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A Cross-Docking Approach for Farfetch Global Delivery

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Resumo

A *Farfetch* não possui qualquer *stock* de artigos, pois tudo o que vende na sua plataforma online vem de parceiros. Com este tipo de negócio, quando uma encomenda é composta por artigos vendidos por parceiros diferentes, a empresa é incapaz de enviar os artigos todos juntos para o cliente. Este tipo de envio afeta a satisfação do cliente e a empresa constatou que precisa de uma forma de resolver este problema.

O presente projeto pretende estudar uma estratégia logística chamada de *cross-docking*. Esta estratégia logística é algo novo para a retalhista, e é importante identificar quais as variáveis com mais impacto nesta estratégia, construir um modelo que permita perceber qual o impacto no processo de envio de encomendas ao usar *cross-docking*, e quais são as principais limitações da *Farftech* em relação a implementação desta estratégia logística. Neste projeto são estudadas duas situações diferentes, onde aplicar a estratégia referida pode trazer vantagens. A primeira situação foca-se em fazer uma análise de como tem de ser o sistema de processamento das encomendas de forma a suportar *cross-docking* e uma simulação, capaz de expressar o que acontece dentro de um *cross-dock*, alimentada com dados reais, fornecidos pela empresa, e que se foca no mercado Chinês, e que tem como objetivo ganhar conhecimento sobre as operações involvidas em *cross-dock* e sobre os aspetos físicos do edifício. A segunda situação consiste numa simulação, com o objetivo de dar uma perspetiva global ao *cross-docking*, olhando para o processo de entrega de uma encomenda a um cliente, desde o momento em que o artigo saí da loja até chegar ao seu destino final, usando, também, dados reais. A simulação do segundo caso representa o fluxo de encomendas entre a Europa e os Estados Unidos da América e representa dois *cross-docks*, um na Europa e outro nos EUA, sendo que é neste segundo onde acontece a agregação das encomendas.

Cada caso tem os seus resultados, criados depois de correr a simulação. Para o primeiro caso, a variável usada para analisar o impacto da estratégia logística é o tempo que as encomendas passam dentro do edifício. Depois de inúmeras simulações com diferentes configurações, os resultados obtidos são satisfatórios, pois o tempo adicionado, devido à passagem das encomendas pelo *cross-dock*, para a maioria das encomendas, não é suficiente para baixar a qualidade geral do serviço de envio, mas é preciso estudar todo o processo para estabelecer o que acontece quando todo o processo de shipping é tido em conta. O segundo caso, não só olha para o tempo que as encomendas passam dentro dos edifícios, como também usa o tempo em trânsito de cada encomenda para avaliar o impacto de aplicar *cross-docking* nas operações da *Farfetch*. O tempo que as encomendas passam nos edifícios é bastante satisfatório e é melhor que aquele obtido no primeiro caso. Para analisar o tempo em trânsito, a companhia forneceu os tempos usuais desta variável para cada estado Americano e para todas as rotas entre Estados Unidos e todos os países Europeus. Os valores obtidos de tempo em trânsito, na simulação, são mais baixos quando comparados com aqueles que foram fornecidos pela *Farfetch* provando que, mesmo que mais variáveis sejam adicionadas ao modelo, como tempo de desalfandegamento, usar *cross-docking* nunca terá um impacto capaz de baixar a satisfação do cliente no que diz respeito ao tempo que este espera para receber os produtos.

Abstract

Farfetch does not hold stock, everything that its sold on farftech.com comes from partners. With this type of business, when an order is composed of articles sold by different boutiques, Farfetch is unable to send all the items together to the client. The method of shipping impacts the client's satisfaction and the company realized that it needs to have a way to solve this problem.

The current project seeks to study a logistic strategy called cross-docking. Cross-docking is something new for the company, and is important to identify the variables with the most impact in cross-docking, build a model that can be used to understand the impact of this strategy in the shipping process, and what are Farfetch's limitations on implementing this strategy. The project studies two different situations were cross-docking can bring advantages. The first situation focuses on doing a To-Be analysis of the company's order processing system and a simulation, capable of expressing what happens in the cross-dock with the aim of gaining knowledge on the operations involved in cross-docking and the physical aspects of the facility, that runs with real data provided by the e-commerce company and looks at the Chinese market. The second situation consists of a simulation with the aim of giving a global perspective to cross-docking, looking to the process of delivering an order to a client, since the moment of the article's departure from the boutique until arriving at its final destination, also running with real data. The simulation for the second case represents the flow of orders between Europe and the United States of America and has two facilities, one in Europe and another in the USA, where the aggregation of the orders happens.

Each case has its results, created after running the simulation. For the first case, the variable used to analyze the impact of cross-docking is the time span of the boxes inside the cross-dock. After running the simulation with different configurations, the results obtained were satisfactory and the time added due to going through the facility, for the majority of the boxes, is not high enough to decrease the overall quality of the shipping service, but there is a need to study the whole process to see what happens when the whole shipping process is taken into account. The second case, apart from the time span in the cross-dock, also uses the time in transit of each box to evaluate the impact of applying cross-docking in Farfetch's operations. The time span of the boxes inside the facilities is very satisfactory and is even better than the one obtained in the first case. To analyze the time in transit, the company provided the usual time in transit for each American state and for the routes between European countries and the USA. The values for this variable, given by the simulation, are lower when compared to what was given by Farfetch proving that, even if more variables are added to the model, like clearance times, cross-docking will never have an impact capable of decreasing the satisfaction of the client regarding the time that it has to wait to receive its products.

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Filipa Coelho Nunes

"Work hard in silence.
Let your success be your noise."

Frank Ocean

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Abbreviations

B2B	Business to Business
B2C	Business to Consumer
C2C	Customer to Customer
EDD	Estimated Delivery Date
FA	Firefly Algorithm
GLNPSO	Particle Swarm Optimization with Multiple Social Learning Structures
HSA	Hybrid Simulated Annealing
IXD	Inbound Cross Dock
JiT	Just-in-Time
LTL	Less-than-Truckload
OMS	Farfetch Order Management Service
OVRP	Open Vehicle Routing Problem
OVRPCD	Open Vehicle Routing Problem with Cross-docking
PDP	Pick-up-and-Delivery Problems
Post-C	Post-distribution Cross-docking
Pre-C	Pre-distribution Cross-docking
PSO	Particle Swarm Optimization
SA	Simulated Annealing
SIT	Atlas' label SHIPS_INDIRECTLY_TO
TL	Truck-Load
TPL	Third Party Logistic
VRPCD	Vehicle Routing with Cross-Docking
WMS	Warehouse Management System

Chapter 1

Introduction

1.1 The Company

Farfetch is an e-commerce platform funded by a Portuguese entrepreneur, José Neves, in 2008. The idea of the company emerged during a trip to Paris Fashion Week when José realized that independent high-fashion boutiques needed a place in the online market.

Neves was involved in the world of fashion before Farfetch. His grandfather owned a shoe factory and, in the mid-1990s, José launched the shoe design business Swear. Later in 2001, he created B Store, a company dedicated to selling a range of up-and-coming designer labels in a physical store.

José was trying to wholesale the B store brand during the trip to Paris and realized that boutiques owners were going through a rough moment and did not have the expertise on how to enter the online market. They knew that could not rely on local shoppers because their businesses targeted a highly specific customer segment and, with his idea, Neves wanted to give the boutiques support to enter the e-commerce market, but, at the same time, allow them to retain their values and beliefs.

The first round of funding only came on July 9 of 2010, with Advent Partners investing $4.5M in the e-commerce platform and, until this point, José was funding his company with personal funds. The investment helped expand the business market to Europe, North America, and to Brazil. Apart from Advent Partners, as of May 31 of 2018, Farfetch has eight more lead investors, Index Ventures, Condé Nast, Vitruvian Partners, DST Global, Eurazeo, IDG Capital Partners and JD.com. In total, the company of José Neves has eight rounds of fundings and sixteen investors.

The second round of investment was on January 15 of 2012, and injected $18M in the e-commerce platform, with Index Ventures being the lead investor of this round. Condé Nast came has an investor on the third round of funding, that resulted in $20M invested in the Portuguese's company on March 3 of 2013. The next round of funding came on May 1 of 2014, with Vitruvian Partners entering as an investor, and resulted in $66M injected in the fashion business, and on March 4 of 2015 DST Global led the fifth round, that brought $86M to Farfetch.

On May 4 of 2016, two new investors came to the online platform, Eurazeo and IDG Capital Partners. On this date, two rounds of funding happened, the sixth had the two investors mentioned as lead investors and brought $110M to the company, and the seventh round only had Eurazeo as an investor and brought a total amount of $20M into the business. The last round of investment came on June 21 of 2017, with JD.com as the only investor, and resulted on $397M injected into the company of the Portuguese entrepreneur.

Apart from farfetch.com, Farfetch owns Browns, a London Boutique, acquired in May of 2015. Before the purchase, Browns was already a Farfetch partner, but with the acquisition of the first physical, comes the opportunity to innovate the physical shopping experience. In 2015, is announced the project named Store of the Future and, in 2017, José Neves unveil some details about it. The project aims to give an augmented reality to the client and completely change the way of purchasing in physical stores, and it is planned to launch later in 2018, in Browns and Thom Browne, a store in New York.

Farfetch also provides a service called Black & White, that allows other brands to use features of farfetch.com platform on their websites. Brands that want a Black & White service can choose the design of their website but can trust their day-to-day operations to Farfetch.

The company also has a unique delivery service called F90. F90 allows a customer to buy and in 1 hour and 30 minutes later, the package arrives at the destination that the client chose at the moment of the purchase. This service is exclusive to Gucci purchases and is available in 10 cities across the globe, London, Paris, Madrid, Milan, New York City, Los Angeles, Miami, Dubai, Tokyo, and São Paulo.

On the operational side, Farfetch has offices in eleven cities across the world, London, New York, Los Angeles, Porto, Guimarães, Lisbon, São Paulo, Shanghai, Moscow, Hong Kong and Tokyo, with over 1500 employees, and sells products from over 700 partners, including boutiques, dispersed all over the globe, and brands.

Farfetch is a multicultural company and assents on the values of Be Human, Be Brilliant, *Todos Juntos*, Be Revolutionary, Think Global and Amaze Customers day to day.

1.2 Objectives

Farfetch has a very particular business model because it does not keep stock of merchandise, everything sold on farfetch.com comes from partners and, although this constitutes a main advantage to the company because it allows offering the clients a vast range of articles, it is also one of the principal disadvantages. It is a disadvantage because Farfetch partners are around the globe, for example, one client that lives in Portugal buys two articles, one sent from a boutique in Italy, and the second one leaves from a British partner. In this circumstances, the customer receives two packages and, most of the times, they will arrive at different times, which impacts the client satisfaction.

To increase customer satisfaction, Farfetch needs to be able to consolidate the packages, without decreasing the quality of the overall service, which means that the consolidation of the order cannot have a great impact on the shipping's price, and in the delivery time, and this need originated the theme of this dissertation. The principal goal of this research project is to understand in which situations a cross-docking approach can increase the client's satisfaction and what impact will this logistic strategy have in Farfetch and in the shipping service.

In order to reach the main objective, is important to understand the requirements to implement a cross-docking solution and what are the factors that need to be evaluated to correctly analyze the problem of Farfetch's shipping operations and, to achieve the principal objective, the project will focus on:

- **Understanding the operations involved in cross-docking:** Inside the cross-dock, the principal operation is the aggregation of products. To avoid rising the shipping's costs and negatively impact the overall shipping process, in the client's perspective, the Estimated Delivery Date (EDD) of each product needs to be analyzed and needs to be established a maximum value for the gap, between the arrival of the products, that allows having aggregation. Another case of interest is the place where the aggregation should happen, in the case of having multiple facilities. To gain knowledge about cross-docking is crucial to do a literature review on what is already done.

- **Identifying and analyzing the variables with impact on a possible cross-docking strategy:** The first step to start this project is to identify what are the variables with possible impact on a cross-docking strategy. For instance, the number of packages that will arrive at the cross-dock in each day will influence the capacity of the cross-dock.

- **Designing a cross-docking strategy:** After the analyzes mentioned above, there is enough data to start building a strategy to implement a cross-docking approach in Farfetch's warehouses and, to evaluate the influence of the developed solution, there is a need to develop a model capable of simulating this new strategy.

- **Understanding Farfetch's limitations:** Is imperative to understand Farfetch's current platforms and what are the limitations on a possible cross-dock implementation.

1.3 Methodology

Due to the complexity of the project, at the beginning of it, a plan was made, including all the project's tasks. This plan was done recurring to a Gantt chart, Annex A. Table 1.1 records the start date and the ending day of the tasks and, for each task, the table shows if it was finished on time or not. Comparing the chart and the table allows checking the evaluation of the project's state and detect possible delays.

The first task of the project was a two weeks Induction Program. During these two weeks, the principal goal was to get to know the company, how it works, how do the different teams interact, who does what, essentially the induction aims to give a global knowledge to help kick off the actual project.

The second task was researching about cross-docking, to gain knowledge on what is already done, what has an impact to implement this strategy, and who uses this logistic strategy.

The third task was the refinement of the project's objectives, to clarify what this thesis would focus. The fourth task consisted of studying the company and understanding what are the main obstacles when considering the implementation of cross-docking.

The next two tasks are more complex and consist on developing a program capable of simulate cross-docking, recurring to the software called AnyLogic. Lastly, the earlier mentioned tasks happen in parallel with the writing of this thesis.

Table 1.1: Tasks Diagram

Task	Planned Duration (days)	Start Date	End Date	Completed on Time?
Induction Program	10	Feb 5th	Feb 16th	Yes
State of the Art	15	Feb 12th	Feb 28th	Yes
Project's Objectives Refinement	5	Feb 16th	Feb 23rd	Yes
Understand Farfetch's Position	10	Feb 26th	Mar 9th	Yes
Implementation of the Chinese Case	30	Mar 5th	Apr 13th	Yes
Implementation of the Transatlantic Bridge Case	35	Apr 16th	May 11th	Yes
Writing the Dissertation	85	Mar 5th	June 6th	Yes

1.4 Outline

Aside from the present chapter, Introduction, this thesis has four more chapters.

Chapter 2, presents the literature review about cross-docking, reviewing works made about this topic, and some companies that apply this strategy in their operations.

Chapter 3 is about the current situation of Farfetch regarding cross-docking and identifies what a cross-docking implementation will affect.

Chapter 4 contains all the information about what was implemented and studied during the realization of the dissertation.

The last chapter, Chapter 5, is the conclusion of this thesis, showing a perspective for future works and the main conclusion of the dissertation.

Chapter 2

State of the Art

2.1 E-commerce

E-commerce refers to buying and selling products on an online platform. This type of transition can be of three different categories:

- **Business to Business (B2B):** this type of transition happens when the two parties involved are businesses.

- **Business to Consumer (B2C):** when a business sells online to a third-party client.

- **Customer to Customer (C2C):** this type of e-commerce happens in auctions websites, like eBay, where a private client sells to another third-party consumer.

With e-commerce, anyone can buy something without leaving home and has a vast range of products at disposal. Another benefit is the 24-hour availability because with online shopping there is no closing time, which provides flexibility for clients that do not have the time or do not like to go to physical stores. The international reach given to brands or stores is another benefit that e-commerce gives, for the reason that even if a company does not have stores in a particular country, customers from that country can still buy products through the company's website. On the other hand, doing shopping online makes the shopper buy before actually holding the products, which can be a huge downside, apart from the fact that they have to wait to receive the products.

One specific sector of e-commerce is the online luxury market, that is slowing expanding to this type of sales method. Not only the big brands are starting to have their websites, but online platforms, like, Farfetch, Net-a-Porter, and Mytheresa are rising in this market, with their platforms, selling a very diversified range of products from brands, and, in Farfetch's case, from boutiques dispersed all around the globe.

2.2 Overview of a Cross-docking Approach

Cross-docking is a logistic strategy used by many companies nowadays in different industries, based on the idea of having a warehouse or distribution center, called cross-dock, that receives packages from multiple inbound vehicles, sorts, and consolidates everything inside the cross-dock before loading the boxes into the outgoing trucks without the need of storing them. This approach creates a Just-in-Time (JiT) shipping process, that aims to increase efficiency and decrease waste by receiving materials only when they are needed, which eliminates the need of having stock. With cross-docking, instead of shipping small orders, that most of the times, do not occupy the entire cargo area of a trailer, the packages are aggregated into one large lot with the objective of fulfilling the cargo area of a truck (Vasiljevic, Stepanovic, and Manojlovic, 2013, [10]).

2.2.1 Warehousing versus Cross-docking

Warehousing has four main steps, receiving, storage, order picking, and shipping (Bartholdi and Gue, 2004, [34]). If the storage of an article occurs, then an operator needs to unload the packages from the incoming vehicles, stored them, and, in the moment of loading, pick them up from the storage, and only after this, the loading of the items into the truck happens. These movements are demanding labor wise and generate handling costs. The storage of items also creates expenses, defined as holding inventory costs, because demands physical space to hold the items and, if an object spends too much time in the warehouse, it can lose value on the market.

In a cross-docking approach, represented in Figure 2.1, the storage, and order-picking steps do not exist, because the storage of packages does not happen, in fact, a box should never spend more than 24 hours on the cross-dock. This type of approach can eliminate, or drastically reduce, the costs mentioned above, and with the aggregation of different orders and the creation of a Truck-Load (TL) shipping method, the reduction of costs can be even lower.

The operations inside the cross-dock include the unloading of the packages, temporary storage, that may or may not occur, depending on the cross-docking type, discussed in Subsection 2.2.3, but if the storage happens, then this step is followed by picking, product's preparation and loading the outbound vehicle.

2.2.2 Direct-shipping versus Cross-docking

With direct-shipping, the packages ordered are delivered directly to the clients without using intermediate facilities. Usually, each vehicle has a route designated to it and performs one or multiple pickups and deliveries along the path. This strategy needs to program courses which ensures that the vehicle picks up the package before making the delivery, and assumes that all vehicles return to a central depot after making the deliveries. These problems are known as Pickup-and-Delivery Problems (PDP) (Savelsbergh and Sol, 1995, [36]). Tarantilis (2013, [4]) study cross-docking strategies problems know as Problems of Vehicle Routing with Cross-Docking (VRPCD). These two types of approaches always consider that vehicles leave from a central depot, which implies

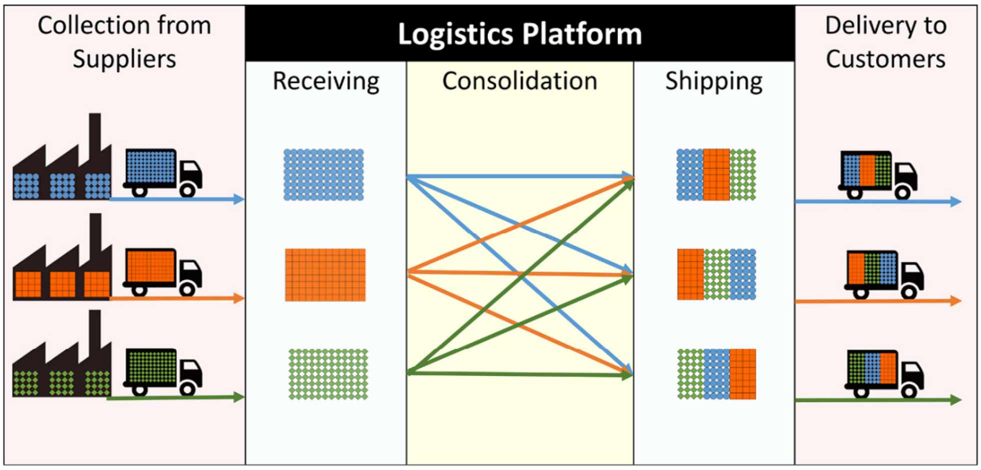

Figure 2.1: A Cross-Docking Approach *in Khalili-Damghani et al., "A customized genetic algorithm for solving multi-period cross-dock truck scheduling problems", [1], 2017*

that the company has its fleet of trucks to make the deliveries. But having a fleet of vehicles can raise the expenses supported by the company, which can be a disadvantage, so the company may hire a Third Party Logistic (TPL) company to make the deliveries. In these cases, the vehicle routing problem is called Open Vehicle Routing Problem (OVRP), and in a cross-docking approach is designated as Open Vehicle Routing Problem with Cross-Docking (OVRPCD). In the problems mentioned, the vehicles do not leave a central depot instead they all converge to the same point, the cross-dock, on schedules times, but the pickup and deliveries happen at different times.

With cross-docking instead of having the trucks delivering their packages to the same stores, the vehicles go the cross-dock, drop all the cargo there, and then the items undergo operations of sorting and aggregation. After these operations, the trucks leave to make the deliveries, but with the guarantee that they will not make the same routes, which lowers the expenses related with shipping when compared with the option of having trucks delivering only one type of product.

Nikolopoulou *et al.* (2017, [26]) used a local-search meta-heuristic algorithm as an optimization framework to compare the PDP and VRPCD models. After various computational experiments, the conclusion reached was that, for a customer located in the same geographic area as the suppliers, the direct-shipping yield fewer costs than deliveries made with cross-docking. On the other hand, when the distance between the pair supplier-customer is abysmal or when the relations between suppliers and customers are many-to-many, cross-docking is capable of reducing costs and, if the location of the facilities is in central positions, the expenses can be even more reduced.

Yu, Jewpanya, and Redi (2016, [28]) considered an OVRPCD and developed a Simulated Annealing (SA) algorithm to solve it. The algorithm uses a constructive heuristic and a local search to improve the quality of the solution found by the SA algorithm. They considered a problem where a retailer supplies a single product to multiple stores in a city. The algorithm determines the optimal number of vehicles needed and their routes.

2.2.3 Cross-docking Types

Cross-docking approaches have multiple classifications across the literature and, one of them, is given by Gue and Kang (2001, [32]) that classifies cross-docking based on different stages. In a single-stage cross-docking system, the items are received and staged on the truck, until being load into the outbound trucks. In the two-stage system, the arrangement of the products happens outside of the truck, following the unloading of the vehicle, and, only after sorting the articles, the loading of the trucks occurs. (Belle, Valckenaers, and Cattrysse, 2012, [15]).

Yan and Tang (2009, [30]) divided cross-docking in two types based on the distribution strategies, identifying Pre-distribution Cross-docking (Pre-C) and Post-distribution Cross-docking (Post-C). Pre-C is a pure cross-docking process with goods being directly loaded onto trucks to be delivered directly to the stores, while Post-C involves sorting the articles according to the needs of the stores. In the Pre-C distribution operation, the supplier is responsible for the preparation and sorting the products according to the store's demand.

Napolitano (2000, [25]) classified cross-docking into manufacturing, distributor, transportation, retail and opportunistic cross-docking. The manufacturing cross-docking involves receiving purchased products needed by the manufacturing processes, while the distributor cross-docking receives products from different suppliers and combines them into a mixed pallet. The customer gets the products when the pallet is complete. In the transportation cross-docking, the inbound products, coming from multiple suppliers, are consolidated to obtain bigger lots, which helps create an economy of scale. The only difference between retail cross-docking and transportation cross-docking is that the first type sends the consolidated packages to retail stores, while the second ships the batches to different industries. Ultimately, any warehouse can have opportunistic cross-docking, where the inbound products are transferred directly to the outbound shipping dock to satisfy the client know demand.

Belle, Valckenaers, and Cattrysse (2012, [15]) divided cross-docking based on physical, operational and flow characteristics.

Physical characteristics are fixed aspects of the cross-dock like its shape, number of doors, internal transportation method, and the existence of temporary storage. A cross-dock assumes a lot of shapes, and the number of recommended doors is calculated based on the volume of packages that it receives, a topic reviewed in Section 2.3.

Regarding the internal transportation, it can be manual or automated, depending on the system implemented in the cross-dock. In respect of temporary storage, in one-step cross-docking, the temporary storage does not exist, but, in most cases, there is temporary storage, and the products stay in front of the outbound door.

The operational characteristics are the service mode, allowance of pre-emption, and occurrence of temporary storage.

Regarding the service mode of the cross-dock, it can operate in an exclusive, mixed, or combination mode. If each dock entry is dedicated exclusively to inbound or outbound vehicles, then the cross-dock has an exclusive service mode, but if a door can either accept incoming or outgoing vehicles, the service mode is mixed. Lastly, the combination mode happens when a subset of doors works in exclusive mode, while the rest of the entries of the facility operates in a mixed mode.

With the allowance of pre-emption, the loading or unloading of a truck can be interrupted, and another vehicle can take its place. The unfinished truck is later docked to finish the process. The temporary storage can be viewed as an operational characteristic, because, in many cases, the decision to not store any products can be made, for instance, to avoid congestion inside the cross-dock.

The flow characteristics considered are the arrival pattern and departure time of the vehicles, product interchangeability, and temporary storage.

The vehicles can come to the cross-dock in a concentrated way if a great number of incoming trucks arrive at the same time to the facility, or scattered, where the incoming vehicles enter the cross-dock at different times during the day. The arrivals times influence the congestion of the cross-dock.

The departure time of the trucks can be restricted or not. If there are no restrictions, the vehicles can leave right after the loading or unloading, but both inbound and outbound trucks can have restrictions on the departures times, depending on the schedule of the truck's next transportation. For instance, if an outbound truck needs to meet a specific time to arrive at its next location, the moment to start loading is set in a way that ensures the departure of the truck at the proper time.

In post-distribution cross-docking, product interchangeability is allowed, and the quantity and type of products to be loaded are known, but the same does not happen in Pre-C.

In some cases, the storage of a particular product is not allowed, for instance, a non-cooled facility cannot be used to store refrigerated products, so the temporary storage has an impact on the flow of products inside the cross-dock and this flow can restrict it.

2.2.4 Advantages and Requirements of a Cross-docking Approach

The main advantages of a cross-docking approach are the elimination, or drastically reduction, of holding inventory and handling costs, as mentioned in Section 2.2, apart from this, cross-docking offers many other advantages (Belle, Valckenaers, and Cattrysse, 2012, [15]). As no storage occurs, the square meters needed for the facility space are lower when compared with usual warehouses, the risks of having overstocks are also lower and, since the operations of handling inventory are less, the probability of damaging the products during the process decreases.

During the unloading of the products, the staff can quickly inspect the inventory and detect defected items, which avoids clients receiving damaged products, so with cross-docking, the quality of the service given to the client improves too. Apart from this, with the facilities allocated on strategic places, the shipping costs are also reduced, because the aggregation of articles decreases the numbers of vehicles going to the same place, which reduces the total distance traveled in the delivery process, making the process more environmentally friendly.

Even if the cross-docking brings a lot of advantages, is crucial to understand that this strategy also has drawbacks, and they need to be taken into account, to accurately determinate the suitability of cross-docking to a specific type of business. Schaffer (1997, [23]) divided into six categories the requirements to implement a successful strategy:

- **Partnerships:** Partnering with the other members of the supply chain is essential because cross-docking can increase their effort and the costs sustained by them.
- **Confidence:** A successful operation depends on the suppliers. The suppliers need to be able to deliver the products at the right time and in perfect condition. If this does not happen, the orders will be late, which impacts the customer's satisfaction because inside the dock there is no margin for error, and wait for delayed articles is not acceptable.
- **Communication:** In a JiT process, like cross-docking, the communication in real-time between the different members of the supply chain is crucial and, to make this possible, the implementation of good channels of communication needs to happen.
- **Control:** Inside the cross-dock, the products need to move quickly, which imposes the need to control and communicate inside the facility, and, to allow this, the cross-dock should have a Warehouse Management System (WMS) available (Belle, Valckenaers, and Cattrysse, 2012, [15]).
- **Staff, equipment, and facilities:** Setting up the cross-docks will take time and requires a large initial investment. The staff needs to be well trained to correctly manage all the operations, and this may involve the necessity of training them.
- **Operational management:** The management involved in the operations is very complicated. Is necessary to ensure that all the previous requirements are met to ensure the efficiency of the cross-dock' operations.

2.3 Strategy to Implement a Cross-docking Approach

To implement a successful cross-docking strategy, the company that wishes to implement this type of approach needs to evaluate a group of factors. First, if the company already has warehouses, it needs to evaluate if the facilities are eligible to become a cross-dock. After deciding the location and shape (Belle, Valckenaers, and Cattrysse, 2012, [15]), the next step is to build a schedule for the operations inside the cross-dock, to avoid having more inbound trucks than those it can accommodate at the inbound docks.

2.3.1 Location of the Cross-docks

Multiple articles discuss the issue of the location of cross-docks. One of them is by Sung and Song (2003, [24]), that applied a tabu search based algorithm to decide the location of a cross-dock from a variety of possible locations. To defined the best place, they considered that each cross-dock has a fixed building cost associated. Another consideration is that only two types of vehicles are available and the transportations costs are related to the distances and the type of vehicle utilized.

A tabu search algorithm is a meta-heuristic algorithm used to avoid local optimization. This type of algorithm consists of having multiple rounds and, in each iteration, is found a potential solution with a solution neighborhood associated with it. At each iteration, the algorithm moves from solution to solution, erasing the previous neighborhood, and saving a new one, until it reaches the best solution for the problem.

Sung and Yang (2008, [7]) extended Sung and Song (2003, [24]) work and implemented a change in the algorithm previous done, that allowed finding exact solutions, introducing a branch-and-price algorithm.

