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Real-Time Dynamic Maps for Delivery Planning Optimization

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Resumo

Em qualquer negócio de *e-commerce*, o serviço de entregas tem um papel importante no desempenho da empresa, visto representar o elo de ligação entre o produto e o consumidor final.

Esta tese procura resolver os problemas atuais de planeamento e gestão de entregas de curta distância recorrendo à implementação de mapas dinâmicos em tempo real. Estes consistem em áreas dinâmicas de entrega baseadas em origens fixas. Esta nova abordagem irá ajudar a gerir e configurar métodos de entrega novos ou já existentes, resultando numa melhor experiência de compra para o cliente final e numa abrangência maior destes serviços de entrega.

Este projeto propõe também uma nova abordagem dinâmica em oposição à solução atual: variáveis estáticas (como restrições de entregas baseadas em códigos postais) são substituídas por informação precisa em tempo real. Garante-se não só um melhor serviço como também um aumento da sua capacidade.

Focado especialmente no serviço de entrega em 90 minutos oferecido pela Farfetch, foi realizado um estudo inicial extensivo deste processo, seguido pelo desenho de uma possível abordagem e solução dos problemas existentes relacionados com o escalonamento e gestão de serviços de entrega em curtas distâncias. Atualmente, a abrangência deste serviço não pode ser aumentada e o seu desempenho oferece grandes oportunidades de melhoria.

Inicialmente foi desenhado um algoritmo de estimação de tempos de entrega pela análise individual das várias componentes do processo. Posteriormente, este deu origem a uma ferramenta de desenho de áreas dinâmicas de entrega calculadas com informação precisa e em tempo real. Esta apresenta-se como a parte mais promissora deste projeto.

Os resultados finais são satisfatórios considerando o tempo de vida deste projeto, mas existe uma grande margem para melhoria e trabalho futuro. Existe a necessidade de continuar a colecionar dados provenientes dos algoritmos propostos e confrontá-los com informação real. Isto irá contribuir não só para o aumento da precisão e robustez do algoritmo como um todo, bem como para encontrar fontes de erro que permtirão a correção do modelo.

Abstract

In any e-commerce business, delivery takes a big stake shaping a company's performance, since it represents the link between the product and the customer.

This thesis seeks to solve current planning and delivery management related issues on short-distance delivery methods, by implementing real-time dynamic maps which consist on possible delivery areas based on fixed origins. This new approach will help to manage and configure new or existing delivery methods, resulting in better customer buying experience and service reachability.

Furthermore, this project intends to provide a new dynamic approach in contrast with the current applied solution: static dependencies (like delivery restrictions based on zip codes) will be replaced with real-time accurate information, granting better service to be provided while allowing process scalability.

Focused specifically on 90 minutes delivery service provided by Farfetch, an extensive study on the delivery process was done, followed by a possible approach to current scalability and management delivery related problems. Currently, this service cannot be scaled and its performance has big room for improvement.

A delivery time algorithm which estimates the whole delivery time by analyzing individually each part of the process was firstly developed which later derived in a full delivery isochrone mapping tool computed with real-time information. This is the most promising part of this project.

Final results are satisfactory when considering the 5 month life span of this project, but there is a big room for improvement in the future. There is a need of keeping collecting algorithm data and compare it with real information. This will not only make the whole algorithm more robust, but new error sources will be identified and used to improve the model.

Agradecimentos

Em Setembro de 2013 tornei-me oficialmente aluno universitário. Estava longe de saber o que se avizinhava e os desafios que teria de enfrentar; contudo, decidi agarrar esta oportunidade e aqui me encontro 5 anos depois.

A noção da passagem do tempo é muito dependende daquilo que estamos a fazer: umas férias passam num abrir e fechar de olhos, enquanto as horas antes da entrega de um trabalho importante por vezes parecem não ter fim.

Na verdade, parece que foi num passado muito próximo que entrei na faculdade mas na verdade já passaram quase 5 anos de muito trabalho, novas experiências e desafios, diversão, viagens, amigos e acima de tudo felicidade.

No meio de tantos livros, trabalhos e exames, sinto que nada seria possível sem as pessoas que me rodeiam no meu dia-a-dia.

Em primeiro lugar a minha família, especialmente os meus pais e avós, que sempre dispuseram do seu tempo e paciência em prol da minha educação e formação como ser-humano: obrigado por me acompanharem nestes anos e me suportarem em todas as minhas decisões. Certamente não teria sido o mesmo sem o vosso carinho e apoio.

Aos meu grupo de amigos, que considero a minha segunda família, obrigado também pela paciência e por partilharem comigo bons momentos que nunca esquecerei: um brinde ao vosso sucesso e que a vida vos sorria o dobro do que sorri a mim todos os dias.

Às pessoas que acompanharam diretamente o meu sucesso académico e que fizeram parte dele, especialmente ao Pedro e ao António aqui na Farfetch, por serem pessoas com interesse e dedicação em orientar este projeto: muito obrigado e desejos de uma vida pessoal e profissional recheada de saúde e sucesso.

Por fim, a todas as outras pessoas espalhadas pelo mundo fora que de certa forma se foram cruzando comigo e com quem tive o prazer de partilhar bons momentos da minha vida: muito obrigado e espero poder ver-vos em breve.

Estes 5 anos fizeram-me perceber algo muito importante: sem as pessoas de valor e respeito que tenho à minha volta diariamente, nunca tinha chegado até aqui. À vossa!

Rodrigo Vaz-Pires

Para o meu Avô Horácio.

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Abbreviations

WWW	World Wide Web
E-commerce	Electronic Commerce
E-mail	Electronic Mail
CS	Customer Service
DDP	Delivery Duties Paid
DDU	Delivery Duties Unpaid
KPI	Key Performance Indicator
EUR	Euro
GBP	Great Britain Pound
JPY	Japanese Yen
BRL	Brazilian Real
HKD	Hong Kong Dollar
GPS	Global Positioning System
UTC	Coordinated Universal Time
USA	United States of America
Zip-Code	Zone improvement planning code
API	Application Programming Interface
UK	United Kingdom

Chapter 1

Introduction

In this chapter, an introductory description of the problem proposed for this thesis will be given. Starting with a brief electronic commerce (e-commerce) history followed by a brief history and description of Farfetch business model. Furthermore, business context will be given, the challenges identified and the main objectives presented.

