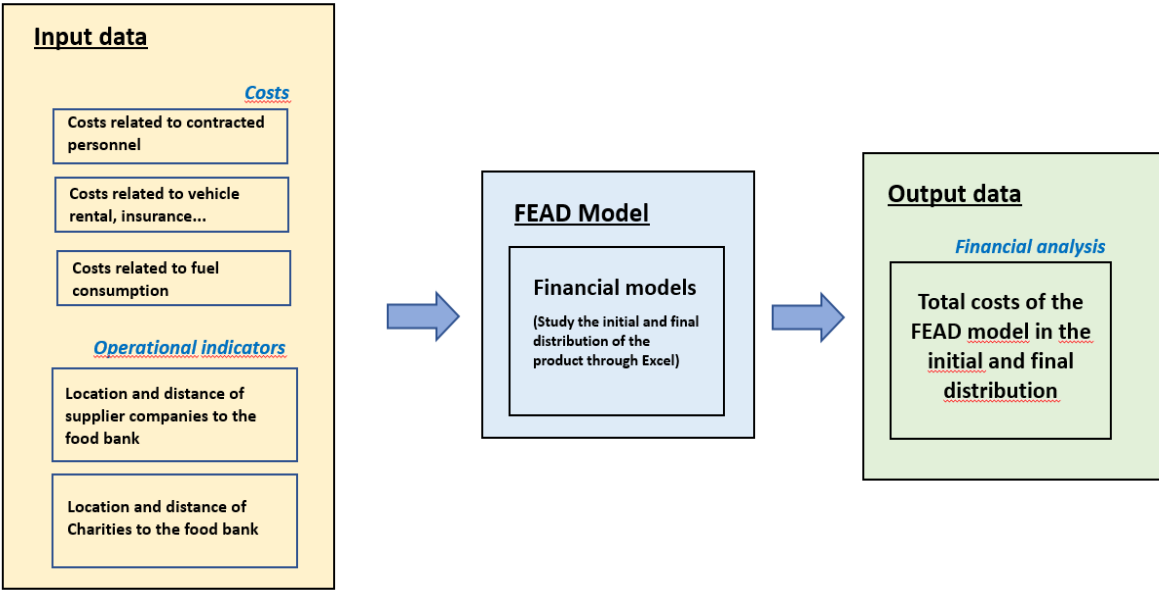


Figure 1. Conceptual scheme "Financial models"

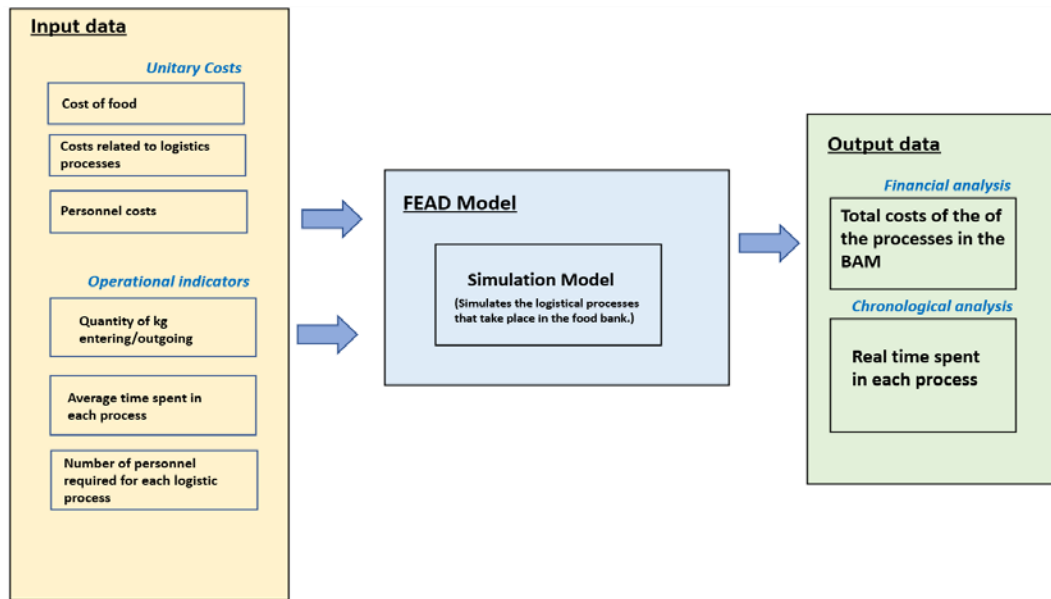


Figure 2. Conceptual scheme "Simulation Model"

Figure 1A represents the conceptual scheme of the simulation model created. By means of the input parameters defined in the schematic relating to unit costs and operation indicators such as the amount of incoming and outgoing kg of food, the average time spent in each process or the number of volunteers, the simulation offers total values of costs in the processes that make up the model as well as queuing times for each product, etc.

On the other hand, Illustration 1B represents the conceptual scheme of the purely financial model designed to calculate the total initial and final distribution costs of FEAD products. Although they are two different models, the results of both models together provide an estimate of the total costs (distribution and processes at the BAM) related to FEAD foods.

Finally, a classification of the input parameters of the simulation model according to whether they are public data or whether they are private information obtained from the Bank's logistics department is added in the following table:

Input data	Public information data	Information data provided by the Logistics Department
Cost of food		
Cost related to logistic processes		
Personnel cost		
Quantity of entering/outgoing kg		
Average time spent on each process		
Number of personnel required for each logistic process		

Table 4. Classification of the information used

2. Modeling assumptions

This section describes the hypotheses that have been assumed in the modeling. Different types of hypotheses are formulated with the aim, on the one hand, of reducing the complexity of the problem under study (simplifying hypotheses) and, on the other hand, of overcoming computational barriers (computational hypotheses). In addition, a series of modeling hypotheses are added for the estimation of the costs associated with the FEAD product line. Each of these assumptions is presented below:

Simplifying modeling assumptions:

- 2.1) FEAD products are considered to arrive continuously for 11 days without taking into account the difference between working and non-working days.
- 2.2) All product types are considered to be received every day (when actually it can be the case that the delivery of certain products is concentrated only in some days).
- 2.3) It is considered that as the truck/trailer arrives with the FEAD products, the unloading process begins without taking into account possible delays due to vehicle maneuvers.
- 2.4) It is considered that for each of the internal processes of the BdA (Reception-Storage-Preparation and Distribution) the number of volunteers remains constant, although the number of volunteers to undertake different processes may vary in a realistic work situation.
- 2.5) The time interval from the time the product is unloaded until it is taken into the warehouse to start its placement is not considered.
- 2.6) The model considers that the time taken by the inspector to check all the products delivered by the supplier companies is exactly equal to 15 days. In addition, if during the inspection phase there are products to be discarded, the model disregards possible wastage.

- 2.7) Machinery for transporting, unloading and placing pallets is considered to be a resource available at any time.
- 2.8) The simulated queuing time in the FEAD product delivery processes belonging to period 1 has been modeled according to a normal distribution that varies according to the TNOW variable whose mean captures the delivery times of all the days of period 1 and whose times have been estimated from the kg of product output/day. However, in the unloading processes of period 2, being a period with less food movement and less variability, the queuing times have been modeled by means of a normal whose parameters do not vary on a daily basis.

Computational modeling hypotheses:

- 2.9) The model simulates 6 product families that encapsulate the 16 existing product types collected according to BAM accounting by computational limits. These product families or clusters are constructed on the basis of the nutritional similarities between foods.
- 2.10) Both in the unloading process of FEAD products and in the placement process, the queuing time generated in the model has been approximated to a Normal distribution whose mean varies according to the variable TNOW (time since the simulation has started) and have been estimated from the time data provided by the BdA and the amount of kg of such products input/day.
- 2.11) For computational limits, the number of orders arriving at the BAM for each food group is considered to be the same during the 11 days of FEAD product intake.
- 2.12) Due to computational limits, FEAD products are considered to leave the BAM, on average, every 1.75 days instead of reproducing a daily

output.

- 2.13) In the storage and delivery phase of the products, the "Legumes" and "Olive Oil" groups have only one output period due to computational limits, and these groups have been chosen according to the variability of the kg of output of these two types of food.

Financial modeling assumptions:

In the initial distribution phase (supplier companies-Food Bank):

- 2.14) All suppliers are considered to have conventional trailers with a load capacity ranging from 24,000 to 27,000 kg.
- 2.15) In the cost analysis it is established that the trucks go to and return from the supplier only once, i.e. in no case will a truck make the journey more than once a day. Thus, in the event that the number of kg transported exceeds the average load established in the previous hypothesis, it will be assumed that the company has more than one transport vehicle to supply a specific order.
- 2.16) Likewise, to calculate the fuel cost for the supplying companies, both the way to the organization (Company-Food Bank) and the way back will be taken into account, assuming that the supplying company delivers only to the BdA on the day in question.
- 2.17) For the calculation of costs in the initial distribution phase, it is considered that the vehicles used are diesel vehicles (as this is the most used type of vehicle) with a fuel price of €1.32/l.
- 2.18) The fuel tanks of the distribution vehicles are considered to be the same for all distribution companies and with a capacity of 500L. In addition, according to the average consumption of a truck with the aforementioned characteristics, it is assumed that the average consumption of the vehicles is 20L/100km.

2.19) Finally, as far as the cost calculations associated with the initial distribution are concerned, in the event that there are different locations of the company in charge of supplying the food, the calculations are made with the location closest to the delegation in the Corredor del Henares.

In the intermediate stages of management by the Food Bank:

2.20) Volunteer work has an assigned social cost (a non-accounting cost) that is considered in the study of economic efficiency as shown in chapter 4 and whose calculation is based on the average wage of an operator multiplied by a coefficient of 0,5.

2.21) Electricity supply costs will be left out of the analysis as they are considered a fixed cost that does not vary with the management of FEAD products.

2.22) To estimate the cost of the machinery used in the intermediate phases, it is considered that the electric pallet has an average cost of 600€ and the forklift of 24.250€, both with a line depreciation rate of 12%.

In the final distribution phases (Food Bank - Charitable Entities):

According to the information provided by the Food Bank, for the calculation of costs associated with the distribution of the Charitable Entities, two types of clearly distinguishable assumptions have been made; firstly, assumptions considered for the calculation of costs associated with fuel and, secondly, assumptions made for an estimate of costs of other characteristics such as vehicle rental, amortization, taxes, etc.

The following assumptions were made to estimate fuel costs:

2.23) The trips are considered to be made with a standard diesel cargo van, with a fuel consumption of 12L/100km and a fuel price settled on hypothesis 2.17.

Due to the high number of Charities that receive FEAD products (214), for the

calculation of fuel expenses, the Community of Madrid has been divided into 9 zones [14]. Each Charity has been assigned the zone to which it belongs according to the map shown below:

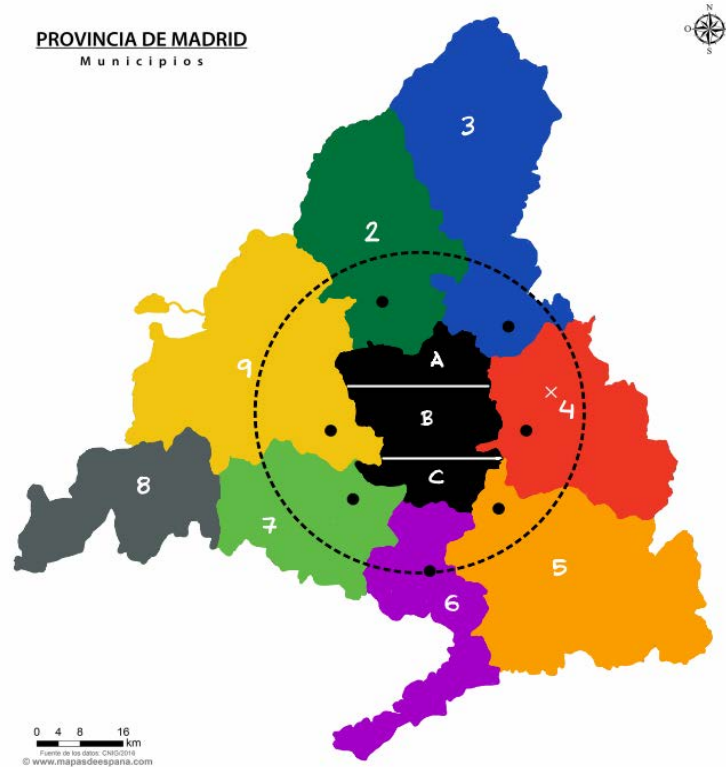


Figure 3. Map of the community of madrid with the classification of the zones.

For the calculation of fuel costs for the Charitable Entities in zones 2 to 9, the following assumptions have been made:

- 2.24) In cases where the different charities are located in the same area and within a radius of less than 10 km, a center of mass of the distribution is considered, obtained from the vector average taking the BAM as the origin.
- 2.25) In the event that there are Charities outside the 10km radius, a dispersion coefficient will be associated to these organizations in order to estimate the distribution costs.

Due to the high number of Charitable Entities concentrated in the central area of Madrid (around 70%), it was decided to divide zone 1 into three subzones

A, B and C for a more accurate calculation. The map used together with the estimated centers of mass for each zone is shown below:

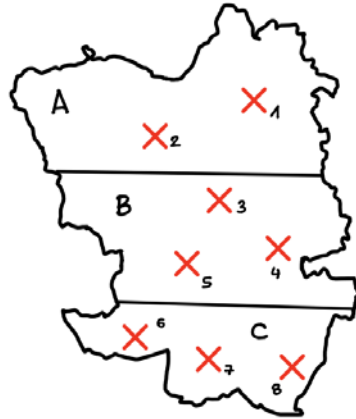


Figure 4. Map of Madrid city with the classification of zones

For the calculation of fuel costs for the Charitable Entities in zones A, B and C, the following assumptions have been made:

- 2.26) Based on the analysis of the location of the Charitable Entities and their accumulation by the Community of Madrid, it is estimated that for zone A there are two centers of mass for the calculation of distribution, 3 points for zone B and three points for zone C.
- 2.27) For a more accurate calculation of costs associated with fuel consumption, scenario 10 is applied in these three zones.

Finally, as regards the assumptions for estimating final distribution costs, the assumptions made are listed below:

- 2.28) The vehicles used by the Charities for the distribution of the products are considered to have the following characteristics: diesel type fuel, consumption of 12L/100km and a fuel price established in hypothesis 2.17.
- 2.29) For further analysis, the time taken by the Charities to distribute the food is considered to be the time taken by the organizations to reach the mass centers calculated from the BdA of Alcalá de Henares.

- 2.30) It is estimated that 70% of the Charities (150 EBs) need to rent a vehicle to transport products from the organization (BdA) to the corresponding EB at a daily cost of 20€.
- 2.31) It is considered that if the number of charities to be supplied is between 15-30, it is necessary to rent two transport vehicles and more than 30, three vehicles.
- 2.32) The remaining 30% of EBs are considered to have appropriate vehicles for transporting the goods and have vehicle-related costs of 1.5€/day for depreciation and 4.5€/day for insurance payments.
- 2.33) Finally, the possible taxes linked to the prices considered have not been taken into account. Since it is a question of representing the social costs linked to a product line of the BdA, taxes have been subtracted since it is assumed that the payment of taxes is directly transferred to a social benefit and therefore does not generate a net social cost.

The following sections of this chapter will present the structure of the model, which is a discrete event simulation model that aims to approximately represent the FEAD product line in the BAM. For this purpose, first, the structure used will be presented.

3. Model structure and analysis of simulation blocks

This section contains the structure of the model used for the simulation of the FEAD product processes and, secondly, a conceptual explanation of each of the blocks together with their computational detail is added in the form of a table.

The model is divided into three main groups:

- 1) First group. Simulates the entry of FEAD products into the Food Bank.
- 2) Second group. It separates the products into six food groups and models the requirement established by the State that the condition of the food must be assessed by an inspector prior to delivery.
- 3) Third group. Models the storage of the product after the inspector's review, as well as the preparation of the orders and subsequent delivery to the Charities.

First group of blocks:

ENTRY OF FEAD_PRODUCTS

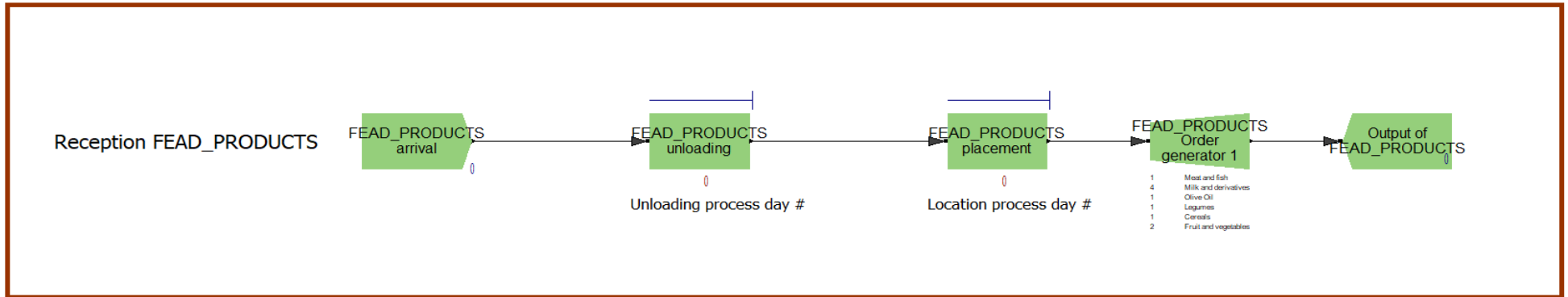


Figure 5. First group of blocks of the simulation model

Phase to which it belongs in the model	Block representation	Conceptual explanation of the block	Computational detail
First group. Receipt of FEAD products		This module represents the daily arrival of FEAD products.	Create an entity of type "FEAD_PRODUCTS" each of the first 11 days of the simulated time to represent the food input.
		This module corresponds to the unloading process of trailers with FEAD products.	It is configured to use the "Volunteer" resource according to a "Seize-Delay-Release" and to generate a "deley" in the model according to a Normal distribution whose parameters vary according to the TNOW dummy variable (hypothesis X).