These two articles did not consider direct routes since all the routes include a passage in the cross-dock. Gümüş and Bookbinder (2004, [11]) studied the problem of cross-docking considering the possibility of direct routes. In their article, they admitted that a cross-dock facility has two expenses, one of them are fixed costs per period related to investments in land, labor, and equipment, and the second one is the cost of throughput of each unit. As for the transportation costs, it has two distinct costs associated, one of them being the fixed cost of each vehicle, and the other is the cost per unit load per unit distance. They used a heuristic based algorithm to solve the problem, using LINGO and CPLEX software packages, and to each case studied, the algorithm chooses the best cross-dock to process the order or if the delivery of that order should be direct.

Mousavi and Tavakkoli-Moghaddam (2013, [2]) also proposed a meta-heuristic based algorithm to deal with the problem of cross-dock location. This article presents a two-stage Hybrid Simulated Annealing (HSA) algorithm, embedded with tabu search. The solution proposed for the cross-dock looks for the least-cost solution, and the algorithm reduces the revisits of solutions and decreases the computational time needed to reach the solution. They also applied this algorithm to the vehicle routing problem, topic discussed in Subsection 2.3.3.

2.3.2 Cross-dock Shape

To know if a warehouse is fitted to become a cross-dock, the company should analyze its current shape. Like it was said in Subsection 2.2.4, the investment to build cross-docks can be quite high, so doing a reform of a warehouse, after deciding what would be the ideal shape, can be an advantage. Sometimes, the determination of the shape depends on the size of the lot available (Bartholdi and Gue, 2004, [34]).

To decide the best shape for the cross-dock is necessary to calculate the number of doors of the facility. The cross-dock has two type of gateways: receiving or inbounding doors and shipping or outgoing doors. The amount of shipping doors is relatively easy to determinate, since, usually, each destination has a gateway assigned to it, except destinations that have large volumes of orders and, in these cases, the same local has more than one entry allocated to it (Bartholdi and Gue, 2004, [34]).

The determination of the number of inbound doors can be more difficult because it demands knowing how many trucks come to the docks at the same time and the destination of the products that they bring. For LTL cross-docks, Little's law provides an estimated number of receiving doors by multiplying the throughput of trucks by the average time that it takes to unload a truck (Bartholdi and Gue, 2004, [34]).

The most usually shape for a cross-dock is an I-shape. When the facility has 150 doors or less, which is the most common case on the cross-docking approach, the shape used is the I-shape. This shape allows having a direct path from the inbounding doors to the outgoing entries, that lowers the amount touches that the materials suffer to the minimum possible, reducing the costs associated with the transportation of the products and decreases the space needed inside of the facility. To larger buildings, with 150 to 200 doors, a T-shape has proven to be the best design, while for facilities with more than 200 gates, an X-shape facility must be used (Bartholdi and Gue, 2004, [34]). For these cross-docks cases, the I-shape design is less effective because the distance between the doors starts to increase, which increases the movement costs.

Is convenient to determinate the most used doors and, to make this determination, there is a need to calculate the distance of one gateway to all of the others in the cross-dock. In the I-shape facility, the most used doors are the central ones, because if a truck goes to them, the products are expected to travel less, no matter the destination door. If the inbound door is not centered, then the outbound door should always be one of the neighbor's doors.

Apart from the mentioned above, is also important to calculate the freight area. The determination of the area is done based on the usual cargo that a truck brings to the cross-dock and, usually, the staging area is located right in front of the dock door (Bartholdi and Gue, 2004, [34]).

2.3.3 Truck Scheduling

Apart from the problems discussed in the last two subsections, scheduling the arrival and departures of trucks is one of the principal obstacles in cross-docking approaches. Khalili-Damghani *et al.* (2017, [1]) chose a genetic algorithm to obtain the best sequence of inbound and outbound trucks, to minimize the time of operations and to optimize the shipping process. They assume that the cross-dock operates in an exclusive mode, discussed in Subsection 2.2.3, where different types of products are loaded and unloaded sequentially, pre-emption is not allowed and the truck changeover time, as well as the time required to move products between doors, is fixed. Apart from this, they do not constrain the capacity of the storage area and allow intermediate storage inside the cross-dock.

Khalili-Damghani *et al.* (2017, [1]) consider a one-period scenario where trucks have due dates and, because of that, the loading or unloading needs to occur at very specific moments. In the same article, they extend the model to a multiple-period planning horizon. To analyze the output data, multiple statistical analyzes where done, and the genetic algorithm showed good results and, for small and medium-sized instances the algorithm was capable of achieving an optimum solution. For cases with larger sizes, the solution has suitable quality.

Wisittipanich and Hengmeechai (2017, [38]) also discussed the problem of truck scheduling in cross-docking by using a modified Particle Swarm Optimization (PSO) model, with multiple social learning structures (GLNPSO). A PSO is an algorithm that optimizes a problem by iteratively trying to improve a possible solution, taking in consideration a given measure of quality, and GLNPSO is based on PSO but uses a different type of learning. They considered a multi-door cross-dock problem and created a schedule for all the trucks going into the cross-dock with the objective of minimizing the wait time for each truck. As constraints to their model, they assumed that the capacity for the temporary storage was infinite, operations like labeling, sorting, packing or unpacking, were not considered. Apart from this, pre-emption is not allowed, the time to unload or load a single product unit is constant, and is not taken into account the sequence of unloading or loading the articles.

Mousavi and Tavakkoli-Moghaddam (2013, [2]) applied the HSA algorithm to VRPCD. The algorithm's objective is to minimize the total transportations costs associated with moving the products, the operational expenses of each vehicle, and the penalty costs for the earliness and tardiness deliveries to customers. Their program gives the number of vehicles used and the best route for each, as well as the time of arrival of each truck at the cross-dock.

Tarantilis (2013, [4]) also studied the VRPCD problem and applied a multi-start tabu search algorithm to solve it. He only considers one cross-dock facility with multi-vehicle routing, but assume a one-to-one pairing between supplier and costumer. With the insertion of a restarting mechanism in the classic tabu search, the algorithm is able to connect different solutions, i.e., instead of always searching for the route with minimum costs, the program is able to find the best solution starting with the solution previously found and by doing this, the algorithm is able to create routes with multi-connected nodes.

2.4 Case Studies of Successful Cross-docking Implementations

In this section are presented some companies that, even though they are not in the fashion business, like Farfetch, use cross-docking in their operations and prove that this type of approach reduces the costs and improves the overall efficiency of the supply chain.

2.4.1 Walmart

Walmart Inc. is an American multinational retail corporation that operates a chain of hypermarkets, called Supercenters, most of them operating in a 24-hour shift, with the first one opening in 1988, discount department stores, with Sam Walton, Walmart's founder, opening the first one in 1962, and grocery stores, called Neighborhood Market, opening for the first time in 1998, and this Neighborhood Market was designed to provide small communities a pharmacy, affordable groceries, and merchandise.

Cross-docking is vital in the supply chain of Walmart because is used to replenish the inventory of the hypermarkets and allows the elimination of extra storage, transferring all the items directly from the inbound to the outbound trucks. The strategy has proved to improve efficiency, minimize transportation time and helped reduce prices.

This approach was implemented in the early 1980s and became quite important because Walmart started to purchasing the items directly from the manufacturer and distributing the products with its fleet of vehicles. As of now, Walmart has more than 150 distribution centers across the United States of America. The network of cross-docks ships general merchandise, dry groceries, perishable groceries, along with other specialty categories daily. Six of the distribution centers are disaster distribution centers, strategically located across the country and stocked to provide rapid response to struggling communities in the event of natural disasters and with the launch of e-commerce, Walmart now also has fulfillment centers, strategically located in the United States of America. Each fulfillment center has unique characteristics based on its location.

Suppliers and manufacturers within Walmart's supply chain synchronize their demand projections, inventory forecasting, and stock replenishment. This integration between the entire supply chain helps everyone knowing the whole process and helps them behave, almost, like a single company.

Over the past years, the company has become the world's largest retailer and one of the most powerful and, in 1989, was named the Retailer of the Decade, with estimated distribution costs at 1.7% of its cost of sales, while its competitors reached values like 5%. And this was only possible because Walmart was one of the first companies to realize the advantages of cross-docking and was successful in its implementation.

2.4.2 Amazon

Amazon is an American e-commerce platform funded in 1994 and, only in 2015, Amazon surpassed Walmart as the most valuable retailer in the United States. In amazon.com, a customer can buy books, music, movies, toys, housewares, electronics and many more types of products. The company also makes the famous e-book reader, Kindle, and since its launch, Amazon became a major force in the book market. As of now, when a client buys more than one item in the platform, an option to consolidate the packages is available, as long as all the orders are sold or fulfilled by amazon.com, and reduces the costs of shipping. Items that ship within 3 days or less of placing the order are sent together and, items that take longer than 3 days to ship are sent together based on their availability.

A diverse type of facilities owned by Amazon uses cross-docking. To receive products from overseas to the U.S., Amazon has facilities called Inbound Cross Dock (IXD). As of now, Amazon owns eight IXD in the United States of America, but the construction of one more, in the first quarter of 2019, is scheduled to happen. Outside America, the numbers are not completely available, but, in Germany, there is information about two facilities, and in the United Kingdom, one will be built. In this cross-docks, the products are received, broke into small bulks and temporarily stored until the fulfillment centers ask for the products. When this time comes, the merchandise is aggregated into truckloads and transported to the fulfillment centers. The IXD facilities are located near the major U.S. ports to minimize inbound ground transportations costs from the port to the facility.

Apart from this facilities, Amazon also has 39 sorting centers, with the plan to build one more in the future, known as cross-docks, just in the United States of America. In these buildings, the packages are sorted by zip codes and, after the sorting, delivered to post offices responsible for each zip code. The boxes are then delivered by the United States Postal Service, which allows taking volume from UPS and FedEx. This system was introduced in the U.S. in 2014 and helped Amazon taking control over its outbound shipping costs.

The number of facilities is not completely available, especially outside of U.S., but in France, Amazon has one sorting center, in Germany, in the future, the company wants to have one, and in India, there is information about Amazon having 25 sorting centers.

2.4.3 Target

Target Corporation was funded in 1902 and is the second biggest discount store retail, losing only to Walmart. Just like Amazon, Target has multiple facilities with different purposes and applies cross-docking in two different type of facilities.

When Target needs a smaller shipment, of less than truckload volumes, the shipment is processed in a domestic consolidation point, that act as a cross-dock. In the present moment, Target has a network of seven of these facilities, all in the United States of America, that are run by third-party logistics companies. In these facilities, the pallets with the products are unloaded and consolidated to enable the transfer of these products to Target's regional distribution centers.

The company has 26 regional general merchandise distribution centers in the United States. These facilities also use cross-docking as logistic strategy and operate in an exclusive-mode, having one side of the dock dedicated to inbound trucks, while the other side is exclusive to outbound vehicles. The operations involved in the cross-docking process are, mostly, done in an automated way, where the packages, pre-labeled boxes, are unloaded from the trucks directly to conveyor belts, and go directly to the outbound dock door, allowing the reduction of costs with material handling.

2.4.4 Sonae

Sonae is a Portuguese retail company funded in 1959 by Afonso Pinto de Magalhães but only started to grow during the 1980s, after Belmiro de Azevedo assumed control of the company.

Sonae's brands are the favorites among the Portuguese consumers.

In 2015, the company had a project to optimize the routes network and, one of the aspects covered was the implementation of cross-docking. According to the company website, the project was born with the need of simplifying the distribution design and reduce the logistics costs and, in order to achieve this, the principal focus of the project was to reduce the number of trips, and the distance traveled.

The redesign of the distribution model was achieved through multi-load planning and cross-docking operations, revising the truck's rental mode and the type of vehicles in the fleet. The company declared more than 1.2 millions euros globally gained during the year and the reduction of costs, in distribution centers, was more than 1.5 million euros. Apart from this, the number of trips in that year reduce 16.4%, and the cargo space of the vehicles occupied increased by 7%.

2.5 Conclusion

E-commerce is a growing business, but to stay ahead of the competitors, Farfetch needs to identify opportunities to differentiate from its business rivals, and one of this opportunities is studying the implementation of a cross-docking strategy.

Inside a cross-dock, only three operations need to happen, and they are the unloading and the loading of the trucks, and the operation of consolidation. Concerning the facility, the most important parameter is the number of inbound and outbound doors, related to the number of packages that the cross-dock will receive in a day, the location of the building, and the shape of it.

Most of the articles available solve a simplified version of the truck scheduled problem in cross-docking. They consider a one-door problem and a one-to-one relation between client and supplier. In the real world, cross-docks have more than one door on the inbound and outgoing side of the facility, and a relation many-to-many is highly probable to happen, especially on an e-commerce platform like Farfetch, but heuristic or meta-heuristic algorithms, like tabu search, genetic algorithms or particle swarm optimization, are generally used to solve problems related with cross-docking.

After reading the case studies mention in Section 2.4 and, taking in account, that the first three companies are among the most powerful companies in the U.S.A., this indicates that they are an example to follow when it comes to supply chain optimization, that, in these cases, includes cross-docking implementation. Sonae, the Portuguese group, has proven that the implementation of cross-docking, improves the overall efficiency of the supply chain, and can reduce the costs of products' transportation. None of the companies are in the same area of business as Farfetch, but the one with most similarities is Amazon, and if cross-docking works so well in Amazon, the fourth most valuable public company in the world, Farfetch needs to look to this case of success and analyze the possibility of implementing cross-docking.

Chapter 3

Farfetch Current Situation

Cross-docking is a new strategy for Farfetch because currently, the e-commerce platform does not apply cross-docking in the shipping process, so is necessary to analyze its system structure to understand what this new strategy would impact.

Figure 3.1 represents the system breakdown structure, and the next subsections of this thesis explore each component. Apart from identifying each part of the system, is also essential to understand the connection between them, and, in order to do this, was drawn an activity diagram, Figure 3.2, that allows getting the full vision of the order processing where a cross-docking strategy will have an impact.

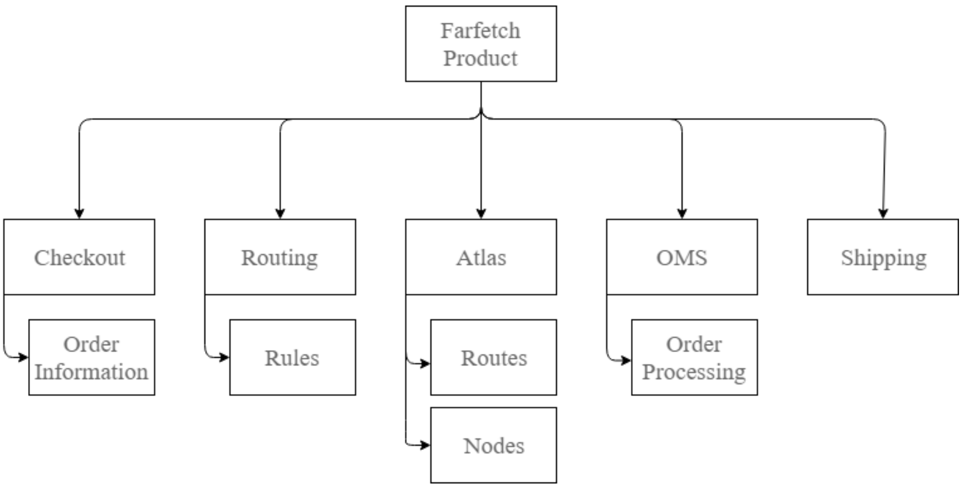

Figure 3.1: Farfetch Order Processing System Breakdown Structure

After this analysis is right to conclude that a cross-docking implementation would affect the Checkout process, that sends messages to Routing, being that this last one consumes data from Atlas. After the client confirms the order, the Order Management Service (OMS) receives information about that order and starts a process with the final objective of shipping the article.

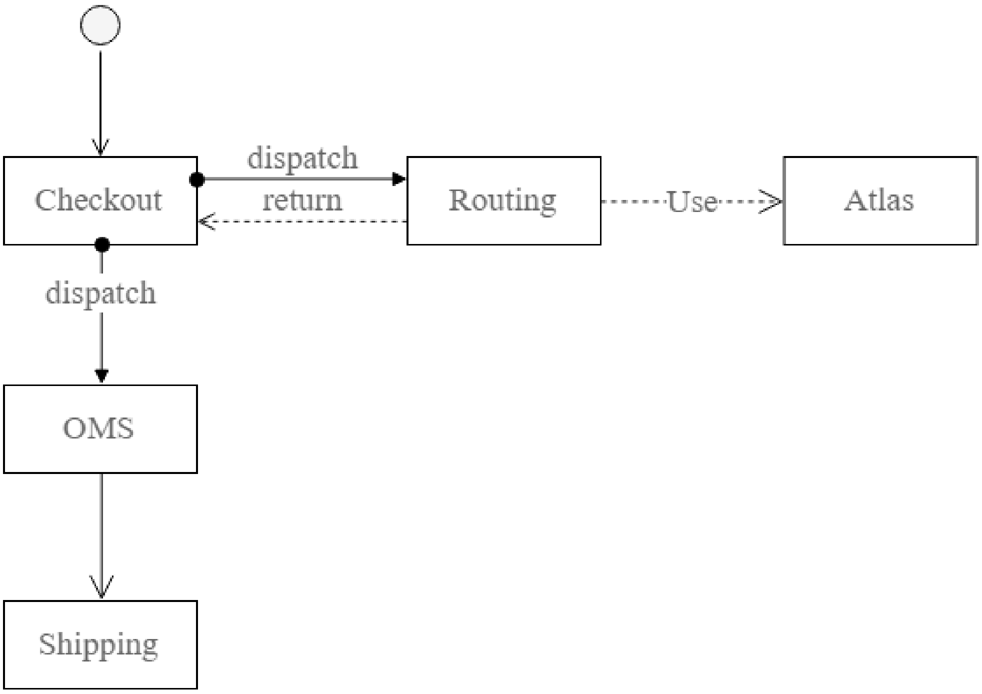

Figure 3.2: Farfetch Order Processing Interactions

3.1 Checkout

Checkout is the section in farfetch.com where a client can confirm the purchase of the desired items and, this action, marks the beginning of the order processing by Farfetch. Currently, three major steps constitute Checkout:

- Shipping;
- Payment;
- Review.

The first step in Checkout is the shipping tab, where the user needs to choose the delivering place of the order and the destination can either be an address or a Click & Collect point.

The succeeding step is the selection of payment method, that varies accordingly to the destination address. Depending on the method of payment chosen, the following steps can diversify. For instance, if a client selected payment with credit card, then information about the card will be asked, but if a user selects to pay with PayPal, Farfetch's Checkout only needs to know what is the email of the client's PayPal account.

After this, the remaining step is the review, where the customer chooses the desired shipping method. The most common method of shipping is standard or express service, but two other services, Same Day delivery and F90, this last already overviewed in Section 1.1, may be available.

The Same Day delivery availability depends on destination city, and is available only in New York, Madrid, Milan, Paris, London, Barcelona, Los Angeles, Miami, and Rome, and with the boutique that sells the item ordered by the client. Only a couple of boutiques in each city are suitable to do services of Same Day deliveries, and, with this type of shipping service, the client receives the order in the same day of placing it.

To be able to decide which shipping services are available, Checkout needs to communicate with the Routing service, because this service is responsible for deciding the shipping methods available at the moment of placing an order. The Routing service is discussed in detail in Section 3.2.

The shipping costs are related to the shipping service selected, and different services can have different couriers assigned, being UPS and DHL the couriers most used. For each shipping service, the client has information about the shipping cost and the EDD. If the client is purchasing more than one item, and the articles come from different boutiques, then Checkout shows information about the client receiving two or more packages.

When a customer confirms the order, all the items inside the client's virtual basket will have a common identifier, designated portal id, associated with the client's order. Each article in the basket will then have a specific identifier, called boutique order, that distinguish the different articles of the same order.

3.2 Routing

As told in the previous section, the Routing service communicates with Checkout providing information about the available shipping services to a specific order, and is responsible for selecting the stock point to fulfill an order.

A stock point is a local where a partner has stock of products. If the partner is a boutique, most of the times, the stock point is the boutique. This type of partners are small businesses and keep all the items in the store, but if the partner is a brand, most of the times, there are multiple stock points capable of fulfilling an order.

In order to determine the best stock point capable of fulfilling a customer request, Routing takes into account information like the stock depth of each fitting stock point, the capacity of satisfying a whole order, and the commission earned by Farfetch with the sale of a certain item in each stock point. The stock point owner defines this commission with Farfetch and, aside from what was already mention, Routing also takes into consideration the preference set by partners from where to ship items and the destination of the order.

Apart from communicating with Checkout, Routing consumes data from another service, called Atlas, discussed in the next section of this dissertation.

3.3 Atlas

Atlas is a centralized service with information regarding shipping's routes, storing information about the expenses associated with each route, the courier assigned to it, and the exclusivity of the route.

This service receives requests from the Routing service and filters the fitting routes. After finding all these routes, Atlas returns them to Routing, even if a route leads to a stock point that does not have stock to fulfill the order.

Atlas consumes this information from a database of graphs, called Neo4J. In this database, a node represents a location identified by its zip code or the location's country name, and the label SHIPS_TO is used to identify the routes between two nodes. Apart from these nodes, there are nodes labeled as All World Nodes that represent a place connected to the rest of the world, in order to lower the complexity of finding a fitting route.

The availability of services like F90 and Same Day is done recurring to nodes identified by zip code, but this type of nodes prove to be a barrier in the countries that do not have zip codes.

3.4 Order Management Service

OMS is responsible for processing an order after it enters Farfetch's system and has six steps, represented in Figure 3.3, and is necessary to understand this process to identify in which steps a cross-docking strategy will have an impact.

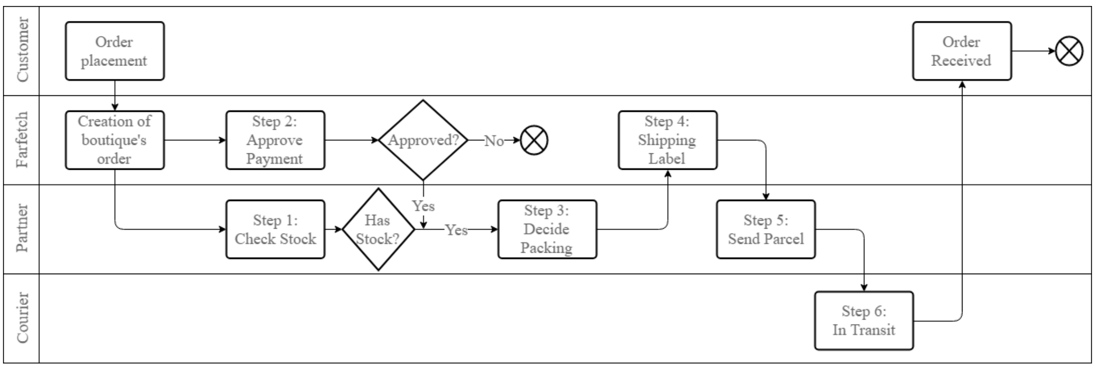

Figure 3.3: Farfetch Order Processing Steps

If a store desires to sell an article on farfetch.com, the boutique has to agree with Farfetch requirements, because the e-commerce company decides the article's display style on the platform. If the boutiques agrees, then it needs to send all the items to one of Farfetch's Production offices. In these offices, a photographer from the eTailer company takes pictures of the items and, after this, the object is ready to be listed on farfetch.com. Lastly, Farfetch sends the article back to the partner. This whole operation happens to all the articles listed on the website.

Step 1, Check Stock, is a responsibility of the boutique chosen by Checkout, and consists of checking if the partner has stock to fulfill the order. Cases of no stock can happen when Checkout chooses a boutique, but this boutique does not have stock, that may happen, due to an offline sale. An offline transaction occurs when a partner sells the article in the store and, after this transaction, it needs to update the stock in a Farfetch application, given to all the partners, used to synchronize the stock between them and farfetch.com. In the case of no stock, the customer receives information about the situation and, sometimes a similar article is suggested, and the customer accepts this suggestion, but, if no similar articles are fitting of being a suggestion or the client does not accept it, the customer receives a refund.

Farfetch is responsible for the execution of *Step 2, Approve Payment,* that occurs at the same time as the previous step. In this step, Farfetch's fraud team checks if the payment is fraudulent or not, which can be an automatic process or not. In order to accelerate the time span of this step, although its time span is much lower than the time span of *Step 1*, the e-commerce platform has a group of lists in the database, about clients that previously made purchases in the platform. The likelihood of being fraudulent is based on the placement of each client in a list. If the client was ever fraudulent than, for that moment forward, all the orders placed by this client are automatically declined, but in the cases that Farfetch does not have any information about the client, a manual process begins and consists in investigating the client to determinate the probability of being a fraudulent payment.

The Step 3, Decide Packing, only beings after the approval of the payment and confirmation of stock to fulfill the order, given by the boutique. Each item has a suggested package, decided when the products are in the Production office, but the boutique can choose another package, not attending to the suggestion. The packages are given to the boutiques by Farfetch, and each partner needs to manage the stock of it in the store, and, when it is low, the boutique oughts to require more.

After packaging the order, the e-commerce platform has the duty of creating the shipping label, *Step 4,* that, most of the times, is an automatic process. When the client did not provide the full information or correct one, the information needs to be edited manually and, only after that, the boutique can print the label, and the order is ready to be sent.

The next step, *Step 5, Send Parcel,* begins automatically after *Step 4* and, if the boutique has daily pickups scheduled, then the package is sent in the next pickup, but if not, the scheduling of pickup with the courier needs to occur.

The last step, *Step 6, In Transit,* is a responsibility of the courier and precedes the reception of the package by the client. When the courier processes the package, the client receives an email with shipping's confirmation and information about tracking.

3.5 Shipping

For shipping an order to the client, Farfetch only does direct routes, which means that the order goes straight from the boutique to the customer, without intermediate stops. A client who purchases multiple articles receives them one by one, with the exception of articles that belong to the same boutique. Indirect routes, made in cross-docking approaches, in the eTailer platform only happen in returns, and this approach is called multi-leg logic.

A multi-leg logic happens when a package suffers a stop, or more, before arriving at its destination, and in Farfetch's returns originated outside of Europe, that are going back to a European boutique, all the packages need to re-enter Europe through the United Kingdom. These orders suffer a stop in London's warehouse, Norsk, and after begin received, they go back to the boutique that sold the article. In this approach, the shipping label received by the client in the article's package, has the address of Norsk and corresponds to the first leg. The shipping label for the second leg is printed in the English warehouse and has the address of the boutique.

The indirect approach allows lowering the taxes of re-entering the European space, that is proven to be inferior when this re-entering happens through the United Kingdom.

Choosing the courier for the deliveries is also an important part of the shipping process. UPS and DHL are couriers generally used, but when the market demands it, the utilization of local couriers to deliver the packages can happen. For instance, in Brazil, the courier used is Correios, the Brazilian post, and for domestic orders in China, Farfetch uses SFExpress to delivery the packages to Chinese clients.

Chapter 4

Proposed Solutions

At the beginning of the project, it was clear that increasing the customer satisfaction had to be studied in different situations, and, in order to do this, were identified two application cases. In order to improve the client's satisfaction, the objective is to aggregate the maximum amount of articles of the same order, reducing the number of packages that a customer receives.

The first application case looks to the Chinese market and, in this case, the aim is to gain knowledge on how cross-docking works and what needs to change in Farfetch's Product to support this type of strategy.

The second case is a transatlantic bridge between Europe and USA and, this case, is an extension of the first case. With the simulation for this case, the aim is to analyze the whole shipping process, since the moment of leaving the boutique until reaching the client, and see how this strategy affects the lead time of the orders.

4.1 Chinese Case

The solution for the Chinese market case is divided into two big groups, one being the To-Be analysis of Farfetch's order processing system, and the other a simulation of the cross-dock, to gain knowledge on what happens inside the physical installation.

4.1.1 To-Be Analysis

Checkout

With cross-docking implemented in Farfetch, the client would have a new choice in Checkout, the option to consolidate the order. The presentation of this option would be a check-box and, if the client clicked on it, then a boolean variable, indicating if a client wants to aggregate the articles or not, would be set to true.

If the customer selects the cross-docking option, services like Same Day delivery or F90 are disabled, and the client can only select standard or express delivery. Besides this, near the check-box, information about the number of packages that the client will receive and the EDD for each box would be displayed. The price to pay for this service is related to the status of the client, which means if a client has VIP status, then the selection of this service does not imply more costs.

Routing

Apart from the EDD, to evaluate the suitability to suffer consolidation is important to look at the route of the parcel and, to know this, is critical to understand what needs to change in Routing, so it can identify in which routes the operation is possible.

For the present case, Routing only allows the aggregation if the order's country of destination is China and if the parcels are not domestic, i.e., if the parcels are not from Chinese partners, which means that consolidation only happens between articles with international origin.

As mentioned in Subsection 2.2.1, is not desirable for a package to stay more than 24 hours inside the cross-dock, so for packages where the difference between the EDD is superior to one day, the consolidation will not be available. Delaying the shipping of one of the parcels is possible, which is overview later on this subsection, although this action needs to be carefully done to prevent decreasing the overall quality of the service given to the client.