1.1 E-commerce

Buying and selling items online (typically over the Internet) is called electronic commerce. This is a fairly new technological term which has been evolving exponentially over the last few years. Around the end of the 80's and mid 90's, after the World Wide Web (WWW) being released for commercial usage, e-commerce started evolving and getting to the level we are used today.

In 2017 alone, the estimated e-commerce sales are 2.290 trillion United State Dollars (USD) and projected to grow to 4.48 trillion USD in 2021 [1]. With a growth of around 23% comparing 2016 and 2017, e-commerce is one of the most popular activities along side web browsing and e-mails [2]. In the beginning, it didn't represent a huge impact on the traditional commerce but nowadays it has changed. In China alone, for example, e-commerce was estimated to represent 19% of all retail sales [1].

This growth followed the technological evolution over the last 30 years. If one looks to the past, there were no affordable computers, smartphones or even the concept of mobile applications. These electronic developments were the foundation where all the new platforms and tools were created and perfected until today. Nowadays, practically everything is sold on the WWW: groceries, sports goods, consumer electronics or clothing; a user anywhere on the globe can easily buy or sell anything online. This globalization and buying simplicity are two strong points of e-commerce.

Keeping up with this technological growth, people are accepting and joining e-commerce more. Currently, there is a wider choice to customers and safer methods to shop but, due to this fast growth, customers are more strict and have higher demands when it comes to online shopping. Internet has took a role in one of the biggest shifts in retailing prices since the Industrial

Revolution [3] and the customer satisfaction is one of the major factors that impacts the market the most. For example: when was the last time we bought something online without looking at the item reviews? Or bought something based on some friend's opinion? These few examples show how the customer is ruling and shaping the services offered on e-commerce.

Regardless its growing, e-commerce still faces challenges when compared with traditional offline retailers [4]. There is no ability to feel or try the products before purchasing them, which makes customer service and return policies two of the most important pillars of any e-commerce business [3, 5].

1.2 Farfetch

Farfetch was founded by the Portuguese entrepreneur José Neves in 2007 and it is an online fashion retail platform. José Neves' idea of initially creating the platform was based on the difficulty that fashion boutiques had on selling locally and their lack of knowledge on e-commerce. The platform is the intermediary, connecting small boutiques and the whole world of e-commerce customers. Since the platform launch, Farfetch has been growing and expanding their business all around the globe. Currently, Farfetch is working with over 1500 different boutiques and major fashion brands spread around 47 different countries.

The main headquarters of the company are located in London (United Kingdom) but with offices in many different cities: Porto, Guimarães, Hong Kong, Lisboa, Los Angeles, Moscow, New York, São Paulo, Shangai and Tokyo. This geographic distribution helps with the logistics, adaptation process to local markets and full operational support in all timezones. At the moment, Farfetch has over 2000 employees and became one of the most known online platforms of fashion retail.

1.2.1 Delivery Process

As products are held by partners everywhere around the world, shipping and delivery operations are a big and important part of Farfetch business. Farfetch works with multiple worldwide delivery couriers to assure reliability and global coverage in the delivery process. The delivery courier selection is a process that depends mostly on where the order is being delivered to and where it is coming from.

Most of the overseas deliveries are made through DHL, but Farfetch also has contracts with other courier services such as SF Express and UPS, as they are more suitable in some specific markets. There are countries with specific laws and purchasing habits that make delivery logistics preferable when made by the local delivery services. Two good examples of this are Brazil and China: in Brazil, Correios do Brasil is the state-owned Brazilian post company that deals all of Farfetch orders inside Brazil; in China, Farfetch opts by local delivery services, such as SF Express, since they provide a better coverage around the whole country than an international courier like DHL.

Farfetch transportation methods can be separated into two groups: Waybill and Metapack.

Waybill includes DHL, UPS and the only Brazilian courier, Correios do Brazil. In these cases, Farfetch has full platform integration, which means waybills are generated and managed automatically. This would be the ideal scenario for all couriers that Farfetch works with.

Metapack is an external company that has integrated services with over 400 couriers. Farfetch interest in these type of services is mainly due to simpler integrations with Asian couriers, more specifically the giant Chinese courier, SF Express. In this case, hiring services like Metapack allows the process to be flexible and scalable while avoiding the initial planning and platform integration that can be very time consuming.

Furthermore, Farfetch holds smaller contracts with local specific couriers in order to fulfill Premium Delivery Services; this subject will be addressed in detail on the next section.

There is also an important country specification when it comes to shipping and handling fees. Farfetch divides countries in two main categories: Delivery Duties Paid (DDP) and Delivery Duties Unpaid (DDU). This separation is caused by specific importing laws that are different from country to country. Dealing with customhouses can be a difficult process; so, in DDP countries, Farfetch makes the process simpler for the final customer, covering all the associated fees.

DDP include the countries where duties are supported by Farfetch and when, upon purchasing some item, the customer is prompted with the final price with taxes included. On the other hand, in DDU countries, the customer needs to support and manage the customs and handling fees.

1.2.2 Delivery Methods

There are two regular delivery methods available on Farfetch: normal and express. These two services are the ones provided by big delivery couriers (such as DHL). In both cases, the delivery time depends mainly on the location of the item and where it is being delivered to. There are also external factors common to all delivery logistics: public holidays, weekends or customs can influence the delivery time window and need to be taken in consideration.

Besides this regular delivery services, Farfetch provides two premium delivery services: f90, a 90 minute delivery, and same-day delivery. These are only working in 12 cities and within some specific areas.

These kind of premium delivery services are getting more demand since e-commerce customers are more strict with delivery times. One of the main problems of e-commerce, when compared to traditional commerce, is the time gap that exists between purchase and the actual product reception. In order to give the customer the best shopping experience, the delivery time should be the shortest possible.

Currently, customers' eligibility to these premium services is based on the customer shipping address zip code. Farfetch holds a list of zip codes where these services are operational, which means that the customer is only eligible when the inserted zip code is present on this list. This represents a big flaw when it comes to scalability, since the eligibility algorithm only checks if the zip code provided by the customer is inside a premium delivery zip code.