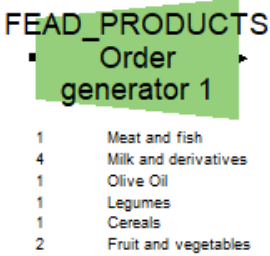
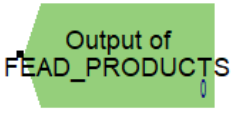
First group. Receipt of FEAD products		This block corresponds to the process of placing FEAD products in the warehouse.	It is configured to use the "Volunteer" resource according to a "Seize-delay-release" and to generate a "delay" in the model according to a Normal distribution whose parameters vary according to the TNOW simulation variable.
		This module generates the number of orders received daily for each product family.	Cloning makes it possible to send the entity that is entering the block to different points of the model through a "Label" module. The block added in the table generates a number X of FEAD_PRODUCTS entities to the 6 types of labels defined according to the food groups. The number of clonings has been calculated in such a way that, by receiving one entity per day during the first 11 days of simulation according to "Create 1", an adequate number of clonings is generated to simulate the number of orders entering the Food Bank from each food group.
		This block represents the exit point of the FEAD product model.	The entity's statistics are programmed to be recorded before it is removed from the model (all "dispose" blocks have the same function).

Table 5. Conceptual explanation and computational details of the First Group.

Second group of blocks:

GROUPING BY TYPE OF PRODUCT

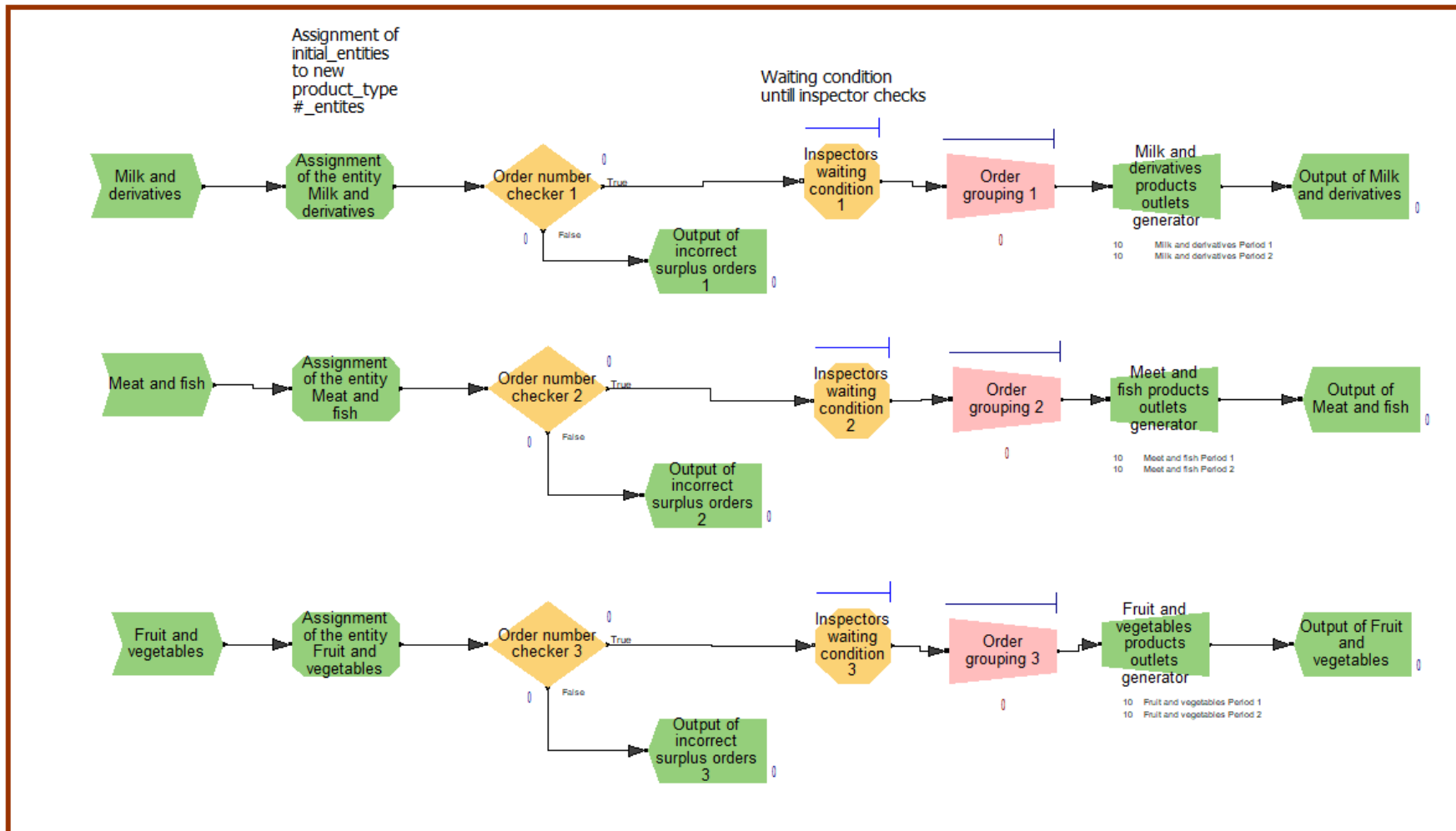


Figure 6. Second Group of blocks of the simulation model.

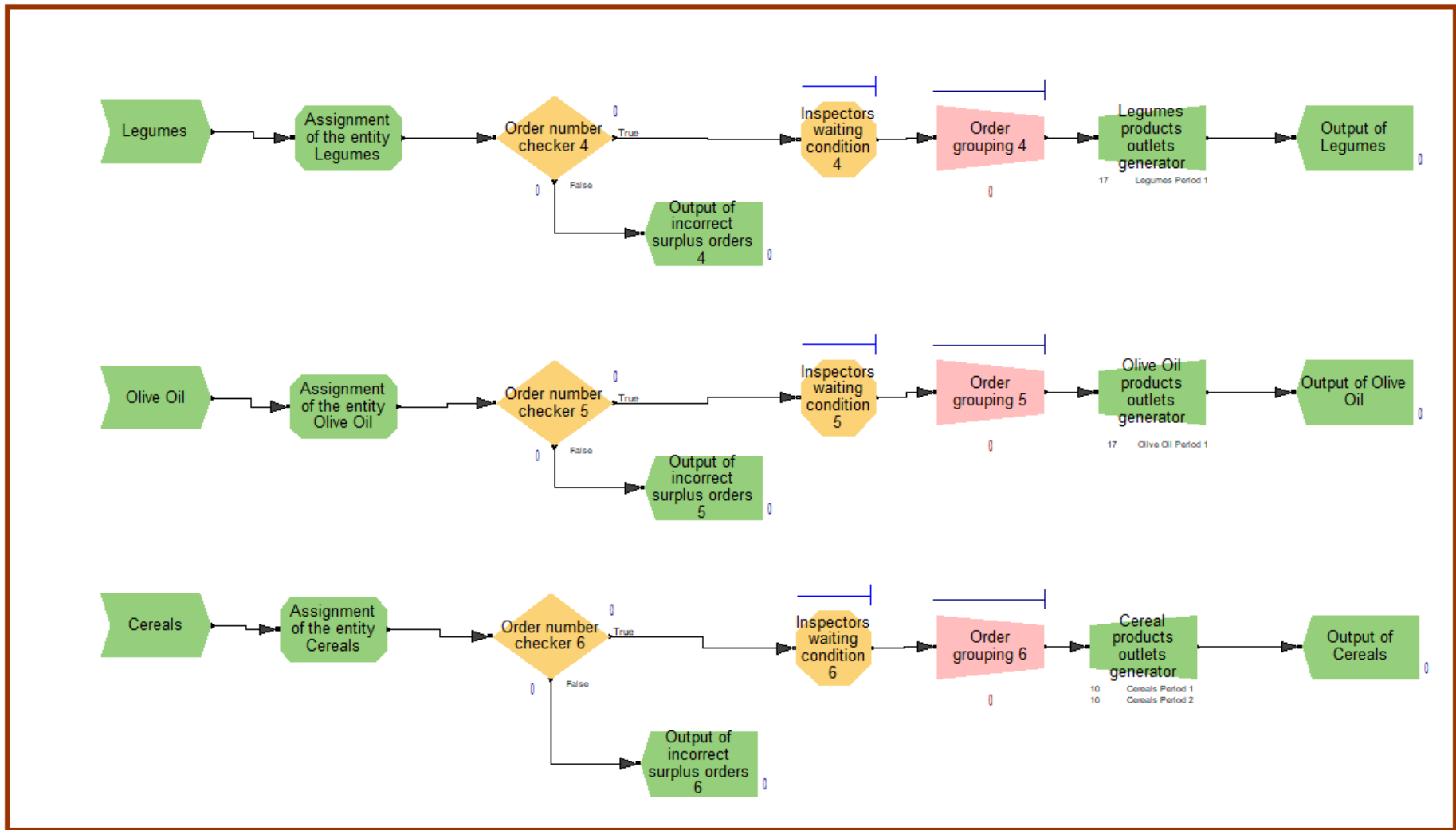


Figure 7. Second Group of blocks of the simulation model.

HOLD CONDITION CONTROLLER

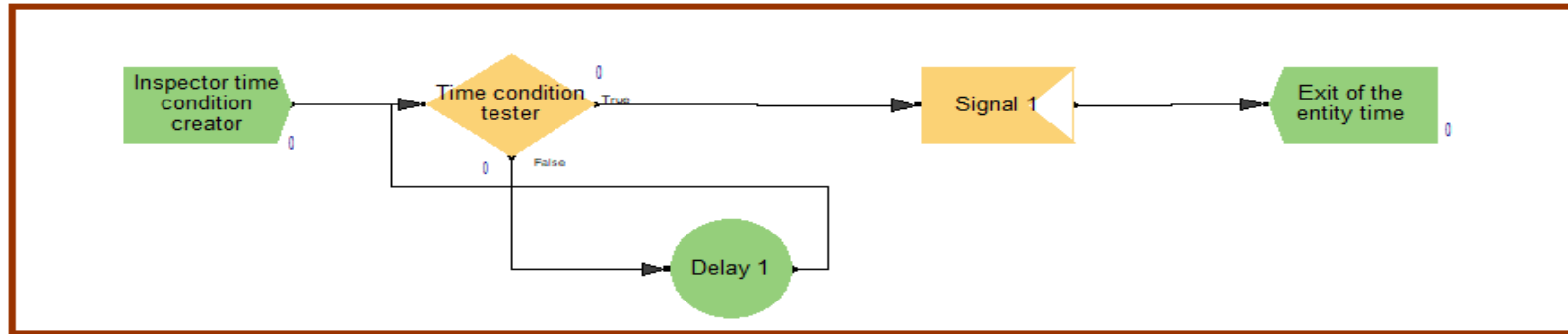
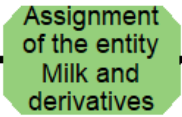
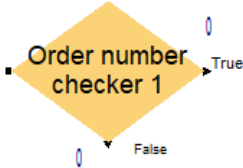
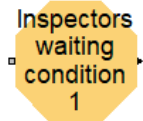
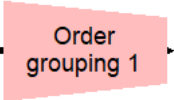
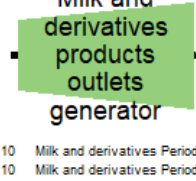
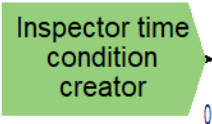
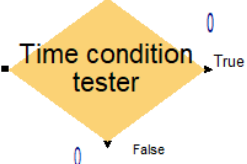



Figure 8. Second Group of blocks of the simulation model.

Phase to which it belongs in the model	Block representation	Conceptual explanation of the block	Computational detail
Second Group. Food grouping		Represents the arrival of orders related to the "Milk and derivatives" group at the warehouse.	This type of module is used to receive the entities generated in a cloning block at an earlier stage of the model. In this case, the "Milk and derivatives" tag allows to receive the entities of FEAD_PRODUCTS that are cloned and has as destination the name of this module (this module has the same function for each of the different food groups).
			This module is used to assign new values to variables, attributes, entity types etc. In the model, the presence of an "Assign" block after a "Label" model implies an entity transformation, from the initial entity arriving at the label generated in the cloning to a new

			<p>entity named after the name of the "Label" block. More specifically, in the module added in the explanation, the block has been configured so that the "Milk and derivatives" entities arriving at the label explained above become a new entity "Milk and derivatives Period 1" (this applies to all other food groups).</p>
<p>Second Group. Food grouping</p>		<p>The block ensures that the right number of orders are coming in for each product family.</p>	<p>This module allows processes to make decisions in the system. There are two exit points in the block and it is configured so that the entities that enter this module advance in the model if a condition related to the number of entities arriving from each type of product is met, in this case, to ensure the number of products they receive from each product family.</p>
		<p>This module represents the inspection of FEAD products prior to distribution.</p>	<p>This module allows entities to be kept on standby until a certain condition is met. In this model, the block has been programmed to keep the entities associated to the different food groups on standby to simulate the days in which the inspection of the products is performed and as a consequence they remain stopped in the system, until it receives a signal of value 1 from the "Signal 1" module, which will be when the inspection of the food has been completed and the products can continue to move through the system.</p>
			<p>This module allows a grouping of a certain number of entities into a single entity with the same characteristics. This block allows in the model to group all the orders of the different FEAD</p>

Second Group. Food grouping			products in a single entity that facilitates later the manipulation of entities in the processes that follow.
		Represents the quantity of kg leaving the warehouse after the inspector's review.	This cloning module generates X number of FEAD_PRODUCTS entities to the 2 types of labels defined according to the output periods of the products. The number of clonings has been calculated in such a way as to have the greatest variability in the analysis of product outputs without exceeding the limit of entities set by the software.
			This module represents the arrival of "Entity time" entities in the simulation model. It creates such an entity on the first day of simulation in order to, together with the "Decide 4", "Delay 1" and "Signal 1" blocks, introduce the condition of food inspection by the State.
		Check that the products have been checked by the inspector.	This module allows processes to make decisions in the system. There are two exit points in the block and it is configured so that entities entering this module advance in the model if a condition related to the TNOW variable is met to simulate food inspection.
			This module generates a delay in the model and has been programmed so that each time an entity enters the block there is a "delay" of one day. Thus, the entities that exit through the "False" branch of the "Decide" module explained above enter this block and the simulation time advances until the


Second Group. Food grouping			condition programmed in the decision module is fulfilled.
		This module represents confirmation by the inspector that all foods have been checked.	The function of this module is to send a signal to the "Hold 1" module with a value of 1 when an entity is entered in the block, i.e. when the condition programmed in the "Decide 4" block preceding it is met.

Table 6. Conceptual explanation and computational details of the Second Group.

Third group of blocks:

STORAGE AND DELIVERY OF THE FEAD_PRODUCTS

Period 1= 17 days

Period 2= 16 days

Milk and derivatives

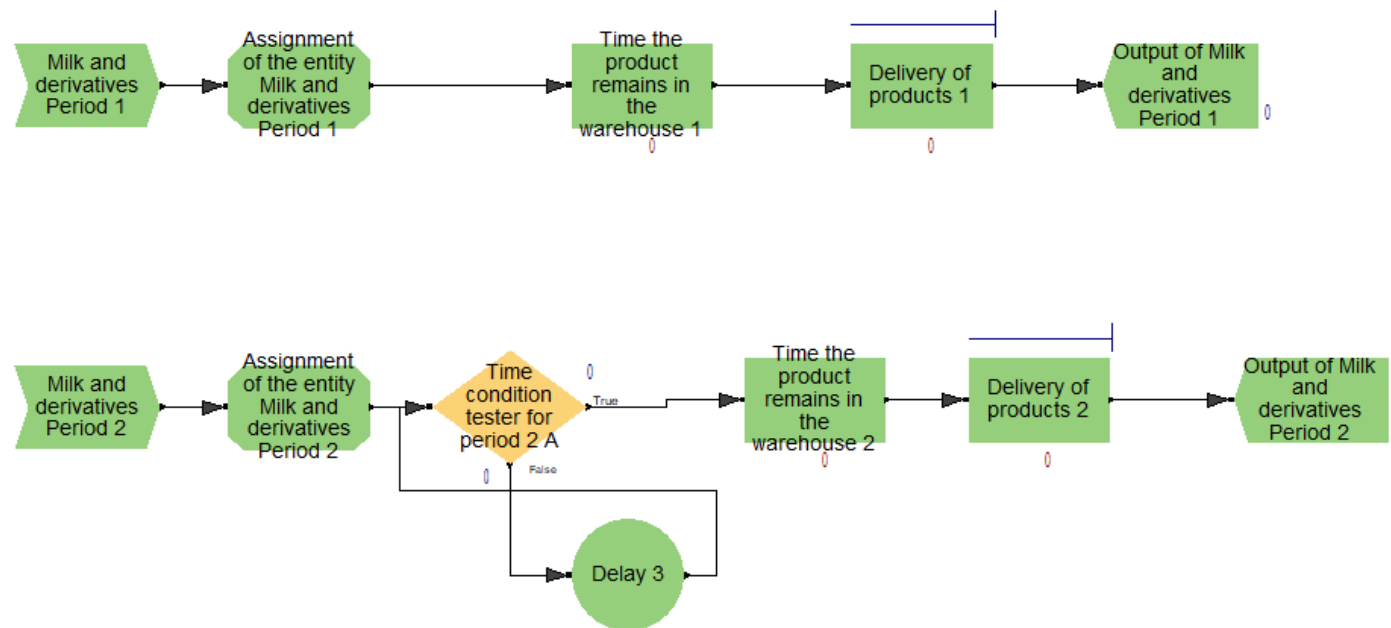


Figure 9. Third group of blocks of the simulation model.