Atlas

Atlas also needs a new configuration, visible in Figure 4.1, to respond correctly to Routing requests. Here, the first step would be to add a new node in Neo4J, representing the cross-dock, configured as an intermediated point, i.e., a node that will be identified by zip code, not considered as a destination, but as a stopping point in a route. The next step would be to add routes from all the nodes in the database, with exception of nodes that represent Chinese cities, to the newly created node and from this node to all the nodes representing Chinese cities, and configure these routes with a new type of label, named SHIPS_INDIRECTLY_TO (SIT).

The SIT label allows distinguishing between direct and indirect shippings. To check for aggregation availability, Routing would check for SIT labels instead of SHIPS_TO, but always use as origin the location of the stock point and client's address as the destination, which means a route is always between the two points mentioned. The only difference between the labels is that, when Routing selects a route marked as SIT, the order will go through the cross-dock.

OMS

Since the consolidation will affect the orders is important to understand what needs to change in OMS to allow the aggregation of the articles from the same order. With cross-docking implemented, OMS needs to be able to know which order will suffer consolidation, information given by Shipping.

The first order to arrive at the cross-dock is the mother-box, which means that all the boxes that arrive after this one, with the same portal identifier, will inherit information from it. The

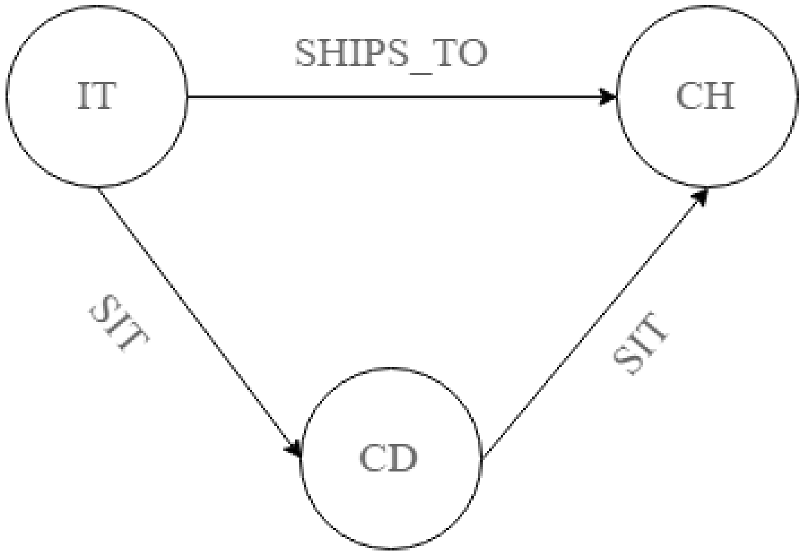

Figure 4.1: Atlas representation with IT, Italy, CH, China, and CD, cross-dock, nodes, and the different type of routes' labels

information to inherit is the tracking number, to allow the client to follow the order with only one tracking number, and the time of dispatch from the cross-dock.

Another new functionality studied for OMS was the possibility of delaying shipping to get EDD compliance. For example, a client makes a purchase of three items, two of the articles arrive at the cross-dock on the 17 of April of 2018, and the other arrives in the 15th of the same month and year. Taking into consideration the rule of the 24 hours inside the cross-dock, mentioned in Subsection 2.2.1, the item arriving in the 15th is not suitable for aggregation with the remaining articles. The possibility of delaying the shipping of the article arriving first at the cross-dock was studied, to enable the consolidation of all the packages.

To make this happen, OMS needs to give information to the boutique responsible for shipping the item, about the delaying of the pickup and when will it happen, allowing the arrival of the boxes at the same time at the cross-dock. Looking again at the example given above, considering that the two items arriving in the 17th are picked up in the 15th, but require two days to arrive at the cross-dock, and the other article is picked up in the 14th and only needs one day to reach facility. With the functionality of delaying an order, OMS would talk with the boutique shipping the article arriving first, and give the information that the pick up will not happen in the 14th, but in the 16th. If the article only needs a day to reach the cross-dock and if it is shipped in the 16th, then it will arrive at the same time as the other two at the cross-dock.

This functionality brings up a concern because, if the pickup is delayed, then the item remains in the physical store, giving the boutique the chance of selling the article in the store, even when this article was already sold in farfetch.com, but this is a question of confidence in the partner. If a partner wishes to have a good relationship with Farfetch, then it will not sell the article. With this new functionality, the boutique needs to confirm the stock of the item twice, so Farfetch knows if the partner sold the item in the physical store. The boutique would need to confirm the stock when the order enters Farfetch's system and before scheduling the pickup and, only after this step, the scheduling of the pickup happens. If in the second confirmation of stock, the boutique marks a no stock, it will be penalized based on the e-commerce platform metrics to evaluate partners' performance.

Shipping

With cross-docking, the shipping in Farfetch will assume a multi-leg logic when the consolidation of the parcels happens, because the order will suffer one stop before arriving the client. In these cases, the shipping label of the first leg will have the address of the cross-dock, and the second leg's label will have the address of shipping inserted by the client in Checkout. The shipping label for the second leg is printed in the cross-dock, after the aggregation of the packages.

Taking into consideration the rule of the 24 hours is necessary to know when the package will arrive at the cross-dock, to calculate the differences in the arrivals of the boxes that belong to the same order. To enable this calculation, Shipping needs to provide an EDD for each package. Aside from this, Shipping also needs to be able to raise a warning flag if any of the package suffers a delay, to recalculate the difference between packages' arrivals. If this difference is bigger than 24 hours and only a package is in the cross-dock, this package needs to be closed, marked as ready to load, and the operator needs to print the shipping label. If two or more articles are already in the cross-dock, these items suffer aggregation, the operator marks them as ready to load, and prints the shipping label for the second leg.

A warehouse management mobile application allows doing the operations of marking as ready to load and print the shipping label. In this application, the operators also mark each article as received in the dock when it arrives at the cross-dock, and can view information about the placement of the packages, in Subsection 4.1.2 these operations are discussed with detail. Farfetch has a platform dedicated to returns, used by Norsk, that allows the user to choose which packages suffer aggregation. This feature is not used, but it would be a good starting point for developing the mobile application, because it allows to reuse what Farfetch already has, and this platform already has the capacity of generating the shipping label for the second leg.

4.1.2 Simulation

Like it was said at the beginning of this section, the principal objective of this simulation is gaining knowledge about the operations involved in cross-dock, and what is the appropriate dimension and shape for Farfetch's case. Is important to enhance the fact of the company only wanting to understand the points mentioned, which means that a topic studied in the literature review, the truck scheduling problem, was not considered in the simulation. In the simulation, the scheduling of the trucks was very simple and will be explained further in this thesis, alongside the other functions developed. In Farfetch's case, the classification for the truck scheduling problem is OVRPCD.

Accordingly to Subsection 2.2.3, cross-docking in Farfetch is classified as a Post-C because the sorting happens in the warehouse of the company, and, for the Chinese case, this strategy resembles with a distribution cross-docking, due to the client only receiving the articles after suffering operations of sorting and consolidation, and receives them all in the same box.

The software used for the simulation is AnyLogic, a simulation modeling tool that supports agent-based, discrete-event, and system dynamics simulation's methodologies, and includes a graphical modeling language with support for Java code. An agent-based simulation has active identities, known as agents, that identify their behavior and the connections between them. An agent can be an operator of the cross-dock, and even the cross-dock can be an agent in the whole supply chain. A discrete event simulation is a sequence of separate, discrete, events, that represent actions, for example, the unloading and the loading of a truck are discrete events because are nothing more than a sequence of actions that lead to empty or to fill a truck's cargo area. A system dynamics simulation is the more abstract type of simulation of the three mentioned, because it ignores the details of the system, such as the properties of the operators or the occurrence of events, like the arrival of a truck to unload, and produces a more general representation of a complex system.

The simulation done in this project is a combination of agent-based and discrete events, and uses graphical modeling language and Java code. This combination allows simulating the behavior of the identities involved in the operations of the cross-dock and, with discrete events, was possible to simulate the operations involved in the aggregation of the packages. The simulation uses data provided by the company, referent to November of 2017. During this month, in China, happens Singles' Day, a Chinese holiday, and, due to this holiday, during November, the volume of orders is higher than usual, helping study the necessary capacity for the cross-dock, to ensure a good performance, especially during spikes of orders. Annex B shows the query used to obtain the data. An excel file was used to save the results obtained by the query and, after this, AnyLogic connects with this file to save the information for the simulation.

The program also has the capability of allowing simulations in 2D and 3D and allows the definition of specific view areas that define what the user sees. In the program developed exists five different view areas. The default area is the 3D view of the cross-dock because it allows understanding what is happening inside of the dock. The other four are the view area of the statistics, the block-logic behind the simulation, the third is the view of the cross-dock in 2D, and the fourth is the area with all the functions and variables created in the main agent, described further in this paper. The user can switch between the areas using a bar that appears in all the views.

Cross-Dock

Regarding the dimensions of the building, the length of the cross-dock is 235 meters, while the width is 51 meters. The cross-dock was designed to have all the inbound dock doors on the same side, and the outbound dock doors on the opposite side, being that the building has 20 gates of each type. Between each door, exists a space of two meters, and each gate has a width of eight meters, but only four of them are space where the truck can dock because the racks, used to store packages, occupy the remaining four.

The packages are stored in the cells of pallet racks, distributed in different levels and sides of the rack. The number of cells is calculated based on the length of the rack, that is 12.6 meters, and the cell width, approximately, 60 centimeters, which means that each level of the rack has 21 cells. The rack has eight levels, each with 60 centimeters of height, making it have 4.8 meters of height. Each pallet has two rows, left and right, and a total width of eight meters, two of it dedicated to the left row, another two to the right row, and the remaining four meters are the space between the rows destined to the circulation of the workers.

The maximum number of items stocked in the loading racks and in the unloading racks are different because the cells of the loading racks can store up to four packages, while each cell in the unloading racks can only hold one item. This configuration is different because of the place where the aggregation takes place.

The consolidation of the packages happens in the loading dock and, in order to facilitate this operation and reduce its duration, the same cell is used to stock the boxes that suffer consolidation, and if more than four packages undergo an aggregation, the nearest cell available is utilized to keep these articles. The operation is smoother as result of the operators knowing that all the items in the same cell will be aggregated together, without even looking for the information about the placement of the packages, which reduces the duration of the task, since the worker does not have to use the mobile application. The unloading dock's racks do not have the same configuration because each agent can only move one box at a time, and having multiple boxes in the same cell does not bring any improvement, besides the gain of additional storage that, in this case, is not needed.

Cross-Dock's Operations

Inside the cross-dock, the principal operation is the consolidation of the orders, but apart from this, also happens the unloading and loading of trucks, and moving the boxes from the inbound storage to the outbound storage. The operation of unloading is done by one operator responsible for taking all boxes out of the vehicle and store them in the unload rack and, when the worker unloads an item, this operator needs to use the mobile application, and marked the box as received. This marking as received allows saving the moment of arrival of the package at the cross-dock and identify on which package the operation of consolidation will happen because it allows identifying which package is the mother-box.

After the storage of the box in the unload rack, an operator is designed to move the package to the load rack. When the operator takes the item from the unload rack, the worker consults the application dedicated to the cross-dock management, to know to which dock door and cell the article needs to go. After placing the package in the right position, the worker needs to use application once again to know if any article suitable for aggregation is arriving, if it is, then the operator leaves the box open, but if not, then two outcomes are possible. If the package belongs to an order of only one article, then the operator moving the box is responsible for printing the second leg' shipping label, close the package, and mark it as ready to load. For the cases where the package moved is the last one arriving suitable for aggregation with boxes already inside the cross-dock, then all the boxes of that order are marked as ready to aggregate. After this operation, another worker does the aggregation of the articles.

The operation of consolidation begins with the operator taking all the packages of the same order, marked as ready to aggregate, out of the racks. After this, the worker will transfer all the articles to the inside of one box, the box that arrived first at the cross-dock, the mother-box. Following this operation, the worker prints the shipping label for the second leg and paste it on the top of the just closed the box, marks the box as ready to load, and stores the package in the cell reserved for the mother-box.

The operation of loading starts after assigning an operator responsible for taking all the boxes from racks and put them into the truck. The worker takes the boxes marked as ready to load, without the needing of using the application, due to the boxes' appearance, since all the packages ready to load are the only closed boxes in the load racks. After loading the packages, the operator needs to mark them as loaded, in order to record at which time the package exited the cross-dock.

Agents

The agents defined in the simulation were the *Boxes*, *Forklift*, *Load dock*, *Unload dock*, *Loading Truck* and *Unloading truck*. Each one of this agents, with the exception of the agents representing the docks, has a parameter called presentation, that defines how the agent looks when the simulation is running. The *Forklift* is represented by an operator sited in a forklift, the *Loading Truck* and the *Unloading truck* are represented by a white and black truck, respectively, while the boxes have three different presentations.

The agent *Boxes* represents each package that enters the cross-dock and the main variables associated with this agent are the portal id of the order, the boutique order of the article, the number of items inside the package, that, by default, is 1. Aside from this, the agent contains variables to store the final destination of the order, the position where the box should be placed in the loading dock, and a boolean variable called *readyToLoad*. This boolean variable is marked as true when the box is moved to the load rack, if it will not suffer consolidation, or after the consolidation of the multiple items from the same order.

In terms of presentation, as mentioned previously, this agent has three different presentations, simulating the appearance of the boxes inside the cross-dock, during the various steps inside the facility. The modification of the box appearance eases the work of the operators that know in which state the package is, without using the dedicated application, as mentioned previously in the loading operation. When the box arrives at the cross-dock, the box is closed and has printed in the top the portal id. After moving the package to the loading racks, the agent can assume two different presentations, if the box will suffer any operation of consolidation then the package appears has an open box that has the portal id printed in one of the sides of the package. After the consolidation, or if no aggregation happens, the box, again, appears as a closed package, but with a paper on top of it, representing the shipping label for the second leg, and the portal id.

For the *Boxes* a state chart was elaborated, Figure 4.2, in order to choose different courses for each box in the system. Not all the boxes that go through the cross-dock are suitable of suffering aggregation, either because the order only has one item, or because the articles arrive with more than one day in between, and, for these cases, is important to let the package leave immediately after arriving at the cross-dock. The initial state of the chart is active when the package is waiting for being unloaded. After being placed in the unloading rack, a message is sent and fires the transition, putting the agent's state chart in the next state, *moveToDockDoor*, that will remain active until the placement of the package in a loading rack, and, in this step, is chosen the path for the box. If the package will suffer an operation of aggregation, then the agent receives a message to wait for aggregation and goes to the state *waitForAggregation*, but if the box will not suffer consolidation, then the message received is that the box is ready to load, and the state active is the *waitForTruck* state. When the chart reaches this state, happens the marking of a package as ready to load, and, when a loading truck arrives, the last state is activated, and the loading starts.

The *Forklift* represents the operator responsible for the operations that happen in the cross-dock. Each forklift only has two variables, one used to mark it as occupied, *inUse*, and another to assign it to an unloading or loading truck. The *Forklift* agent is placed in the cross-dock in a specific place, in order to control where the forklifts are when they are not in use.

The *Load dock* and the *Unload dock* agents represent the outbound dock and the inbound dock, respectively. Each one of these agents has parameters related to simulation's configurations, like the storage rack, the place where the packages are stored, assigned to it, the node where the unload or load happens, and the number of the dock. Apart from this, the two mentioned agents also have the spot where the truck should dock and where it should turn to start approaching the dock, and, for the loading dock, an extra parameter is used to identify where the operation of consolidation takes place.

Apart from these parameters, the two agents mentioned have a group of variables in common giving information about the occupancy of the dock, that refers to the existence of a truck suffering any operation in that dock, the forklift assigned to do the operations of loading or unloading, and the space available for storing more packages. Besides the two already mentioned, the agent of the load dock also has a vector of strings with the cities assigned to that dock. Like mentioned in Chapter 2 is a good practice to have cities assigned to each dock, and that principle was applied in the simulation.

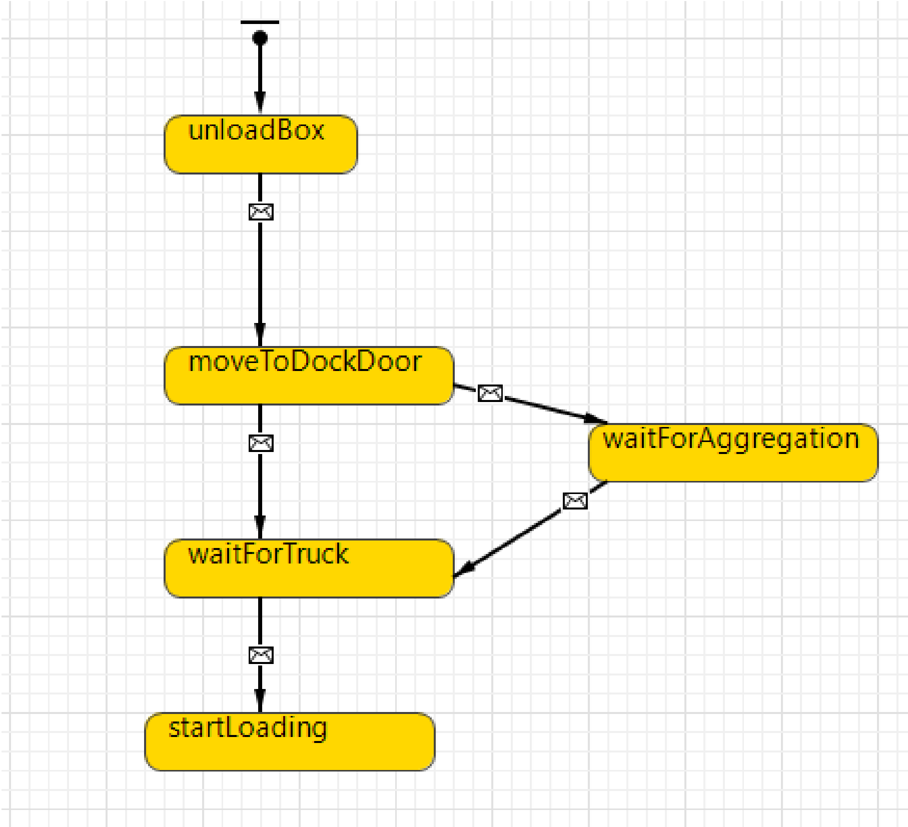

Figure 4.2: State Chart for the *Boxes* agent

The *Loading Truck* and the *Unloading Truck* agents represent the vehicles that come to the cross-dock. These agents have a variable indicating the number of packages already processed, meaning the number of packages already loaded or unloaded, respectively. Apart from this, the two agents have a variable to store information about the dock where the parking of the vehicles will happen, and a variable about the capacity of the truck, that needs a further explanation because of Farfetch's business model. Farfetch does not have a fleet of vehicles, so the shipping process is all made by external companies, which means that it does not control how the courier will make the pickup of the merchandise in the boutiques. Due to this fact, the information about the capacity of the trucks was not available, and, to the simulation, the capacity of the vehicles was crucial. The way for working around this problem was by calculating the capacity of the vehicles, but in different ways to the agents mentioned.

For the *Loading Truck* is assumed almost infinite capacity, meaning that each incoming truck carries everything marked as ready to load in the dock assigned to it. The capacity of the *Unloading Truck* is based on the number of packages received in each day and is calculated by dividing this value by 24, that represents the 24 hours available in a day to do the operation of unloading. If the amount of packages received in a day is lower than 24, then only one agent is created and is assumed that it brings all the articles.

Apart from these parameters, each of these agents has a function responsible for incrementing the number of processed packages, that returns true when this number equals the capacity of the agent, and this marks the ending of the process of unloading or loading.

Lastly, in order to run the simulation, the program needs to have a top-level agent that can connect all the other agents, named *Main*. All the previous agents, excluding the *Forklift*, have a population located in the main agent, and the parameters of the other agents are defined in this agent. This agent also has parameters that, in this case, are user's inputs, and are the total number of loading and unloading docks, and the number of loading docks that store only articles going for Hong Kong. Apart from these parameters, the user also needs to choose the number of operators of the cross-dock, the speed of the trucks that arrive at the cross-dock and the time needed for using the dedicated application, but Table 4.1 lists all the variables able for configuration.

Table 4.1: Configurable parameters in the simulation for the Chinese Case Study

Parameters configurable	
At the beginning of the simulation	**Through coding**
Number of loading docks	Maximum and minimum value of loading docks allowed
Number of unloading docks	Maximum and minimum value of unloading docks allowed
Number of loading docks to Hong Kong	Maximum and minimum number of loading docks to Hong Kong allowed
Number of operators	Maximum and minimum number of operators allowed
Truck speed	Maximum and minimum value allowed for the truck's speed
Time needed for using the mobile application	Maximum and minimum time to use the application allowed
	Loading Schedule
	Time between arrivals to enable consolidation

Simulation's Logic

Four major groups compose the simulation's logic. The first group is the logic for the unloading process, followed by the logic of moving the unloaded packages from the racks in the inbound dock to the storage in the load docks. After this, is evaluated if the article will suffer consolidation, if not the box moves to the loading logic block, but if it will suffer consolidation, then the agent, representing the item, goes to the logic block of the aggregation.

Apart from these four groups, were define blocks of resources. The resources identified were the loading docks, the unloading docks, the operators responsible for the aggregation of the packages, the workers in charge of doing the loading of the trucks and then a group of operators responsible for all the others operations previously mentioned. Each resource has a capacity established, and these capacities are the input parameters of the main agent. The resource pool of the loading dock has a capacity equivalent to the parameter of the number of loading docks, and the resource pool for the unloading docks has a capacity equivalent to the parameter of the number of unloading docks. For this pool, each resource created is added to the correspondent population, load docks, and unloading docks, respectively, and they are configured as static resources, meaning that these resources do not move.

The forklifts deserve special attention because the resource pool for the forklifts is divided based on their location in the cross-dock. For aggregation, exist two pools of resources, one in the right side of the cross-dock and one in the left side. This division also happens for the forklifts responsible for loading the trucks and the group that does the remaining operations. The number of forklifts allowed to do consolidation operations is stable and is always two, because in the loading docks, as previous mention, the cells can hold more than one item and work with cell depth was more challenging than what was expected. Due to this difficulty, only one aggregation can happen at each moment in each side of the cross-dock, because the aggregation's logic is divided in two based on the number of loading docks, but this will be explained with detail later in this section.

Is necessary to enhance that the dock has 20 entries, a value given by Farfetch based on a warehouse that is planned to be used by the company, but the simulation may not need to use them all, and because of this, is crucial to explain the actual capacity of each resource pool. The capacity of the forklifts, in the left side, responsible for the operation of loading is always 10, because the minimum value of loading docks, in this simulation, is 11, so the simulation always uses the left half of the cross-dock's entries. The capacity of the forklifts on the right side is the result of subtracting 10 from the number of loading docks.

Lastly, the pool of operators assigned to do the operation of unloading and moving the boxes has the remaining forklifts. The capacity of this pool is the result of the difference between the number of operators, a user's input, and the capacity of the resources pools explained above. This capacity is split by the forklifts in the left side and on the right side, and Equation 4.1 shows the formula used to obtain the capacity of the pool in the left side. The objective of the equation is to set the number of forklifts available for each unloading dock, and then multiply this value by the number of docks served by the pool of forklifts in the left side. The number of docks served by this pool is always 10, because, in order to run, the simulation needs to have, at least, 12 unloading docks. The capacity of the pool of forklifts in the right side follows the same logic and Equation 4.2 shows the formula used.

$$\frac{Number\ of\ Forklifts\ -\ Number\ of\ Loading\ Docks\ -\ 2}{Number\ of\ Unloading\ Docks} \times 10 \tag{4.1}$$

$$\frac{Number\ of\ Forklifts\ -\ Number\ of\ Loading\ Docks\ -\ 2}{Number\ of\ Unloading\ Docks} \times (\ Number\ of\ Loading\ Docks\ -\ 10\ ) \quad (4.2)$$

These resources have a configuration of moving resources and is necessary to define their speed, set to 5 km/h. The value for the speed was chosen based on the recommended safety speed for forklifts that move inside warehouses.

Starting with the logic of the unloading process, the arrival of the first truck triggers the activation of a one-time occurrence function responsible for the attribution of destinations to the load docks and of a function responsible for doing initializations of vectors. The amount of docks to Hong Kong is an input of the user, with a minimum set to five docks, because, after analyzing the data, was possible to conclude that 53.57% of the orders made during November of 2017 have as destination Hong Kong. This volume of orders to Hong Kong happens because of the difference in the laws of importing between China and this city, and due to this, people often tend to ship articles that come from outside of China to Hong Kong and, after arriving there, they ship the items to China.

At midnight of each day, a function is responsible for checking, from the database with data about the orders, which orders have the EDD equal to the present day and for storing in an array the portal id, boutique id, country and city of destination for the orders that will come to the cross-dock in that day. Apart from this, the function also sets the total number of boxes that will come to the cross-dock.

The arrival of the first vehicle in each day sets the calculating of the number of trucks that will arrive in that day and is calculated based on the total number of packages, arriving in this day, divided by the capacity of the unloading truck. If the value obtained multiplied by the agent capacity does not equal the number of packages, then it means that the calculation produced a non-integer value, and the truck that arrives first, will have its capacity adjusted to compensate the difference between the total packages received and the multiplication mention.

After arriving in the dock, the truck needs to seize a dock where the unloading can happen. Each time that a vehicle seizes a dock from the unloading docks' pool of resources, this dock is marked as occupied, until the vehicle that seized it leaves the cross-dock. If a truck comes into the cross-dock, and no dock is available, it waits until a dock is available. Following this task, the vehicle parks in front of the entrance to start the unloading process, and, when the vehicle stops, an operator is chosen to do this operation, based on the number of the dock. If the number of the dock divided by two is lower or equal than half of the maximum amount of unloading docks in the cross-dock, always considered as twenty because this is the maximum amount of entries that can be used, then the forklift chosen is from the resource pool on the left, but if not, then the forklift chosen comes from the pool in the right. As soon as the worker starts moving, the operator is marked as busy. Following the unloading of one package, happens the creation of an agent in the population of boxes. The moment of creation sets the portal id, boutique id, country and city of destination, of the agent and, after setting this information, a counter used to know which row of the array, containing the information mentioned, needs to be checked, increments. The truck leaves the dock when all the packages that it brought are unloaded and, when it leaves, the truck's seized dock is released and marked as free, and the truck is deleted from the system.

The unloading of a box triggers a function responsible for associating the number of boxes to be aggregated with the one that just arrived. This function checks all the packages with the same portal id coming in the current and following day. The base for the time gap between arrivals is the 24-hour rule, but is important to understand that the EDD provided by Farfetch defines the moment of arrival. This value does not give an estimation in terms of hours, which causes, for some packages, spending more than 24 hours inside the cross-dock, depending on the hour of arrival of the trucks, that is random. For instance, if a box arrives in the 5th of November, then the packages to be aggregated with this one, need to come during that day and during the 6th. If the first box arrives at 8:00 and the last one, already arriving in the following day, arrives at 14:00, then it is cleared that the total time span inside of the cross-dock is larger than 24 hours. So, for this case, the limit time span inside of the building is set to 48 hours. Apart from this, is important to understand that because of considering the EDD as the date of arrival in the cross-dock and only considering orders placed in November, the first and the last days of the month have lower volume than normal. No orders can arrive on the 1st of November, and in the second day of this month only five come to the dock, because, during this first days, the clients are making the orders. The simulation finishes in the 27th of December, but only two boxes arrived in this day, as result of the last order considerate being placed in the 30th of November and the larger part of the packages arrived before the 7th of December.

Aside from what was mentioned, the function triggered by the unloading of a package, also verifies which load dock is assigned to the box's destination and reserves space for the package in the load rack, in accordance to what was already mentioned in the case of already having a box with the same portal id inside the cross-dock. If the article is the first one of the order arriving or if no consolidation will happen, the space reserved is the nearest to the dock door, on the lowest level of the rack, and on the right side of the rack. This preference is set to speed up the process of loading because the closest the boxes are to the entrance of the dock, fewer steps the operator need to give, and placing the boxes in the lowest level has the same purpose, considering that with this, the worker does not need to lift the forklift, which reduces the time to take the packages from the rack.

Following the unloading of a box, starts the second major step, the moving of the package, occurring in parallel with the unloading of a vehicle. For each article, one free agent from the forklifts pool is selected, based on the same principle of choosing the forklift responsible for the unloading of the trucks. An explanation about the operation of moving the boxes is given in one of the previous subsections, and the simulation replicates the process described. To simulate the use of the mobile application, the agent stops moving and stays in front of the racks.

If the box is going to suffer consolidation, in the simulation, the agent waits in a block, that resembles a queue, but with a functionality that allows releasing agents in a custom way. Is important to explain that when the agent enters the logic of consolidation, the block where the agent waits depends on the number of the agent's load dock. If the number of the load dock is lower or equal to ten, half of the maximum number of loading docks, then the agent will wait in a block that leads to the box being consolidated by the forklift in the left side responsible for this operation. If the number of the load dock is greater than ten, the agent will wait in a block that leads to the operator on the right side. Each time a box enters this block, a function checks if the packages that already are inside the block have the same portal id and batch size, and for each found, it increments a counter. After checking all the agents in the block, if the counter matches the desired size of boxes to aggregate, the packages are released, and the operation of consolidation starts. The simulation follows what was explained previously about the operation of aggregation.

In the simulation, the variable *itemsInside* of the mother-box, after the consolidation, equals the batch size, and, for the remaining packages, the variable is zero. At the end of each consolidation, a function checks which boxes have the number of items inside equal to zero and deletes them from the population of boxes.