This evaluation generates a lot of false positives and false negatives: in one hand, a customer address can be eligible to 90 minute delivery but, due to an external reason (like rush hour traffic

or bad weather conditions) the order will take eventually more than 90 minutes to deliver. On the other hand, a customer address can be classified as not eligible but in fact the 90 minute delivery could have happened and fulfilled with success.

The zip code dependency and the static evaluation of customer address eligibility is considered to be one of the main problems in these services planning and scalability and it will be one of the research topics of this thesis.

1.3 Problems and challenges

One of the main problems of any e-commerce business is the experience replication of brick and mortar stores. There is a big difficulty of replicating the in-store customer experience online, making this one of the main reasons why the fashion industry slow-started on the e-commerce [4]. Nowadays, technological advances enabled a far way better experience to the customer, creating an interactive and exciting shopping experience. This resulted on clothing becoming the fastest-growing online category of goods bought in several countries, like the United Kindom [4].

Currently, customers have higher standards when it comes to e-commerce. They tend to explore more while seeking more variety than consumers who buy using a single channel [4]. Typically, these customers browse multiple channels and decide which one is more suitable for their needs. In the specific case of fashion, customers tend to prefer physical stores, since there are opportunities for social interaction, product evaluation and sensory stimulation [4]. In e-commerce and in the specific case of luxurious items, there are also customers who do not feel safe when buying online, regardless the payment options given nowadays so, they take physical stores as alternative.

Another big subject on any e-commerce business is the delivery process. For an e-commerce business to succeed it should have an efficient, quick and clear delivery process. Farfetch holds no stock: all items sold on the platform are held by partner boutiques and brands physically on their stores, meaning all the products are spread around the globe. This might look not like a big problem but, to keep all stock synchronized around all stores and to manage the delivery related processes becomes a very complex task.

Farfetch has partner presence in 47 different countries and delivers to 237 different countries and autonomous regions through around 15 different couriers. Considering only 2017, there were over 2 million orders placed on Farfetch portal. Numbers like around 5000 orders per day show why Farfetch is betting on the delivery development and optimization. Delivery related teams are working mainly with transport and collection problems, day to day operations, new contracts with more couriers and expansion and optimization of the delivery scheme and routes.

1.4 Work structure and objectives

This thesis started as a broad theme around estimating delivery dates of Farfetch orders. The main goal is to develop a responsive and accurate toolkit that will help improve Farfetch delivery

services quality and planning.

Ideally, this work would cover both short and long delivery distances but, as will be concluded, there is a need of separating both cases. This project will focus mainly in short-distance deliveries (f90 service in specific) since it involves a smaller time windows, which imply smaller error margins and more precise planning. Part of the same logic applied to shorter delivery times can be applied and adapted to longer delivery times, but the time frame available to perform this project was not enough to do both analysis.

This project is divided in 3 major parts:

- Initial study to understand current situation, available data and platform limitations;
- Problem analysis, possible solution and in-depth algorithm analysis;
- Simulation results, possible business applications and future work.

The first part consists on studying how Farfetch business model is implemented and how it is ran. This initial study will provide the knowledge needed to solve the proposed problem with more efficiency, which will eventually provide better final results. Also, it will give the ability to locate and study in detail the gaps and needs of the platform, while getting familiarized to the tools Farfetch has already available. Another important part of this work is to identify data sources as well as external services needed. At the end, better performance and accuracy are two expected results of this project.

After all these studies, the proper development phase starts. The final result should be a fully functional and suitable toolkit, which should be capable not only to estimates delivery times with small error margins, but also to provide data to help scale and plan the actual delivery methods. It should be also scalable, sustainable and fully programmable, in order to be used in the future with ease and clarity.

A big part of this project will be the validation of this algorithm when confronted with real information and real estimations. This work should be accurate enough, in order to it incorporated onto the business platform and changed or adapted while still in development.

Summing up, this project should be valuable to Farfetch in two main aspects:

Firstly, by dynamically giving new flexible planning methods, allowing the company to provide a better service on the current deliveries. This means not only improving the internal flow of this service, but the overall service level to the final customer while shopping at Farfetch.

Secondly, the developed toolkit must be useful to scale, create or re-plan short-distance delivery services like f90 or same-day delivery. The solution should discard current static dependencies and make results the more accurate possible.

Chapter 2

State of the Art

This chapter main objective is to give a current status of the various topics covered by this thesis, while providing the reader some basic notions of the topics that will be discussed later on. It will start with a brief discussion about actual and common e-commerce service challenges, followed by an overview of Farfetch biggest competitors and their delivery services.

2.1 E-Commerce Service Challenges

Any e-commerce business faces multiple challenges that do not exist in an equivalent traditional brick-and-mortar business. E-commerce businesses tend to offer a wider range of products while having the ability of reaching more customers. Also, it is substantially easier to start any e-commerce business since the initial investments and operational costs are rather low when compared with traditional commerce [3].

Customer satisfaction in e-commerce is directly linked to four main aspects [3]:

- Website design;
- Delivery and refund service;
- Detailing extent with respect to product information provided;
- Product variety.

Website is related with the interface that the customer is prompted with. It needs to be a solid, appealing and easy to use platform. Ideally, it should be designed for the targeted audience which can show great diversity.

Delivery and refund are both very important aspects of any e-commerce business. This is where the biggest contrast with brick-and-mortar stores happens. In a traditional store, customers are able to see and feel the product before purchase. Also, if expectation is not met after the purchase, the customer can always go back to the store and return it easily. To replicate the lack of these two possibilities, e-commerce businesses need to invest a lot in delivery and refund, since they represent the linking part between the product and the final customer.

In continuation, the extent detail of the products being sold works as a solution for the lack of visibility and product feel before purchase. Product descriptions need to be as accurate as possible and represent a big factor in customer conversion. Farfetch, for example, has specific dedicated production teams that describe the item regarding all sort of details.

Lastly, variety is also a crucial detail in any e-commerce business, specially on fashion branches. Fashion related e-commerce businesses need to keep up with fashion trends, while presenting a big variety to the final customer. In the specific case of Farfetch, there are over 200,000 different items sold, which are categorized in 6 different main categories that derive on more than 50 different sub-categories.