Cereals

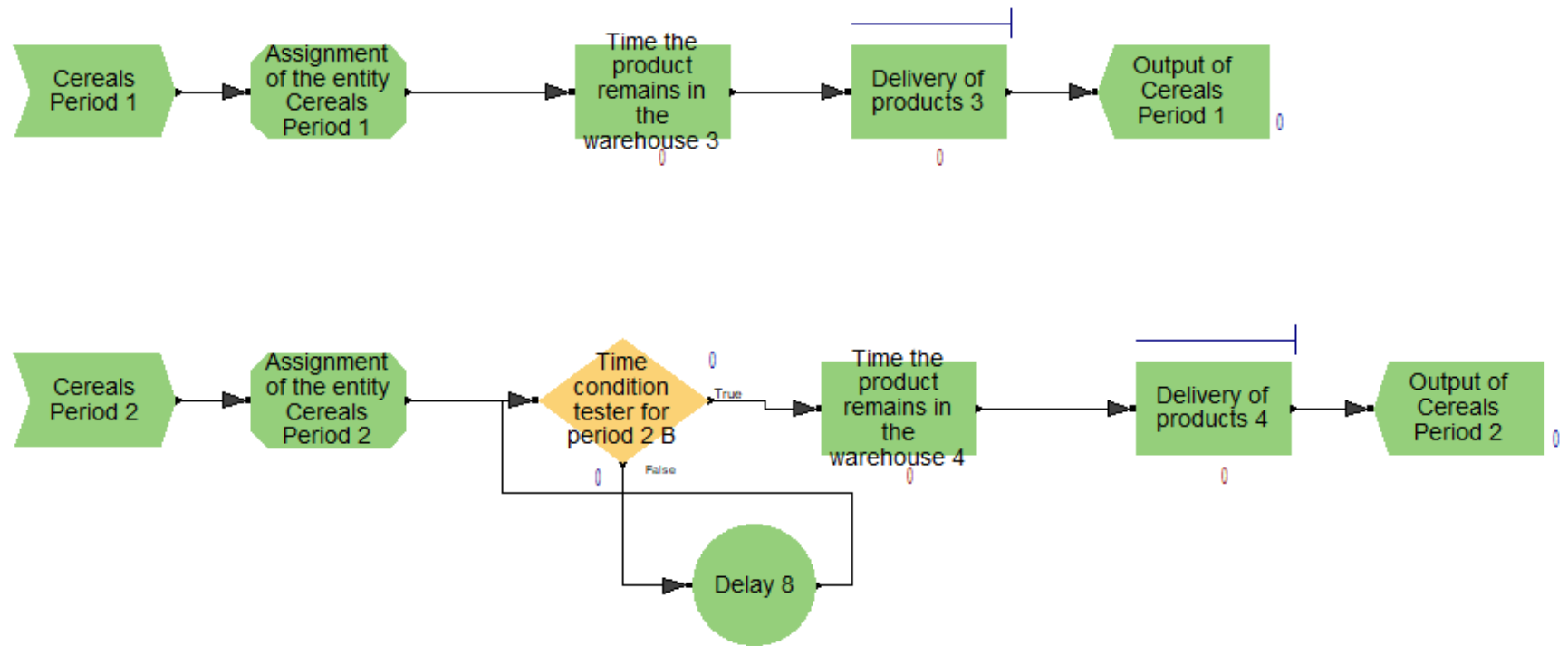
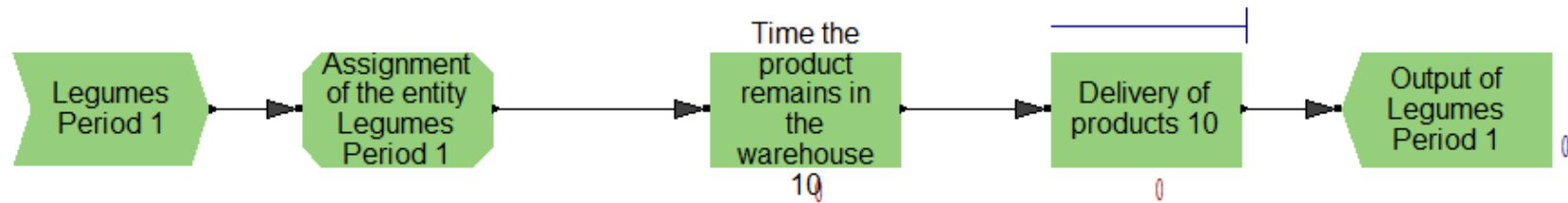


Figure 10. Third group of blocks of the simulation model.

Legumes



Olive Oil

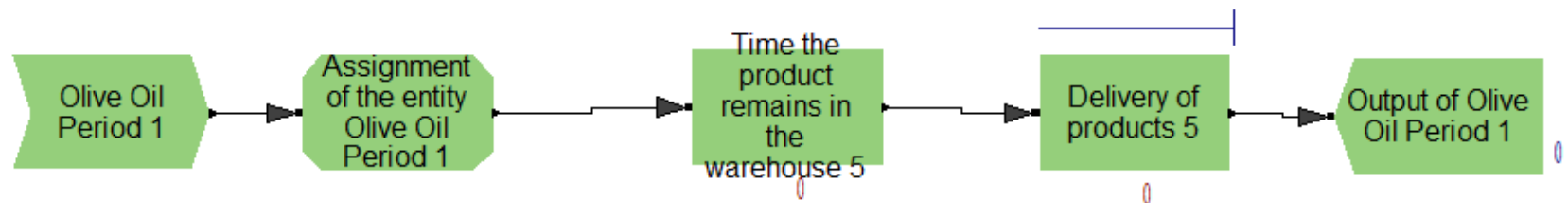


Figure 11. Third Group of blocks of the simulation model.

Fruit and vegetables

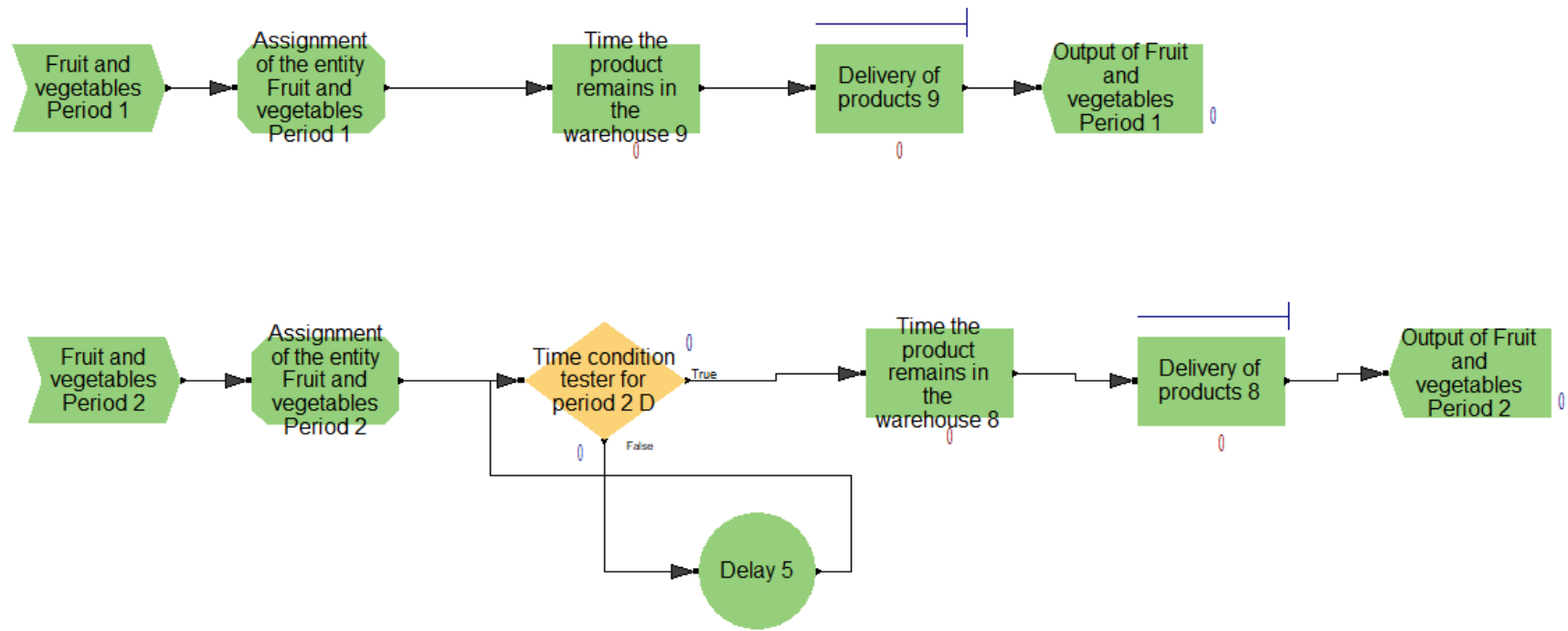


Figure 12. Third Group of blocks of the simulation model.

Meat and fish

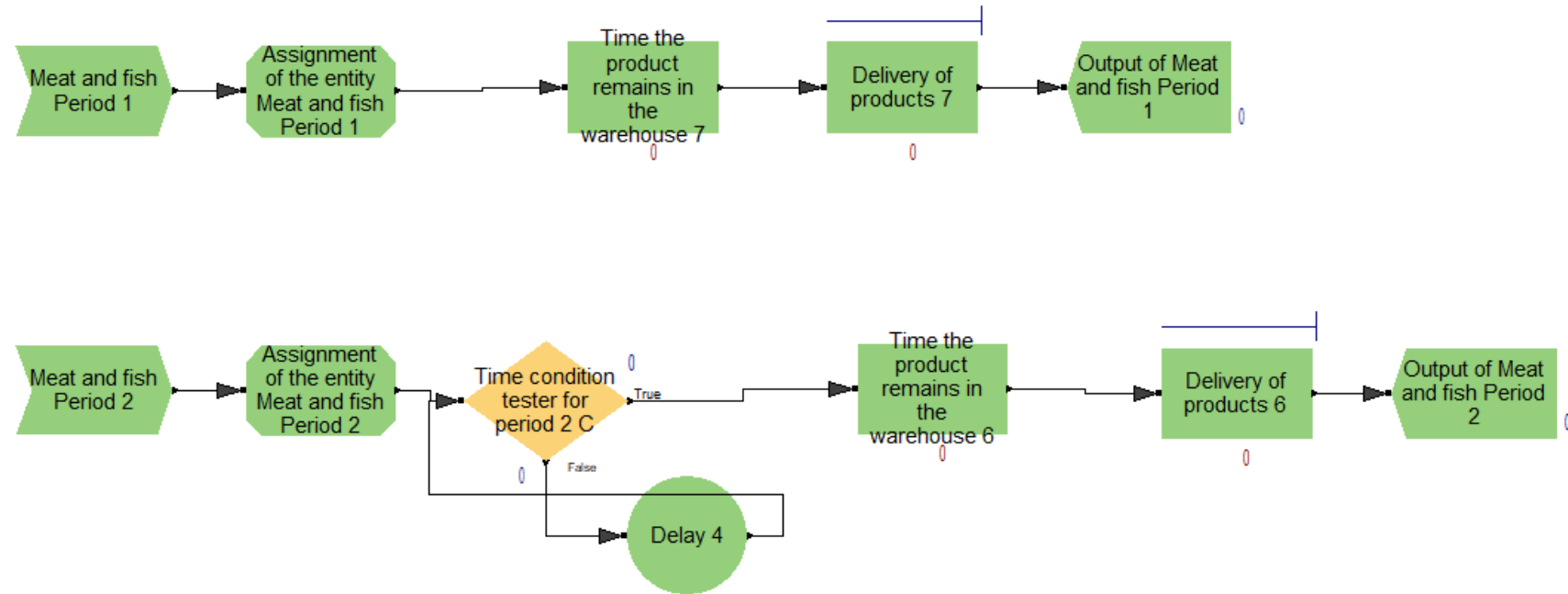
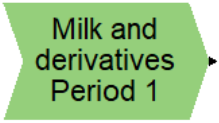
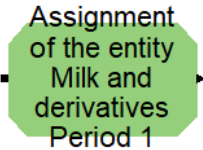
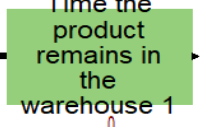


Figure 13. Third Group of blocks of the simulation model.

Phase to which it belongs in the model	Block representation	Conceptual explanation of the block	Computational detail
Third Group. Storage, preparation and distribution of FEAD products.		Represents the arrival of FEAD products leaving the warehouse in Period 1 (first 17 days).	In this model, this type of module is used to receive the entities that are generated in a cloning block in a previous phase of the model. In this case, the "Milk and derivatives Period 1" tag allows to receive the "Milk and derivatives" entities that are cloned and has as destination the name of this module (this module has the same function for each of the different food groups).
			This module is used to assign new values to variables, attributes, entity types etc. In the model, the presence of an "Assign" block after a "Label" model implies an entity transformation, from the initial entity arriving at the label generated in the cloning to a new entity named after the name of the "Label" block. More specifically, in the module added in the explanation, the block has been configured so that the "Milk and derivatives" entities arriving at the label explained above become a new entity "Milk and derivatives Period 1" (this applies to all other food groups).
		Represents the time that each product family remains in the warehouse after inspection.	It is configured to generate a "delay" in the model according to the period to which it belongs (period 1=17 days, period 2=16 days or single period=33 days) and the number of entities to be received in the simulation.

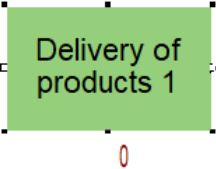
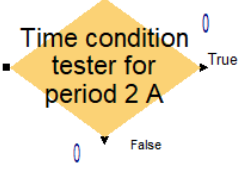

Third Group. Storage, preparation and distribution of FEAD products.		Represents the process of placing the products in the vehicles of the Charitable Entities.	It is configured to use the "Volunteer" resource according to a "Seize-delay-release" and to generate a "delay" in the model according to a Normal distribution whose parameters vary according to the TNOW simulation variable.
		Ensures that the products start to be shipped in the right period	It allows processes to make decisions in the system. There are two exit points in the block and it is configured so that the entities entering this module advance in the model if a condition related to the TNOW variable is met to simulate the second exit period of the FEAD products.
			Identical operation to "Delay 1" explained above.

Table 3. Conceptual explanation and computational details of the Third Group.

Chapter 4. Model input data

This chapter describes in detail the sources and processing of the model input data used to generate the different scenarios evaluated in the model and to obtain the information needed to carry out the study.

Before proceeding, it should be noted that much of the input data to the model is based on information provided by the BAM management team, which is not of a public nature. Such information may be made available to the reader upon request, and after approval by the BAM management team composed of (Javier Garzón and Cristina Puente). In what follows in this document, for those cases in which the source of information is the aforementioned team, it will be cited as:

"[14] Information provided by BAM – Input and Output files, April 2021".

For the preparation of the inputs to the simulation model, we used the food input and output files for the year 2019, as well as an additional file with information on the number of volunteers and operators, and times related to the different processes of the model provided by the BAM logistics department [14]. Likewise, [21] was used to perform the grouping of the 16 FEAD products into 6 nutritional clusters, which shape the simulation model, as discussed in the previous chapter.

On the other hand, in order to carry out the financial analysis proposed in the project, official and audited reports of the BAM in the fiscal year 2019 were used. In addition, to perform an analysis of the distribution costs in the initial and final stages of the products, we have used the food input and output files previously mentioned, [A], from which we have obtained useful locations to perform the analysis. Finally, the table of linear depreciation coefficients of the Tax Agency has been taken into account to estimate some costs associated with certain processes of the FEAD product line SOURCE.

The data will be presented in the order in which they have been mentioned in the previous paragraphs, that is, firstly, the nutritional contribution and the biological function of the different FEAD products studied to support hypothesis 2 (see 1) and to start the modeling and the relevant analyses according to the 6 established meal groups. Secondly, the input data to the model related to the product input and output files together with the survey of times and volunteers present in the management of FEAD products. Thirdly, all the information used to carry out an economic analysis of the case study is presented later in the report (see Chapter 5-6).

1. Nutritional contribution and biological function of Fead products in the body

As mentioned above, FEAD products are a type of product that belongs to a program co-financed between the European Union and the State in which they establish a certain number of different products with the macronutritional characteristics that they consider most convenient to provide and feed a high number of beneficiaries each year. In 2019, 16 different types of products were established, namely *olive oil, white rice, chocolate milkshakes, canned tuna, meats and sardines, fruit in syrup (cocktail) and fruit in syrup (pear), cookies, cooked chickpeas, whole milk, canned vegetable salad, spaghetti-type pasta, children's fruit and chicken jars and canned tomato.*

However, the computational limitations of the program and the established model design were not compatible (related to the limit of entities imposed by the ARENA software university license). Therefore, it is necessary to apply hypothesis 2 stated above ("6 families of product groups are simulated in the model instead of the 16 existing product types due to computational limits. "). The grouping of the 16 FEAD products into 6 major food groups is done on the basis of the information detailed below:

Product group	Group characteristics	FEAD products assigned
Group 1. Milk and dairy products	Plastic function. They participate in the formation and maintenance of the different structures of the organism. They are protein foods.	Chocolate milkshakes, whole milk.
Group 2. Meat and fish	Plastic function. They are foods that incorporate proteins of high biological power, iron and vitamin B.	Canned tuna, canned meat, canned sardines, baby chicken jars.
Group 3. Legumes	Plastic and energetic function. Energetic since they provide energy thanks to their carbohydrate content. In addition, they provide proteins of vegetable origin with high fiber content.	Cooked chickpea
Group 4. Fruits, vegetables and greens	Regulatory function. They provide large amounts of vitamins, minerals and trace elements, fiber, in addition to a high percentage of water and few calories from its low proportion of carbohydrates, proteins and fats.	Fruit in syrup (pear), fruit in syrup (cocktail), children's fruit jars, vegetable salad, canned tomatoes

Group 5. Cereals and derivatives	Energetic function. They provide calories from their carbohydrates and have a high contribution of B vitamins.	White rice, crackers, spaghetti type pasta
Group 6. Fats, oil and butter	Energetic function. This group is rich in fat-soluble vitamins.	Olive oil

Table 4. Classification of FEAD products

2. Analysis of incoming and outgoing Fead product files of the food bank

As already mentioned, the food input and output files provide the basic and fundamental information for the elaboration of the chronology in the simulation model. Below are the graphs extracted from the files used for the analysis of the BAM's management of FEAD products [14].