The only remaining group is the loading process and is crucial to understand that the arrival of load trucks to the cross-dock follows a schedule. This schedule defines at which hour the loading trucks come to the facility and the number of pickups that happen in a day. When the moment of a pickup arrives, a function checks which dock has packages marked as ready to load. If it has, then the dock is marked as can be seized and a counter is incremented, to know how many trucks will come into the cross-dock. If the dock does not have packages ready to load, then no truck comes to that dock because the dock is not marked as can be seized, and the counter does not increment in these cases. The number of pickups is programmable before running the simulation, as well as the moment of occurrence.

The process of entering the dock is similar to the one explained for the unloading process, with the difference that only loading docks, marked as can be seized, are available for seizing. When the truck parks in front of the dock, a function responsible for counting the number of boxes marked as ready to load in the dock seized by the vehicle, that now has the status of occupied, defines the number of packages that the truck will have to carry away. The parking of the truck triggers the beginning of the loading process that follows the process described in the Subsection 4.1.2. The loading truck leaves when all packages are loaded and, when it exists the cross-dock, the assigned loading dock is also released and marked as free. Lastly, the vehicles and all the articles that it carries are deleted from the system.

<u>Results</u>

The simulation has minimum requirements to run, and the results mention below are obtained with the parameters set to these minimums. There are 11 loading docks, 5 of them dedicated to Hong

Kong, 12 unloading docks, the time dedicated to using the warehouse application is 35 seconds, the speed of the trucks is set to 25km/h and exist 107 operators inside the cross-dock. The number of operators was set to avoid having wait time for lack of operators, despite the simulation running with less but at the cost of increasing the average time inside the facility. For this case the schedule has three pickups, the first one happens at midnight, the second occurs at 8:00, and the last moment of loading is at 16:00.

To evaluate the impact of cross-docking in Farftech, aside from the programming of the operations inside the cross-dock, were elaborated some statistics, that can be seen in Annex C. First, there are two graphs made at the start of the simulation that remain static during it. The graphs are both pie charts, and one of them shows the number of orders with more than one item and the number of orders with only one item. This graph shows that 35.9% of the orders made by Chinese customers, during the month of November, can be suitable for aggregation, a value superior to what the company was expecting. This graph does not take into account the 24-hour rule, and the percentage of 35.9% represents a total of 12553 orders, from the total of 34979 made during that month, and represents a total of 36819 articles.

The other pie chart takes into consideration the 12553 orders that can suffer consolidation and divides all the orders based on the number of articles that each order has. There are nine partitions that go from orders with two articles to orders with ten or more. This graph shows that 56.9% of these orders have two items, which represents a total of 7144 orders, but the number of orders with ten or more items, representing 1.2% of the total orders that can suffer aggregation, which is equivalent to 154 parcels, surpasses the number of orders with eight and nine articles.

The pie charts mentioned are in the view area of the statistics, alongside two others that have the input data altered during the simulation. One of this non-static graphics is a pie chart, just like the static pie charts, but the other is a stack chart. The pie chart shows the number of packages aggregated, to understand the impact of the rule of the 24-hour, because this rule causes the non-aggregation of packages that, without it, can suffer consolidation. At the end of the simulation, the graph showed that from the 36819 items that could suffer aggregation, only 22.4% did not go through this operation, which means that 28555 articles suffer an operation of consolidation. The stack chart has the same propose as the pie chart, but shows the number of items sent in each package that leaves the cross-dock. This graph has the nine partitions previous mentioned and allows comparing the two graphs with this division. Taking, for example, the case of orders with two items, at the end of the simulation, 7032 packages exited the cross-dock with that amount of items inside, which represents a difference of 112 boxes between what could be and what was actually aggregated, after considering the rule of the 24-hour. For the case of boxes with ten or more articles, only 56 packages left with this amount of items inside, less 98 boxes when compared with the static chart.

Aside from these four graphics, three more can be seen in the 3D view area, that change during the simulation and, one of them, is a time plot that shows the average time to unload and to load a truck. In this graphic the unit of measure is minutes and, by the end of the simulation, the average time to unload a truck is 75 minutes, while the time to load a truck is around 20 minutes. The second one is also a time plot, that uses hours as the unit of measurement, and shows the average time that a box spends inside of the dock and, for the case of the three daily pickups, the average time inside the dock is 9.2 hours.

The average time inside the dock is mainly related to the gap between each pickup. For instance, if two articles from the same order arrive at the cross-dock with a space of one hour, where the first arrives at 8:30, and the other arrives at 9:30. If the boxes were aggregated and shipped immediately, then the time inside the dock would be around one hour, because the operation of aggregation does not take long. In the case of three pickups, the next load truck only arrives at 16:00, which causes the box to spend 6.3 hours inside the cross-dock. In order to confirm the relation between the time spent in the dock and the number of pickups, this last variable was incremented to four. The time gap between the pickups, for this case, was reduced to six hours, instead of eight, meaning that the first pickup happens at midnight, the second at 6:00, the third at 12:00, and the last occurs at 18:00. After running the simulation, with all the parameters equal to the initial simulation, except for the loading schedule, the time plot showed an average time inside the dock of 7.5 hours.

The last case considered has four pickups but with different time gaps between them, where the first one still happens at midnight, but the second occurs at 4:30, the third pickup is at 8:00, and the last batch of loading trucks arrive at 16:00. With this loading schedule, the time plot shows a average time inside the cross-dock of 6.5 hours. This three different configurations for the loading schedule show that, not only, the amount of pickups influence the lead time inside the dock, but also, the moment of the pickup is also a variable with influence.

The last graph in the 3D view area is a bar chart that shows the number of packages aggregated per day and the information in this graph updates at the beginning of each day. Each day where, at least, one operation of aggregation took place has a bar in the graph and, each bar, has a label with the date of the day, with this format YYYY-MM-DD, and the number of orders aggregated. The day with most aggregations is the 30th of November, with 863 orders suffering consolidation.

Aside from all the graphs mentioned above, at the end of the simulation happens the creation of an excel file with two sheets. The first sheet has information about every package that exited the cross-dock, showing the portal order id associated with the box and the time of arrival of the mother-box at the cross-dock. Apart from this, exists a column with the moment of loading the box into a truck, the number of packages aggregated with the mother-box, and the total time spent inside the dock. This sheet has 41455 records, a number that represents the total amount of packages that left the cross-dock, taking into consideration all the boxes, and not only the ones that suffer aggregation. This sheet allows a deeper knowledge of the time spent inside the cross-dock and the number of items in the boxes when departing from the dock. After observing the data in the file, is possible to see that the package that holds more items left the dock with 20 articles inside, and the biggest time span in the cross-dock was 46.491 hours, fulfilling the limit of 48 hours inside the facility. Lastly, some calculations were made to realize the number of orders that spent more than 24 hours inside the dock, the preliminary limit of time span inside the dock, and to determine the number of packages that spend 9.2 hours, the average time inside the dock, or less in the facility. Only 3884 packages, representing 9.37% of the boxes that left the cross-dock, surpassed the time mark of 24 hours, and the data reveals that 36111 packages, 87.11% of the total packages, spend less or equal time inside the dock that the average time.

After doing the others simulations, more calculations were added to this sheet to compare the results obtained in the different situations. Each case has a report, and the results of each case are in Table 4.2.

Table 4.2: Results of the three simulations for the Chinese Case

	Case with 3 pickups	**Case with 4 pickups and 6-hour gap**	**Case with 4 pickups and different time gap between them**
Number of packages and percentage that spent more than 24 hours in the facility	3884/9.40%	4020/9.70%	4120/9.94%
Number of packages and percentage that spent 9.2 hours or less in the facility	36111/87.11%	35995/86.82%	35579/85.83%
Number of packages and percentage that spent 7.5 hours or less in the facility	25435/61.36%	35303/85.16%	34510/83.25%
Number of packages and percentage that spent 6.5 hours or less in the facility	13853/33.42%	33928/81.81%	33712/81.32%
Biggest time span inside the dock (hours)	46.491	41.783	46.111

After analyzing the data, is possible to see that the number of packages that spend more than 24 hours increased slightly when the average time reduced. In the case of an average time of 7.5, the case represented in the second column, the longest time span inside the dock, was decreased in, almost, 5 hours. The case with four pickups and a time gap of 6 hours between pickups showed overall better results, except for the number of packages that spent more than 24 hours in the cross-dock, and the case of four pickups with different time gap performed worse than this one in all the results. In the second case, 81.81% of the packages spent 6.5 hours or less inside the facility, while with the three pickups only 33.42% of the packages have a time span lower or equal to this value.

The second sheet is related to the operations inside the cross-dock and has a line for each day of the simulation. Each row has a column showing the number of packages received in each day, the number of boxes and orders that suffer consolidation, the amount of incoming and outgoing trucks, and another column that shows the percentage of boxes that suffer aggregation. The column of the packages aggregated does not take in account only the amount of received articles but also the packages that are already in the cross-dock waiting for other boxes to arrive, which helps to know the number of packages that suffer aggregation to evaluate if cross-docking is viable for Farftech or not. The day with the highest amount of received items is the 27th of November, and 5560 boxes entered the facility, and the day with more packages aggregated is the 16th of November, with 2551 packages aggregated, but this day does not represent the day with more orders aggregated, already mentioned. An excerpt of the excel file is in Annex D.

4.2 Transatlantic Bridge

As mentioned previously, the transatlantic bridge is between Europe and the USA, because of the high volume of orders between the European continent and the United States. The main focus of this case was giving a global amplitude to cross-docking, instead of only looking to what happens inside the cross-dock. In this case, the analysis start when a package leaves the boutique, and only ends when the article arrives at the client. The simulation allows seeing the process in a world map, with the option of clicking in the cross-dock and then seeing what happens inside the facilities.

This section is about the simulation for the transatlantic bridge case, programmed after the Chinese case, which allowed the re-utilization of code and eliminated the necessity of a to-be analysis. The simulation for this case is an extension of the one previously made, so everything said about cross-docking and AnyLogic at the beginning of Subsection 4.1.2 applies to this case. The month picked to provide the data was also November but because of Black Friday, a holiday in the US that always makes the volume of orders increase, and not because of Singles' Day. Apart from the data of the orders, to this model was important to have information about the European boutiques, so a query to obtain information about them was used, Annex B.

Is important to notice that all the operations inside the cross-dock are the same as described in the previous section, so the subsection about these operations will not be a topic in the current section.

Cross-Dock

This case study has two cross-docks, one located in Rome, Italy, and the other is in New York, in the United States of America. The location of the Italian cross-dock was determinate based on the concentration of boutiques in that zone. For the American facility, the company provided information about the placement of the building, so the topic about the location of the cross-docks, reviewed in Subsection 2.3.1, was not studied in this project.

In terms of configuration, the Italian warehouse is equal to the cross-dock described in the Chinese Case, with the exception that the cells in the loading racks do not have depth, because in this cross-dock, no operation of consolidation happens, so there is no need to configure cells with depth.

The American facility has the same dimensions as the other two, but the same cannot be said about the configuration of the racks. The unloading racks have a length of 16.8 meters with the cells measuring, approximately, 60 centimeters, which means that each level of the rack has 28 cells, instead of 21 as the other cross-docks. The loading racks have a depth of 5, instead of 4, to increase the storage in the facility, without increasing the maximum number of entries. To achieve this increment in the depth of the cell the width of the load rack was incremented by 1 meter, since each row gained 50 centimeters, measuring now 2.5 meters, and the space between each loading dock door was decreased to 1 meter. The loading racks also have more levels than the other, having twelve levels, instead of eight, making the rack with a total height of 7.2 meters.

Agents

The agents defined for this case were *American Warehouse*, *Boutiques*, *Boxes*, *Forklift*, *Italian Warehouse*, *Load Dock*, *Truck*, *Unload Dock* and *Vehicle*.

The *Forklift* agent is equal to *Forklift* agent in the China case study and, the same can be said to, the *Load Dock* and the *Unload Dock* agents.

The *Boxes* is an extension of the agent done in the previous case study, having all the variables as this agent, and some new variables essential to this case. One of the new variables is the origin of the box, an array of strings that stores the country of the boutique that sold the item. The variable needs to be an array because, after the consolidation of the packages, is important to know the origin of each article, and not only of the mother-box. Another new variable is, also, an array that stores the total time in transit for each box and, again, not only of the mother-box in cases where consolidation happens, and, apart from the arrays, there is a set of four boolean variables associated with the transport from Italy to the USA. One of the variables in this set, indicates if the package has reached the destiny, while another informs if the item left the Italian cross-dock bound to the United States of America. The third boolean variable is set to true if the box is on its way to the USA, and these last two mentioned variables allow knowing which packages are indeed in the facility in New York. The last variable shows if the arrival at the facility in the American continent happens in the day after the departure of the article from the boutique. This last variable is extremely valuable because of the batch sizes, a topic overviewed with detail in the next subsection. Lastly, is necessary to emphasize the fact that, although the variable that stores the time of arrival at the dock exists, it became an array, because, to this case, is important to know the time of arrival of each box.

The *Truck* agent is an aggregation of the Chinese *Loading Truck* and *Unloading Truck* agents, in order to reduce the number of agents in the model, because of the limitation of the number of agents imposed by the free version of AnyLogic. This version only allows ten agents, and besides the nine mentioned in the beginning, there is the *Main* agent, completing the ten. So to surpass this limitation, the *Truck* agent became only one, and represents the trucks visible in the cross-dock. This agent has three different presentations, one of them represents the loading trucks, another one represents the unloading trucks that bring packages that come by plane to the cross-dock. This second presentation is set to active when the packages departure from European boutiques, not located in Italy, and go to the Italian cross-dock, and when a plane arrives at the American cross-dock, with origin in Italy. The last presentation is for the vehicles that departure from Italian boutiques and go the cross-dock in that country. The only difference between these presentations is the color of the trucks that are red, silver and blue, accordingly to the order of mention.

The *Truck* agent has a set of variables for each one of the trucks that it represents, meaning that a single truck will not use all the variables of the agent. First, it has one variable for storing the unloading dock where an unloading truck should stop and another with the same purpose, but for the loading dock, used by loading trucks. This agent has two variables used by all the vehicles that are the capacity of the truck, and the number of processed packages, that can be either the amount of unloaded or loaded boxes. The agent has variables to store the information about the origin and destination of the vehicle. The origin is the location of the boutique from where the truck departed, and the destination is the state indicated by the client at Checkout. There is also an important function inside this agent responsible for associating what packages a truck brings, and a variable, the id of the stock point, that indicates from what boutique the vehicle left. Lastly, the *Truck* agent has variables to store multiple times, like the departure time from the boutique, the time of arrival and departure from the cross-dock, and other variables, mainly counters, that only having meaning for simulation's purposes.

The agent named *Boutiques* represents the partners' stock points. This agent only appears on the world map, and its presentation is a retail store, an AnyLogic's object. When the user clicks on the store, the view area changes, and it shows the variables of the partner providing information about the stock point. These variables are the identification of the stock point, *idStockPoint*, the address, city, country and zip code of the stock point. Apart from this, it has a variable named *location*, that shows what parameters are used to search for the location of the stock point, because not always all the variables previously mentioned are used, due to some limitations in AnyLogic's search, the next subsection approaches this topic with detail.

Another agent created is the *Vehicle* that represents all the vehicles visible on the world map, that can be either trucks or planes. In terms of presentation, this agent has three different presentations, and the most used is the one representing a plane. The other two presentations represent trucks, one of them is the presentation for the trucks that departure from boutiques with destination to the cross-dock in Rome, while the second is for vehicles that departure from the American facility with destination to the state of New York. The only difference between these two presentations is the color of the trucks, that is either blue, matching the *Truck* last mentioned presentation, and red, matching the loading trucks in the *Truck* agent, respectively.

The *Vehicle* has variables to store the origin and destination of the vehicle, the number of packages it carries, the departure date, and two boolean variables that help decide which presentation to set active. Another variable of the agent is a boolean variable that allows knowing if the vehicle is in route to the cross-dock in the American soil. Lastly, the agent has an array to store information about the packages' stock points it carries and has another set of variables declared, with meaning for the simulation only, for example, counters. This agent has a flowchart, Figure 4.3, that allows knowing when the agent arrives at its destination. Following the creation of the agent, the state set to active is the *startMoving* state and the state changes after receiving the message telling that the agent is actually moving. The state only changes from *moving* to *arrivedAtDestination* when the agent reaches the destination, identified by the end of the agent's movement, and in this state exists a logic to determine where did the agent arrive. The place of arrival can either be at the cross-dock in New York, the facility in the European continent or the state of destination, but this logic is a topic of the next subsection.

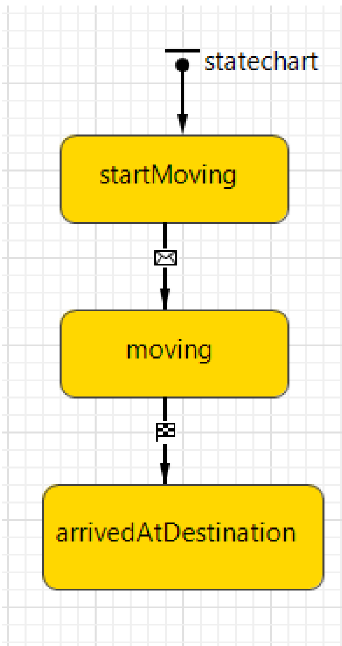

Figure 4.3: State Chart for the *Vehicle* agent

The *American Warehouse* and *Italian Warehouse* represent the cross-dock located in New York and the one located in Rome, respectively, and these agents are far more complex than the agents previous explained. The superior complexity is related to the fact that these agents have the whole logic of the Chinese Case, because these agents represent the cross-dock, and resemble the main agent in that simulation, even the parameters defined by the user. So, is essential to understand what is the *Main* agent of this simulation.

The *Main* agent in this simulation has the purpose to control what happens in the world map, having a population of *Boutiques* agents, of *Vehicles*, a population to the *American Warehouse* and to the *Italian Warehouse*, these last two with only one agent. Apart from the populations, the agent has two parameters defined by the user, one is the speed of the plane, and the second is the truck's speed on the world map. This agent does not interact directly with the variables of the last two mentioned population, but acts upon the population of vehicles that interacts with the agent *Truck*, located inside the agents representing the cross-docks, and does not have any block logic defined. The presentation for this agent is the world map, where are visible the boutiques, the two facilities and the vehicles moving from the origin until reaching its destination. AnyLogic has a variable, called route provider, that defines the routes for the movement of agents. Due to having different methods of transportation in the world map, planes or trucks, the simulation needs different variables to provide routes. For the trucks in the world map, the variable defines routes that follow roads making their movement closer to reality, and even subjects the vehicles to speed's limitations. The routing method influences the choice of roads, and it can be either the fastest or the shortest route. For this simulation, the routing preferred for the trucks is the fastest, and, for the planes, the routes defined are a straight line between the origin and the destination of it.

In the world map, the representation of the *American Warehouse* and the *Italian Warehouse* is a warehouse, an AnyLogic's object, that has the same functionality as the boutiques' presentation. When the user clicks on the building, the view area shows the inside of the cross-dock, instead of showing the world map.

Table 4.3 lists all the configurable parameters of the simulation, and the parameters configurable in each cross-dock, means that the parameter is an input for the *American Warehouse* and for the *Italian Warehouse*.

Simulation's Logic

The present case has five major steps. The first one is the movement of vehicles from the boutiques to the Italian cross-dock and what happens inside of it is the second major step. The third step is the exit of the vehicle from the facility located in Rome, with destination to the one in New York and, the arrival at the destination marks the beginning of the fourth step that is the operation inside of the American cross-dock. Lastly, the fifth step is the delivery of the products to the client, represented by a vehicle exiting the American facility, bound for the client's state.

Before the first step begins, the program does a search to map the positions of the boutiques and assigns destinations to the loading docks in the American cross-dock. To do this search, AnyLogic connects with a third-party search engine, Nominatim OpenStreetMap, but this search engine has some limitations and does not find all the combinations of address, city, country, and zip code, and, when this happens, the location of the boutique, in the map, is random. After running the simulation for the first time, was seen to which boutiques this random placement happened, and the combination of parameters used to map the building was different. For some boutiques the location to search for is only the city and country, other case is when the search only looks to the address and city. The third circumstance is stock points placed due to the address and country,

Table 4.3: Configurable parameters in the simulation for the Transatlantic Bridge Case Study

Parameters configurable	
At the beginning of the simulation	**Through coding**
Number of loading docks in each cross-dock	Maximum and minimum number of loading docks allowed in each cross-dock
Number of unloading docks in each cross-dock	Maximum and minimum of number unloading docks allowed in each cross-dock
Number of operators in each cross-dock	Maximum and minimum number of operators allowed in each cross-dock
World map's truck speed	Maximum and minimum speed value allowed for the world map's truck
World map's plane speed	Maximum and minimum speed value allowed for the world map's plane
Cross-dock's truck speed	Maximum and minimum speed value allowed for the trucks in the cross-docks
Time needed for using the mobile application in each cross-dock	Maximum and minimum amount of time allowed to use the application in each cross-dock
	Loading Schedule in each cross-dock
	Location of the cross-docks
	Number of boutiques in the world map
	Time between arrivals to enable consolidation for the American cross-dock

and the last case is when the search only looks to the city, country and zip code. This manual identification was time-consuming, but since external factors dictated the problem, that was no working around the issue.

In the American cross-dock, each door has states assigned to it and, in total, were considered the 50 American States, plus Porto Rico, the Virgin Islands, and the Northern Mariana Islands, and the attribution of these destinations to the docks only happens once. Due to the high volume of orders to California and New York, 27.61% and 19.93%, respectively, of the total orders, the American facility has two doors exclusively to each one of these destinations. To obtain the number of states for assigning to the other doors, the total number of states, 53, subtracted by 2, because New York and California do not belong to this assignment, was divided by the number of loading docks in the American facility subtracted by 4, since four docks already have assignments. If the division does not return an integral value, for instance, with 15 loading docks, the result of the division of 51 by 11 is 4.63, for this case, each dock has assigned four destinations, but with this amount of destinations, six destinations will not have a dock. To compensate for this difference, then the first six docks have one more destination assigned.

The first step begins at midnight of each day. At midnight, a function checks all the packages with EDD equal to the present day and, after this, starts checking the boutique that has a stock point id identical to the one associated with the order. Due to the number of partners that Farfetch has, not all the partners were represented in the map, to avoid crumbling it, and, when the function does not find a stock point id equal to the one associated with the article, then the item is assigned to leave from a random boutique. To assure the arrangement of the packages, that do not have a stock point id correspondence, through all the boutiques, the first package will come from the first boutique in the population of boutiques, the second box comes from the second agent in the population and so on. If this attribution reaches the last boutique in the population, then the counter resets, and the next item originates from the first boutique.

After all the articles having a boutique associated with them, is time to set the departure of vehicles. To verify if a boutique has packages to send, a function checks if the variable named *ordersToSend* is bigger than zero, if it is happens the creation of a vehicle, and its capacity is the same as the number of packages that the boutique needs to send. If the boutique is in Italy and the city is not Palermo or Catania, the two biggest cities of Sicily, an Italian Island, the presentation of the vehicle is the blue truck, and the variable *isATruck* changes to true, but if the boutique is located outside Italy or in one of the two Sicilian cities, the presentation is the plane. In order to know what packages the vehicle is carrying, the information about the stock point of the boutiques and, if the boutique has articles placed randomly there, the stock point id of these articles, are stored in an array named *idStockPoint*.

Following the creation of the vehicles, they are bound to the Italian cross-dock, and the first step ends when they arrive there. When they reach the facility, the state chart of the vehicle is in state *arrivedAtDestination* and is important to understand what happens in this state. If the vehicle that arrived at its destination has the boolean variables *toAmerica* and *americanTruck* set to false, the default option for these variables, then the function, defined inside the state, creates a truck in the population of *Trucks* placed inside the *Italian Warehouse* agent. After the creation of the agent, a function checks which items have the EDD equivalent to the present day, and stock point id equal to the ones contained in the array of stock point id of the vehicle, and the capacity of the truck created is identical to the capacity of the vehicle. If the vehicle has the variable *isATruck* set to true, then the presentation for the truck is the blue one, but if the variable is false, then the truck inside the cross-dock presents itself as a silver truck.

After the creation of the truck, the vehicle, associated with it, is deleted, and the process described in the Chinese case begins, i.e., the truck seizes a unload dock, the process of unloading begins and so on. The operations inside the cross-dock will not be explored in this section, taking into account that they were already explained in detail previously. The only difference that needs to be enhanced is the fact that, in the Italian facility, does not exist any operation of consolidation, because this operation happens in America. In this facility, the boxes do not have the batch size set, and the docks do not have a location assigned, due to the fact that all the packages go to the same place. The attribution of loading docks is sequentially, i.e., the first package will go to the first dock, the second box goes to the second dock and so on.

The moment of loading trucks follows a schedule and, in this case, the vehicles arrive to load at 2:00, 12:00, and 20:00. After loading the trucks, an event that marks the beginning of the third step, they take the articles to a plane, a process not visible in the simulation, that takes all the items together to the USA. After being loaded into the trucks, the variable *sentToUnitedStates* is set to true to each box that leaves the cross-dock. This boolean variable indicates which boxes already went to the cross-dock in New York. Aside from this, happens the creation of a vehicle marked as *toAmerica* to later identify which agent from the population of vehicles is the one that carries the packages that left the Italian facility, and the capacity of this agent is equal to the number of packages marked as *sentToUnitedStates* and not marked as *onWayToUnitesStates*. This last variable is set to true when the plane starts moving and indicates the packages that no longer exist in the Italian building. This variable is important because the boxes are not immediately deleted from the population of boxes in the cross-dock after leaving, and this variable allows not setting the capacity of the next vehicle bound to the USA wrongly.

The fourth step begins when the vehicle arrives at the American facility, and the variable *toAmerica* is used to check what needs to occur upon its arrival. First, is important to set the capacity of the trucks, because when the plane brings a great number of packages, more than one truck needs to carry them to the cross-dock, because one truck only needs one dock door, and, using only one dock door is inefficient. If a large group of trucks comes to the facility, the total time of the unloading operation decreases, when compared with unloading only one truck that brings a high volume of packages. So, the number of packages that a truck can carry was set to 200, because the unloading racks in the cross-dock located in the US hold 448 items, and, the amount of packages set for the truck's capacity, allows unloading two trucks without having to wait. While the unloading of the second vehicle happens, the operators are already moving the articles to the loading racks, which avoids having a great set of trucks waiting for unloading, due to lack of space in the unloading racks. For each agent created, the number of packages carried by the vehicle decreases by the capacity of the truck, until being less than 200. When this occurs, is conceived the last agent, bringing the remaining packages.

To check which boxes are inside the plane, a function checks which articles inside the *Italian Warehouse* have the *sentToUnitedStates* and *onWayToUnitesStates* set to true, and copies all these packages, until meeting the capacity of the truck, to the population of boxes inside the American cross-dock and deletes them from the population of boxes of the Italian facility.

Another important function that happens to all the boxes unloaded in this cross-dock is the function responsible for setting the batch size. This function works in the same base as the one described in the previous section, but with the difference that a package can arrive at this facility in the day after being shipped from the boutique, because of the time spent traveling between Europe and the United States, and is important to know if the box is arriving in the day of shipping or in the next day. To determinate the day of arrival of each package, a function compares the date of arrival at the Italian cross-dock and the date on the moment of arrival in the other facility. If the days are different and no boxes with the same portal id are in the facility, then the batch size is the sum of the number of packages shipped in the same day as the box that just arrived and the boxes shipped in the day of arrival at the facility in New York. If the days are equal and, again, no boxes with the same portal id are already in the American facility, then the batch size is the amount of boxes shipped in the same day as the mother-box and the ones with EDD set to the following day. If the box is not the mother-box, then the batch size will be equal to the one set in the mother-box.

After this process, begins the usual operations inside the cross-dock, again this was explained in Section 4.1. The loading schedule defined in this cross-dock has four pickups, the first at 2:00, the second occurs at 5:00, the third happens at 15:00, and the last batch of loading trucks comes at 20:00. These times were chosen based on the pattern of arrivals of the planes to this cross-dock. Is important to enhance that at each loading moment, more than one truck can come to the same dock door. In this simulation, each state will have a vehicle delivering the packages to it, if, at least, one package marked as *readyToLoad* inside the cross-dock has that state as its destination. If a loading dock has four states assigned and has packages to deliver in the four, then four trucks come in one moment of loading, and each vehicle takes the packages bound to one of the four states.

The last major step begins when the loading trucks leave the American cross-dock. For each truck exiting the facility, is created an agent in the population of vehicles in the *Main* agent. The newly created agent takes every box loaded into the truck and is bound to the destination of the boxes that it carries, and the variable *americanTruck* switches to true. If the destination is New York, then the presentation of the agent is the red truck, if not, the agent is the plane. When the vehicle arrives at its destination, the variable *americanTruck* defines what happens upon its arrival. When the vehicle arrives, the total time in transit of each article inside of the boxes that it carries, if it brings more than one, is recorded and the package has the variable *wasDelivered* set to true.