2.2 Delivery process: Farfetch competitors

This section will review one of the biggest e-commerce businesses, Amazon.com and two of the major Farfetch competitors, Asos.com and Net-a-porter.com. Analyzing the competition and reviewing their working processes is very important due to their innovation and process similarity.

2.2.1 Amazon.com

With over 177 billion USD in revenue on 2017, Amazon is the largest Internet retailer in the world [6]. Despite the fact of not representing a direct competitor of Farfetch, Amazon can be a element of research due to its success and complexity. Amazon's first approach became the inspiration and role model of many smaller e-commerce companies. Regarding delivery, Amazon provides one of the more complete and vast services available. The next list shows some examples of available delivery methods in the United States of America [7]:

- Two-Day Shipping: over 100 million items that arrive two business days after being shipped;
- Same-Day and One-Day: available in over 1 million items and in more than 5,000 cities and towns;
- 2-Hour Delivery: available in select major US cities;
- Release-Date Delivery: pre-order items like video games, music, etc.;
- Amazon Key In-Car Delivery: secure delivery to your car where you parked it;
- Amazon Key In-Home Delivery: orders get delivered inside your house by using Amazon smart locks.

These examples of delivery methods show why Amazon has one of the most complete delivery processes, becoming a huge example to all other e-commerce businesses. Amazon has a paid subscription service (120 USD per year) called Amazon Prime that makes all these delivery services free with selected items. In April 2018, Amazon Prime had more than 100 million subscribers [8]. In the US specifically, Amazon holds logistic facilities that allow short-distance deliveries to

happen very quickly. These are carefully located in strategic points to reach out the maximum number of clients with the minimum time span.

Also, Amazon is one of the leaders in delivery innovation. In December 2013, Amazon announced a new delivery system called Amazon Prime Air, which objective is to deliver parcels in 30 minutes or less using unmanned aerial vehicles [7]. These parcels should weigh less than 2.25 kg and the final customer destination should be within 16 km radius of Amazon's order fulfillment center [7]. This is still in development phase, since it implies a lot of security measurements and government negotiations.

All these details and service complexity make Amazon a good case study for anyone interested in the e-commerce business.

2.2.2 ASOS.com and Net-a-porter.com

ASOS and Net-a-porter are two online fashion and beauty e-commerce platforms also based in London, United Kingdom. Net-a-porter, like Farfetch, is more focused on high-end fashion while ASOS takes part of the middle-end.

Both are very good comparison examples since they represent Farfetch competitors. With over 15 million active customers in 2017 and generating over 1.9 billion GBP in revenue, ASOS stands as a giant in e-commerce fashion [9]. When it comes to delivery besides the typical Normal and Express deliveries to almost every country in the world, ASOS also has next-working-day, nominated day and click & collect deliveries to a list of 244 countries and autonomous regions [10]. Also, like Amazon Prime service mentioned in 2.2.1, ASOS has a premium delivery service subscription that allows a customer to get next-working-day or nominated-day delivery with no minimum order value for a whole year [10].

Net-a-porter (now part of the Yoox Net-a-porter group after 2015 fusion) stands as the leader of online luxury fashion market [11, 12]. In 2017, with over 3 million active users, Net-a-porter generated over 2 billion Euros (EUR) in revenue. Also in 2017, the platform counted with almost 850 million visits and 9.5 million different orders [11, 12].

Net-a-porter delivers to 170 different countries and also provides same-day delivery in Manhattan, London and Hong Kong and next-day delivery in UK, United States of America (USA), Germany, France, Australia and Singapore [13].

Both companies reached notorious positions and both set certain standards in the market but, unfortunately, logistic planning and delivery topics are always private matters. This means it is impossible to fully understand the logistic and planning made behind both company's delivery process.

2.3 Delivery couriers logistics

Delivery couriers assure the delivery process in any e-commerce business. The majority e-commerce businesses subcontract delivery services, but some big businesses (like Amazon, for example) also

have their own couriers. Contracting a courier depends mainly on the distance of delivery and on the service coverage.

2.3.1 Long distance delivery

To the matter of this project, long distance deliveries are all deliveries happening outside a range of a city: inner country deliveries within different cities, deliveries happening between countries in the same continent and lastly, intercontinental deliveries.

Obviously, all of these differ a lot regarding delivery times. A order from London to Manchester falls in a different category than an order from Melbourne, Australia to London, United Kingdom. In these type of deliveries, big international couriers like DHL, UPS or FedEx normally assure the best possible service, due to business dimension and having presence in almost every country in the world. DHL, for example, has service reachability in Cuba and Democratic People's Republic of Korea [14, 15].

In Farfetch case, the pattern follows the same idea: Farfetch subcontracts big international delivery couriers in order to make all its long distance deliveries, having DHL as their biggest logistic partner. In 2017, over 80% of deliveries were assured by DHL alone.

2.3.2 Short distance delivery

As mentioned in subsection 1.2.2, Farfetch has two premium delivery services: same-day delivery and a 90 minute delivery called f90. For this project, these are considered to be short distance deliveries. Both same-day and f90 are currently working only inside each city that supports it.

For this type of deliveries, Farfetch does not work with the same couriers. For this purpose, deals are made with smaller companies that work only locally, since big international couriers do not have these type of services. Farfetch works with 9 different couriers to assure both services in twelve different cities.

When comparing both cases, a big different delivery time window can be noted. Long distance deliveries can take from two until eight days or more, while short distance deliveries vary from 90 minutes to 24 hours. This major difference is the big reason behind this separation and focus on short distance deliveries.

2.4 The key driver: data

Data is the solid base of almost every research project of this kind and this one is not an exception. Data represents the major key in order to develop an estimation model and helps defining milestones to the project in development.

There are multiple methods of treating data but one of the most used concept is data mining. Data mining is the process of discovering useful patterns and trends in large data sets [16]. Data

mining combines the examination of large pre-existing databases with machine learning and statistics. All of this is supported by the mass evolution of data storage and computing capabilities that occurred over the last decades.

Data mining techniques are used in a lot of different fields: industry, science, engineering and even government. Data mining is believed to have a profound impact on our society [16].

2.5 Delivery time estimation

Currently, estimating a delivery time is simply evaluating a static variable list: where the order is from, where is it being shipped to and which courier is in charge for the service.