To facilitate the reader's understanding of this chapter, the time horizon of the case study is redefined below. The entry of FEAD products begins on May 20, 2019. From this date, the entry of FEAD products of different characteristics (fruit, preserves...) will take place during 11 working days. After the entry of the last FEAD product, a storage process begins in which all the goods must remain for 15-20 days due to the inspections imposed by the state. And finally, after the supervision of an inspector of the products, a period of departures begins, which lasts from the first product to the last one, 33 days.

In addition, due to the organization of the BAM with the charities, the outflows of foodstuffs are higher during the first 17 days of outflows (period 1) and considerably lower during the remaining 16 days (period 2). For this reason, comments, analyses and references to these two outflow periods are constantly made in the report.

Analysis performed on the input data:

Days of entry	Kg input Group 1	Kg input Group 2	Kg input Group 3	Kg input Group 4	Kg input Group 5	Kg input Group 6
20/05/2019	201060	7983		5776		
21/05/2019	44640	16128	9059	26195	33264	
22/05/2019	156420	16128	14677	21047	9444	
23/05/2019	66960		10645	63917		
24/05/2019	44640	12053		36993	13448	63420

27/05/2019	74292	18628	9159	68766	16992	49500
28/05/2019	133218	2037		39615	84960	
29/05/2019	21000			36016	32712	
30/05/2019	66000	16128	30966	37548		
31/05/2019	10920					
03/06/2019		27132				

Table 5. Analysis of the Kg of input for each group.

Number of orders received from Group 1*	Number of orders received from Group 2	Number of orders received from Group 3	Number of orders received from Group 4	Number of orders received from Group 5	Number of orders received from Group 6
38	7	6	20	11	5

Table 6. Number of orders received

Each order represents the average number of kg entering the Food Bank from that group. An illustrative calculation is added below:

$$\frac{\text{Kg total input of group 1}}{\text{Number of incoming orders during the 11 days}} = \frac{819150}{38} = 21556,57 \text{ kg}$$

The following pie chart represents the percentage of each of the 6 groups with respect to the total number of kg entering the 11-day period:

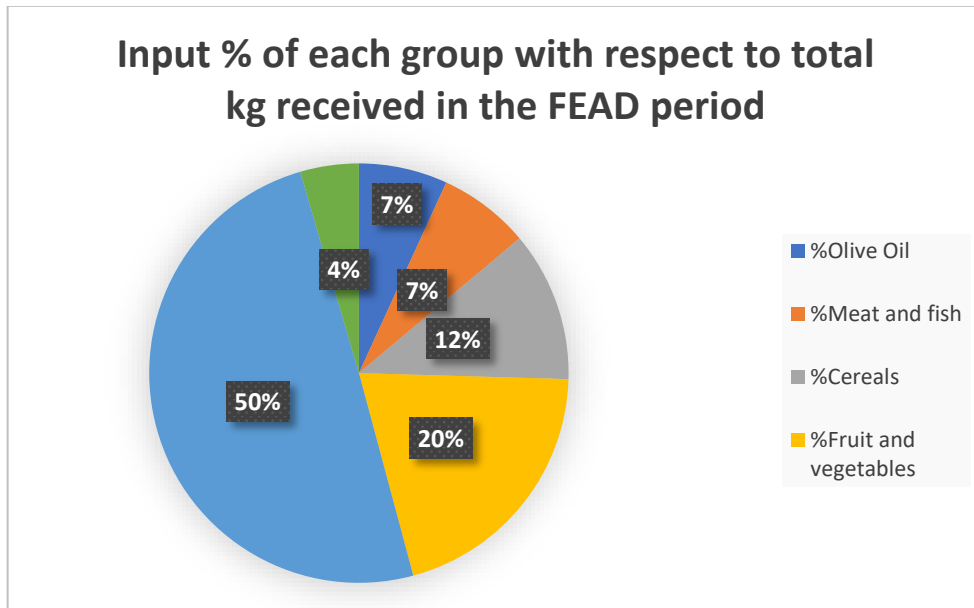


Figure 14. Input % of Kg received.

From now on, the graphs in this section correspond to the graphs extracted from the output files of the products in question.

Next, graphs are added regarding the proportions between the FEAD products within each group (as group 3 and group 6 are made up of a single product, the product itself represents 100% of the total and these graphs are not added) in the period of outputs, in order to know the quantity of kg that are processed or leave the system of each product from the study of the defined groups.

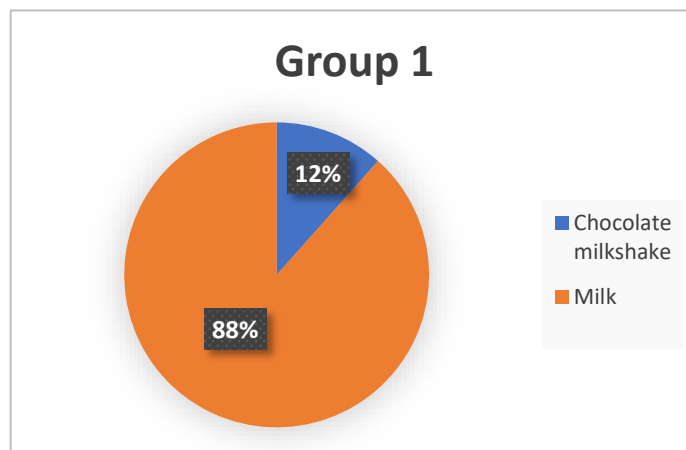


Figure 15. Proportion of products within Group 1.

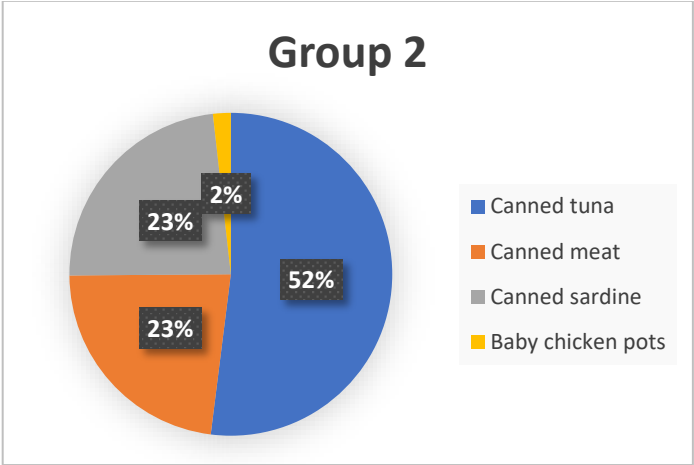


Figure 16. Proportion of products within Group 2.

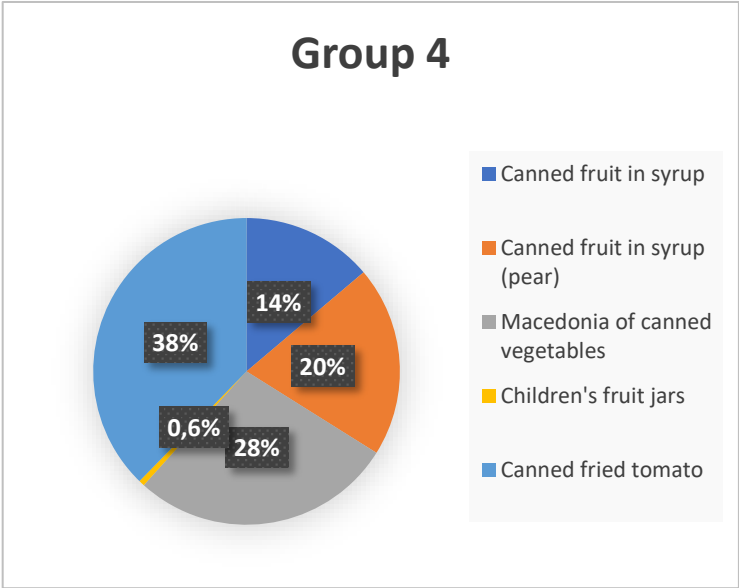


Figure 17. Proportion of products within Group 4.

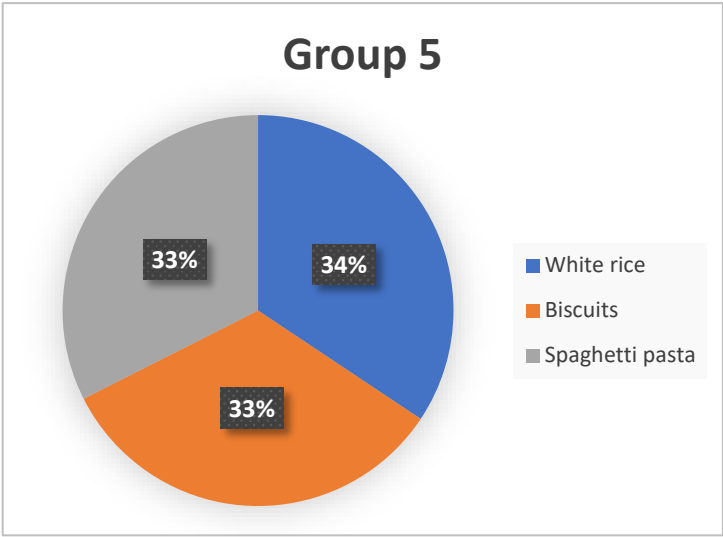


Figure 18. Proportion of products within Group 5.

In order to simulate as accurately as possible the process of storage and dispatch of FEAD products to the Charitable Entities, a brief study is carried out in which the number of kg of each group of products dispatched is related to the day on which this dispatch takes place.

The purpose of this analysis is, based on the graphs, to study the variability of times associated with the storage and dispatch processes according to the corresponding day of dispatch and the quantity of kg dispatched in order to map this information on the computational modeling blocks. In addition, two time periods of 17 and 16 days, respectively, have been considered.