In this simulation, the function responsible for deleting the agents from the population of boxes in the American cross-dock, happens after each consolidation checking which packages have the number of items inside equal to zero, just like in the Chinese case, but also verifies the agents that have the variable *wasDelivered* set to true. Another moment of triggering this function is after unloading a package and loading a truck, checking more times if an operation of deletion has to occur. The moment of deleting the agents is crucial since, in this case, the creation of the boxes' agents happens when the truck enters the logic of the unloading process and not after being unloaded, like in the previous case. The simulation needs to know which was the unloaded package and, to recognize, the boxes the program recurs to the index of the agent in the population. If the index of the agents changes before unloading all the packages, it can cause errors in the program, and this is why is so important to control the moments of deleting agents from the boxes' population because deleting an agent can change the index of all the other agents. Apart from checking the two variables mentioned above, in the moment of deleting, the function also checks if the variable *packagesInbound*, a variable equal to the number of packages currently being unloaded, is zero, if all the conditions are satisfied, the elimination of the agents can happen.

Results

The simulation for this case uses 12 load docks and 12 unload docks in the Italian facility, and 15 loading entries and 14 unloading gates in the American cross-dock. Each cross-dock has 150 operators, and the truck speed and the time to use the mobile application is equal to the value used in the Chinese simulation. Lastly, the plane has a speed of 750 km/h and the truck in the world map moves at 80 km/h.

All the statistics used in the Chinese case are used in this simulation too, and all the graphs obtained are in Annex F. In respect to the time plots in the 3D view, each cross-dock has its own. The Italian facility only has two graphics, the two time plots, one showing the average time, in minutes, to unload and to load a truck, and the second shows the average time spent by the packages inside the facility. For this cross-dock, the average time to unload a truck is 44 minutes, while the average time to load a vehicle is 12 minutes, and the average time spent by the packages here is 6 hours. Unlike what happens in the Chinese Case, the average time spent in the cross-dock is highly variable during the simulation and, during the spikes, this variable can reach 14 hours. The amount of packages, in the normal days, is between 2000 and 3000, approximately, and, the biggest spike on the number of orders, happens in the 29th of November, represents 9290 packages passing through the facility on only one day. The Black Friday happened in the 23rd of November and this holiday causes this spike, because, usually the average time to delivery to the United States is around six days, so the great number of orders placed during the American holiday will have the EDD set to 29th. The time spent in the cross-docking during the spikes is expected to be higher since the number of orders triplicates, and, taking into account, that the average time is around the double of the normal average time, the value of 14 hours is satisfactory.

The American cross-dock, on the other side, has the three graphs talked in the previous section. In this facility, the operations of unloading a truck needs, on average, 180 minutes, while loading a vehicle takes around 18 minutes. The average time to unload is higher than the other cases since this cross-dock receives a great number of packages at the same time. Because of this, the items need to wait an extended time before the unloading actually starts, and due to always carrying an immense amount of packages, usually 200, this also raises the overall time to unload a truck. The day with most aggregations is the 28th of November, with 967 orders suffering consolidation, and the boxes spent, in average, 5 hours inside the dock. This lead time suffers from the same mentioned for the Italian cross-dock, reaching a pike of 35 hours and, again, the orders arriving in the 29th of November are responsible for this spike. The time plot of the average time shows the spike between the 1st and 2nd of December since some packages, placed on the 29th, arrive in the following day, so a lot of boxes spend, just because of this, more than 24 hours in the facility. Adding the time to suffer the operations inside the cross-dock and the wait time for loading, in the worst case, they can wait 10 hours for the loading trucks, which easily increases the time inside the cross-dock. To conclude the analysis of the average lead time, the packages, from orders that have the EDD set to the 29th of November and suffer aggregation, are, highly probable, to only leave during the 30th.

The graphs visible in the statistics view in the Chinese Case, are also visible in this simulation, and show, for this case, that 24.0% of the orders made during November of 2017, have more than one item, and the articles of these orders represent 46.35% of all the items bought during this month with the USA as destination. The total amount of packages suitable for aggregation is 32939, before considering the 24-hour rule, and, at the end of the simulation, the pie chart that contains information about the number of packages aggregated, shows that 23.5%, 7731 items, did not suffer aggregation because the time gap between the arrival of the boxes of the same order is bigger than one day. The other static pie chart, the one with nine partitions that gives information about the number of items in each order, shows that 63.7% of the orders, with more than one item, are composed by two articles, representing 7677 of the orders. The number of orders with ten or more items, 0.7%, that represents 81 orders, surpasses the number of orders with eight and nine articles, just like in the Chinese Case. Lastly, the stack chart, at the end of the simulation shows, that 6927 packages leave the cross-dock with two articles inside, a reduction of 750 boxes when compared to the value obtained before considering the 24-hour rule, and 33 boxes leave the cross-dock with ten or more items, less 48 than the value initially obtained in the static pie chart.

Apart from these results, the excel file created at the end of the simulation now has five sheets, Annex G. The first two sheets are the sheets referent to the Italian cross-dock. The first sheet is the operations sheet and has the information mentioned for this sheet in the previous case, with the exception of the column with the number of aggregations and the percentage of aggregations, because, in this cross-dock, the operation of consolidation does not exist. The day where most packages came to the facility was the 29th of November, the spike previously mentioned, and 9290 boxes pass in this cross-dock. The second sheet for the cross-dock in Rome is the report sheet, showing the portal id, arrival and departure time from the cross-dock of each box, and the total time span of each box. In this sheet was calculated the amount of packages that spend less than 24 hours in the dock and was verified that all the packages meet this criteria, and the largest time span in the facility is 18.998 hours, so the results obtained here are satisfactory and respected the 24-hour rule, that is the aim for cross-docking. This sheet has some more calculations and Table 4.4 shows them.

Table 4.4: Results obtained for the Italian cross-dock

Number of packages and percentage that spent less than 24 hours in the facility	71064/100%
Number of packages and percentage that spent 6 hours or less in the facility	19170/26.98%
Number of packages and percentage that spent 14 hours or less in the facility	69192/97.37%
Biggest time span inside the dock (hours)	18.998

The second and third row of the table presents the number of boxes that have a time span inferior to the average time obtained and to the value of spike. The amount of boxes that spend less than 6 hours, the average time, inside the facility is relatively low and shows that the spikes, in this particular case, are extremely important and need to be taken into account. Looking now at the value of spike, 14 hours, is possible to see that the lead time of, almost, every box is below the value of spike, and this is a great result because, not only the 24-hour rule is fulfilled, but also 97.37% do not need this amount of time to leave the facility.

The two sheets mentioned are also created for the cross-dock in New York. The sheet related to the operations shows that in the 28th of November represents the day where more boxes, 10818 packages, came to the facility. The day where most packages suffer aggregation is the 23rd of November, and 2401 boxes suffered consolidation. The column with the percentage of orders aggregated, in this case, shows that a lot of packages that come in day suffer aggregation only in the next one. The case with most highlight happens in the 3rd of December, where only 22 boxes arrive at the cross-dock, but 452 suffer aggregation, giving a percentage, of aggregated packages, of 2054%. Another case is the 2nd of December, where 263 packages arrive at the American facility, but 1778 suffer consolidation, again the percentage surpasses 100% and reaches 676%. These are the only cases where the percentage goes above the 100%. The report sheet for the facility in the USA shows that the biggest time span inside the facility in American soil is 61.435 hours and has 55750 records. This sheet also shows that only 1.35% of the packages spent more than 24 hours inside the dock, which is a phenomenal result and is really close to actually meeting the 24-hour rule. Table 4.5 lists the calculations added in the sheet.

Table 4.5: Results obtained for the American cross-dock

Number of packages and percentage that spent more than 24 hours in the facility	755/1.35%
Number of packages and percentage that spent 5 hours or less in the facility	40422/72.51%
Number of packages and percentage that spent 20 hours or less in the facility	54773/98.25%
Number of packages and percentage that spent 35 hours or less in the facility	55667/99.85%
Biggest time span inside the dock (hours)	61.435

The table with the results of the American cross-dock has the same purpose as the one created for the Italian facility, with the only difference of the average times considered. The lead time in the second row is 5 hours and 72.51% actually spent less than this time in the cross-dock, which is a really good value, because adding only 5 hours to the time in transit of the boxes due to going through the American cross-dock is, almost, meaningless. In the calculations were considered two spikes, one of 20 hours and, the biggest spike, of 35 hours and, practically, all the packages have a time span below 20 hours, showing that the spike only affects a small percentage of orders, which is amazing because shows that the cross-dock has the necessary capacity for dealing with spikes of orders, without affecting the usual time inside the facility.

Lastly, another excel file shows the lead time of all the articles ordered during November, taking into account the origin and the destination of the box. This file is important to evaluate the impact of cross-docking in the process of shipping, considering that this solution looks at the whole process of delivering the orders to the clients. With the data mentioned, was created a pivot table. This pivot table has the origin and destination of the boxes and shows the average time in transit for each combination. Farfetch provided the usual times in transit for each American state and for each route between Europe and the USA. The pivot table has 25 origins, and 53 destinations, each origin is a European country and the destination is an American state, and always shows the average time in transit for each combination selected. Table 4.6 shows the main cases analyzed. Three of them are related to three American states that represent the main percentage of orders made by the clients. The routes in the table are the three top routes provided by the company.

Table 4.6: Average times in transit

	Average time in transit (days)		
	Given by Farfetch (2)	**Obtained in the simulation (1)**	$\frac{(1)}{(2)}$
To California	3.4	1.32	0.39
To New York	2.3	0.96	0.42
To Florida	3.3	1.19	0.36
Between Italy-US	3.5	1.17	0.33
Between UK-US	2.8	1.49	0.53
Between Poland-US	3.5	1.09	0.31

After analyzing the six cases listed in the table, is possible to see that the value given by the simulation is always lower than the one given by the company, and it is about 39% of the time given by Farfetch. This value is very good because gives space for enriching the model, with variables like the clearance time of each article, and shows that the whole cross-docking strategy may not have a big impact on the shipping service. The time in transit, in the simulation, includes the time of traveling between the boutiques and the cross-dock in Italy, the time to unload the truck and, if the truck brings items that came to the cross-dock by plane, this time is multiplied by two, to simulate the time that would take to unload the packages from the plane. After the unloading, the time in transit updates when the package leaves the Italian cross-dock, and total time inside this dock is added to the time in transit. The total time necessary to load the trucks is added three times to the total in transit, one for the actual time of loading all vehicles, the second addition is to simulate the time to load the packages into the plane, and the third is to account the time to unload the plane in America. When the packages arrive in America, the time of traveling is added to the time in transit, as well the time to unload the boxes from the trucks, in the American cross-dock, and, again, the time inside the dock is added when the boxes leave the facility. If the packages need to go by plane, then the same logic of adding the time of loading three times happens, and, when the vehicle arrives at its destination, the last addition happens that consists on adding the time of the travel between the facility and the destination to the time in transit.

Chapter 5

Conclusions and Future Work

5.1 Conclusions

One of the major goals of any e-commerce platform is to fully satisfy the client. In Farfetch case, one point affecting the client's satisfaction is the way of delivering when the client purchases more than one article. The main goal of the present project is to study cross-docking and how could it be implemented in the company. Cross-docking is something totally new in the company, due to this there was nothing to start from, and was important to understand what is this logistic strategy, setting what needs to be study to successfully implement it.

The literature review allowed to understand the main operations inside a cross-dock and the steps needed to implement this type of logistic strategy. The operations identified, in the order of occurrence, is the unloading of the trucks, followed by moving the packages from the unload docks to the load docks. If the package is suitable for aggregation, then the next operation is the consolidation of packages, and the last operation is the loading of the packages into the loading trucks. To simulate this strategy in Farfetch was used a software called AnyLogic.

Before staring the simulation of cross-docking, the current situation in Farfetch needed to be studied. First, were identify the different parts of Farfetch's order processing system that will be affected if cross-docking is implemented, and, for each, part identified, was done an As-Is analyze.

Cross-docking was analyzed in two different situations. The first case study, the Chinese Case, focus on understanding what needs to change in Farfetch to allow cross-docking and in the logic inside the cross-dock with the aim to gain knowledge about the variables that impact cross-docking and the operations that happen inside a cross-dock. To understand what needs to change in Farfetch, was done an To-Be analyze for all the part of the system in the As-Is analyze. With these two analysis is easy to know how Farfetch is before cross-docking and what will it be after implementing cross-docking, allowing the evaluation of the necessary work to make this strategy happen, in terms of system's configurations, and what are Farfetch's current limitations.

After the theoretical analyze, the programming of the simulation begun. The first step in the simulation was decide the shape of the cross-dock, followed by building the facility and setting up all the docks. Following this, happened the programming of all the operations identified in the literature review. The determination of the capacity of the cross-dock is crucial, because if the capacity is lower than needed, then it will not have capacity to process the packages at the right time, and the impact on the lead time of the packages will increase, but if the facility is bigger than needed, it can generate more costs to be supported by Farfetch, which is undesirable. After analyzing the results, it can be concluded that the variables with more impact are the loading schedule and the amount of pick-ups.

In the second case, the main focus was to start developing a simulation that could represent Farfetch's supply chain and analyze the impact of cross-docking in it. This second case applies the whole logic of the previous case in the facilities where cross-docking happens, one is in New York, and the other is in Rome. The main variable to evaluate the quality of the solution is the time in transit of each box, and, after having this value, is necessary to compare it with the one provided by the company. After this, was possible to conclude that the average times in the simulation are below the ones given by the company in, about, 61%. If the time in transit given was equal or bigger than the ones provided by the company, then Farfetch should not invest in cross-docking, because with the addition of more variables, the time would only increase and would affect client's satisfaction, that is exactly the opposite of what is intended to do. Having a value lower than the one provided by Farfetch is excellent because gives space for enriching the model, and shows that cross-docking can increase the client's satisfaction without impacting the overall quality of the shipping service.

The main objective of this project was to study a strategy to implement cross-docking in Farfetch and the results obtained show that cross-docking may not have a big impact on the operation of shipping and, with the second simulation, the e-commerce business has a tool capable of representing the whole supply chain. If this tool is further developed, Farfetch can make strategic decisions based on the simulation, and the decision of applying cross-docking will have with the simulation, developed during this project, as a base. Decisions like the loading schedule, the number of pickups to establish with the couriers, when can the courier change, for instance after leaving the Chinese cross-dock a national courier, preferred by the clients, could be used, the shape of the dock, the necessary capacity, the number of workers, every single one of this variables can be decided based on the simulation.

5.2 Future Work

Considering the complexity of Farftech's business and of implementing cross-docking is important to enrich the simulation with the largest amount of variables possible like:

- **Clearance times:** One variable not considered in the simulation is the clearance time for the packages when they arrive in the United States. The addition of this variable will, inevitably, increase the lead time, but the model would be even closer to reality.

- **Shipping's costs:** Apart from the analysis of lead times another possible analyze, is the expenses of shipping in bulk. Another possibility is studying the shipping's costs between the boutiques and the cross-dock in Italy, and the costs associated with delivering the items between the facility in New York and the states of delivering the packages. Considering the three costs mentioned, there is enough information, not only, to decide if cross-docking is suitable for Farfetch, but also, to choose when a package should go through the cross-dock or be delivered directly to the client.

- **Client id:** Another variable with interest is the client id. Each time a customer buys something on farfetch.com, the order created has a client id associated with it. Instead of taking into account the portal order id, another possibility is to take into account the client id and aggregate the packages with the same client id. If the aggregation happens between boxes with the same client id, is important to check the delivering address, because a client can make two different purchases with different delivering address, so only orders with the same delivering address could be aggregated.

Aside from the variables mentioned, cross-docking can be useful for the returning services. If the client wishes to return more than one article, the client needs to return them one by one, meaning that it has to schedule multiple pickups and prepare all the items separately, which impact its experience. Studying cross-docking to returns would be very interesting, allowing to study the impact of making returns in bulk. One possible approach for this case is to happen cross-docking in the client's country, for instance in the USA. After shipping the items in bulk, it would suffer deconsolidation in London, to then suffer consolidation based on the boutique of destination.

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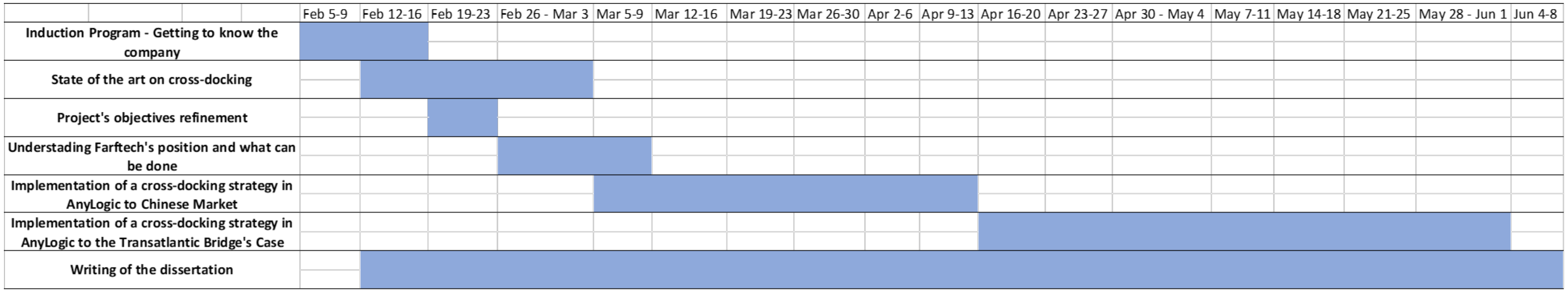
Annex A: Gantt Chart



Annex B: Queries

Query Used to Obtain the Data for the Simulation of the Chinese Case

```
select X.Country as StockPointCountry,
    X.CountryId as StockPointCountryId,
    GLB.Country as UserCountry,
    GLB.CountryID as UserCountryId,
    GLB.City as UserCity,
    GLB.OrderCode as PortalOrderId,
    GLB.OrderId as MerchantOrderId,
    GLB.DataCriado as CreatedDate,
    EstimatedDeliveryDate as EDD
from BI_SYNC..glborders GLB
join [FFLIVE\BI Analysts].OPS_Del_KPI_Time EDD on GLB.OrderID = EDD.OrderID
cross apply (select AD.*
            from BI_SYNC..StockPoint SP
            inner join BI_SYNC..AddressInfo AI on SP.IdShippingAddress = AI.IdAddressInfo
            inner join BI_SYNC..Address AD on AI.IdAddress = AD.IdAddress
            where SP.stockpointkey = GLB.siteid ) X
where GLB.DataCriado >= '2017-11-01'
    and GLB.DataCriado < '2017-12-01'
    and ( GLB.Country = 'Hong Kong' or GLB.Country = 'China')
    and EstimatedDeliveryDate is not null
    and EDD.siteid = GLB.SiteID
order by GLB.DataCriado ASC
```

Query Used to Obtain the Information about the Boutiques Placed on the Map in the Transatlantic Bridge Case Simulation

```
select top 401 IdStockPoint, Address1, Country, City, ZipCode
from BI_SYNC..StockPoint SP
```

```
inner join BI_SYNC..AddressInfo AI on SP.IdShippingAddress = AI.IdAddressInfo
inner join BI_SYNC..Address AD on AI.IdAddress = AD.IdAddress
where Country <> 'Australia' and Country <> 'Brazil'
    and Country <> 'Canada' and Country <> 'United States'
    and Country <> 'China' and Country <> 'Hong Kong'
    and Country <> 'India' and Country <> 'Japan'
    and Country <> 'Korea, Republic of' and Country <> 'Kuwait'
    and Country <> 'Lebanon' and Country <> 'Macau'
    and Country <> 'Malaysia' and Country <> 'Morocco'
    and Country <> 'New Zealand' and Country <> 'Georgia'
    and Country <> 'Saudi Arabia' and Country <> 'Singapore'
    and Country <> 'South Africa' and Country <> 'Taiwan'
    and Country <> 'UAE' and City <> 'not set'
order by IdStockPoint
```

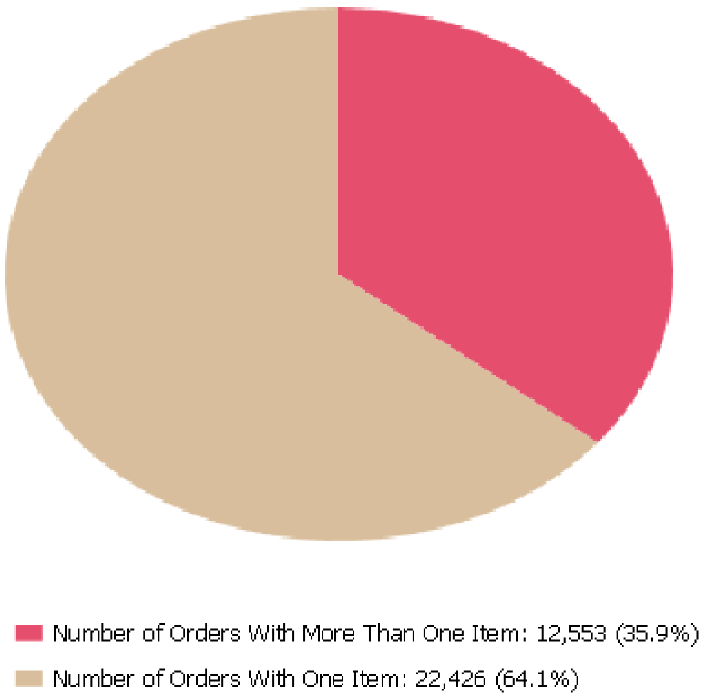
Query Used to Obtain the Data for the Simulation of the Transatlantic Bridge Case

```
select X.IdStockPoint as IdSTockPoint,
    GLB.Country as OrderCountry,
    GLB.State as OrderState,
    GLB.OrderCode as PortalOrderId,
    GLB.OrderId as MerchantOrderId,
    GLB.DataCriado as CreatedDate,
    EstimatedDeliveryDate as EDD
from BI_SYNC..glborders GLB
join [FFLIVE\BI Analysts].OPS_Del_KPI_Time EDD on GLB.OrderID = EDD.OrderID
cross apply (Select SP.*
            from BI_SYNC..StockPoint SP
            inner join(
                select top 401 IdStockPoint, Address1, Country, City, ZipCode
                from BI_SYNC..StockPoint SP
                inner join BI_SYNC..AddressInfo AI on SP.IdShippingAddress = AI.IdAddressInfo
                inner join BI_SYNC..Address AD on AI.IdAddress = AD.IdAddress
                where Country <> 'Australia' and Country <> 'Brazil'
                    and Country <> 'Canada' and Country <> 'United States'
                    and Country <> 'China' and Country <> 'Hong Kong'
                    and Country <> 'India' and Country <> 'Japan'
                    and Country <> 'Korea, Republic of' and Country <> 'Kuwait'
```

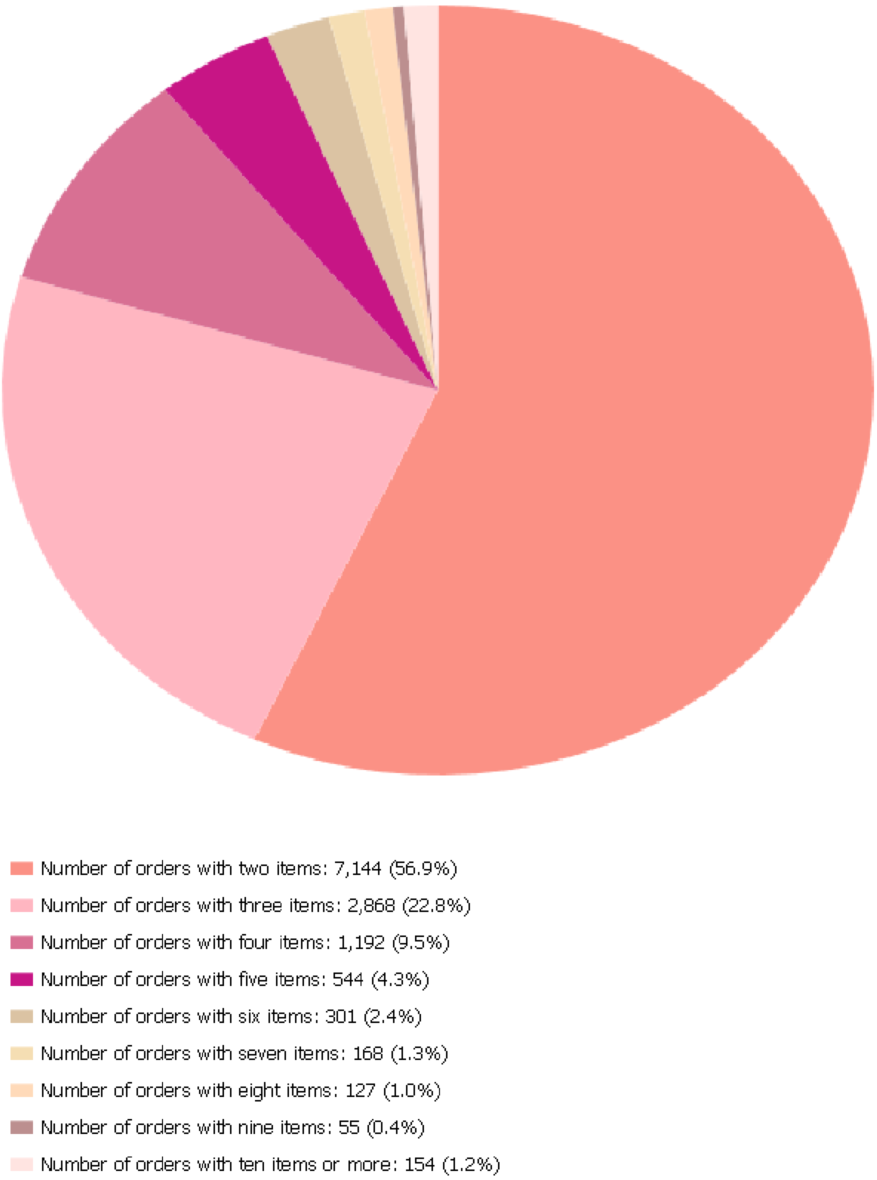
```
                and Country <> 'Lebanon' and Country <> 'Macau'
                and Country <> 'Malaysia' and Country <> 'Morocco'
                and Country <> 'New Zealand' and Country <> 'Georgia'
                and Country <> 'Saudi Arabia' and Country <> 'Singapore'
                and Country <> 'South Africa' and Country <> 'Taiwan'
                and Country <> 'UAE' and City <> 'not set'
            order by IdStockPoint) SPId on SP.IdStockPoint = SPId.IdStockPoint
        where SP.stockpointkey = GLB.siteid) X
where GLB.DataCriado >= '2018-01-01'
    and GLB.DataCriado < '2018-04-01'
    and GLB.Country = 'United States'
    and EstimatedDeliveryDate is not null
    and EDD.siteid = GLB.SiteID
order by GLB.DataCriado ASC
```

Annex C: Chinese Case's Statistics

Static Pie Chart for the Amount of Orders that can Suffer Aggregation

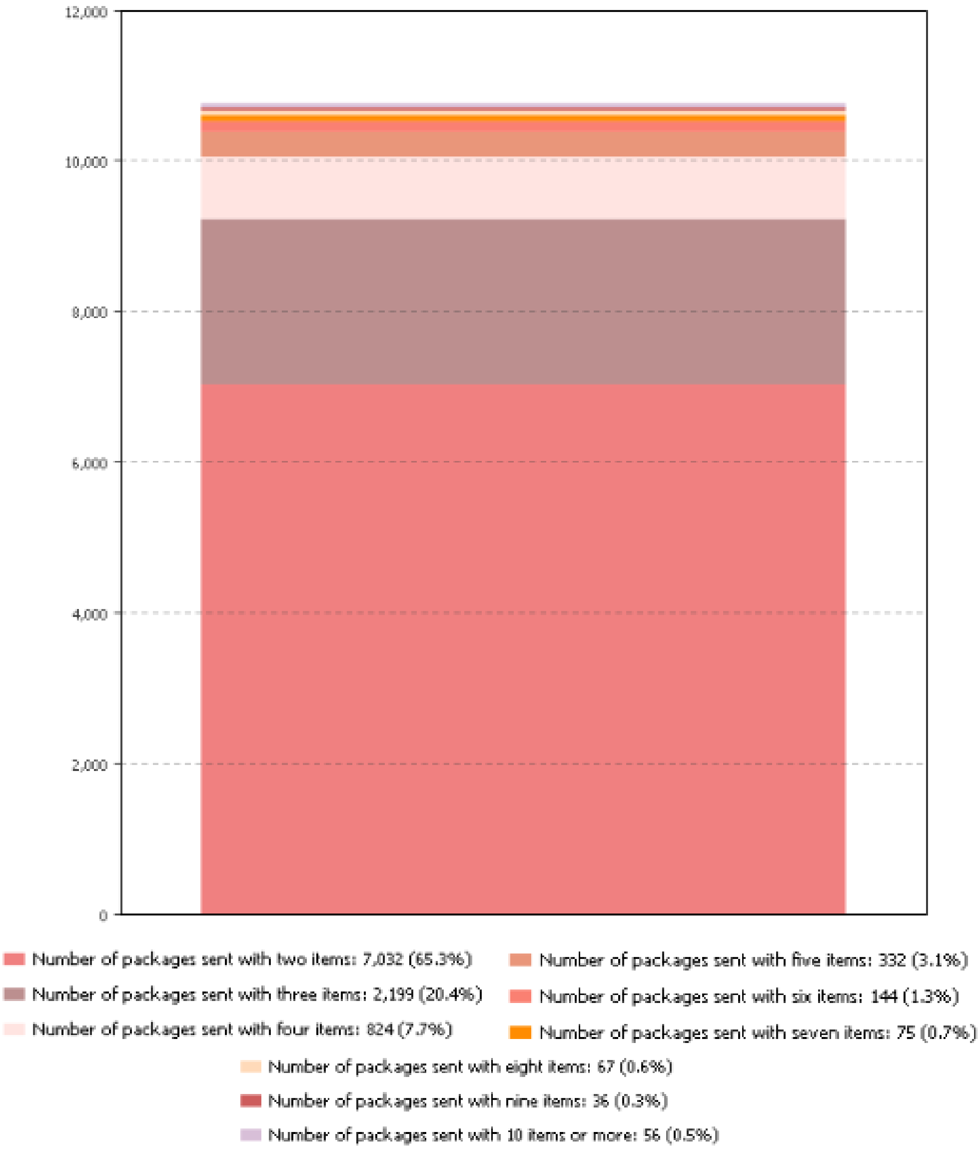


Static Pie Chart Divides the Orders that can Suffer Aggregation Based on the Amount of Articles