On Farfetch side, long distance delivery times are established and prompted to the final customer upon checkout based on an intern computation. This computation takes in consideration the same static variables and order history and it usually outputs an interval of days where it is most likely that the order will be delivered. Also, estimating times in long distance deliveries is not a trivial process. The longer the distance the more intermediary steps an order has to go through: air transportation, security checking or even customs can be unpredictable processes that can influence negatively the delivery time frame. All of these factors are very dependent on the countries involved in the delivery: inside European Union, for example, these tend to be smaller but, regarding South American markets, like Brazil for instance, these can be completely random.

On the other hand, premium delivery services have a completely different analysis. The delivery time window is rather small and predictions are based on a fixed length: f90 will be 90 minutes and same-day guarantees that orders get delivered in the same day or in the following day if placed after 11AM. By having a rigid delivery schedule, these orders are processed with priority by Farfetch delivery support teams.

Providing an accurate delivery time is very important regarding overall customer experience and ideally should be the shortest possible. Customers nowadays will not hesitate to abandon shopping baskets if they encounter unsatisfactory delivery options [17]. According to a study by Research Now on behalf of MetaPack, over 50% of online shoppers confirmed that they have lost interest in an online order due to unsatisfactory delivery options [17]. The main reasons were that delivery could not be guaranteed by a certain date or would take too long to fulfill [17].

Again, delivery times should be the shortest possible in order to provide the customer the best shopping experience, but there are multiple factors that can make speed less important. Two important ones are pricing and customization [17].

In one hand, delivery pricing is a very important part of any e-commerce order and it is dependent from culture to culture. For example, low cost delivery is a priority for 49% of UK consumers and 47% of US consumers while Dutch shoppers care more about speed [17]. For this reason, Farfetch has implemented flat shipment rates over different total order values. This means that, above certain thresholds, a Farfetch customer only pays a fixed shipping fee which is independent from how many different items put in the basket.

On the other hand, delivery customization is also a very important factor, since the customer tends to value flexible and innovative delivery methods. A customer needs to be able to choose the best time for delivery, while being prompted with various delivery options. Regarding this matter, Farfetch implemented Click & Collect services (fig. 2.1). These consist on picking up your order in specific pre-determined places rather than the customer's home address. Other delivery methods, such as secure box outside home, delivery to a secure locker or delivery pick up at a train station, proved to be preferable in different countries [17].

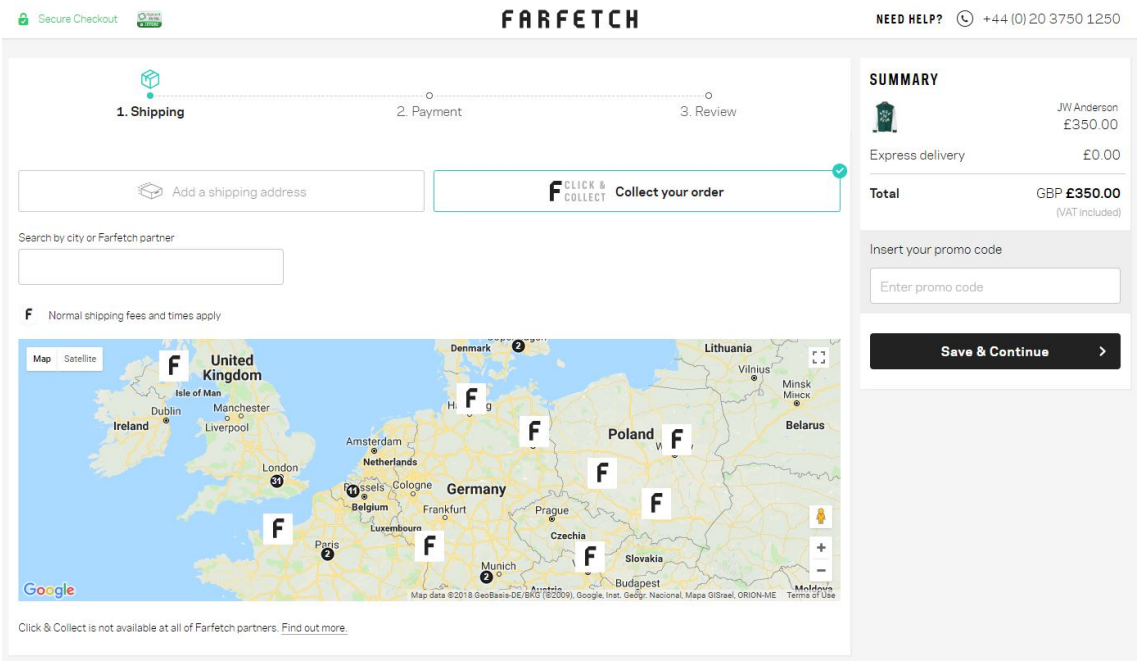

Figure 2.1: Click & Collect example upon order checkout

Chapter 3

Understanding current limitations and problems

This chapter represents the beginning of the project development itself, starting with analysis of the problem complexity followed by a detailed explanation of Farfetch order flow. A basic explanation of the initial approach and solution strategy will also be delineated while giving a deep description of Farfetch f90 delivery service, its current problems and why it was chosen to start the project. This chapter should give the reader full comprehension of the whole delivery process and how the problem is going to be firstly addressed.

3.1 Delivery time complexity

As discussed in chapter 1, estimating a delivery time is not an easy task. There are a lot of variables involved and a big part of these are not controlled by the retail business itself. Usually, the bigger the business, the more complex the delivery process. So it is very important for a business to guarantee that all the parts are working together correctly so that the best service is provided to the final customer.

In the specific case of Farfetch, and due to having stock spread around the globe, it is indispensable to clarify and explain the order flow, all the parts involved and how they are related with each other. Understanding the actual order flow should be the main basis to develop a valid solution for the identified problems.

3.1.1 Farfetch order flow

All orders after being placed on Farfetch website follow 8 essential steps being the last two optional.