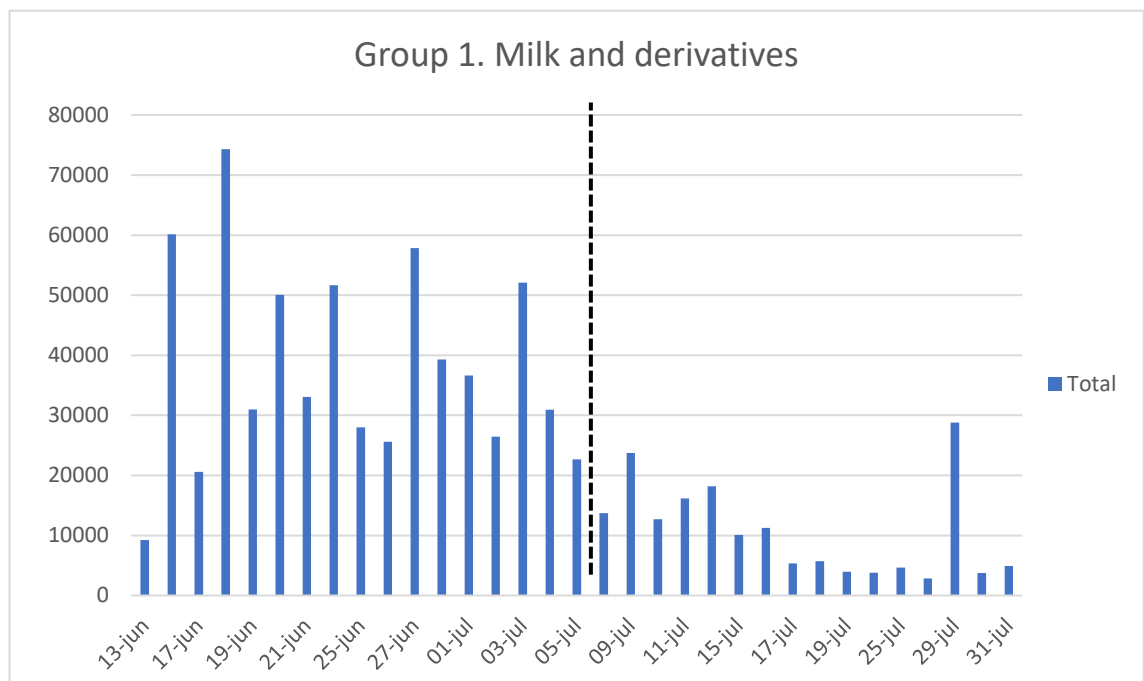


Figure 19. Outputs of Group 1 food products

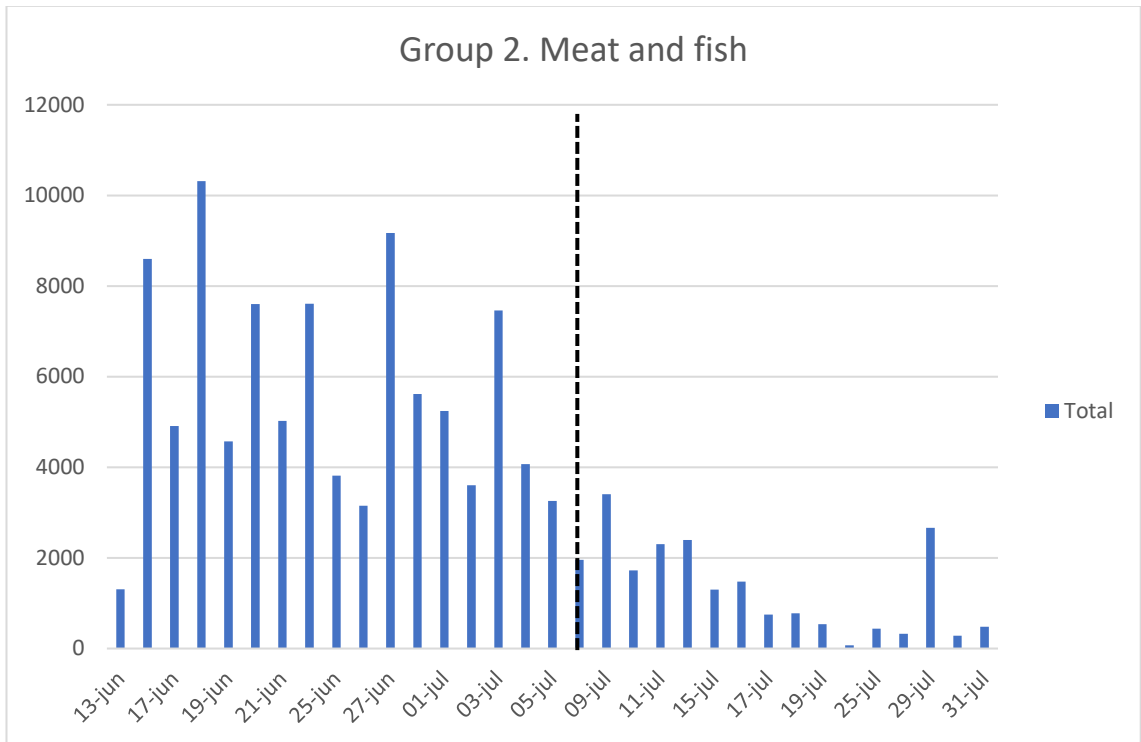


Figure 20. Outputs of Group 2 food products

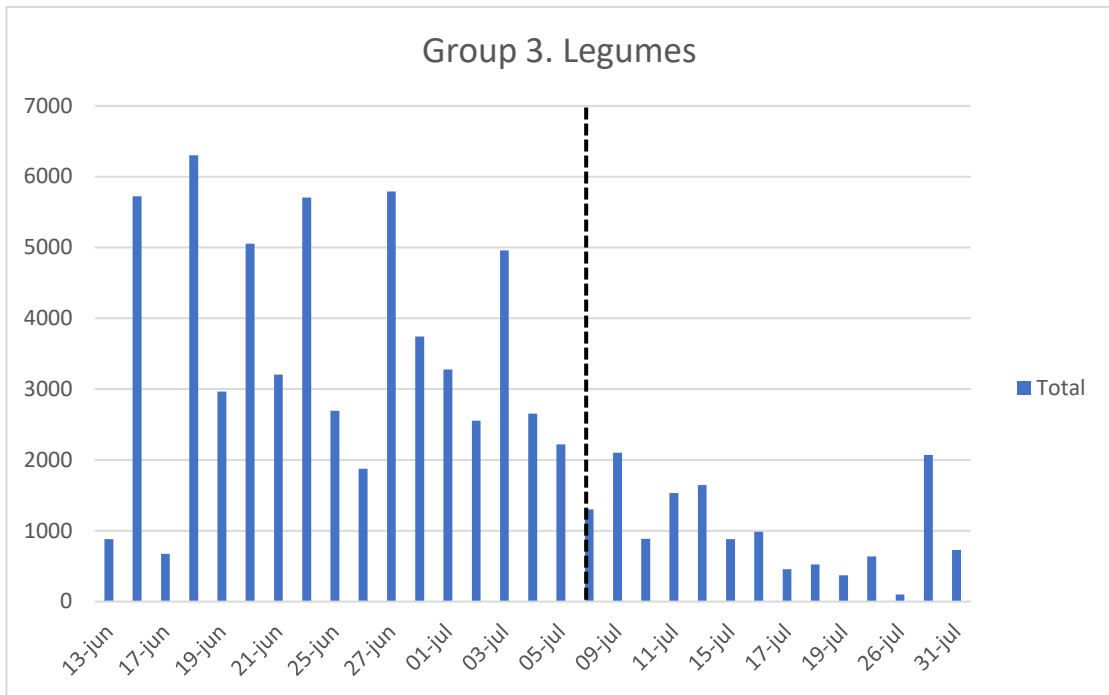


Figure 21. Outputs of Group 3 food products

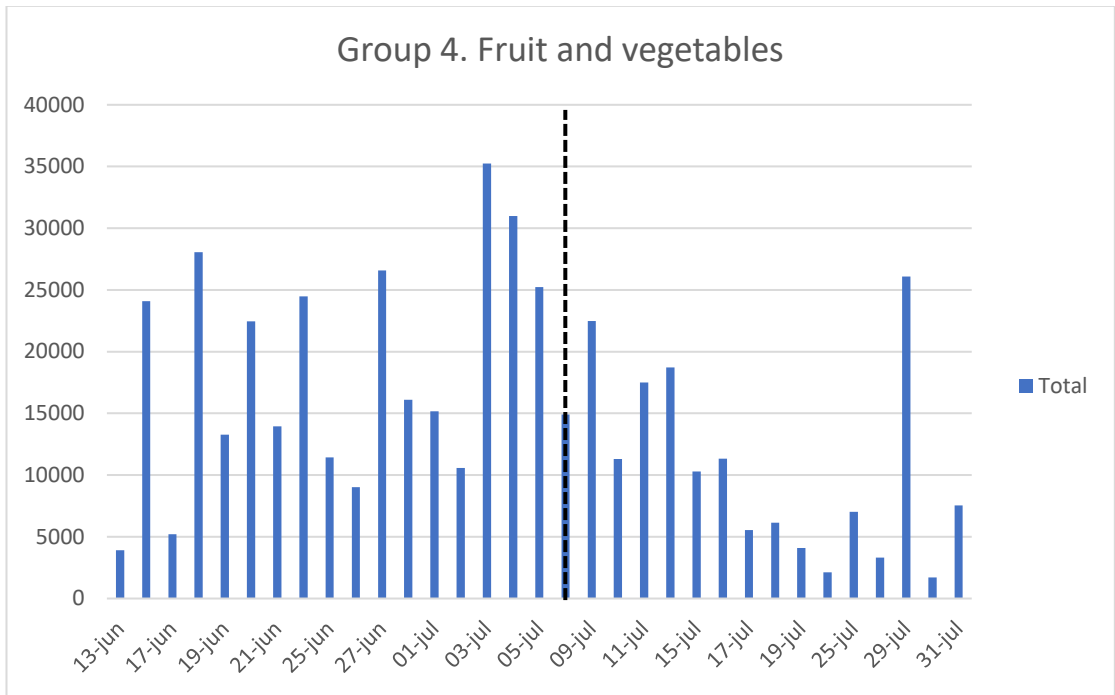


Figure 22. Outputs of Group 4 food products

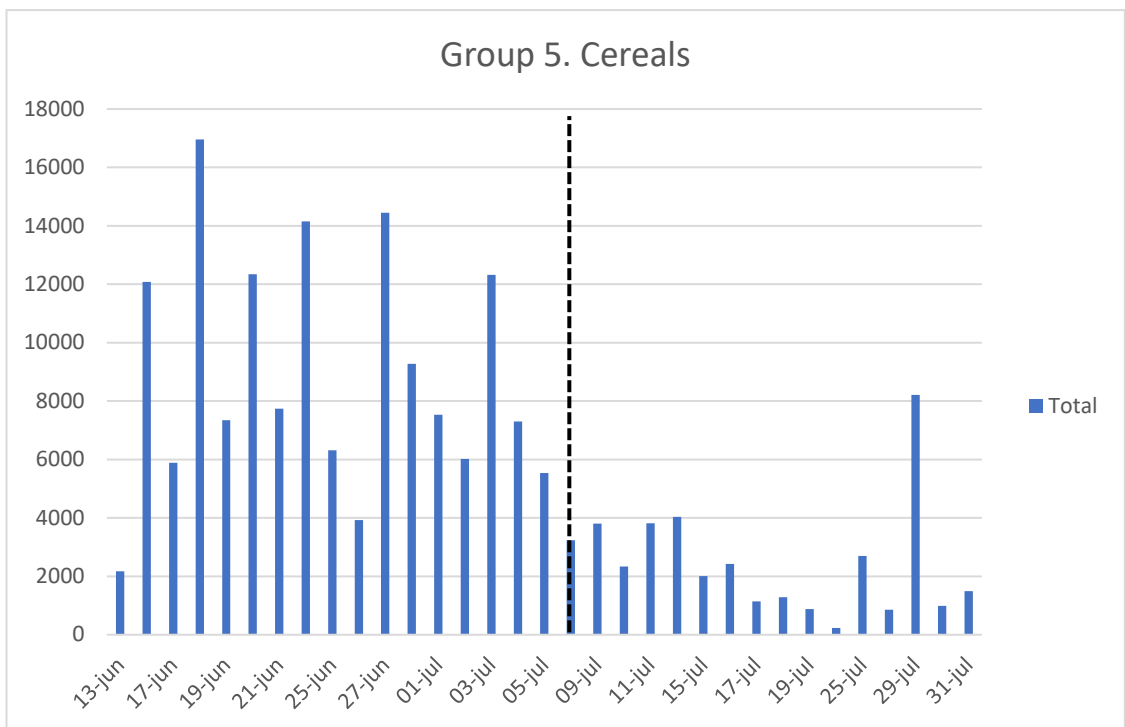


Figure 23. Outputs of Group 5 food products

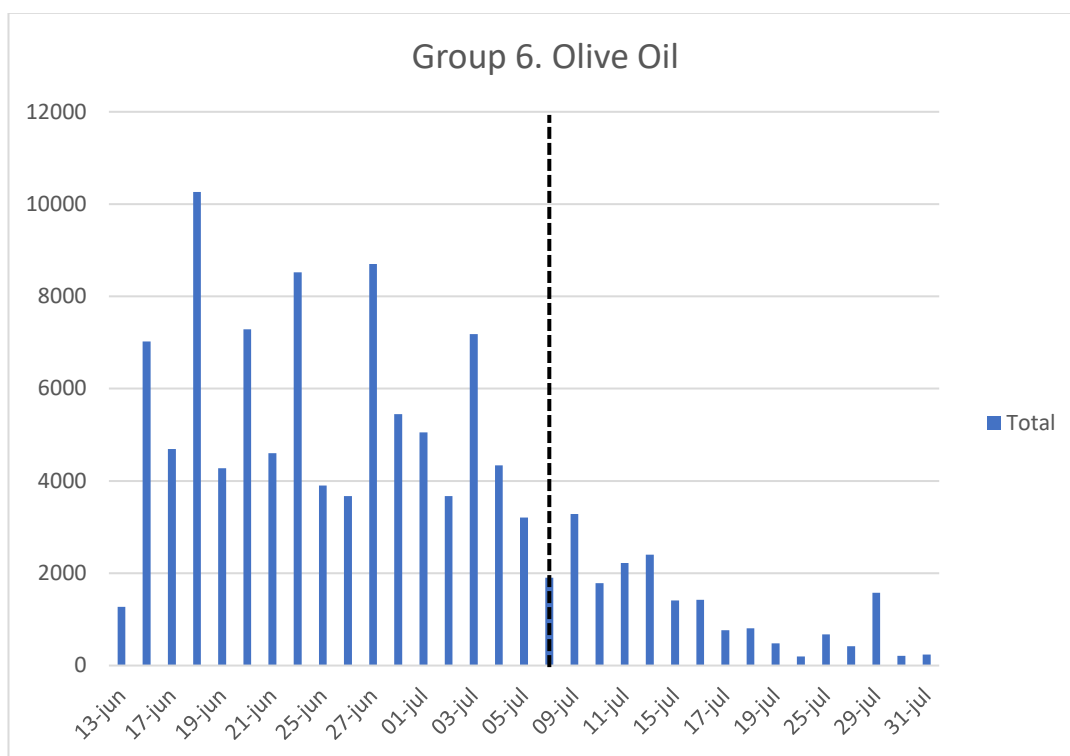


Figure 24. Outputs of Group 61 food products

However, due to the computational limitations of the program, it is necessary to apply hypothesis 2.13 and the calculations performed to assume this hypothesis are added below:

Food group	Standard deviation of kg of each product
1	19217,348
2	2876,16
3	1858
4	9229,14
5	4570,62
6	2783,39

Table 10. Analysis of the typical deviations of each food group 7

3. Input data related to the time spent and the number of volunteers used in the different phases of the study.

One of the main objectives of the creation of the model is to obtain, from the simulation, time-related data that will allow an estimation of the costs associated with the internal processes (Unloading-Storage-Order preparation and delivery) of the BAM. For this reason, the table below is essential, with information related to the times mentioned and the number of volunteers needed for each process, which are two closely related and fundamental variables to carry out the study presented here. In addition, the following tables show a comparison of the data highlighted in a period of entry of FEAD products versus a normal situation of operation of the Food Bank without the entry of these products.

Personnel table:

	Grassroots volunteers needed at Food Bank	Additional number of volunteers needed in a period of FEAD products [14]
1. Number of volunteers working on unloading trucks with FEAD products?	3	3
2. Number of volunteers working on the placement of FEAD products on the shelves?	1 a 2	1
3. Number of volunteers working in the preparation of orders and placement of products in the vehicles of the Charities?	5 a 10	5

Table 8. Comparative table between the number of volunteers in two different periods.

Table relating to times:

	Period FEAD* products [14]	Period WITHOUT FEAD products
1. How long does it take on average for volunteers to unload a truck?	45'	40'
2. How much time do volunteers spend on average placing FEAD products on the shelves?	45'	45'
3. How much time do volunteers spend on average preparing orders?	30'	30'
4. How much time do volunteers spend on average loading charity trucks/vans?	30'	30-40'

Table 9. Comparative table of the times used in two different time periods.

Here again it is important to analyze the times of the FEAD period column as if it were additional time that volunteers have to spend on the different processes, in addition to continuing to work with the products that the Food Bank manages and do not belong to FEAD.

4. Information used for the cost estimation of the initial and final product line for Fead products

In the following section, the information used to evaluate the costs, associated with the different processes that FEAD products undergo, is presented.

Firstly, the data used for the calculation of the costs of the initial distribution are presented, that is, the processes that the products from the European Funds for Aid to the Disadvantaged undergo from the supplier companies to their reception at the Food Bank of Corredor del Henares. Secondly, the information used for the estimation of economic costs related to the internal processes of the Food Bank (Reception-Placement and Storage-Delivery to the Charitable Entities) is shown and, finally, the data related to the calculation of costs linked to the distribution of the products in question from the BAM to each of the Charitable Entities are presented.

Initial distribution:

Average monthly salary of a heavy vehicle driver	Weekly hours limit	Wage/hour of a heavy vehicle driver
1500€	40	9,375€

Table 13. Information regarding the cost of an authorized driver.

Max Capacity/Trailer	Average consumption Trailer	Fuel	Price Diese/L
24,000 kg (27,000 kg*)	20 L/100km	Diesel	1,32€/L

Table 10. Information used to calculate fuel consumption costs.

Supplier Company [14]	Location	Distance to bda (km)	# of times the journey is made
ACICO, S.A.	N-232, km. 288, 50561 Bisimbre, Zaragoza, Zaragoza	287	8
RICE AND CEREALS, S.A.U(ARCESA)	Km 216, N-332, 0, 46780 Oliva, Valencia	422	2
BOLTON FOOD S.L.	Rúa Víctor Pita, 30, 36611 Vilagarcía de Arousa, Pontevedra	678	4
MEATS AND VEGETABLES, S.L.	Polígono Industrial El Prado. 06800 Mérida (Badajoz)	380	10
GULLÓN COOKIES S.A.	Ctra. A Burgos, Km. 1,5, 34800 Aguilar de Campoo, Palencia	343	4
GOLDEN FOODS, S.A.	Av. Cronista Ricardo Montes, 42, 30565 Las Torres de Cotillas, Murcia	394	4
HERO ESPAÑA S.A.	Av. de Murcia, 1, 30820 Alcantarilla, Murcia	406	1
ITALFRUTTA, SRL	via Reale, 9, 48123 Ravenna RA, Italy	1800	4
LACATIS FOOD SERVICE IBERIA, S.L.U.	Calle de Juan de Mariana, 17, B, 28045 Madrid	35,5	16
LACTOGAL PRODUCTOS ALIMENTARES, S.A.	Rua do Campo Alegre 830, 4150-177 Porto, Portugal	625	22
LEGUMBRES LUENGO, S.A.	Ctra. Nacional VI, km 314, 24794 Riego de la Vega, León	349	4
MACEIRAS ESPAÑOLA S.A.	Ctra. Barcelona, Km 5, 46132, Almasera Valencia	363	2
OLEO MASIA, S.A.	Ctra. de Isla Menor, 0, 41703 Fuente del Rey, Seville	575	5
THENAISE PROVOTE	Estrada de Chan das Pipas 23, Louredo, 36415, Pontevedra	616	1

Table 11. Information used to calculate the initial distribution of each of the supplier companies.

Intermediate processes at the Food Bank:

The costs associated with the processes that take place within the Food Bank are classified in three phases; firstly, a phase of "unloading and placement of FEAD products". Secondly, a "Storage" phase and, thirdly, a final phase of

"Order preparation and truck loading".

The table with the costs related to the above processes is added below:

Machinery	Average price	Number of machinery available	Annual depreciation rate [17]	Daily cost per unit
Electric pallet	600€	17	12%	20 cent.
Forklift truck	22500€	1	12%	7,4€

Table 12. Information used for machinery costing.

On the other hand, attributing a cost to the hours of work performed by volunteers is essential for an economic valuation of the BdA processes, since more than 86% [A] of the staff working in the Delegation where FEAD products are managed are volunteers.

According to the *"Manual for Measuring Volunteer Work"* [19] there are two possible ways to measure the economic value of volunteering. First, the *opportunity cost approach*, which essentially measures the economic value of volunteering to the volunteer. It consists of assigning to the hours of volunteer work the average wage that the volunteer would earn if he/she worked in a regular job for the same hours. For example, if the person who is volunteering works as a lawyer, this cost evaluation method would assign the average hourly wage of a lawyer to the number of hours volunteered.

Second, *the replacement cost approach*, which more accurately estimates the economic value of the volunteer's work. This approach attributes to the volunteer hours the amount of money that would have to be spent to pay a person to do the work that the volunteer did for free.

Of these two approaches, the *replacement cost approach* is generally considered to be the most appropriate by consensus. While it is true that there are researchers who apply a reduction to the wage rate of paid workers using a coefficient between 0 and 1 to indicate the insufficiency of the volunteer's productivity compared to that of a specialist in that activity, in this case, the appropriate weighting for the study has been considered to be 0.5 (Hypothesis 2.20).

Below is a table showing the average salary of a Food Bank worker:

Workday	Average hourly wage	Average monthly salary
6h	9,3€	1004,4€

Table 13. Information regarding the average salary of a BAM operator.

According to the classification of operating costs depending on their logistic function, storage costs are represented by the costs of space, facilities, handling and stock holding. Thus, the expenses considered most relevant for estimating the logistics costs related to storage are, firstly, the depreciation corresponding to both the building of the Alcalá de Henares warehouse and the pallets and racks used and, secondly, the maintenance costs associated with the racks occupied by FEAD products. (Reference [18])

Description	Depreciation [18]
Buildings	5%
Pallet racks	10%
Pallets	20%

Table 18. Depreciation of the objects under consideration

Storage media	Numerical expression [18]
Pallet racks	0.25% of the capital value

Table 19. Cost associated with pallet racking maintenance

In order to materialize these costs, the following information must be taken into account:

Capital value of building used [13]	Average capital value of a pallet	Average capital value of a pallet rack
518.813,56€	30€	800€

Table 20. Economic value of items to be considered in storage

Number of pallets available	Average weight of incoming pallets	Number of pallet racks available
6400	700 kg	530

Table 21. Information about pallets and pallet racks

Total number of pallets entering from group 1	Total number of pallets entering from group 2	Total number of pallets entering from group 3	Total number of pallets entering from group 4	Total number of pallets entering from group 5	Total number of pallets entering from group 6
341	251	251	253	275	319

Table 22. Total number of incoming pallets of each group.

**Calculated from the number of orders, the average number of kg on incoming pallets and kg incoming/order for each group and the number of days on which food is incoming.*

Therefore, the input data to the model are shown in the table below:

Daily cost of group 1 storage	Daily cost of group 2 storage	Daily cost of group 3 storage	Daily cost of group 4 storage	Daily cost of group 5 storage	Daily cost of group 6 storage
83,06€	78,42€	78,42€	79,97€	80,74€	82,29€

Table 23. Daily cost of storage of each group

Final distribution:

Finally, the data used to calculate the final distribution of FEAD products in the value chain are added.

Areas of the Community of Madrid	Number of Charities	Distance (Km) from the Bda to the estimated center of masses	Dispersion coefficient EB/ZONE
A1	5	24	5%
A2	5	32	5%
B3	26	30	2%
B4	21	24	-
B5	40	35	2%
C6	14	43	5%
C7	14	43	7,5%
C8	22	33	5%
2	3	39	10%
3	5	21	10%
4	15	11	10%
5	1	27	15%
6	9	58	25%
7	23	56	20%
8	0	-	-
9	11	47	15%

Table 24. Information used for the calculation of costs of the Charitable Entities in the final distribution phase.