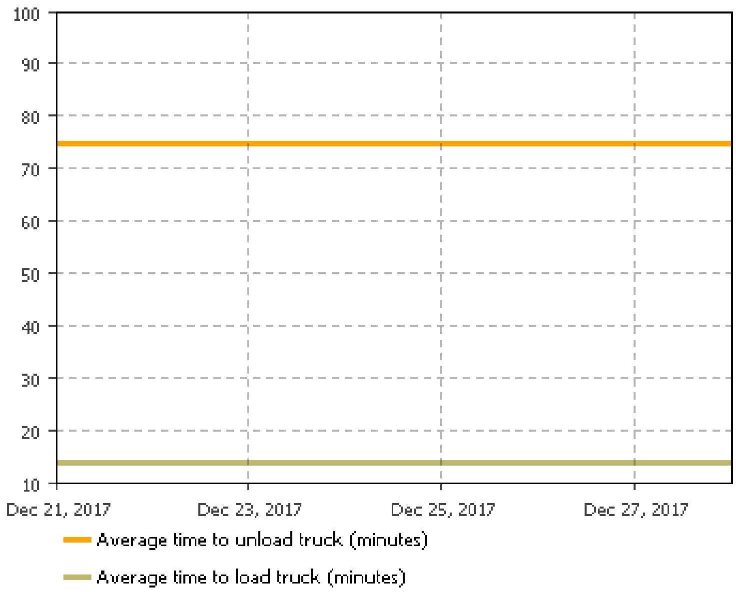


Non Static Pie Chart that Shows the Amount of Packages that Suffer Consolidation

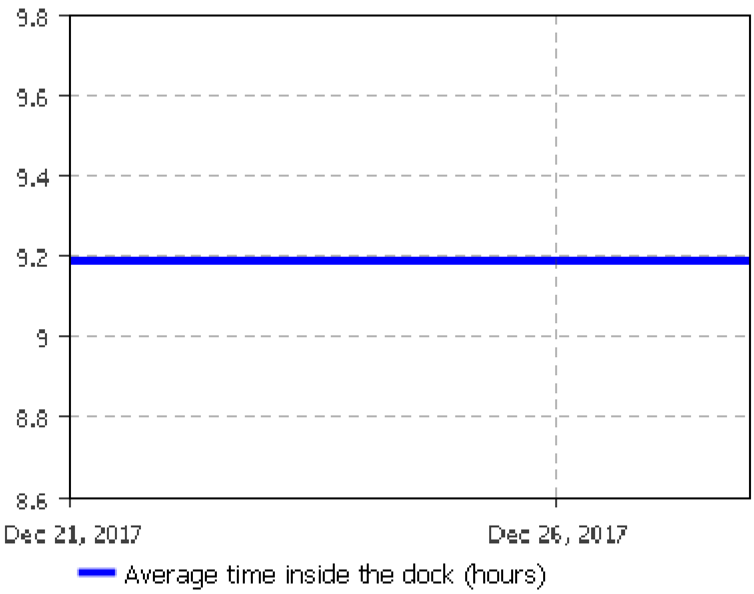
Non Static Stack Chart that Shows the Amount of Packages Sent Based on the Number of Articles Inside the Boxes



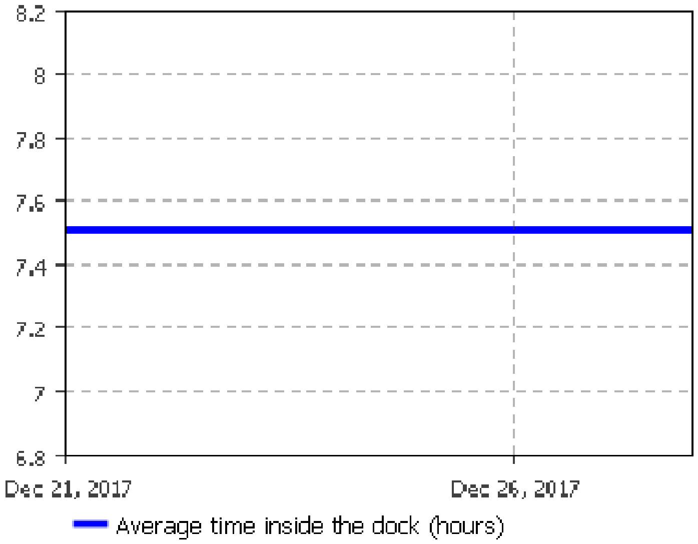
Time Plot for the Average Time of Unloading and Loading a Truck



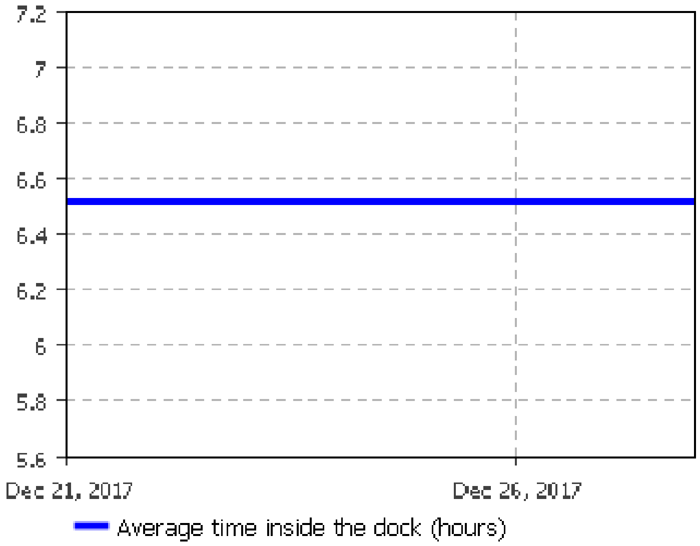
Time Plot for the Average Time Spend by Packages for the Case of 3 Pick-ups



Time Plot for the Average Time Spend by Packages for the Case of 4 Pick-ups with 6-Hour Time Gap



Time Plot for the Average Time Spend by Packages for the Case of 4 Pick-ups with Different Time Gaps



Annex D: Chinese Case's Reports

Excerpt of Sheet "report" from the Report Generated for the Case with 3 Pick-ups

portal order id	arrival time	departure time	total hours in the dock	num articles inside
HFCB5L	29/11/2017 01:46:30	01/12/2017 00:16:01	46,491	4
GJANN6	29/11/2017 01:50:37	01/12/2017 00:16:00	46,423	2
HFKFTL	29/11/2017 02:21:07	01/12/2017 00:16:14	45,918	3
HFTVML	29/11/2017 02:46:07	01/12/2017 00:16:13	45,501	2
9BRWT9	29/11/2017 02:47:03	01/12/2017 00:15:56	45,481	2
TGNTUH	15/11/2017 03:34:51	17/11/2017 00:17:40	44,713	2
VT7VBB	15/11/2017 03:58:44	17/11/2017 00:17:37	44,314	2
VTF59B	15/11/2017 04:04:59	17/11/2017 00:17:55	44,215	4
WSRTDU	15/11/2017 04:14:27	17/11/2017 00:21:35	44,118	2
KLWCA7	29/11/2017 04:42:13	01/12/2017 00:23:17	43,684	2
SBMEEF	15/11/2017 04:42:28	17/11/2017 00:21:08	43,644	3
N7HF25	29/11/2017 04:47:40	01/12/2017 00:12:58	43,421	2
N7L225	29/11/2017 04:57:47	01/12/2017 00:13:17	43,258	2
PMY6X3	15/11/2017 05:08:31	17/11/2017 00:20:54	43,206	4
PMPUT3	29/11/2017 05:01:47	01/12/2017 00:13:38	43,197	2
KLUWK7	29/11/2017 05:03:34	01/12/2017 00:13:04	43,158	2
SBMZBF	15/11/2017 05:16:53	17/11/2017 00:21:12	43,071	2
VMJV2B	29/11/2017 05:10:14	01/12/2017 00:13:51	43,06	3
Z66PAQ	29/11/2017 05:28:36	01/12/2017 00:13:58	42,756	4
QUBHQC	29/11/2017 05:29:07	01/12/2017 00:13:37	42,741	3
TGAEJH	15/11/2017 05:31:51	17/11/2017 00:11:39	42,663	2
UGEG4V	29/11/2017 05:44:10	01/12/2017 00:23:21	42,652	4
XEKABY	15/11/2017 05:36:32	17/11/2017 00:12:33	42,6	3
TGALFH	15/11/2017 05:37:18	17/11/2017 00:12:40	42,589	2
RTD93K	29/11/2017 05:44:13	01/12/2017 00:13:28	42,487	3

Excerpt of Sheet "report" from the Report Generated for the Case with 4 Pick-ups with 6-Hour Time Gap

portal order id	arrival time	departure time	total hours in the dock	num articles inside
7AFZ5Z	29/11/2017 00:14:41	30/11/2017 18:01:41	41,783	2
MKNQF8	14/11/2017 00:50:53	15/11/2017 18:06:34	41,261	3
W38KCU	28/11/2017 01:28:15	29/11/2017 18:42:07	41,231	2
VMDB2B	29/11/2017 06:59:16	01/12/2017 00:11:37	41,206	4
7A2UJZ	23/11/2017 00:54:48	24/11/2017 18:04:59	41,169	2
PCLFL3	28/11/2017 01:21:33	29/11/2017 18:30:22	41,147	2
RTTRSK	28/11/2017 01:08:10	29/11/2017 18:12:07	41,065	4
HF7EVL	29/11/2017 00:59:33	30/11/2017 18:01:49	41,037	2
N3AWX5	28/11/2017 01:13:27	29/11/2017 18:12:56	40,991	2
YWHVRJ	28/11/2017 01:33:51	29/11/2017 18:30:24	40,942	2
XZCGPY	28/11/2017 01:27:40	29/11/2017 18:21:21	40,894	2
XZ9DZY	28/11/2017 01:21:25	29/11/2017 18:12:19	40,848	3
RTPYLK	28/11/2017 01:11:22	29/11/2017 18:01:47	40,84	3
YAZA6J	14/11/2017 01:14:01	15/11/2017 18:01:01	40,783	2
TGNE5H	14/11/2017 01:17:20	15/11/2017 18:04:13	40,781	2
W3SJRU	29/11/2017 07:26:11	01/12/2017 00:11:41	40,758	3
RTXJBK	28/11/2017 01:16:56	29/11/2017 18:01:55	40,749	2
YWKBJJ	28/11/2017 01:29:04	29/11/2017 18:12:57	40,731	4
XZAHYY	28/11/2017 01:29:40	29/11/2017 18:02:10	40,541	2
UG7WEV	29/11/2017 07:39:58	01/12/2017 00:11:38	40,527	2
SX2YWF	28/11/2017 01:43:01	29/11/2017 18:12:46	40,496	2
Z63R4Q	28/11/2017 01:44:36	29/11/2017 18:13:00	40,473	3
UGZ53V	28/11/2017 01:46:01	29/11/2017 18:12:54	40,448	2
YWKRMJ	28/11/2017 01:37:47	29/11/2017 18:02:19	40,409	2
SBSLKF	28/11/2017 01:40:42	29/11/2017 18:01:52	40,352	2
XER6WY	23/11/2017 01:41:47	24/11/2017 18:02:08	40,339	3
TKEL7H	28/11/2017 01:44:20	29/11/2017 18:01:48	40,291	2
Z6VW7Q	28/11/2017 02:17:46	29/11/2017 18:30:47	40,216	4
7APVQZ	29/11/2017 01:49:35	30/11/2017 18:01:41	40,201	2
L4FRQP	28/11/2017 01:55:15	29/11/2017 18:01:08	40,098	2

Excerpt of Sheet "report" from the Report Generated for the Case with 4 Pick-ups with Different Time Gaps Between Them

portal order id	arrival time	departure time	total hours in the dock	num articles inside
YWBZYJ	28/11/2017 02:08:40	30/11/2017 00:15:21	46,111	2
XZCGPY	28/11/2017 02:17:15	30/11/2017 00:15:18	45,967	2
TGNTUH	15/11/2017 03:34:10	17/11/2017 00:23:15	44,818	2
VT7VBB	15/11/2017 03:58:02	17/11/2017 00:23:24	44,422	2
VTF59B	15/11/2017 04:04:57	17/11/2017 00:23:27	44,308	4
WSRLPU	15/11/2017 04:05:09	17/11/2017 00:19:42	44,242	2
WSRTDU	15/11/2017 04:14:17	17/11/2017 00:20:00	44,095	2
TKY4QH	29/11/2017 04:22:12	01/12/2017 00:15:40	43,891	3
SBMEEF	15/11/2017 04:42:08	17/11/2017 00:19:31	43,622	3
KLWCA7	29/11/2017 04:42:04	01/12/2017 00:15:25	43,555	2
W3EYVU	29/11/2017 05:03:27	01/12/2017 00:16:06	43,21	2
PMY6X3	15/11/2017 05:07:51	17/11/2017 00:19:14	43,189	4
MQ3BC8	29/11/2017 05:03:19	01/12/2017 00:13:05	43,162	3
U4A4PV	15/11/2017 05:08:05	17/11/2017 00:17:10	43,151	2
VMJV2B	29/11/2017 05:10:48	01/12/2017 00:14:33	43,062	3
SBMZBF	15/11/2017 05:16:13	17/11/2017 00:19:46	43,058	2
UG7ZEV	29/11/2017 05:20:49	01/12/2017 00:15:37	42,913	2
VTYR8B	15/11/2017 05:26:48	17/11/2017 00:17:20	42,842	2
TGAEJH	15/11/2017 05:31:37	17/11/2017 00:11:38	42,666	2
UGC4VV	29/11/2017 05:36:49	01/12/2017 00:15:56	42,652	3
TKVXVH	29/11/2017 05:38:37	01/12/2017 00:16:27	42,63	2
XEKABY	15/11/2017 05:36:35	17/11/2017 00:12:35	42,6	3
TGALFH	15/11/2017 05:37:19	17/11/2017 00:12:40	42,588	2
ZPJG6Q	15/11/2017 05:53:29	17/11/2017 00:24:12	42,511	2
JFXT9W	15/11/2017 05:42:11	17/11/2017 00:12:23	42,503	2
UGEG4V	29/11/2017 05:45:57	01/12/2017 00:15:43	42,496	4
TGAGEH	15/11/2017 05:48:34	17/11/2017 00:11:34	42,383	8
L4CXPP	29/11/2017 05:58:08	01/12/2017 00:15:27	42,288	2
XEKCDY	15/11/2017 05:55:29	17/11/2017 00:12:28	42,282	2
QL7J3C	15/11/2017 05:58:30	17/11/2017 00:14:39	42,269	3

Excerpt of Sheet "operations_report" from the Report Generated for the Case with 3 Pick-ups

day	packages received	packages aggregated	orders aggregated	incoming trucks	outgoing trucks	**% of packages aggregated**
2017-11-02	5	0	0	1	4	0
2017-11-03	49	8	4	24	17	16,32653061
2017-11-04	0	0	0	0	0	0
2017-11-05	1	0	0	1	1	0
2017-11-06	651	222	83	24	19	34,10138249
2017-11-07	162	116	37	27	19	71,60493827
2017-11-08	918	314	125	24	19	34,20479303
2017-11-09	694	397	136	24	20	57,20461095
2017-11-10	718	432	163	24	18	60,16713092
2017-11-11	0	0	0	0	0	0
2017-11-12	1	0	0	1	1	0
2017-11-13	1625	562	213	24	19	34,58461538
2017-11-14	864	436	143	24	18	50,46296296
2017-11-15	4592	1837	712	24	27	40,0043554
2017-11-16	3534	2551	853	24	26	72,18449349
2017-11-17	3806	2106	809	24	29	55,33368366
2017-11-18	1480	891	346	24	19	60,2027027
2017-11-19	0	0	0	0	0	0
2017-11-20	3971	1099	458	24	24	27,67564845
2017-11-21	1753	1250	441	24	22	71,306332
2017-11-22	3167	1149	440	24	28	36,28039154
2017-11-23	2124	1677	563	24	27	78,95480226
2017-11-24	2695	1586	601	24	30	58,84972171
2017-11-25	6	4	2	1	5	66,66666667

Excerpt of Sheet "operations_report" from the Report Generated for the Case with 4 Pick-ups with 6-Hour Time Gap

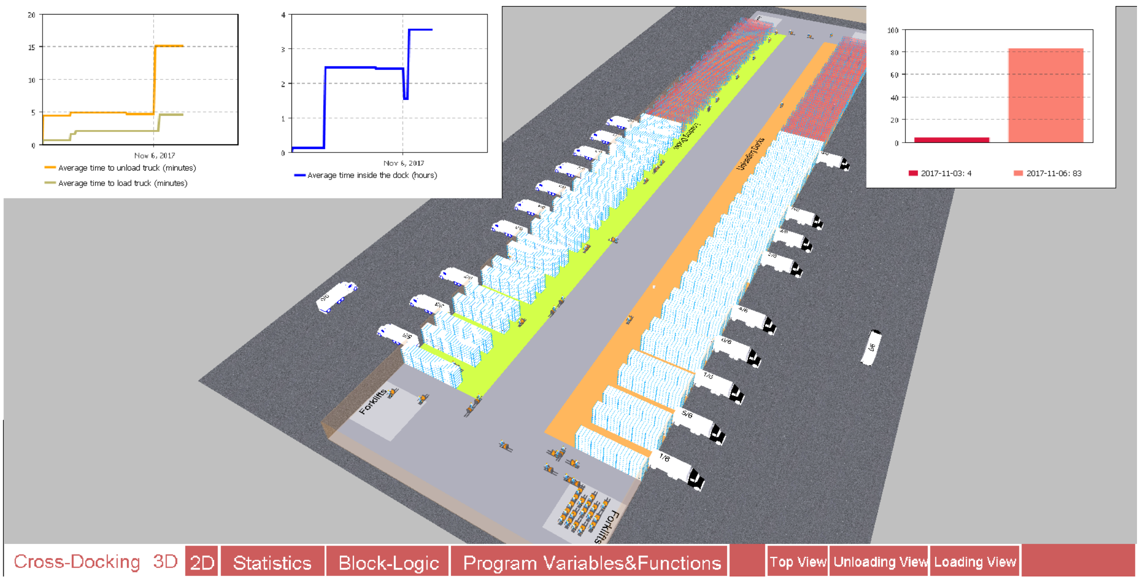
day	packages received	packages aggregated	orders aggregated	incoming trucks	outgoing trucks	**% of packages aggregated**
2017-11-02	5	0	0	1	4	0
2017-11-03	49	8	4	24	17	16,32653061
2017-11-04	0	0	0	0	0	0
2017-11-05	1	0	0	1	1	0
2017-11-06	651	222	83	24	19	34,10138249
2017-11-07	162	116	37	27	19	71,60493827
2017-11-08	918	314	125	24	19	34,20479303
2017-11-09	694	397	136	24	20	57,20461095
2017-11-10	718	432	163	24	18	60,16713092
2017-11-11	0	0	0	0	0	0
2017-11-12	1	0	0	1	1	0
2017-11-13	1625	562	213	24	19	34,58461538
2017-11-14	864	436	143	24	18	50,46296296
2017-11-15	4592	1837	712	24	32	40,0043554
2017-11-16	3534	2551	853	24	36	72,18449349
2017-11-17	3806	2106	809	24	39	55,33368366
2017-11-18	1480	891	346	24	24	60,2027027
2017-11-19	0	0	0	0	0	0
2017-11-20	3971	1099	458	24	30	27,67564845
2017-11-21	1753	1250	441	24	27	71,306332
2017-11-22	3167	1149	440	24	31	36,28039154
2017-11-23	2124	1677	563	24	28	78,95480226
2017-11-24	2695	1586	601	24	35	58,84972171
2017-11-25	6	4	2	1	5	66,66666667

Excerpt of Sheet "operations_report" from the Report Generated for the Case with 4 Pick-ups with Different Time Gaps Between Them

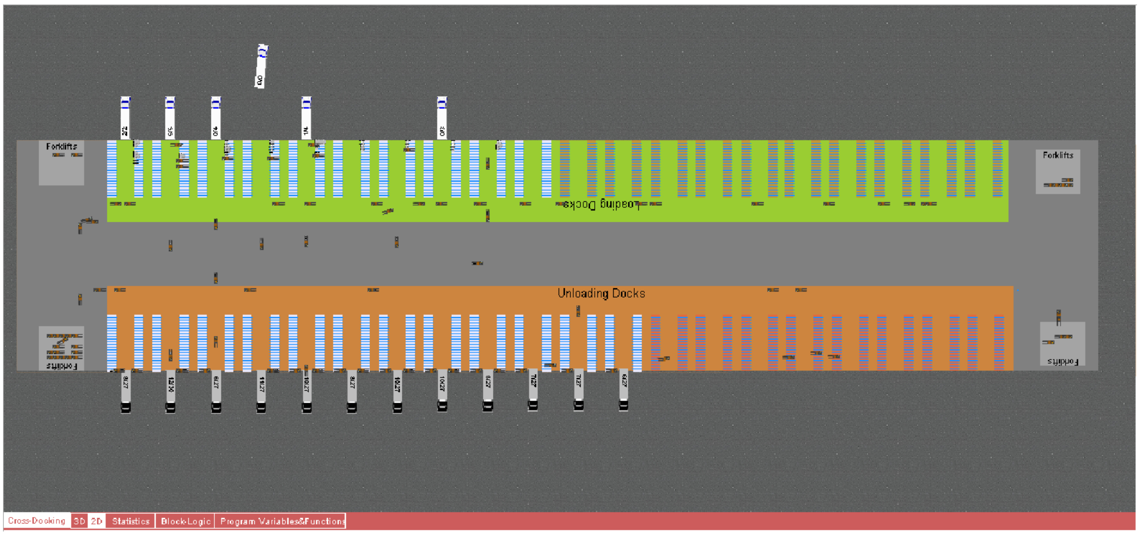
day	packages received	packages aggregated	orders aggregated	incoming trucks	outgoing trucks	**% of packages aggregated**
2017-11-02	5	0	0	1	4	0
2017-11-03	49	8	4	24	17	16,32653061
2017-11-04	0	0	0	0	0	0
2017-11-05	1	0	0	1	1	0
2017-11-06	651	222	83	24	19	34,10138249
2017-11-07	162	116	37	27	19	71,60493827
2017-11-08	918	314	125	24	19	34,20479303
2017-11-09	694	397	136	24	20	57,20461095
2017-11-10	718	432	163	24	18	60,16713092
2017-11-11	0	0	0	0	0	0
2017-11-12	1	0	0	1	1	0
2017-11-13	1625	562	213	24	21	34,58461538
2017-11-14	864	436	143	24	18	50,46296296
2017-11-15	4592	1837	712	24	37	40,0043554
2017-11-16	3534	2551	853	24	36	72,18449349
2017-11-17	3806	2106	809	24	39	55,33368366
2017-11-18	1480	891	346	24	27	60,2027027
2017-11-19	0	0	0	0	0	0
2017-11-20	3971	1099	458	24	33	27,67564845
2017-11-21	1753	1250	441	24	31	71,306332
2017-11-22	3167	1149	440	24	39	36,28039154
2017-11-23	2124	1677	563	24	37	78,95480226
2017-11-24	2695	1586	601	24	40	58,84972171
2017-11-25	6	4	2	1	5	66,66666667