After order placement in Farfetch website, step 1 starts. In this step the assigned partner for the sale needs to check if there is stock for the sold item and where is it located. Boutiques or brands usually have multiple stock points where the items can be sent from. This step can only output two states: it exists in stock or it does not. If there is product stock, the partner registers an

Table 3.1: Farfetch Order Flow

Step 1	Check stock
Step 2	Approve Payment
Step 3	Decide Packaging
Step 4	Create Shipping Label
Step 5	Send Parcel
Step 6	Parcel In Transit
Step 7	Collect in Store
Step 8	Ready to Collect

affirmative answer on the Farfetch platform, telling at which stock point the item is located and the process continues. If there is no stock for the desired product, there are a lot of scenarios: Farfetch can cancel the order and return the money to the customer or customer service (CS) teams can contact the customer suggesting product alternatives or purchasing benefits such as free shipping for another order. This depends a lot of different factors and the whole process will not be explored by this thesis. The partner's agility in this step is also very dependent from partner to partner and Farfetch has Key Performance Indicators (KPI) to evaluate the performance of their partners. Later this will be helpful to characterize partners and to estimate and model their agility when it comes to order preparation.

In step 2, which occurs simultaneously to step 1, Farfetch internal fraud detection and payment approval teams work on evaluating payments. At a first glance, it looks like an effortless function but it is not. Farfetch owns client evaluation lists which categorize clients into white lists or black lists. A white list client is a client whose payment is automatically approved since, for example, it already bought products via Farfetch. On the contrary, black listed clients are clients whose payments are already considered fraudulent due to past history and orders get automatically canceled. In the middle, there are payments that need to be carefully studied, in order to determine with precision if they are fraudulent or not. This evaluation, among other fraud detection techniques are well optimized and the time to process a payment is usually short.

After these two initial steps, on step 3 Farfetch partners must pack the order and make it ready for transport. This includes using Farfetch packages and predetermined packaging methods. This time is also an important KPI to Farfetch, since it is also helpful to model partner's agility.

In step 4, shipping labels (also known as waybills) are generated and attached to the ready to send package. This represents an important step, since it is the last one before the actual shipment. In this step, Farfetch has system integrations with a lot of the major transportation couriers, such as DHL, which makes the generation of waybills an automated process. In all other cases, this process has to be done manually which, in some specific scenarios, can take a considerable amount of time. This makes platform integration one of the major and important projects in the shipping department.

After these four initial steps, the package is ready and goes to step 5. This means the designated courier should pick the order up at the partner shipping location and deliver it to the final customer. The step 6, represents the order in transit. Afterwards, this is where step 7 and step 8 can exist.

The customer can choose to get the order delivered to a specific address (home or work address, for example) or decide to get it delivered to a list of pick-up points provided by Farfetch for more convenience.

Step 7 represents when the order is already at the designated pickup point but still not available for pickup and step 8 represents when it becomes available for pickup.

As demonstrated, a single order passes through multiple steps that involve a lot of complexity, so it is important to understand how these parts work and how related are with each other, to be able to optimize this whole process.

3.2 f90 application case

The first idea of this project was to develop a toolkit to estimate delivery times but, as previously mentioned in chapter 2, there were some initial decisions to be done: it would not be possible to aggregate all Farfetch orders into one single category, since they vary so much between themselves. As stated in section 2.3 there are two main categories where deliveries can be put into and, after some initial briefing, it was decided that the best option was to focus on short-distance deliveries. They involve more criteria and better planning, since the delivery time window is smaller.

3.2.1 Why f90?

f90 is the 90 minute delivery service provided by Farfetch launched in April 2017. Being fairly new and an uprising service, a big chance to develop and improve a more sustainable and scalable approach was expectable. This was considered a big opportunity not only because it is a promising project, but also because Farfetch cannot fulfill more service demand. This is the reason why this whole project is focused mainly on f90 orders.

Until today, (June 23rd 2018), 997 f90 orders were placed but, only 63% were delivered on time. All the others were either delayed or canceled (Figure 3.1). Also, on 2017 the average f90 orders was 31.3 per month, while on 2018 (data until end of May 2018) this value triples to 97.8. These numbers reinforce why focusing on creating a new and adaptable approach could be useful for the company.

3.2.2 f90 cities

Currently, f90 delivery is up and running in 12 different cities: Los Angeles, New York City, Miami, São Paulo, Paris, Berlin, London, Milan, Madrid, Dubai, Tokyo and Hong Kong.

There is a big disparity in order numbers between the cities. The majority of the orders are placed in London and New York City and cities like Tokyo or Hong Kong barely have any orders. Figure 3.2 illustrates this distribution.

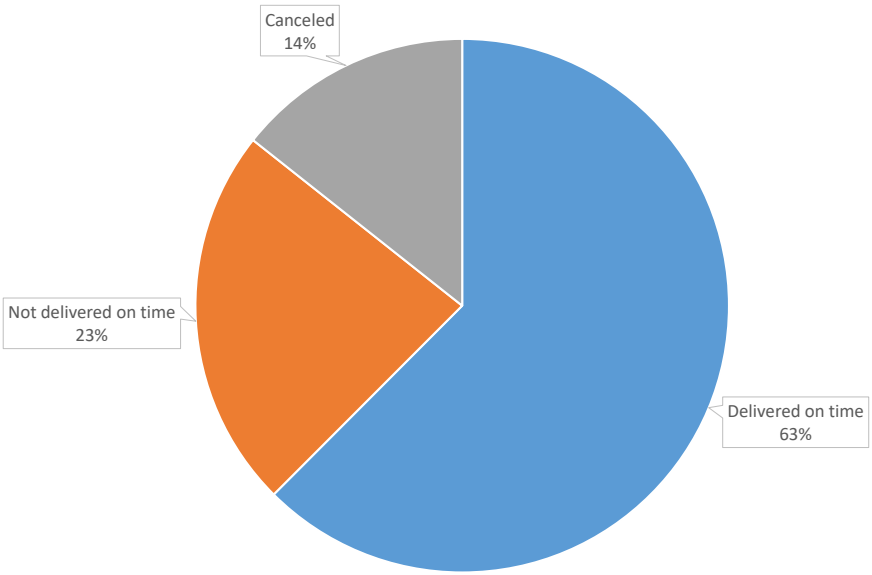

Figure 3.1: f90 order volume

3.2.3 f90 couriers

f90 is a special delivery service, so it is planned and handled in a different way. Big transportation couriers usually don't do this kind of short-time and short-distance deliveries. To ensure this service, Farfetch deals with smaller and local couriers. Frequently these consist on a small business that only runs inside a specific city and because their small working scale (when compared to big international couriers), all the deals and service conditions need to be set prior to the service launch.