Maximum capacity of the distribution vehicle	Average vehicle consumption	Fuel	Fuel price/L
4250kg	12 L/100km	Diesel	1,32€/L

Table 25. Information used to calculate fuel consumption costs.

Number of Charities that require vehicle rental	Daily rental cost
150	35€

Table 26. Information regarding the cost of renting a vehicle with the appropriate characteristics to carry out the final distribution.

Number of Charities that have their own vehicle	% of vehicle depreciation	Daily cost related to insurance payments
64	16%	1,4€

Table 27. Information regarding the costs considered for Charitable Entities with their own vehicles.

Zone	Number of trips made according to hypothesis 16 during months 6 and 7 (FEAD product outflow)
A	32
B	362
C	270
2	10
3	14
4	52
5	2
6	32
7	84
8	0
9	28

Table 28. Information used for the calculation of costs of the Charities in the final distribution phase.

Chapter 5. Case studies of the simulation model

In the previous chapters, assuming certain simplifying hypotheses, a model representing the value chain of the FEAD products of the BAM has been proposed and developed, with the ultimate aim of estimating the costs associated with the activity and carrying out a comparative study between the current scenario (centralized model) and an alternative scenario (decentralized model), based on direct economic aid to the beneficiaries.

In this line of thinking, the proposed simulation model has some potential to determine (quantitatively) the costs related to FEAD products in the various internal processes of the BAM. Due to the way it is modeled, interesting results related to the efficiency of the volunteers' work or the real needs of operators for the management of FEAD products could also be extracted.

This chapter presents the case studies of this work, which serve, among others, to test and verify the sensitivities of the model. As already mentioned, two case studies are presented, namely:

- 1) Study of the sensitivity of the model to i) variations in the number of volunteers working in the last phase of preparation and delivery of FEAD products to charities and ii) variations in the chronological profile of food outlets. More specifically, an analysis is made of the queuing times generated by the orders in the aforementioned process and their variation when faced with i) a change in the number of volunteers during the periods established for the outputs and ii) a uniform FEAD food output profile, i.e., the same amount of food is delivered every day.
- 2) The study of the real operation of BAM related to the management of FEAD products during the months of May-June-July 2019. It consists of using as input data: 1) the amount in kg of FEAD products entering and leaving BAM during the mentioned months 2) the number of volunteers collaborating, in addition to the times used in the different logistic processes. Thus, on the one hand, it will be possible to check the response of the model to a realistic case of operation and, on the other hand, the case study will allow an estimation of the costs associated with each of the internal processes of the BAM: a fundamental variable for possible logistical reformulation processes of the BAM. At this point, it should be

noted that the management team expects to obtain from this work a theoretical model that will allow them to evaluate different operational scenarios, and on which they can leverage for future strategic decision making.

1. Case study 1: model validation

As already mentioned, the objective of this case study is to validate the internal consistency of the model, i.e. to verify that the model's response is qualitatively and quantitatively reasonable in the face of certain variations in the input data. In addition to verifying that the simulation results are consistent, this first case study seeks to propose a possible efficiency improvement in the management of FEAD products within the BAM based on the modification of simulation model parameters for the months of May, June and July 2019. The variation of queuing times generated in the last phase of the logistics chain is analyzed by incorporating an additional volunteer, in the first case only in the first period and in the second case, only in the second period. This is carried out independently, since the two periods in which the quantities of kg of food leaving are so different, the impact generated by the incorporation of a volunteer in one period or the other can be significant.

In addition, as a last sensitivity analysis, a study of the queuing times is performed after the imposition in the model that the FEAD product outputs are carried out in a uniform way eliminating the radical difference between the output kg of each period.

The most relevant results of the model are shown and discussed below. The results will be presented in the following order: first, a graph will be presented with a comparison of the queuing times generated in period 1 between the base case, i.e., with the actual number of volunteers versus the scenario in which there is an additional volunteer. Secondly, the same comparative time graph is presented as applied to period 2 of departures. And thirdly, the comparison of the queuing times generated between the base case and the imposition of a uniform output of products in period 1 is presented.

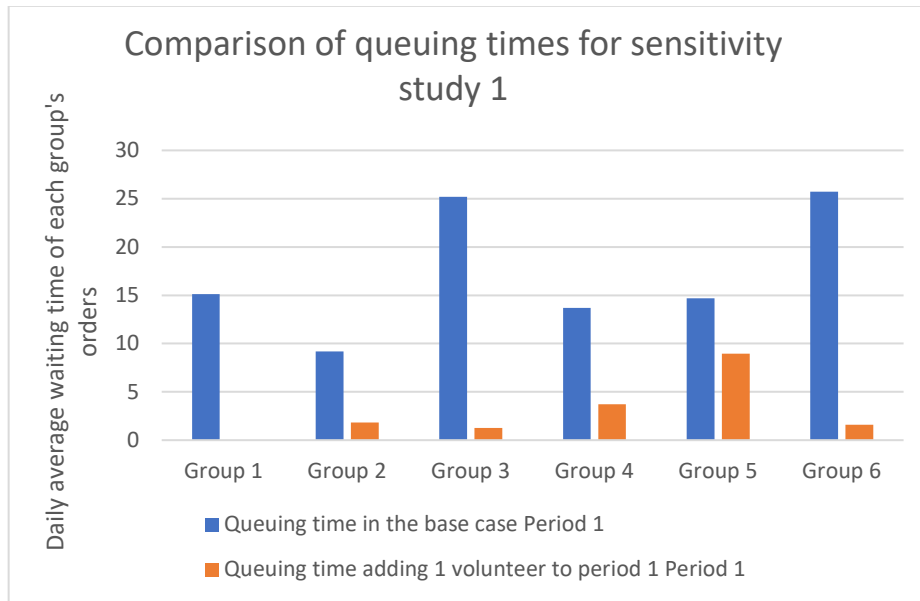


Figure 25. Comparison of queuing times for sensitivity study 1.

The graph above shows the results obtained from sensitivity analysis 1. It is evident how the incorporation of an additional volunteer in the processes experienced by each of the product families has a strong positive impact on the queuing times generated. In all groups, queuing times are reduced from 40% (group 5) to 100% in group 1. This improvement in performance leads to a number of benefits in logistical terms that will not be analyzed in this thesis but which ultimately translate into a reduction in costs and a slight improvement in warehouse efficiency.

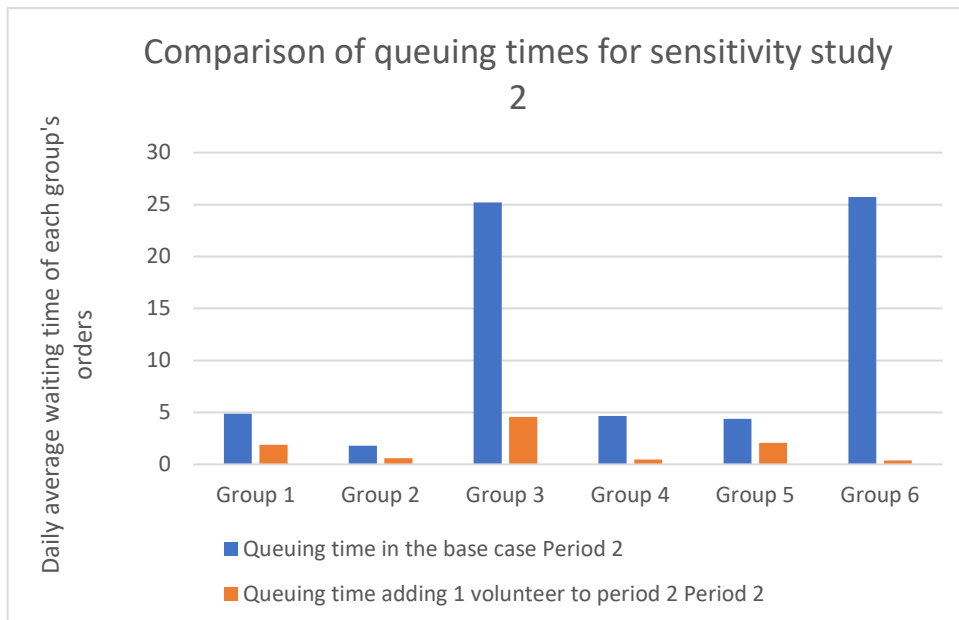


Figure 26. Comparison of queuing times for sensitivity study 2.

As in the graph presented for sensitivity study 1, in this second assumption the queuing times associated with each of the groups also show a clear improvement. Before commenting in detail on the results, it is necessary to remember that the absence of groups 3 and 6 from the previous graph is justified by hypothesis 2.13, since these two groups have to be modeled with a single 33-day departure period, it is not possible to incorporate a volunteer in period 2 only. The previous graph again shows that the model responds as expected (times decrease with the addition of a volunteer), however, it shows that the costs associated with the addition of an additional volunteer may not compensate for the reduction in queuing times in period 2, since the waiting times are considerably lower than those obtained in period 1.

To conclude the sensitivity analysis, we present the results provided by the model in a hypothetical case in which FEAD product outputs were performed in a uniform and constant way (making the same amount of total product output each day, i.e., the sum by product type and divided by the total number of output days). The purpose of this analysis is to shed light on how it would impact the value chain if the output model were to avoid saturation of volunteers, who otherwise experience very heterogeneous levels of work, with pronounced peaks and valleys (see for example the differences between June 18 and July 18 for products associated with group 1, Figure 19).

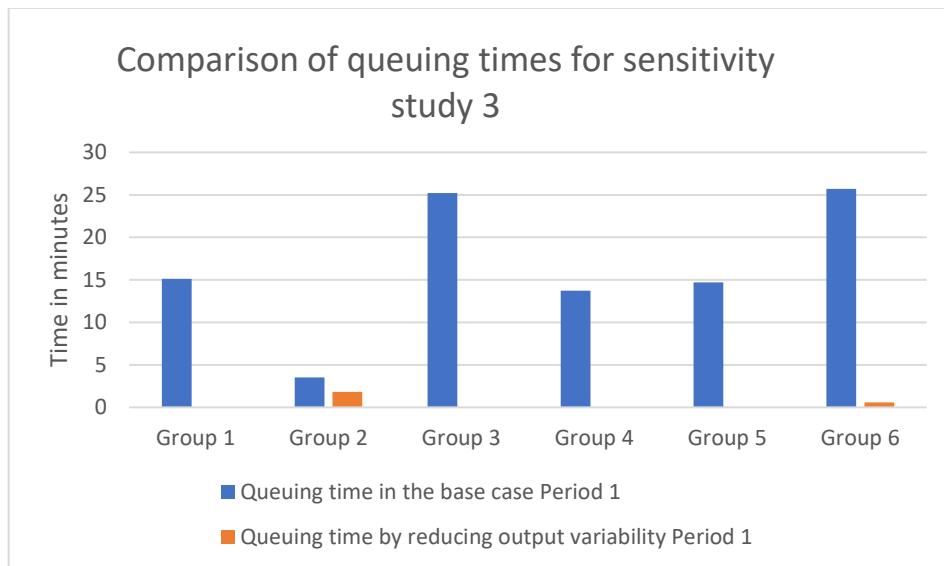


Figure 27. Comparison of queuing times for sensitivity study 3.

It is logical that by regulating the outlets of FEAD products in such a way that approximately the same amount of food of each product group per day will leave the bank's logistic chain, the results will be positive. By means of a correct organization of the outgoing orders, it is possible to reduce the queuing times of groups 1, 3, 4, 5 and 6 by (approximately) 100%. Although it is true that this outbound method seems to be beneficial for BAM, the possible logistical problems that this organization can generate for the charities would have to be analyzed to really contrast the results and evaluate if it is a really feasible alternative.

2. Case study 2: simulation of the months of May June and July 2019

This second case study is oriented to analyze the operation of the Food Bank of Madrid during the year 2019, more specifically in the months of May, June, and July, taking into account the number of volunteers working in the BAM and the average times used for each of the processes. The structure in which the document has been organized is; firstly, the presentation of results of the simulation model and, secondly, the cost estimation of the financial model.

2.1 Simulation model analysis

The following table shows a summary of the input data used, which will help to understand the subsequent presentation of results with less effort (the grey squares indicate that no resources of such kind are needed to complete that specific task).

	Food discharge	Food placement	Storage	Delivery
Number of volunteers required	3	1		5
Number of trucks daily received	5			
Time spent	45'	45'	15-20 days + variable time dependent on product type	60-70'

Table 29. Information related to each internal logistic process of the BAM.

In order to analyze the results obtained in the simulation model, the study is structured in four groups: unloading, placement, storage and preparation of orders and delivery of products.

In the unloading process, the times extracted from the simulation are shown in the following table.

Average time spent	Max. time spent	Min. time spent
46.416'	69.6'	29.72'

Table 30. Results obtained in the discharge process.

In accordance with the criteria established for cost estimation, only the work of the volunteers is considered as an expense for the BAM in the initial unloading process. The daily costs associated with the unloading process are calculated according to the formula below, and the results are presented in the following graph:

$$\text{Total reception cost} = \text{Average time spent in discharging a truck (minutes)} * \\ \text{Cost per minute of the volunteer} * \\ \text{Number of volunteers working} * \\ \text{Number of days of FEAD product reception} * \\ \text{Average number of trucks daily received}$$

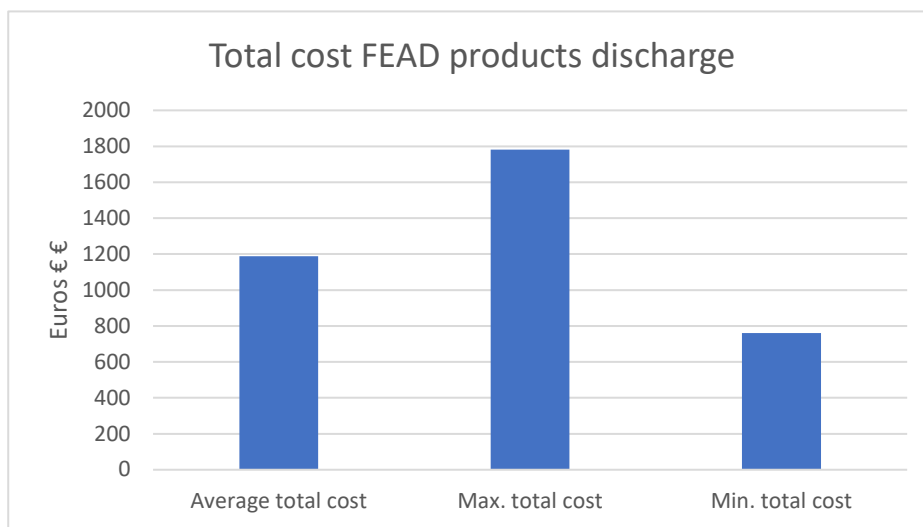


Figure 28. Total cost FEAD products discharge.

In the process of placing FEAD products the times employed by the volunteers are:

Average time spent	Max. time spent	Min. time spent
49.728'	73.488'	25.69'

Table 31. Results obtained in the placement process.

For the cost estimate of this phase, in addition to taking into account the cost related to the work of the volunteers, the use of electric pallet trucks and two forklifts is also added as an expense. The costs have been calculated with the formula shown below and the results are represented in the following graph:

Total placement cost =

- = Average time spent
- * Number of days of FEAD products reception
- * Number of trucks daily received
- + (cost per minute of the volunteer
- + minute depreciation of machinery used)

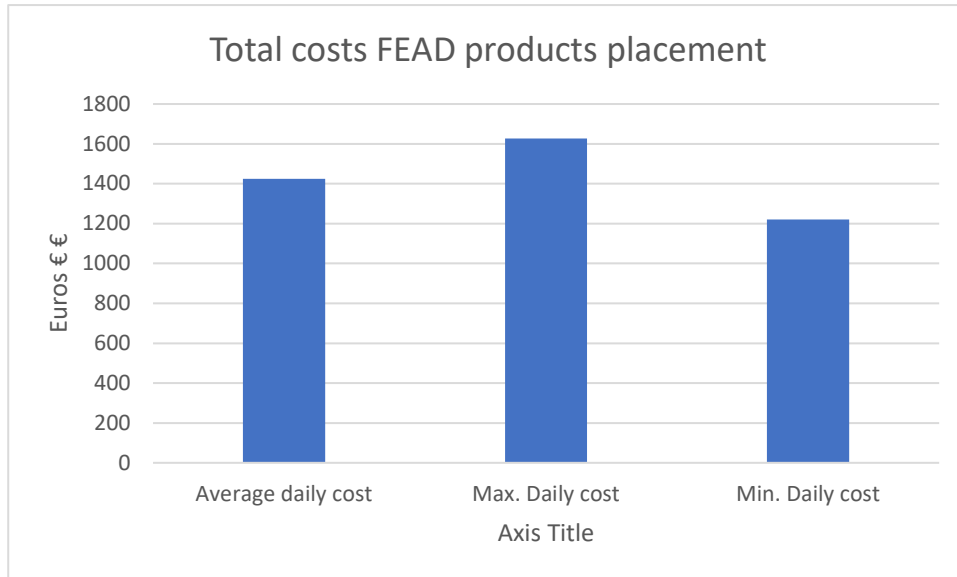


Figure 29. Total cost FEAD products placement.

After the process of placing the food in the BAM warehouse, a storage period begins in which the products remain immobilized until they have been inspected as discussed earlier in the report. At this stage of the logistics chain, the associated costs are related to the demands of keeping approximately 1,700,000 kg of food in a warehouse for a considerable period of time. In logistical terms, the immobilization of inventory entails a great deal of cost and inconvenience for the proper functioning of the warehouse. Reducing the stock would reduce the capital tied up, an investment that can be allocated to other items, thus relieving the company's liquidity. In addition, the costs linked to maintaining this stock, which is an important item within the logistics storage costs, are reduced and space is freed up in the warehouse for new uses.