Annex E: Chinese Case's View Areas

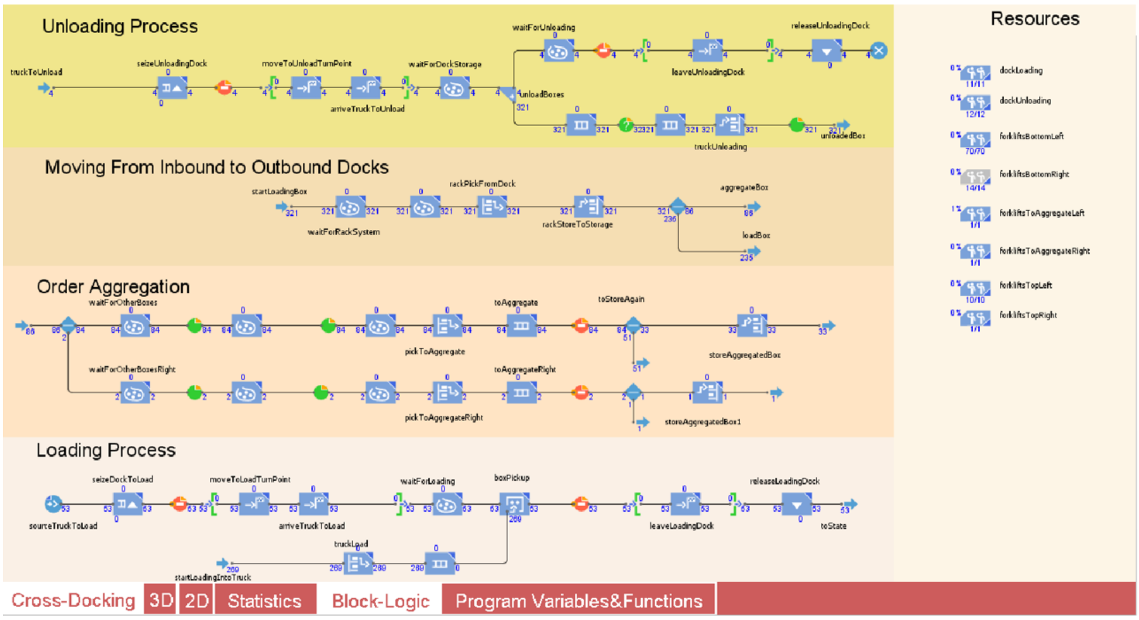
3D' View Area



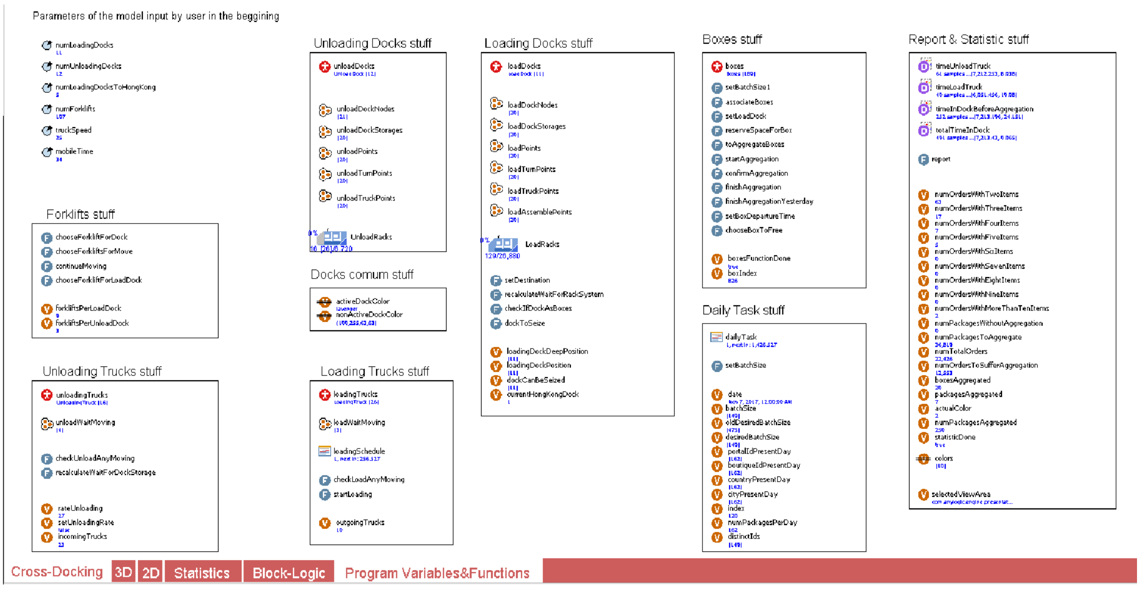
2D’ View Area



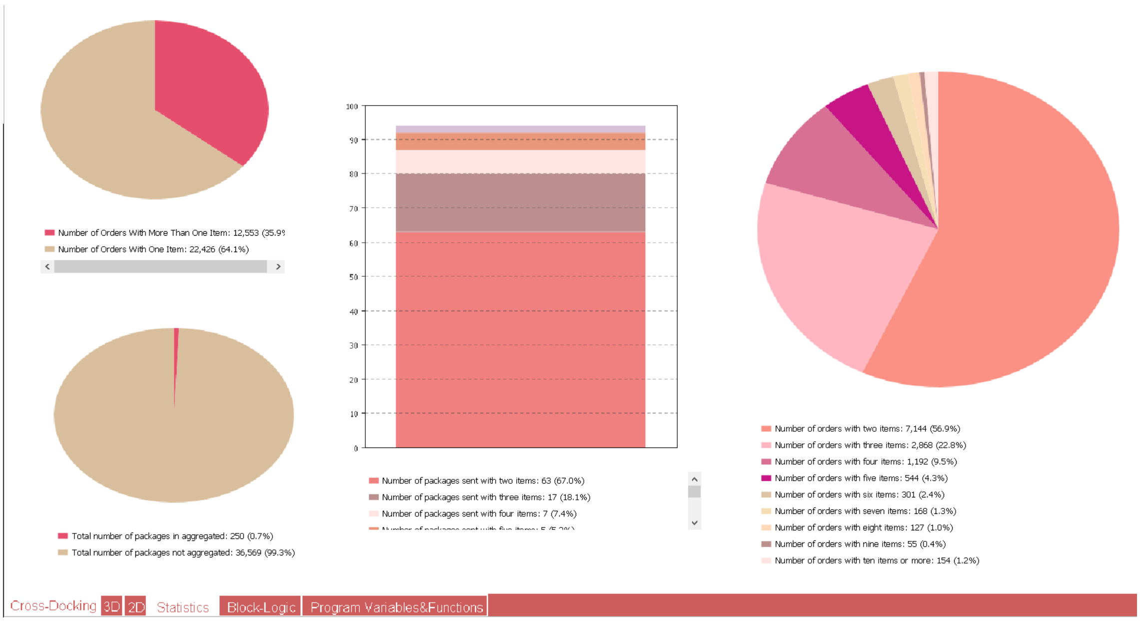
Block Logic’s View Area



Program & Stuff' View Area

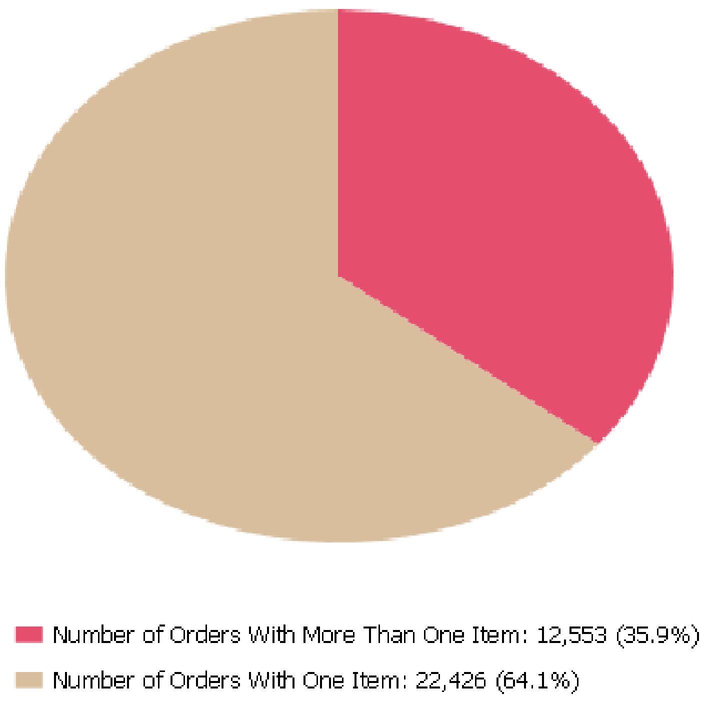


Statistics' View Area

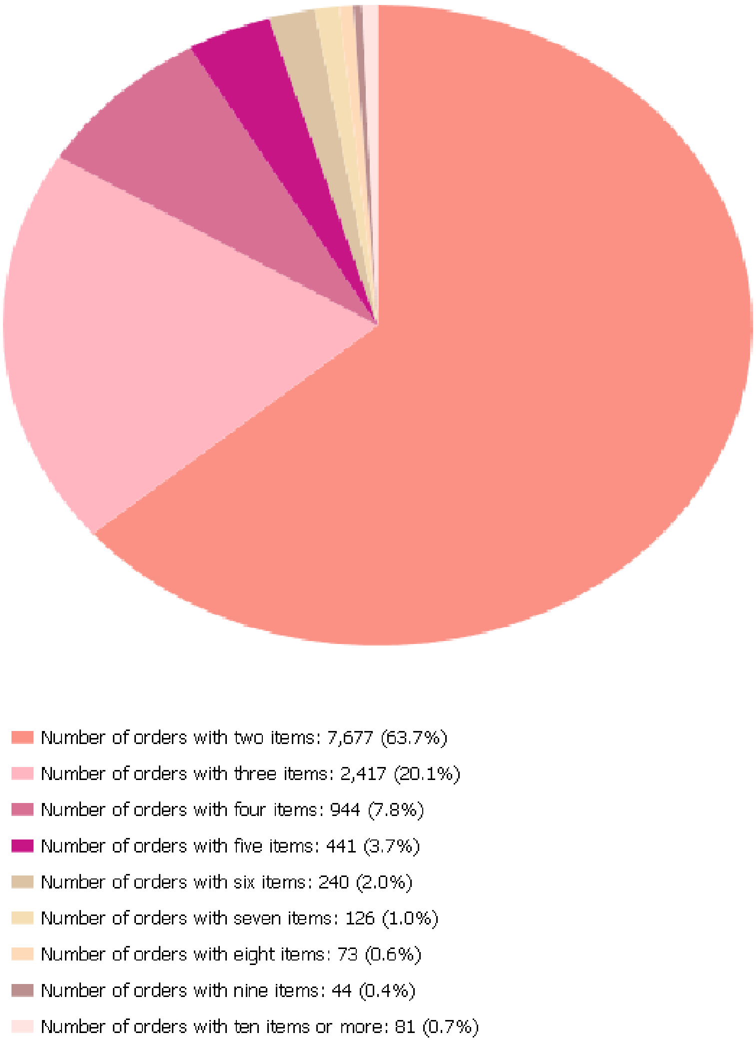


Annex F: Transatlantic Bridge Case's Statistics

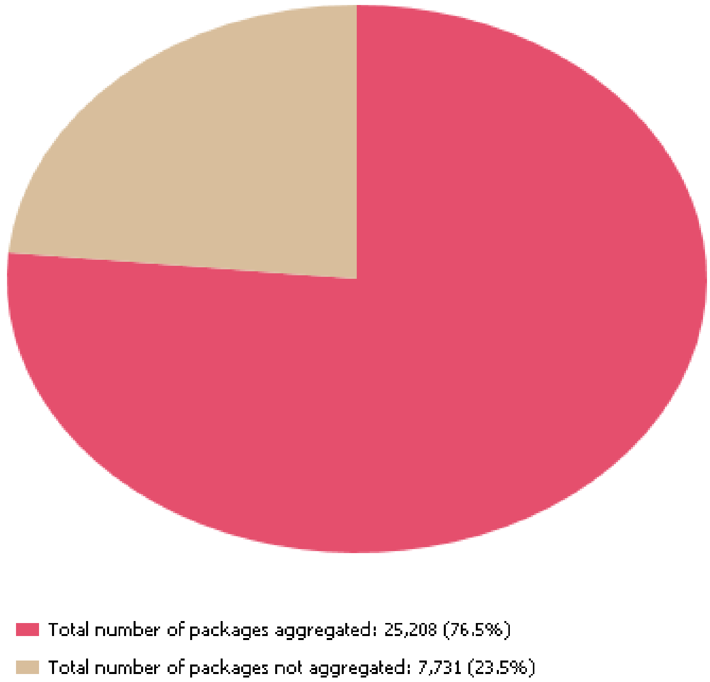
Static Pie Chart for the Amount of Orders that can Suffer Aggregation



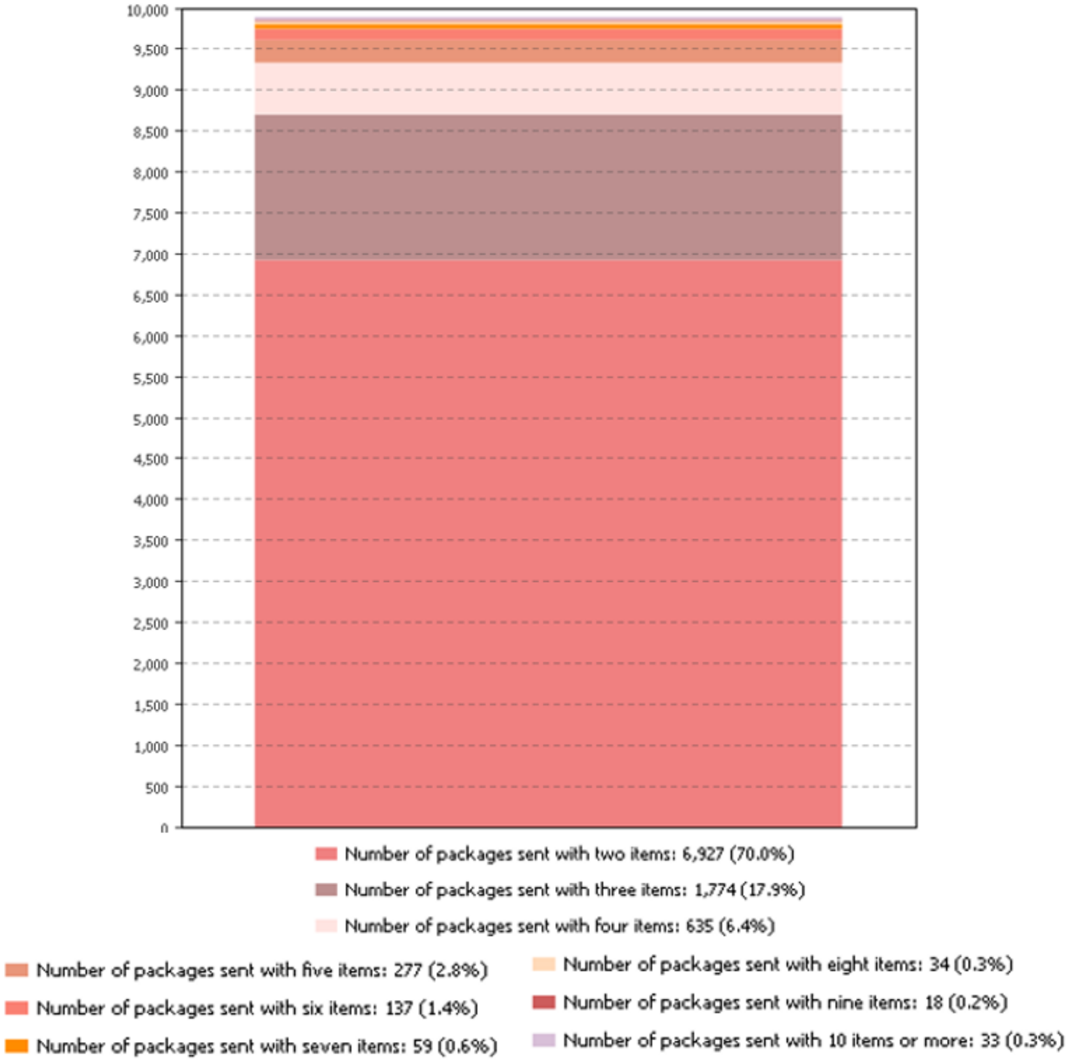
Static Pie Chart Divides the Orders that can Suffer Aggregation Based on the Amount of Articles



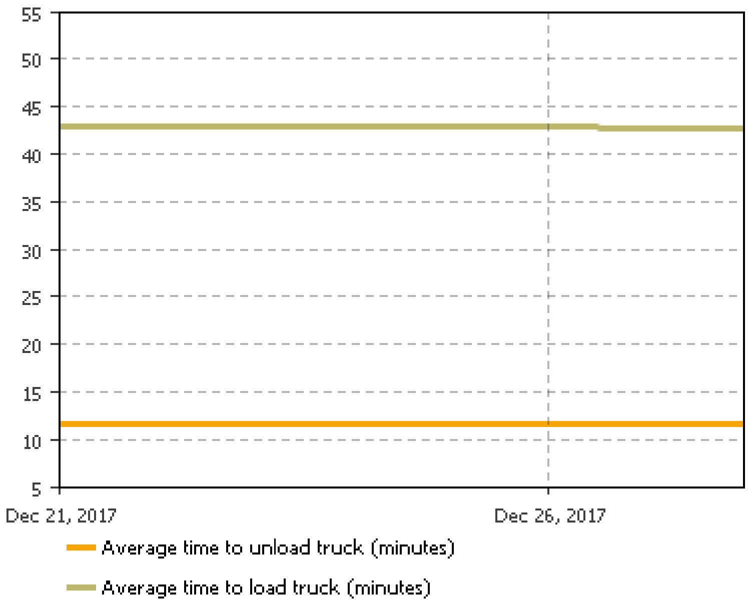
Non Static Pie Chart that Shows the Amount of Packages that Suffer Consolidation



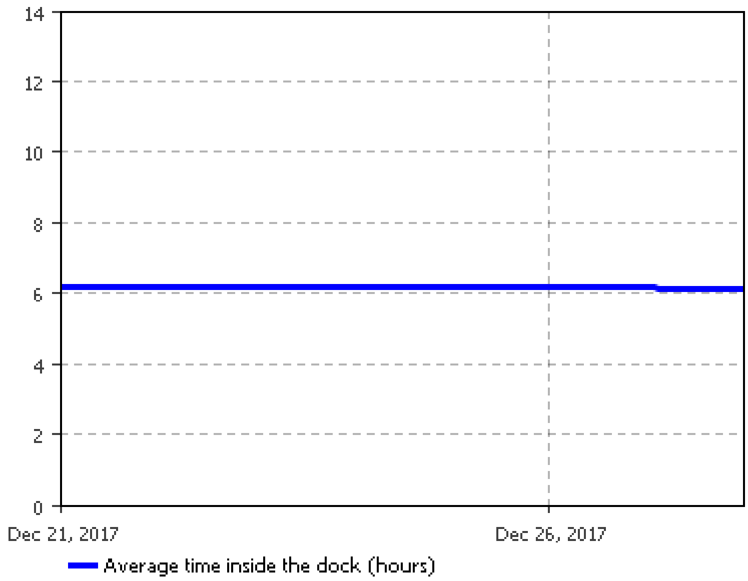
Non Static Stack Chart that Shows the Amount of Packages Sent Based on the Number of Articles Inside the Boxes



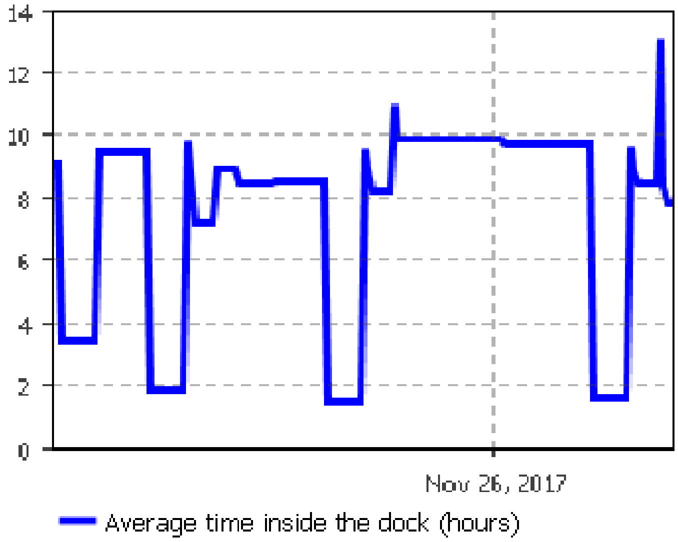
Time Plot for the Average Time Spend by Packages in the Italian Cross-Dock



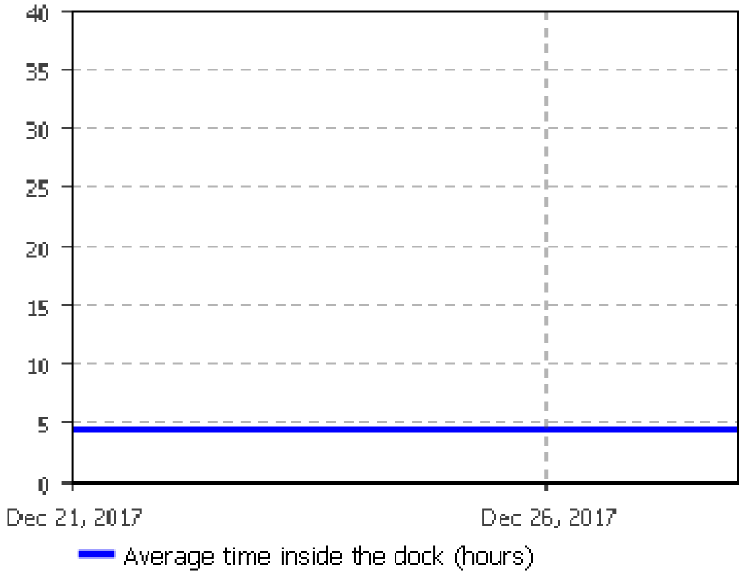
Time Plot for the Average Time Spend by Packages in the Italian Cross-Dock



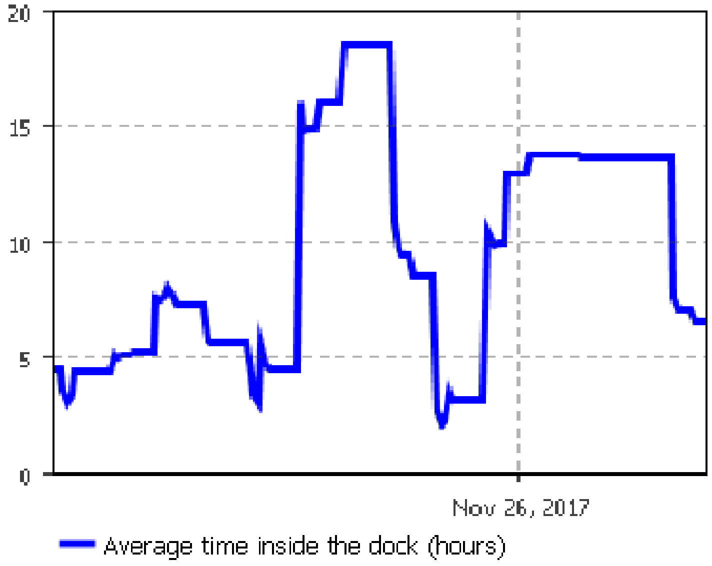
Time Plot for the Spike of the Average Time Spend by Packages in the Italian Cross-Dock



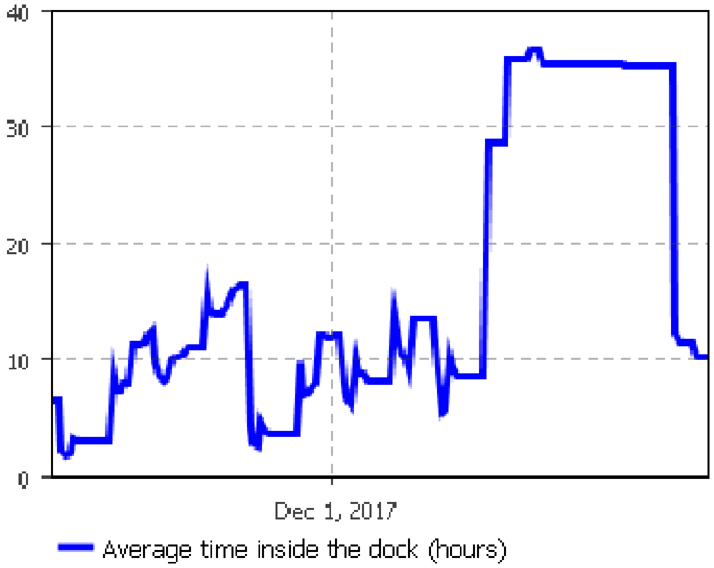
Time Plot for the Average Time Spend by Packages in the American Cross-Dock



Time Plot for the First Spike of the Average Time Spend by Packages in the American Cross-Dock



Time Plot for the Second Spike of the Average Time Spend by Packages in the American Cross-Dock



Annex G: Transatlantic Bridge Case's Reports

Excerpt of Sheet "report" from the Report Generated for the Italian Cross-dock

portal order id	arrival time	departure time	total hours in the dock
35ALES	29/11/2017 03:21:22	29/11/2017 22:21:15	18,998
GJU7Z6	29/11/2017 03:21:22	29/11/2017 22:21:18	18,998
PC9X33	29/11/2017 03:21:22	29/11/2017 21:53:47	18,54
BEZ6NX	29/11/2017 03:21:22	29/11/2017 21:53:31	18,535
QUTV5C	29/11/2017 03:21:22	29/11/2017 21:53:18	18,532
59378A	29/11/2017 03:21:22	29/11/2017 21:53:21	18,532
8VPLBN	29/11/2017 03:21:22	29/11/2017 21:53:14	18,531
59S7MA	29/11/2017 03:21:22	29/11/2017 21:53:12	18,53
QUTW5C	29/11/2017 03:21:22	29/11/2017 21:53:07	18,529
UGVZPV	29/11/2017 03:21:22	29/11/2017 21:52:42	18,522
VM8YXB	29/11/2017 03:21:22	29/11/2017 21:52:33	18,519
W3YWPU	29/11/2017 03:21:22	29/11/2017 21:52:34	18,519
N7FNL5	29/11/2017 03:55:21	29/11/2017 22:21:38	18,438
5933CA	29/11/2017 03:55:21	29/11/2017 22:21:35	18,437
PCSWZ3	29/11/2017 03:55:21	29/11/2017 22:21:25	18,434
FNJC4M	29/11/2017 03:55:21	29/11/2017 22:21:22	18,433
FNHHAM	29/11/2017 03:55:21	29/11/2017 22:21:18	18,432
7ANWYZ	29/11/2017 03:55:21	29/11/2017 22:21:19	18,432
BESHKX	29/11/2017 03:21:22	29/11/2017 21:25:52	18,074
TKRDBH	29/11/2017 03:21:22	29/11/2017 21:25:48	18,073
UGQ5QV	29/11/2017 03:21:22	29/11/2017 21:25:40	18,071
J2QZQW	29/11/2017 03:21:22	29/11/2017 21:25:26	18,067

Excerpt of Sheet "operations_report" from the Report Generated for the Italian Cross-dock

day	packages received	incoming trucks	outgoing trucks
2017-11-02	24	12	18
2017-11-03	297	126	22
2017-11-04	0	0	0
2017-11-05	0	0	0
2017-11-06	1514	247	22
2017-11-07	724	203	22
2017-11-08	1794	291	22
2017-11-09	1357	241	22
2017-11-10	1202	253	22
2017-11-11	0	0	0
2017-11-12	4	4	4
2017-11-13	1737	276	22
2017-11-14	1132	219	22
2017-11-15	3051	294	22
2017-11-16	2384	269	22
2017-11-17	1989	252	22
2017-11-18	0	0	0
2017-11-19	4	4	4
2017-11-20	2675	306	22
2017-11-21	1853	234	22
2017-11-22	4919	303	33
2017-11-23	116	75	22
2017-11-24	6592	302	33
2017-11-25	1	1	1
2017-11-26	9	8	9
2017-11-27	8031	331	33
2017-11-28	3953	287	22
2017-11-29	9290	341	33

Excerpt of Sheet "report" from the Report Generated for the American Cross-dock

portal order id	arrival time	departure time	total hours in the dock	num articles inside
Z6BJUQ	01/12/2017 01:40:11	03/12/2017 15:06:19	61,435	7
VMMWUB	30/11/2017 08:52:38	02/12/2017 15:33:56	54,688	7
FND5DM	30/11/2017 09:15:51	02/12/2017 15:39:00	54,385	14
7AAPRZ	30/11/2017 09:20:25	02/12/2017 15:27:45	54,122	7
YWWVVJ	30/11/2017 09:33:59	02/12/2017 15:14:06	53,668	9
597WGA	30/11/2017 10:44:03	02/12/2017 15:24:48	52,679	13
8R8WKN	21/11/2017 23:46:21	24/11/2017 02:06:39	50,338	9
59UM5A	01/12/2017 03:07:31	03/12/2017 05:06:43	49,986	6
CRF4ZT	30/11/2017 13:40:23	02/12/2017 15:03:39	49,387	8
3553ZS	30/11/2017 15:11:03	02/12/2017 15:25:26	48,239	7
59W6LA	01/12/2017 02:16:46	03/12/2017 02:11:41	47,915	9
8VR6QN	29/11/2017 02:43:26	01/12/2017 02:17:58	47,575	6
N3DXW5	21/11/2017 21:59:01	23/11/2017 15:47:30	41,808	14
2N4RX2	21/11/2017 22:32:03	23/11/2017 16:12:25	41,672	11
59ZFNA	30/11/2017 02:59:19	01/12/2017 20:20:05	41,346	13
RUF4LK	15/11/2017 22:53:24	17/11/2017 15:30:16	40,614	6
BE9GBX	28/11/2017 23:20:09	30/11/2017 15:41:50	40,361	10
SBT4SF	15/11/2017 23:18:35	17/11/2017 15:36:50	40,304	15
CQ8RAT	22/11/2017 00:01:53	23/11/2017 16:08:54	40,116	6
9BB5L9	30/11/2017 10:30:18	02/12/2017 02:27:27	39,952	7
PCZ4E3	30/11/2017 10:36:12	02/12/2017 02:25:03	39,814	8
Z66CFQ	01/12/2017 23:30:28	03/12/2017 15:04:43	39,57	3
59CB6A	01/12/2017 00:09:26	02/12/2017 15:41:08	39,528	6
W3297U	01/12/2017 23:52:03	03/12/2017 15:13:28	39,356	8
SB89QF	16/11/2017 00:46:43	17/11/2017 15:27:58	38,687	11
GJUGR6	30/11/2017 12:13:23	02/12/2017 02:49:09	38,596	7
W33AZU	01/12/2017 00:41:13	02/12/2017 15:15:19	38,568	7
ZPMM8Q	16/11/2017 00:53:31	17/11/2017 15:27:27	38,565	8
68Z3HD	01/12/2017 00:55:42	02/12/2017 15:19:27	38,395	6
KL6EE7	28/11/2017 02:00:33	29/11/2017 15:52:09	37,86	18

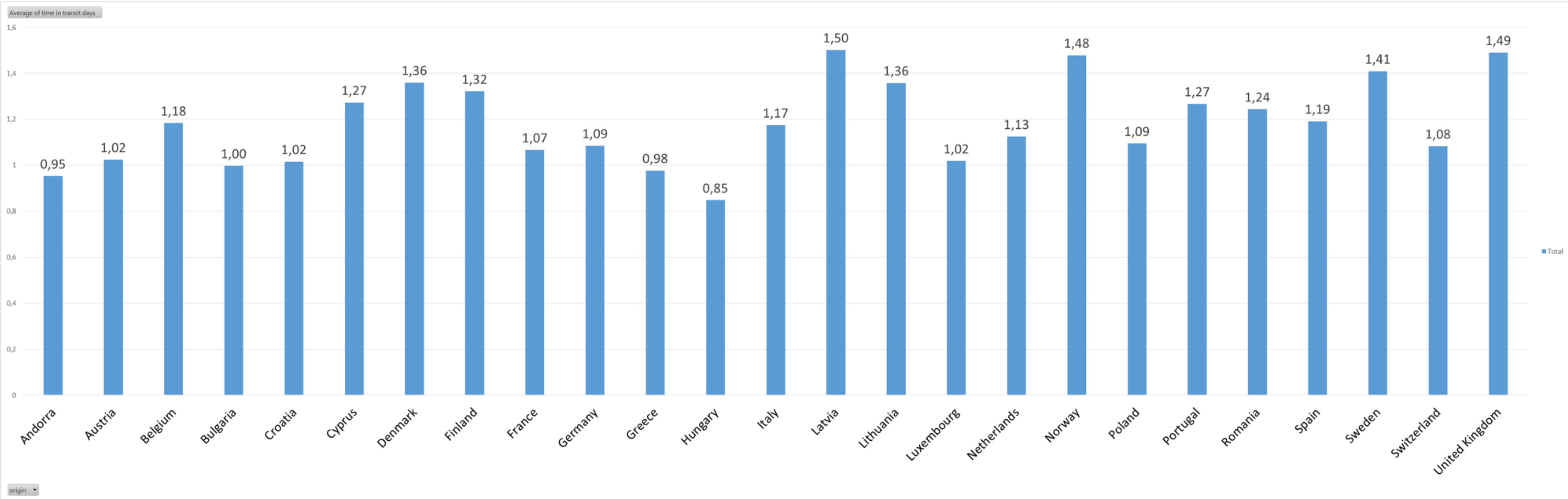
Excerpt of Sheet "operations_report" from the Report Generated for the American Cross-dock

day	packages received	packages aggregated	orders aggregated	incoming trucks	outgoing trucks	**% of packages aggregated**
2017-11-02	24	4	2	2	4	16,66666667
2017-11-03	297	82	32	3	27	27,60942761
2017-11-04	0	0	0	0	22	0
2017-11-05	0	0	0	0	0	0
2017-11-06	1514	229	104	9	41	15,12549538
2017-11-07	724	346	131	4	68	47,79005525
2017-11-08	1794	363	148	10	74	20,23411371
2017-11-09	1357	564	219	8	83	41,56226971
2017-11-10	1202	460	184	7	79	38,26955075
2017-11-11	0	131	51	0	43	0
2017-11-12	4	0	0	1	3	0
2017-11-13	1737	188	81	10	39	10,82325849
2017-11-14	1132	463	188	7	77	40,90106007
2017-11-15	3051	382	155	17	82	12,52048509
2017-11-16	2384	1356	500	13	111	56,87919463
2017-11-17	1989	1499	504	11	112	75,36450478
2017-11-18	0	489	172	0	60	0
2017-11-19	4	2	1	1	2	50
2017-11-20	2675	198	88	15	45	7,401869159
2017-11-21	1853	868	338	10	100	46,84295737
2017-11-22	966	550	202	5	93	56,93581781
2017-11-23	4069	2401	942	23	141	59,00712706
2017-11-24	1081	79	35	6	80	7,308048104
2017-11-25	5512	2321	933	30	159	42,10812772
2017-11-26	9	0	0	1	16	0
2017-11-27	1102	19	9	6	55	1,724137931
2017-11-28	10818	2288	969	57	165	21,14993529
2017-11-29	1141	1822	680	6	140	159,6844873