Besides this fact and until now, Farfetch has no platform integrations with any of the assigned couriers, which means all the courier booking involved in the process needs to be done manually. This job is spread among the delivery support teams in Porto, Tokyo and Los Angeles to cover all world timezones.

Another important topic is the working method of these fast delivery courier services. Typically, courier services have big headquarters to help their logistic processes but, in this situation, they have not. It is also important to point that, in some specific situations, unusual transportation methods, like motorbike, bicycle or walking, can happen.

An analogy with the famous transportation network *Uber* comes in handy: instead of having fixed headquarters where delivery drivers are waiting for service bookings, drivers are spread around cities and receive the service booking through some specific mobile application. This

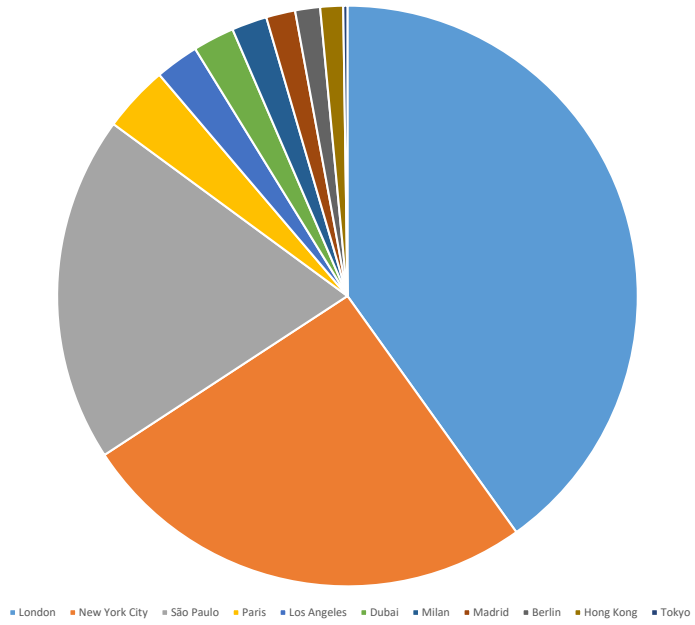

Figure 3.2: f90 order distribution by city

allow delivery companies to have a better coverage of the delivery area, which means providing a quicker response time.

In the specific case of this project, this kind of distribution, will imply a careful estimation since their location upon booking has a big level of randomness. On chapter 5 the full approach to this problem will be explained and a possible solution presented.

3.2.4 f90 pricing

Pricing for f90 is city dependent. This might not be very relevant to this project but a basic notion of the pricing can help to justify some data patterns in the future. Table 3.2 illustrates this city division and pricing.

3.2.5 f90 delivery flow

An f90 order can be partitioned into multiple key events that happen with the order flow. In this specific case, f90 orders follow the regular order flow pointed in section 3.1.1 but with slight changes.

Right after an order being placed on the Farfetch website, three components start working on the delivery process: the fraud team, the delivery support team and the assigned partner. The fraud

Table 3.2: f90 delivery pricing

City	Price (local currency)	Price Approx.(EUR)	Courier
Los Angeles	20 USD	17	Dropoff
New York City	20 USD	17	Dropoff
Miami	20 USD	17	Dropoff
São Paulo	70 BRL	15	B2Log
Paris	18 EUR	18	Kronos Delivery
Berlin	22 EUR	22	Tiramizoo
London	12 GBP	14	Addison Lee
Milan	18 EUR	18	Nexive
Madrid	18 EUR	18	Serwell
Dubai	15 USD	13	Fetchr
Tokyo	1400 JPY	11	By-Q
Hong Kong	120 HKD	13	Tiramizoo

team approves the payment, the delivery support team (usually after the payment approval by the fraud team) starts the courier booking process and the partner checks the stock availability.

After stock availability is confirmed and payment approved, the delivery support team books the courier service in their specific website. This is courier specific since all couriers are independent and have different booking platforms. After this step, the delivery process is dependent mostly on the partner and courier performance.

Simultaneously, the partner is getting the order ready and the courier is moving towards its pick up point. This is where performance is a major factor of analysis: most of the times, when the courier reach the store, the package is already prepared and ready to send but, sometimes, it can happen that for some unusual reason the courier needs to wait at the pick up location for the preparation of the package. All these timings and possible situations are also important to consider and studied in order to improve the reliability of the final time estimation.

Afterwards, the courier delivers the package to the customer's final address. Figure 3.3 tries to illustrate the order flow and the parts involved.

In green, stands the parts managed by Farfetch services and teams: payment approval and courier booking. Represented in yellow, is the partner which takes care of checking stock and further order preparation. Lastly, in red, is the courier assigned for the delivery.

3.3 Main delivery problems

Farfetch order flow seems rather simple and understandable but there are a lot of nuances behind each step. Ideally, all orders would flow through the steps seamlessly but, unfortunately, that does not always happen. There are a lot of factors which can explain why, but one of the biggest is the size and complexity of Farfetch delivery services.

There is a big part of the Farfetch business that goes into delivery effort but for this specific project the focus goes, once again, to f90 orders.

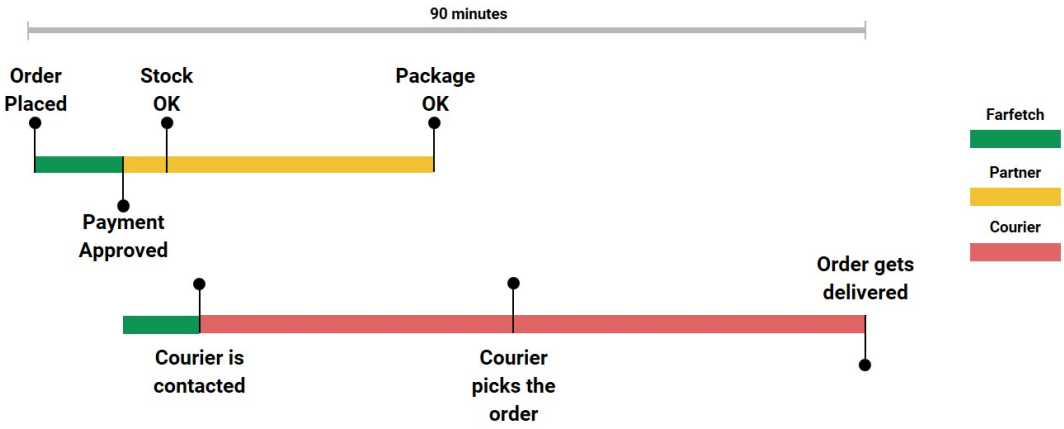

Figure 3.3: f90 order flow

3.3.1 f90 planning and development problems

f90 service is, at this moment, a zip-code based service. This means that the delivery is planned based on zip-code areas.