Based on the input parameters defined for the storage process in Chapter 4 and the actual time that each FEAD food group remains in the warehouse, the results obtained in this phase are:

Average time spent group 1	Average time spent group 2	Average time spent group 3	Average time spent group 4	Average time spent group 5	Average time spent group 6
21,52 days	21,79 days	23,79 days	21,03 days	20,80 days	23,29 days

Table 32. Resultados obtenidos en la fase de almacenaje.

Total cost of group 1 storage	Total cost of group 2 storage	Total cost of group 3 storage	Total cost of group 4 storage	Total cost of group 5 storage	Total cost of group 6 storage
1787,45€	1708,77€	1865,61€	1681,77€	1679,40€	1916,53€

Table 33. Total storage cost of each group.

Finally, the last phase of BAM operations before final distribution begins is the process of preparing and loading the orders into the charities' vehicles. The costs to be considered in these processes are: the use of electric pallet trucks, forklifts and the non-accounting cost associated with the work of the volunteer.

Finally, the average time taken to prepare and load a food group order in periods 1 and 2 is added below:

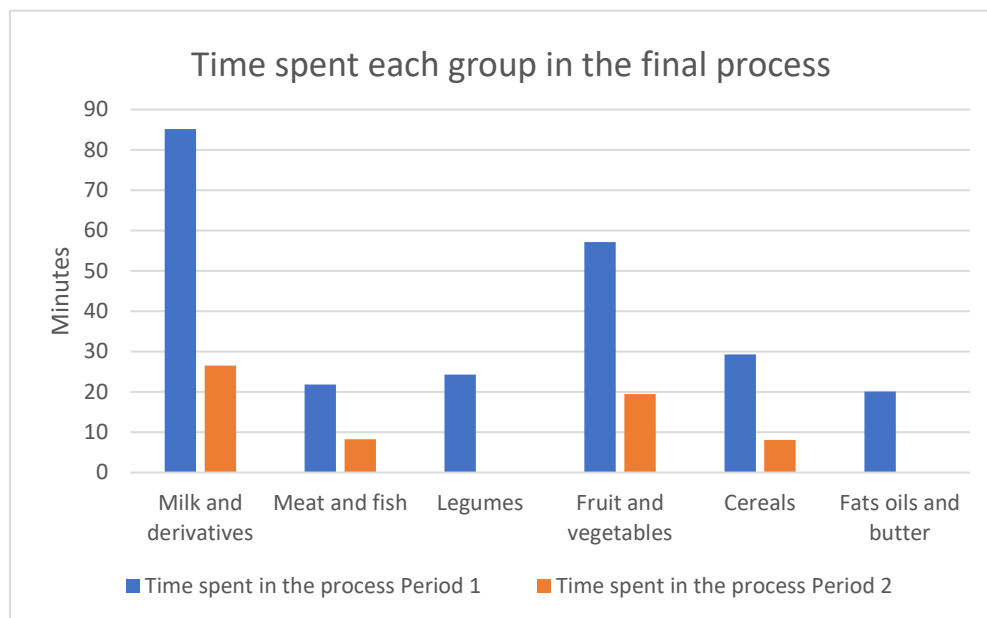


Figure 30. Time spent of each group in the final process.

It is clearly distinguishable the difference in times used by the operators in the two output periods considered (it is recalled that both vegetables and olive oil have only one output period) to manage the output orders and load the

products on the vehicles of the charities. According to the time results obtained and the model input data related to the costs of this last phase, the formula used and the results obtained are shown in the following table:

Total cost per groups =

- = Average time spent in preparing and delivering one order of each group
- * Number of volunteers working
- * Average number of outgoing orders of each group
- * (cost per minute of the volunteer
- + minute depreciation of machinery used)
- * Number of days FEAD product exit

Average total cost in the last phase	Period 1	Period 2	Total
Group 1	2177,76€	678,72€	2856,48€
Group 2	558,32€	210,24€	768,56€
Group 3	621,2€	621,2€	1242,52€
Group 4	1460,88€	496,96€	1957,84€
Group 5	749,36€	206,08€	955,44€
Group 6	513,76€	514,32€	1028,1€

Table 34. Average total cost in the last phase for each Group.

To conclude with the analysis of the results of the simulation model of case study 2, a final summary table is presented with the costs associated with each of the logistics phases to which FEAD products are subjected in the BAM:

Total reception cost	Total placement cost	Total storage cost	Total preparation-delivery cost	TOTAL FINAL COST
1188€	1424,89€	10639,53€	8808,94€	22061,36€

Table 35. Total cost of each phase

2.2 Financial model analysis

In the previous subchapter, the costs offered by the simulation model of the BAM's internal logistics operations (unloading-positioning-storage-preparation and dispatch of orders) were presented. In the following section we will present the results obtained from the financial model related to the initial and final distribution of FEAD products in order to conclude with the cost estimation of the FEAD product line.

The costs related to the distribution phases of the FEAD products will be presented in the following order; firstly, the costs of the supplying companies associated with the transportation of the goods from the company in question to the BAM and, secondly, the costs incurred by the charities to transport the food from the organization to each of the charities.

Although the input data used from the supplier companies for the calculation of the costs are added in Chapter 4, they are added here again to facilitate the reading of the chapter, incorporating a final column with the expenses calculated by applying the assumptions of Chapter 3 regarding personnel expenses and fuel consumption.

Initial distribution cost per food supplier

= Distance between the supplier company and BAM
** average cost of fuel*
** number of time the company makes the trip*
** (average fuel consumption with the truck loaded*
+ average fuel consumption with the truck unloaded)
+ average time spent by the driver to make de distribution
** cost per hour of the certificated driver*

Supplier Company	Location	Distance to bda (km)	Number of times you make the trip	Total fuel costs	Time taken for initial distribution	Total personnel costs
ACICO, S.A.	N-232, km. 288, 50561 Bisimbre, Zaragoza, Zaragoza	287	8	1363,824€	6h	56,25€
RICE AND CEREALS, S.A.U(ARCESA)	Km 216, N-332, 0, 46780 Oliva, Valencia	422	2	501,34€	8h 30'	79,69€
BOLTON FOOD S.L.	Rúa Víctor Pita, 30, 36611 Vilagarcía de Arousa, Pontevedra	1592	4	3782,59€	32h	300€
MEATS AND VEGETABLES, S.L.	Polígono Industrial El Prado. 06800 Mérida (Badajoz)	48,1	10	285,71€	2h	18,75€
GULLÓN COOKIES S.A.	Ctra. A Burgos, Km. 1,5, 34800 Aguilar de Campoo, Palencia	343	4	814,97€	7h	65,63€
GOLDEN FOODS, S.A.	Av. Cronista Ricardo Montes, 42, 30565 Las Torres de Cotillas, Murcia	394	4	936,14€	4h 30'	42,19€
HERO ESPAÑA S.A.	Av. de Murcia, 1, 30820 Alcantarilla, Murcia	39,6	1	23,52€	1h	9,375€
ITALFRUTTA, SRL	via Reale, 9, 48123 Ravenna RA, Italy	1800	4	4276,8€	37h	346,88€
LACATIS FOOD SERVICE IBERIA, S.L.U.	Calle de Juan de Mariana, 17, B, 28045 Madrid	35,5	16	337,39€	1h	9,375€
LACTOGAL PRODUCTOS ALIMENTARES, S.A.	Rua do Campo Alegre 830, 4150-177 Porto, Portugal	625	22	8167,5€	13h	121,88€
LEGUMBRES LUENGO, S.A.	Ctra. Nacional VI, km 314, 24794 Riego de la Vega, León	349	4	829,24€	6h 40'	62,81€
MACEIRAS ESPAÑOLA S.A.	Ctra. Barcelona, Km 5, 46132, Almasera Valencia	363	2	431,24€	8h	75€
OLEO MASIA, S.A.	Ctra. de Isla Menor, 0, 41703 Fuente del Rey, Seville	575	5	1707,75€	11h 40'	109,69€
THENAIISE PROVOTE	Estrada de Chan das Pipas 23, Louredo, 36415, Pontevedra	616	1	365,904€	12h 40'	119,06€

Table 36. Information used and costing of the initial distribution.

The following two tables include the costs of the final distribution of FEAD products, i.e. the calculation of fuel costs, rent, insurance payments and vehicle depreciation.

Total fuel cost

= Distance between CM calculated and BAM
 * Average fuel consumption * Number of trips made
 * Average fuel cost * (1 + * Dispersion coefficient)

Areas of the Community of Madrid	Number of Charities	Distance (Km) from the Bda to the estimated center of masses	Dispersion coefficient EB/ZONE	Number of trips made	Total fuel cost	Total cost of volunteer personnel ⁵
A1	5	24	5%	8	31,92€	24,38€
A2	5	32	5%	8	53,22€	29,38€
B3	26	30	2%	53	321,12€	186,32€
B4	21	24	-	32	152,10€	97,5€
B5	40	35	2%	96	678,89€	375€
C6	14	43	5%	60	536,38€	271,88€
C7	14	43	7,5%	19	173,90€	86,10€
C8	22	33	5%	56	384,20€	210€
2	3	39	10%	5	42,47€	21,10€
3	5	21	10%	7	32,02€	19,70€
4	15	11	10%	29	62,29€	52,81€
5	1	37	15%	11	8,42€	4,06€
6	9	58	25%	16	229,68€	91,25€
7	23	56	20%	42	558,84€	232,97€
8	0	-	-	-	-	-
9	11	47	15%	14	149,83€	67,81€

Table 37. Information used and final distribution costing.

⁵ The calculation of the cost of volunteer work has been made in the same way as in BAM's internal processes, applying a reduction factor of 50% with respect to the average salary of an operator.

Areas of the Community of Madrid	Number of vehicles rented per area (scenario 2.31 ⁶)
A1	1
A2	1
B3	2
B4	2
B5	3
C6	1
C7	1
C8	2

Table 38. Number of vehicles rented per area.

Total rent cost

- = Number of vehicles rented per zone
- * Number of days there is a FEAD product delivery
- * Daily rent cost

Total insurance cost

- = Daily cost of insurance * Number of owned vehicles
- * Number of days there is a FEAD products delivery

Total depreciation cost

- = Number of owned vehicles * %depreciation
- * Average cost of the $\frac{\text{vehicles}}{365}$
- * Number of days there is a FEAD product delivery

Total cost of vehicle rental applied to 70% of charities	Cost of insurance payment for vehicle insurance owned by 30% of charities	Depreciation of vehicle owned by 30% of charitable entities
15015€ ⁷	1293,6€	2835,29€ ⁸

Table 39. Costs associated with final distribution.

To conclude with the analysis of the results of the FEAD model (centralized model) of case study 2, a comparative study is made between the cost estimate and the assumptions made, versus the value of expenses associated with the management of FEAD products provided by the BAM audit report.

⁶ It is considered that if the number of charities to be supplied in an area is between 15 and 30, two transport vehicles should be rented, and if more than 30, three vehicles should be rented.

⁷ A total of 28 owned vehicles are considered to be responsible for distribution to charities in zones 2-9.

⁸ The average price of the vehicle is considered to be 7000€.

This is a key exercise to determine to what extent the model adequately performs the cost estimation and whether the assumptions adopted are appropriate. Since the economic cost of the audit report represents a purely accounting cost, it is necessary to remove the expenses associated with volunteer staff from the FEAD model to make a proper cost comparison.

Total initial distribution cost	Total placement cost	Total storage cost	Total preparation-delivery cost	Total final distribution cost	TOTAL FINAL COST
25240,49€	102,20€	10639,53€	2669,26€	22566,82€	61218,3€

Table 10. Total costs of each phase of the proposed model.

Support for FEAD expenses, year 2019	Amount of kg FEAD, year 2019	Management cost/kg	Quantity of kg managed in the case study	Management cost in the case study
256195,63€	5740533 kg	0,044629€	1649515kg	73616,60€

Table 11. Total costs obtained from the audit report.

According to the tables presented, it can be concluded that the proposed FEAD model presents estimated costs of 61218.3 € compared to the 73616.60 € extracted from the audit report. This 17% difference may be due to the assumptions made in the development of the FEAD model, as well as some of the variable costs that have not been taken into account, such as electricity supply.

In addition, the distribution of expenditure that has been made to estimate the management expenditure of FEAD products from the audit report has been linear. This is an approximation since according to the following graph, the percentage of BAM occupancy in the period studied is considerably lower than in the other periods of FEAD product inflow (February-March, September-October). Thus, the logistic costs/kg of product would be higher in these periods and lower in the case study, coming closer to the estimated 61218.3 €.

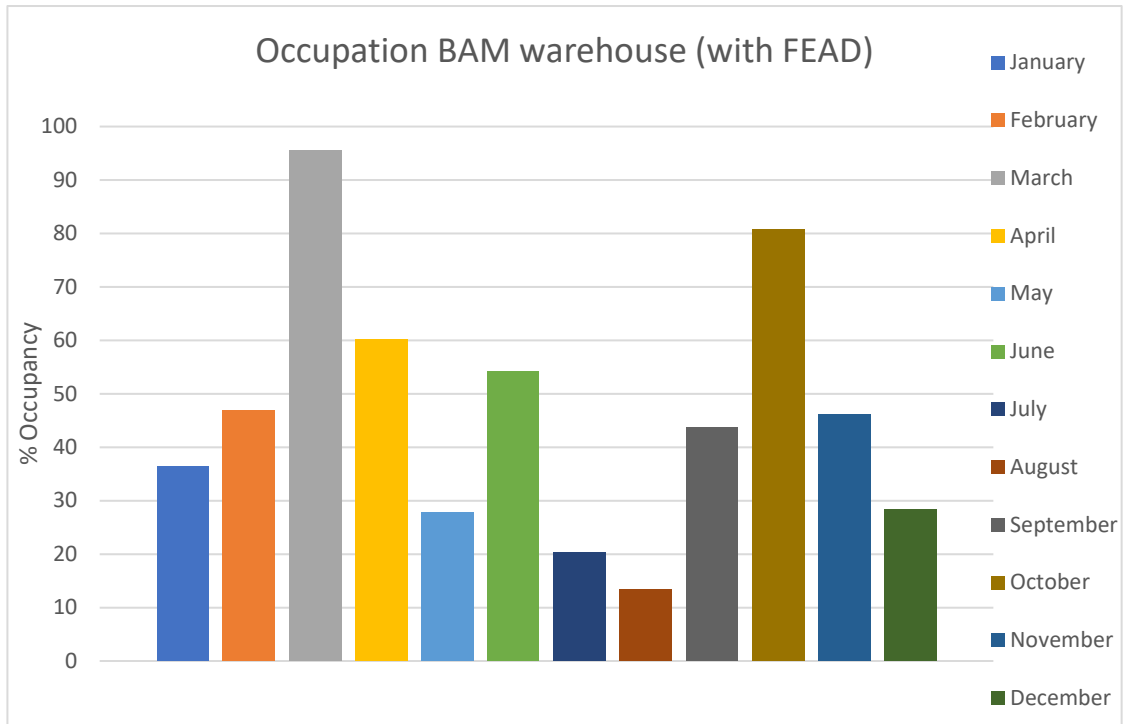


Figure 31. BAM occupancy analysis.

Chapter 6. Economic estimation of the alternative scenario and comparison of results

Once the cost estimation of the proposed financial model has been completed, the costs of the alternative scenario are estimated. The alternative scenario consists of eliminating the BAM as a distributor of FEAD products by incorporating economic aid cards offered by the European Fund so that the beneficiaries themselves can go directly to the nearest supermarket chain and receive their orders.

At the logistical level, this model has the following main implications: the initial distribution phase remains relatively unchanged, since the supplier companies will continue to distribute the FEAD products agreed with the European Funds, but instead of going to the BAM in Alcalá de Henares, they will have to go to the supermarkets that declare themselves as collaborators. Secondly, the entire final distribution phase is eliminated from the logistics chain of FEAD products. Instead of forcing the charities to go to the Corredor del Henares organization to pick up the assigned orders, the beneficiaries themselves go directly to supermarkets near their usual place of residence to pick up the orders assigned to them.

However, there is still no clearly defined organization for this possible new logistic model for the FEAD product line, so there are infinite possibilities and decisions that cause some costs or others. Therefore, the following hypotheses are proposed in order to make a first cost estimate and analyze this possible scenario from an economic point of view:

- 1) It is considered that the supermarket chain with which an agreement is created for the management of FEAD products is Mercadona, as it is one of the most widespread supermarkets in the community of Madrid.

- 2) The initial distribution costs are considered to be the same as in the financial model added in the previous chapter. Although it is true that the suppliers would have to distribute the food to different supermarkets instead of to a single point, the difference between supermarkets will be negligible compared to the distance that the suppliers have to travel to reach Madrid.
- 3) To calculate the cost of placing the products on the supermarket shelves, the cost of two people hired with an average salary of €1,325 is considered as the only expense.
- 4) For the cost estimation of hypothesis 3, the times provided by the logistics department of the BAM are taken as a reference, but as the quantities of FEAD products that will reach each supermarket are lower than those that reach the BAM, for the time estimation it is considered that of the 170 Mercadona supermarkets available in the Community of Madrid, 30% of them will be distribution points as it is considered an adequate number of supermarkets for the management of FEAD products.
- 5) Finally, the cost of storing the FEAD products in the supermarket will be realized as if it were an opportunity cost of losing some shelf space that could be used for the sale of everyday products to generate profit. In addition, the worst case scenario will be considered as if the space occupied by the FEAD products were replacing part of the availability of bags of potatoes, which are one of the products that generate the most revenue annually [20].