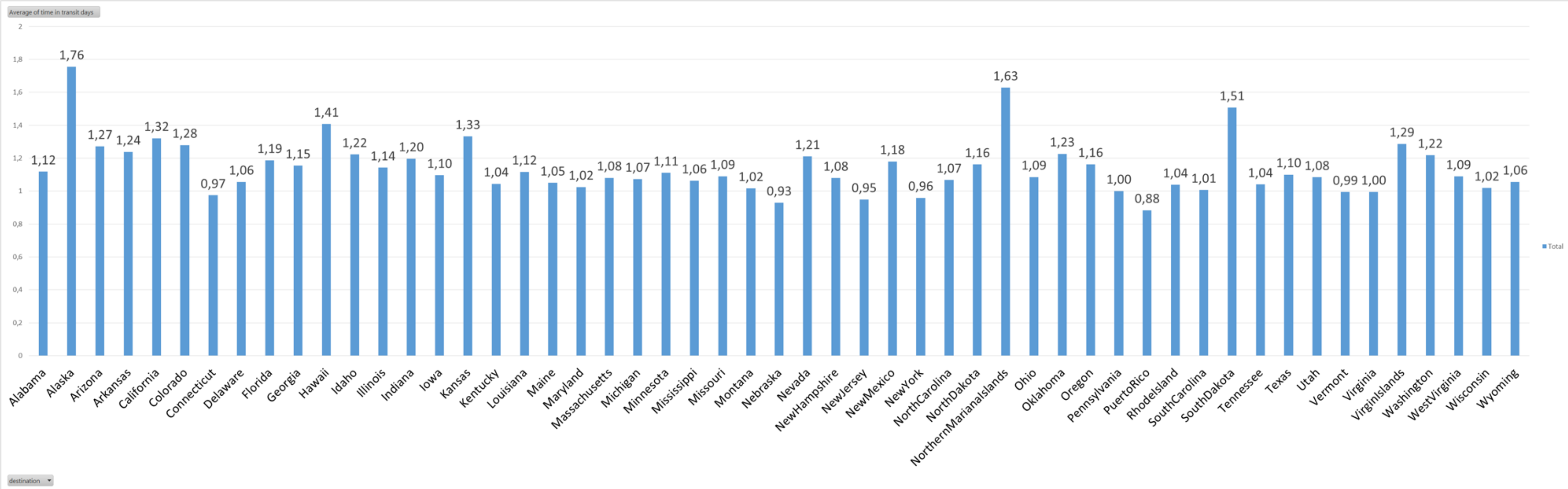
Excerpt of Sheet "time_in_transit" from the Report Generated for the Transatlantic Bridge Case

origin	destination	time in transit days	time in transit hours	num of packages
United Kingdom	Connecticut	0,628496215	15,08390917	1
Switzerland	NorthCarolina	0,625301921	15,00724611	1
Netherlands	NorthCarolina	0,661255648	15,87013556	1
United Kingdom	Florida	0,709749815	17,03399556	1
United Kingdom	Colorado	0,770483727	18,49160944	1
Portugal	NorthCarolina	0,724749398	17,39398556	2
Italy	NorthCarolina	0,717612199	17,22269278	2
Italy	NorthCarolina	0,719166655	17,25999972	1
Portugal	NorthCarolina	0,722495787	17,33989889	2
Portugal	NorthCarolina	0,728874525	17,49298861	2
Portugal	NorthCarolina	0,726800509	17,44321222	1
Portugal	NorthCarolina	0,725720972	17,41730333	1
Portugal	NorthCarolina	0,723634306	17,36722333	1
Portugal	NewMexico	0,846636065	20,31926556	1
Portugal	NewMexico	0,845854213	20,30050111	1
Portugal	NewMexico	0,844426991	20,26624778	1
Portugal	NewMexico	0,840401343	20,16963222	1
Italy	Connecticut	0,561284074	13,47081778	1
Italy	Connecticut	0,569714618	13,67315083	1
Spain	Connecticut	0,562739988	13,50575972	1
France	Connecticut	0,552729132	13,26549917	1
Belgium	Connecticut	0,522342037	12,53620889	1
Germany	Maryland	0,561289421	13,47094611	1
France	Maryland	0,557562951	13,38151083	1
Germany	Maryland	0,550086215	13,20206917	1
Switzerland	Massachusetts	0,591786782	14,20288278	1
Italy	Massachusetts	0,578163194	13,87591667	1

Pivot Table Showing the Average Time Between All the European Countries and the USA

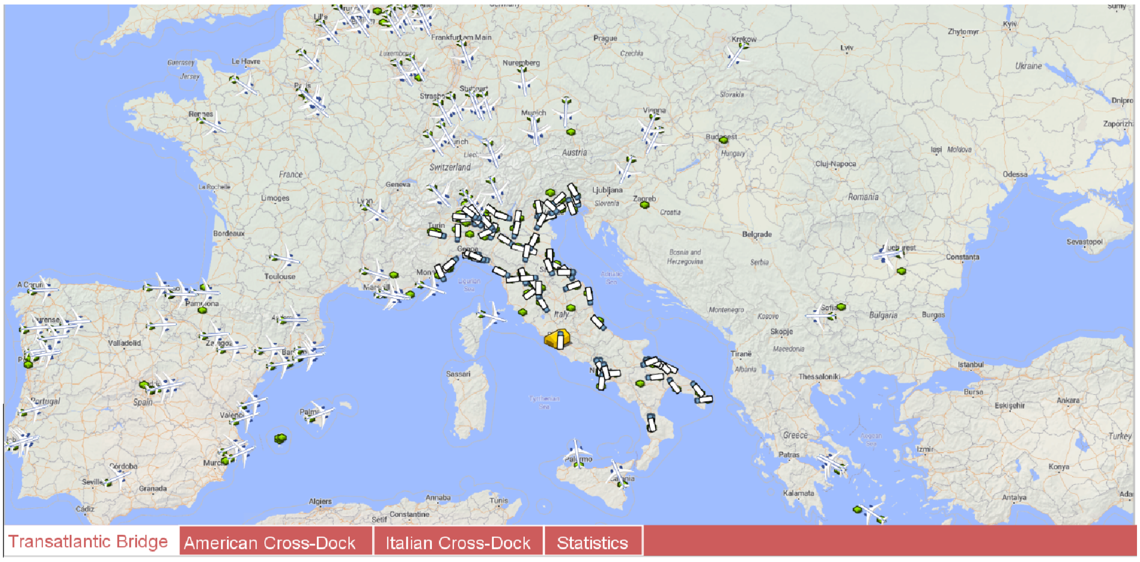


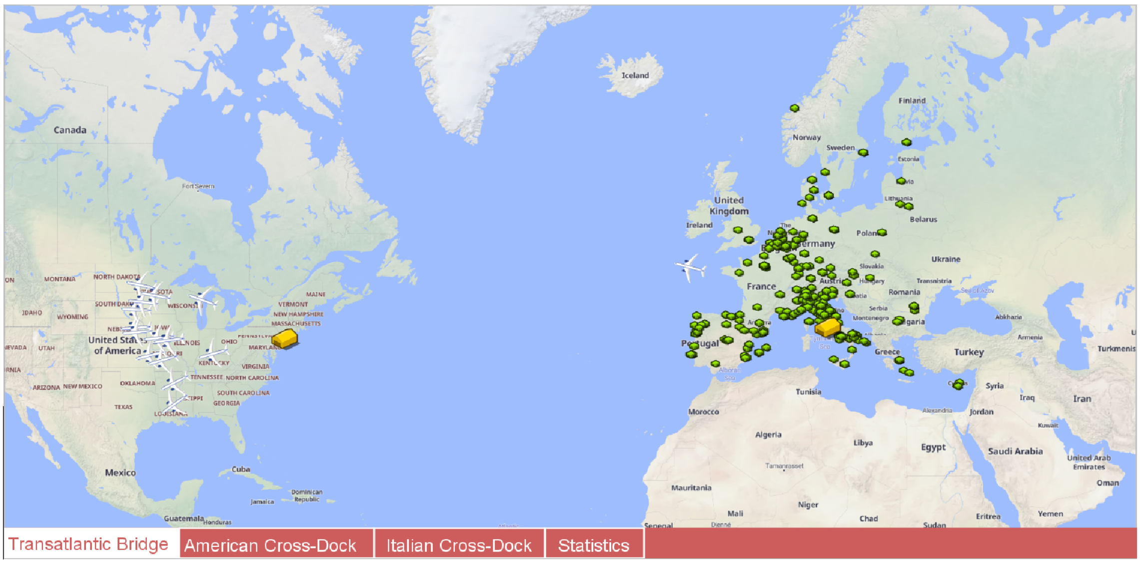
Pivot Table Showing the Average Time to All the American States



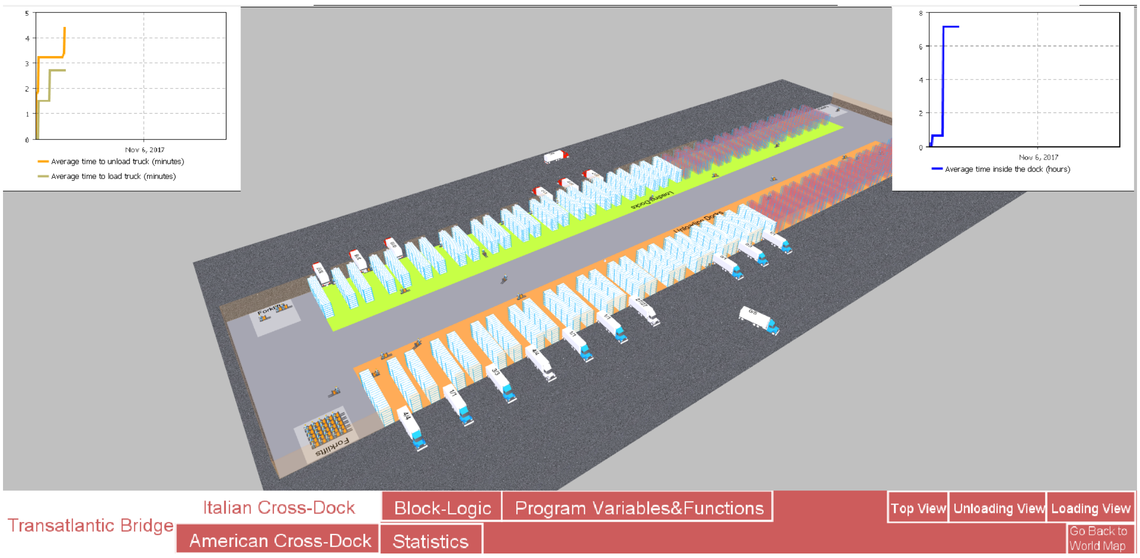
Annex H: Transatlantic Bridge Case's View Areas

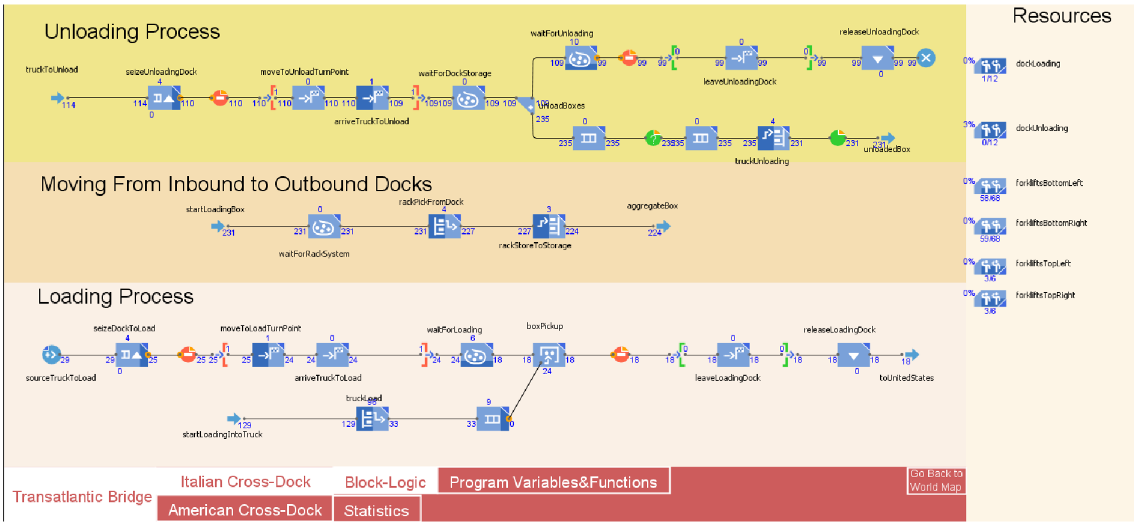
World Map's View Area

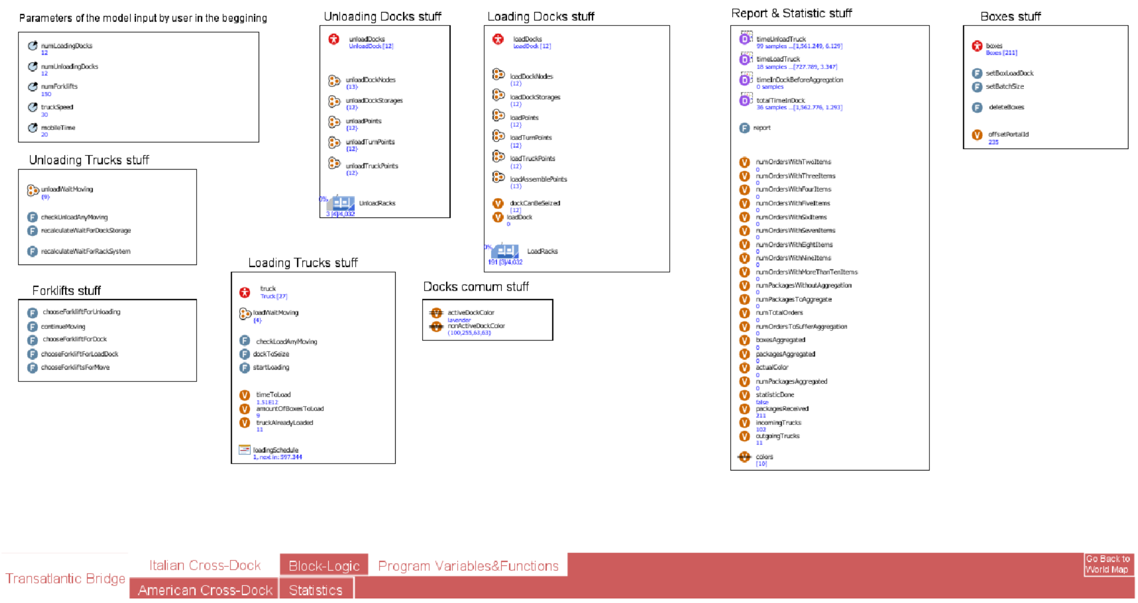




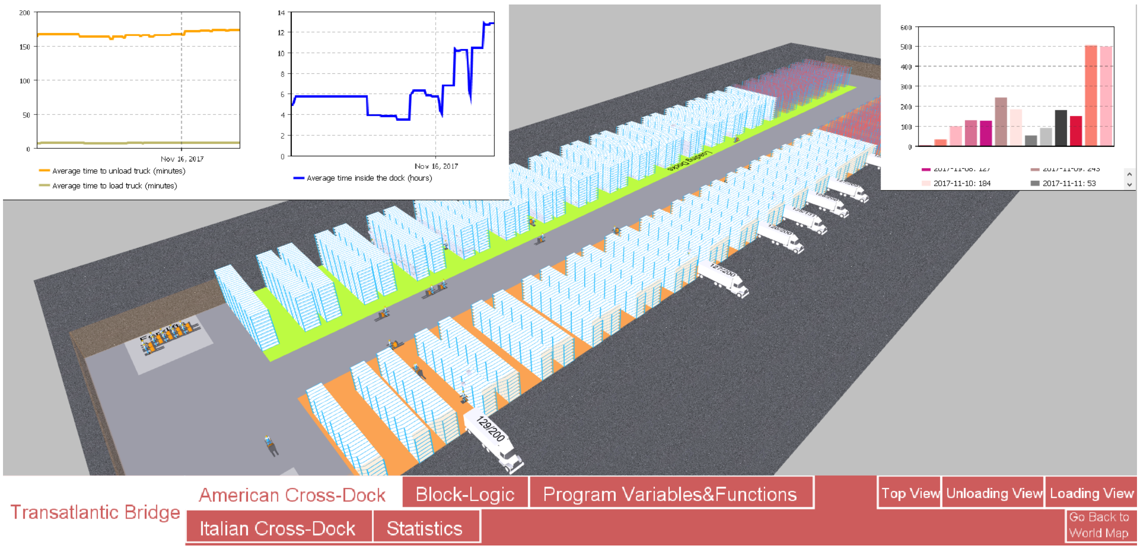
Italian Cross-Dock's View Areas

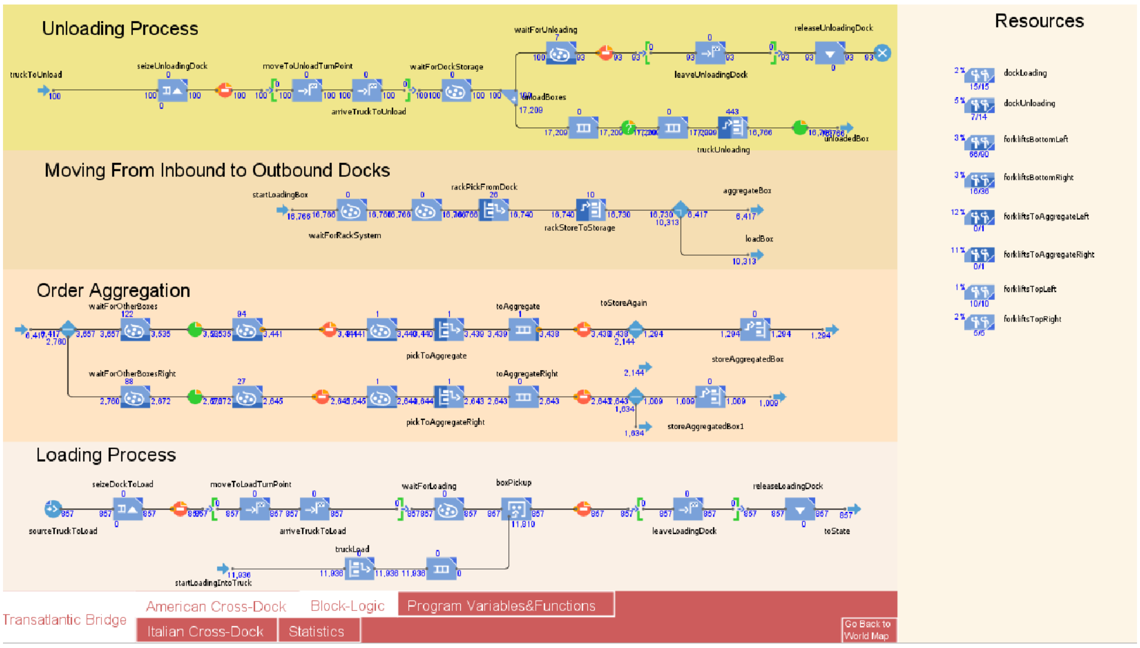


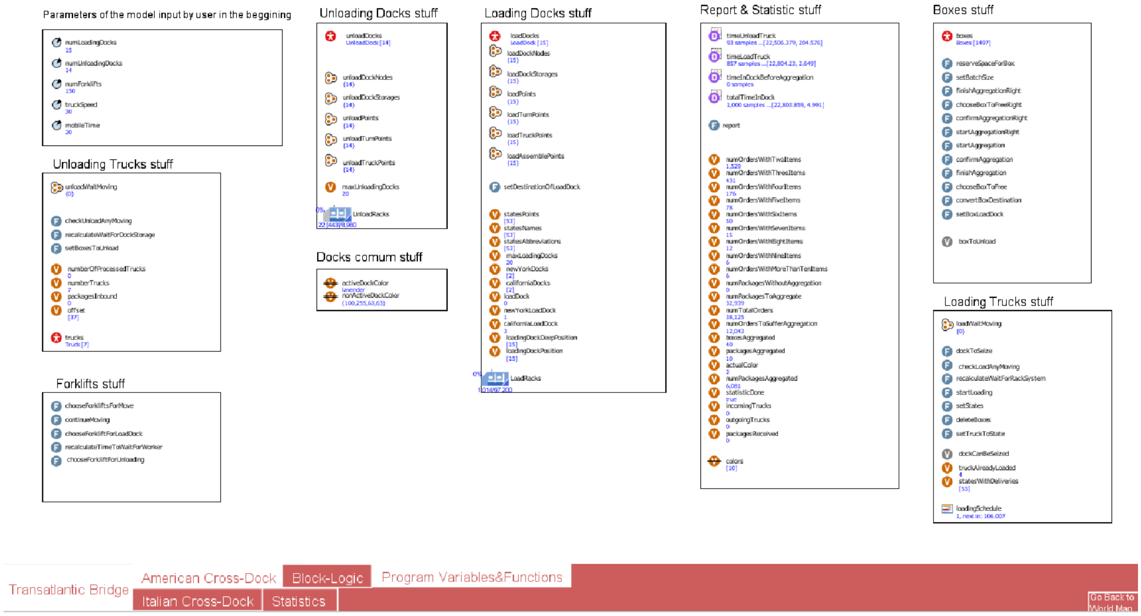

Unloading Process
Resources
Moving From Inbound to Outbound Docks
Loading Process
Transatlantic Bridge
Italian Cross-Dock
Block-Logic
Program Variables&Functions
American Cross-Dock
Statistics
Go Back to World Map


Parameters of the model input by user in the beggining
Unloading Docks stuff
Loading Docks stuff
Report & Statistic stuff
Boxes stuff
Unloading Trucks stuff
Forklifts stuff
Loading Trucks stuff
Docks comum stuff
Transatlantic Bridge
Italian Cross-Dock
Block-Logic
Program Variables&Functions
American Cross-Dock
Statistics
Go Back to World Map

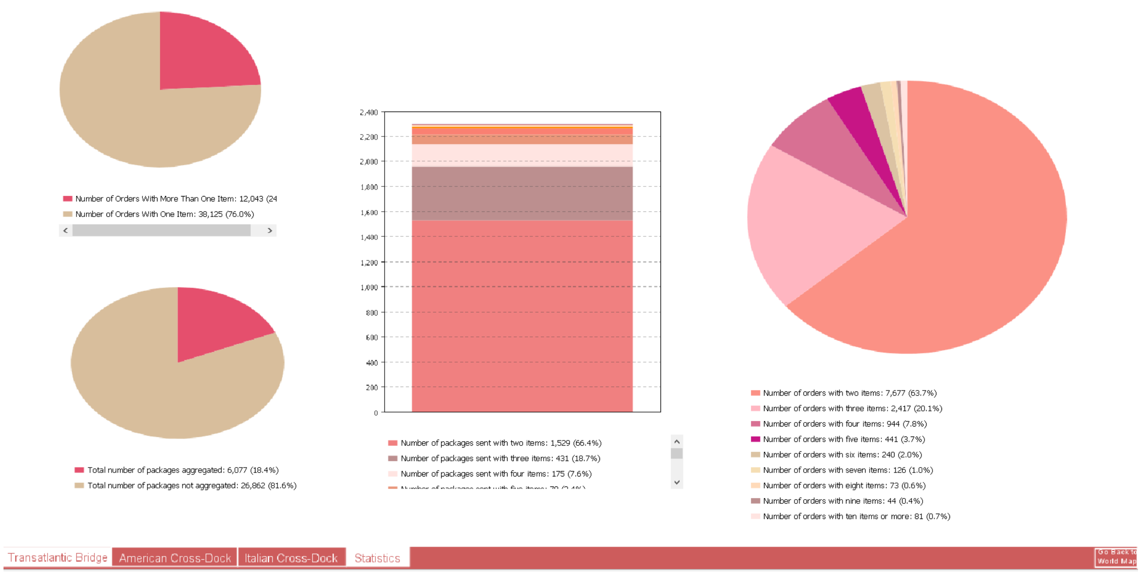
American Cross-Dock's View Areas







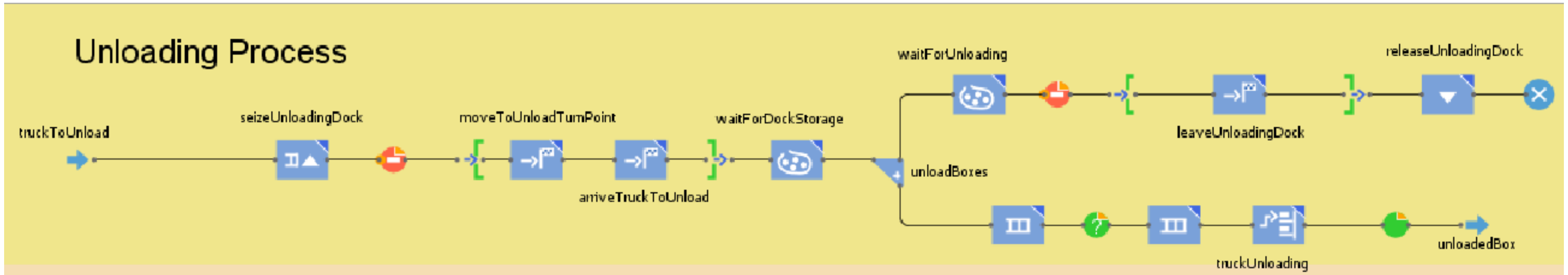
Statistics' View Area



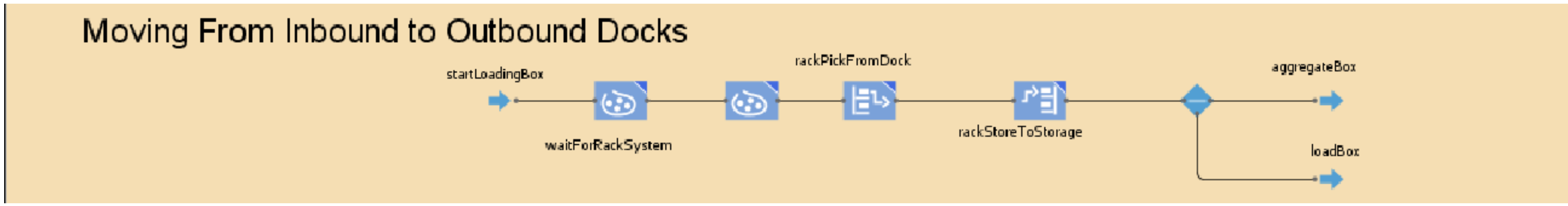
Annex I: Simulation's Logic

Resources Pools

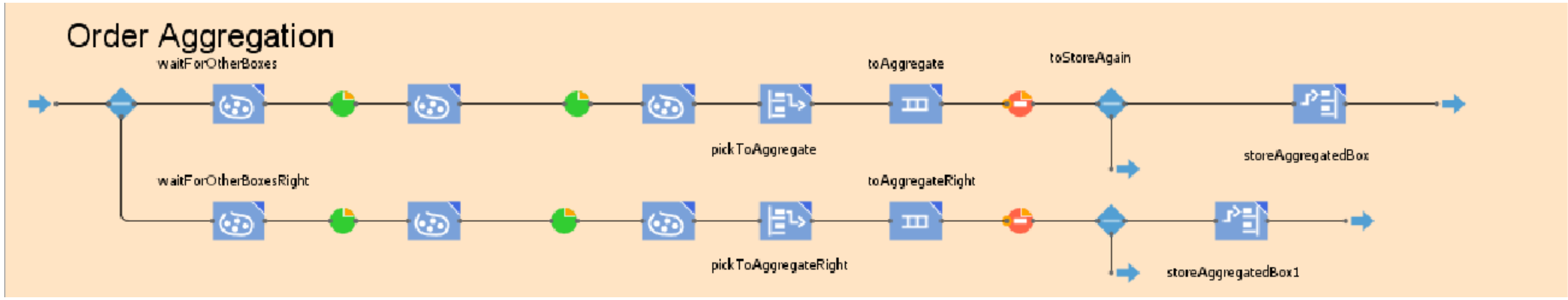
Unloading Logic



Moving From Inbound to Outbound Docks Logic



Consolidation Logic



Loading Logic