The results obtained by applying the aforementioned hypotheses are shown below: firstly, the estimated costs of receiving and placing the FEAD products received for the supermarket and, secondly, the data used for the calculation of the opportunity cost to which the storage costs are associated:

Total reception cost

$$= \text{Average time (minutes) spent unloading}$$

$$* \text{Average personnel cost per } \frac{\text{hour}}{60}$$

$$* \text{Number of supermarkets}$$

$$* \text{Number of days of incoming products}$$

Total placement cost

$$= \text{Average time (minutes) spent in the allocation}$$

$$* \text{Average personnel cost per } \frac{\text{hour}}{60}$$

$$* \text{Number of supermarkets}$$

$$* \text{Number of days of incoming products}$$

Total cost of reception for Mercadona	Total cost of products placement for Mercadona
2956,94€	11088,52€

Table 42. Product reception and placement costs for Mercadona.

	Average volume occupied/kg of products	Average entering kg/supermarket	.m3 occupied per day	Number of shelves occupied	m3 available in a standard dsheve
Milk and derivatives	0,001	1460,16	1,46	1,01	1,44
Meat and fish	0,00232	207,21	0,481	0,33	
Legumes	0,00232	116,66	0,271	0,188	
Fruit and vegetable	0,00232	598,71	1,389	0,964	
Cereaks	0,013	340,15	4,42	3,068	
Fat oils	0,001	217,43	0,217	0,151	

Table 43. Estimate of the volume of occupancy of each of the products.

Total number of shelves occupied by FEAD products	Average volume occupied by a bag of potatoes in m3	Average cost per unit of a potatoe bag	Total daily storage cost	Total storage cost ⁹
5,718	0,06	3,99€	380,257€	12547,5€

Table 44. Total storage cost estimation.

⁹ Considering that all the products would have to be stored for the 33 days that make up Periods 1 and 2 of outflows, i.e., the worst case of all.

Finally, by proposing an alternative scenario eliminating BAM as the distributor of the product and the hypotheses proposed, the aim was to carry out a comparative study between the two scenarios in order to evaluate, based on economic results, the possibility of making changes in the logistic organization of the product. The following results and conclusions are obtained from these analyses:

- In the initial distribution phase, costs have been estimated at €25240,49. Based on the assumptions defined in previous chapters, the costs in both scenarios are considered to be the same since the companies supplying FEAD products will continue to perform the same work in one scenario or the other.

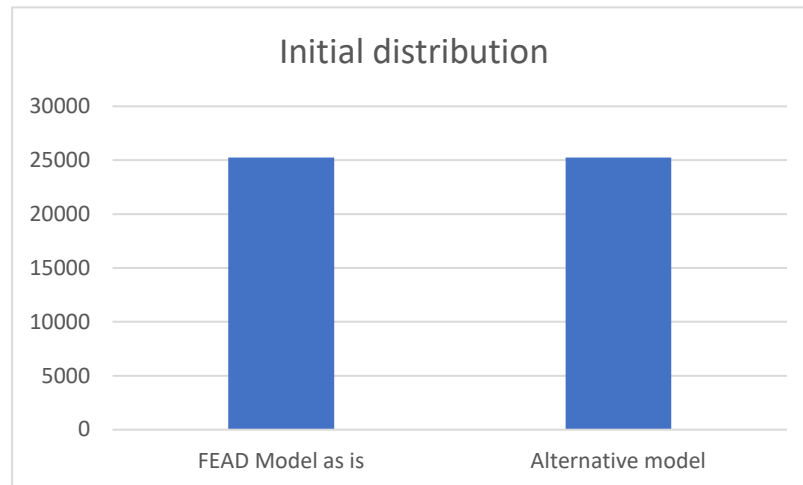


Figure 32. Comparison of costs in the initial distribution.

- In the product reception phase, the FEAD model as it is established, estimated costs are €1188 compared to the €2956.54 estimated in the alternative model. This difference is due to the cost estimate of the voluntary work performed in chapter 5, applying a reduction factor of 50% compared to the cost of a professionalized operator, and the quantity of incoming products in relation to the number of centers.

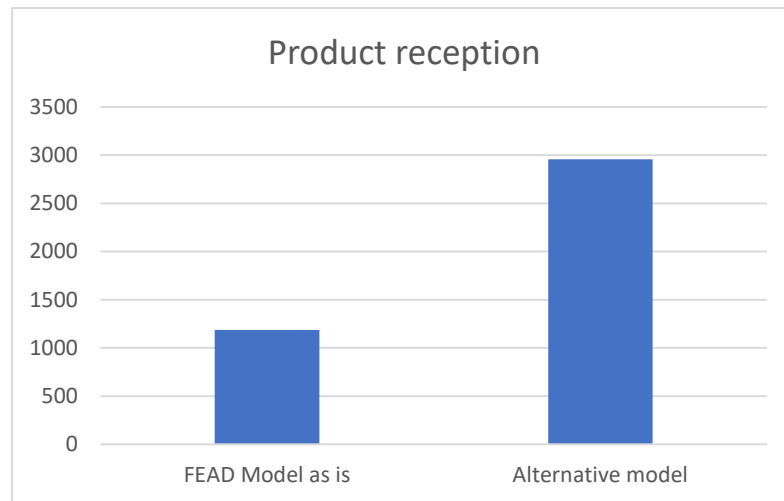


Figure 33. Comparison of costs in the products reception.

- At the stage of placement of the products received, the results obtained are shown below. This phase presents a considerable difference in costs between the two scenarios. This is due to the fact that the placement of FEAD products in the current model is done by means of pallets and their direct placement on shelves suitable for this purpose. However, the placement of these products in a supermarket requires a greater amount of time since they are placed on the shelves individually and thus the cost of personnel increases considerably.

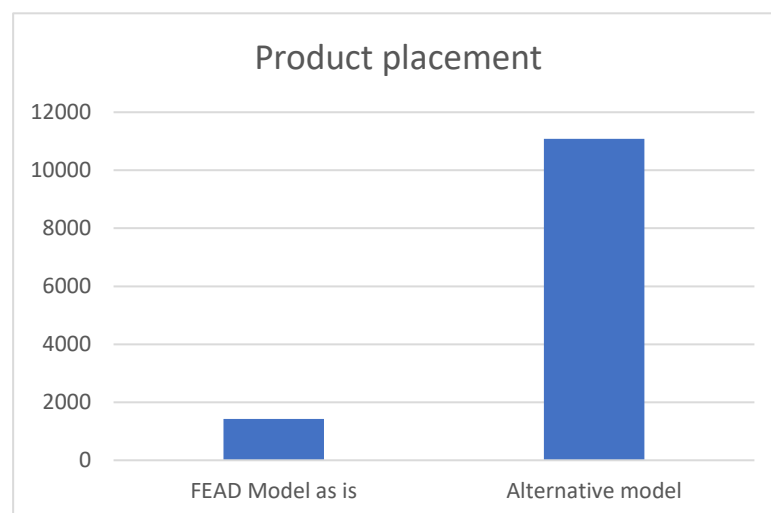


Figure 34. Comparison of costs in the products placement.

- In the FEAD food storage process, the costs for each scenario have

been estimated at 10639.53€ and 12547€ respectively, according to the hypotheses proposed.

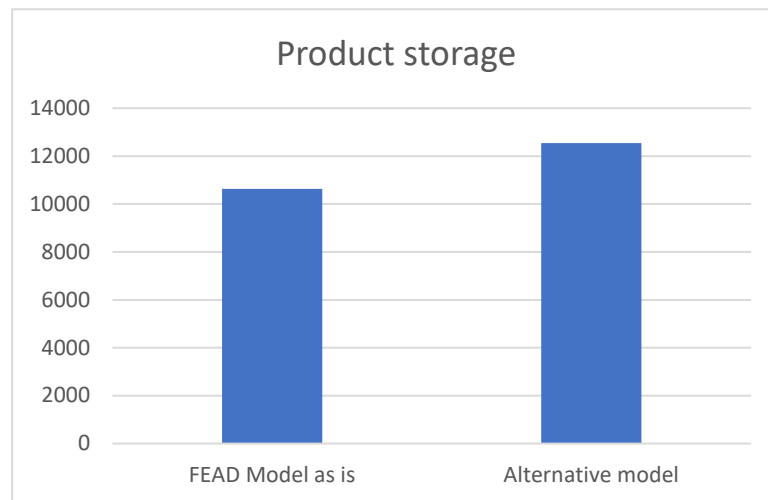


Figure 35. Comparison of costs in the products storage.

- In the last phase of order preparation and delivery as well as in the final distribution, the results are radically different. This is due to the disappearance of the aforementioned processes in the alternative model, since the beneficiaries themselves are in charge of selecting the food and it is not necessary to prepare the orders and transport the products from the BAM to each of the charities, as is the case in the current model. A possible saving of 8808.94€ in the preparation of the orders and 24337.10€ in the final distribution is estimated.

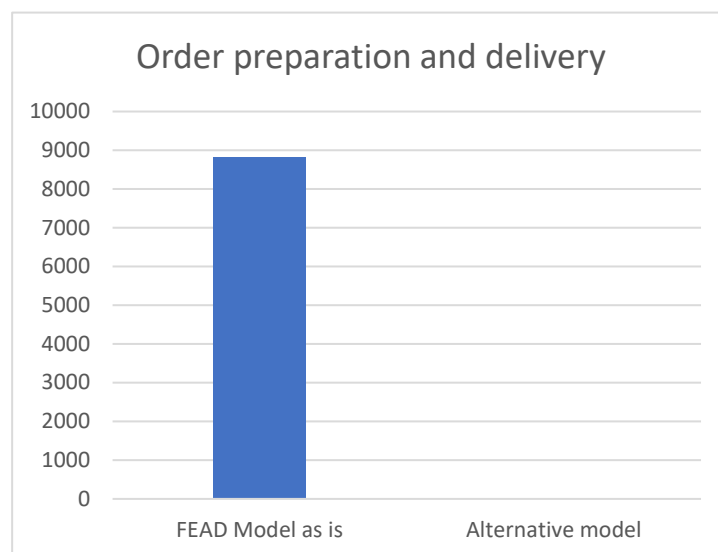


Figure 36. Comparison of costs in order preparation and delivery.

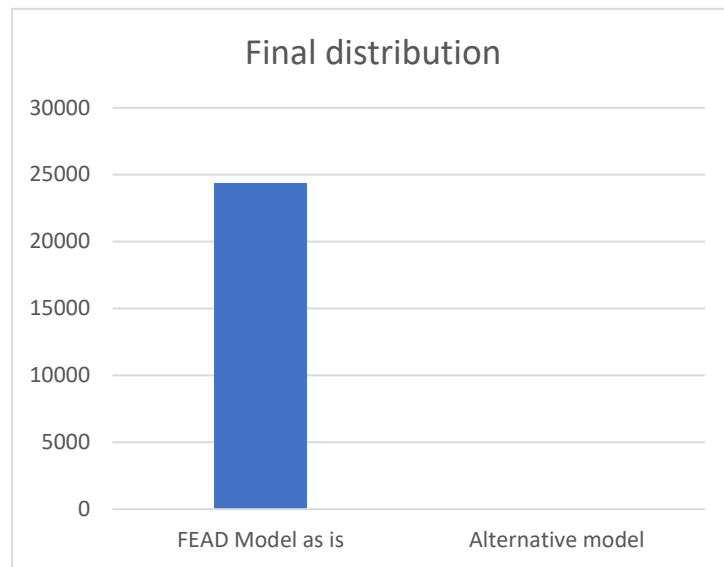


Figure 37. Comparison of costs in the final distribution.

- To conclude with the presentation of the results, the total cost estimate of the current logistics model for FEAD products and the alternative model proposed are finally shown. According to the hypotheses defined and the costs associated with each of the different processes in the logistics chain of FEAD products, it is concluded that the consideration of modifying the current organization of the products studied could lead to a total cost saving of around 30%, to be distributed among the different actors.

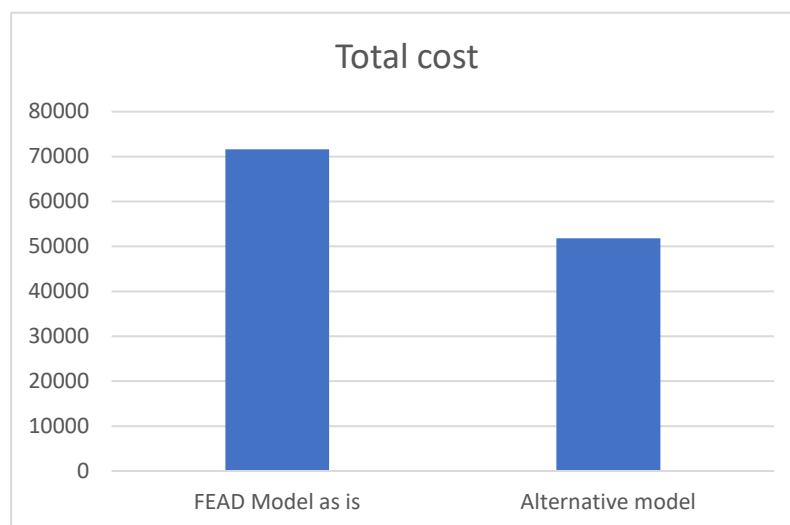


Figure 38. Total cost comparison.

Chapter 7. Conclusions, contribution to the SDG's and future developments

This project has proposed a cost estimation model for the line of products offered by the European Fund for Aid to the Disadvantaged, which could be an interesting tool to support strategic decision making, such as the formulation of proposals to change the logistical organization linked to these products. The model takes into account cost factors of purely economic origin, such as the price of fuel needed for food distribution, as well as non-accounting costs of a social nature, such as volunteer work hours.

The main objective is, on the one hand, through the simulation model, to estimate the logistics costs present in the stages to which the products are subjected, from the perspective of the BAM, which is understood as an organization that seeks to improve the efficiency of its processes and with it a reduction in costs. And, on the other hand, through the financial model defined, to provide approximate data on the initial and final distribution costs of FEAD products in order to compose a holistic and granular view of the costs associated with the value chain of these products.

The restrictions and hypotheses considered for the cost calculation are related to the difficulty of the study, since the main purpose of the project is not to calculate precisely the costs of each of the logistic processes that FEAD products undergo, but to provide an indicative economic data for future decisions.

On the other hand, in order to check the robustness and coherence of the model developed, through the case studies presented in Chapter 5, it has been subjected to a sensitivity analysis, obtaining satisfactory results.

The case studies that have been designed have been oriented, on the one

hand, to the validation of the model under different scenarios identifying possible inefficiencies in the processes together with proposals for change to generate added value to the chain and, on the other hand, to obtain an economic estimate during the real case of the year 2019 in the months of May, June and July. In addition, by proposing an alternative scenario eliminating the BAM as a distributor of the product and the hypotheses raised, the aim was to carry out a comparative study between the two scenarios in order to evaluate, based on economic results, the possibility of making changes in the logistics organization of the product. The following conclusions can be drawn from these analyses:

- The incorporation of just one volunteer (10% increase) in the internal processes of the BAM can lead to a reduction in queuing times of more than 40%.
- Homogenizing the distribution of food distributed daily (distributing the same amount of food every day) could result in a substantial reduction in queuing times in some of the BAM processes (30 hours in total).
- The proposed model estimates total logistics costs of 61218.3€, a value that is close to the results offered by the BAM, thus validating the model. Of the total logistics costs, it is estimated that 35% represent the initial distribution costs, 30% the costs related to the BAM (receiving-storage-preparation and delivery processes) and the remaining 35% to the final distribution.
- The cost comparison between the models proposed concludes that the transition from a centralized model (current model) to a decentralized model would result in potential savings of 30%. This would make it possible to offset the additional costs that the collaborating supermarkets would experience, in addition to promoting the self-management of the products and the dignity of the beneficiaries by not having to go to a charitable entity to receive the food.

- The solution proposed by the model could help to manage FEAD products in a more appropriate way to feed even more beneficiaries and to fight the SDG goal number 2 "zero hunger".

It is important to clarify that all the results obtained are only an estimate, and that they can be useful to carry out possible evaluations of certain processes or changes in the logistical organization of the products, but a considerable number of hypotheses have been applied to reduce the complexity of the study, as well as computational problems that distance the results from an exact reality.

In short, this project makes a first estimate of the costs associated with the value chain of Fead products of the current centralized model and proposes the transition to an alternative decentralized model with possible improvements in terms of social benefit.

7.1 Contribution to the SDG's

The proposed work results in a novel and significant contribution to the SDGs, with particular reference to point 2 ("Zero hunger"), point 1 ("End of poverty") and 3 ("Health and Well-being").

This project has been developed in close collaboration with the management team of Banco de Alimentos de Madrid in order to maximize the opportunities of the work carried out having a relevant social impact.

Indeed, given the increase in the number of beneficiaries of the Banco de Alimentos de Madrid since the beginning of the COVID-19 crisis, this work proposes a new scheme for the BAM value chain that translates into a potential increase in social benefit of 30%.

In the coming months we will continue to work with the organization's management team to study the implementation and development of the initiative. In addition, this work is expected to result in an academic

publication to promote research in social projects such as the one described here.

Consequently, this work is intended to be a decision-making tool for possible reformulation and improvement of the current Banco de Alimentos de Madrid and, on the other hand, a launching pad for future research projects between the academic world and organizations critical to the functioning of society that help to mitigate hunger and inequality.

7.2 Future developments

Therefore, possible future developments of the work will be oriented to:

1. Improve the representation of the BAM's internal logistic processes in the simulation model and study each FEAD product independently (without groupings forced by computational limitations) to analyze their efficiencies more rigorously and to propose possible real alternatives to the model's responses.
2. To propose a possible incorporation of the initial and final distribution phases in the simulation model for the creation of a final FEAD model that combines both models and allows for new case studies.
3. A more precise conceptualization of the costs associated with the initial and final distribution phases, as these are the phases in which there is a greater accumulation of expenses, and a reduction of the hypotheses proposed and an increase in the detail of the parameters to be considered would bring us closer to realistic conclusions.
4. To further investigate and analyze supermarket supply chains, the logistical phases they present and the methods used by real companies for the analysis of logistical costs, in order to propose, with greater precision, the economic costs in the alternative model.

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