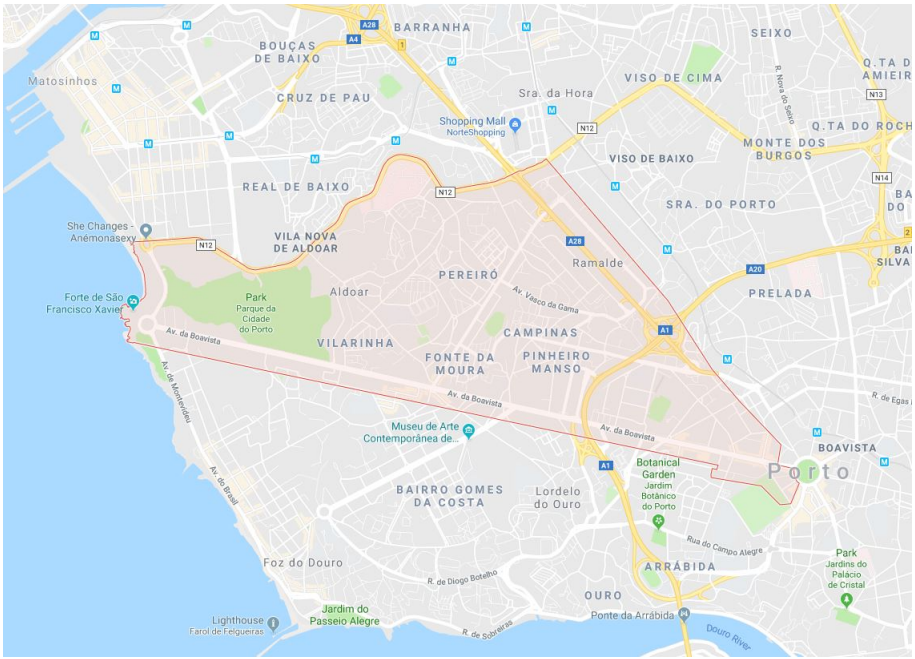

Figure 3.4: Example of 4100 Portuguese zip-code area (source: Google Maps)

Zip-codes (zone improvement planning) are delineated delivery areas planned by national posting companies and are not areas with easily defined boundaries. As represented in figure 3.4 it is easy to understand that the logic behind the zip-code area is unpractical to understand or study. Furthermore, these areas change with time and are defined differently from country to country.

This zip-code dependency is presented as one of the main problems of the current solution. Farfetch plans the deliveries based on the zip-codes of where the courier can deliver and on the location of the partner and the final customer. It is a simple algorithm that evaluates a zip-code list and provides a binary answer: either the customer is inside a covered zip-code area or not. This is rather a rigid approach and this work will focus on removing this dependency, replacing it with a more flexible and scalable solution.

This dependency is also a big barrier when approaching new cities for this service. The whole planning is done manually and zip-code areas need to be negotiated with local couriers, making this service difficult to implement between cities and countries.

3.3.2 Scalability

Restricting the delivery model to the order and customer location is not a viable option when it comes to scalability and customer experience improvement. The current problem with Farfetch delivery services is that this process does not take into consideration variables that can improve the deliver process and consequent results.

There is a big need for considering real-time variables, like traffic or weather conditions, in order to improve not only the customer service, but the whole delivery service quality and amplitude.

The actual f90 service was designed with static assumptions and rigid planning rules. This makes it difficult to scale and will quickly reach a point of maximum threshold. The main idea behind this project is to turn the usage of static variables, like zip-codes, obsolete and look for a more dynamic and accurate ways of predicting delivery times. The big advantage of a dynamic approach is the fact that the delivery development can look further and explore new solutions with simplicity.

3.4 Other delivery services

Again, one of the main goals of this project is to design a scalable method of delivery planning while and, at the same time, improve customer experience. This means not only to estimate delivery times with precision but, also to find ways of doing it dynamically.

Focusing mainly on f90 orders should not be seen as a barrier to that. Surely this service is not yet very popular among all other shipping methods, but the concept and logic of this project can be applied to other delivery methods. Also, it is important to refer that f90 service demand is growing and the algorithm behind this project should be ready to support it.

Besides f90, Farfetch has same-day delivery services, where the planning and logic is practically the same. Being able to apply all this project's logic to these services is an important detail, since there are more demand for same-day delivery services but yet the same planning problems.

This section is just a brief future plan and its applicability will be discussed in chapter 6 and chapter 7 with more detail.

Chapter 4

Estimate delivery times

This chapter will explain the concept, development and approach used to get a valid problem solution. All the mathematics, algebra, theoretical principles and technical details will be described.

Firstly, a brief study on data will be done: Data sources, management, storage and consequent data quality are the main topics of the first section.

Secondly, the main algorithm will be presented and all the parts and assumptions will be explained. Afterwards, the dynamic isochrones algorithm will also be presented and its potentiality will be described in full detail. This is one of the most important sections of this work as a whole.

Thirdly, a deep analysis of the main algorithm caveats will be done besides the possible mitigations for these problems. This is an important step since, it is helpful for further development, if it is the case.

Lastly, a more technical study on how to evolve the algorithm into usable software will be done. In this section not only actual and implemented solutions are going to be described but also possible future implementations.

4.1 Available data

When starting any project (especially an engineering project) it is important to study and understand what is available and what is helpful to its development. Upon arrival in a business with this dimension and complexity for the first time, it can be challenging to understand how the data is stored and managed. Also, searching for specific data can be very demanding and time consuming. Consequently, a lot of the initial time of this project was spent understanding and getting familiarized with the company's tools and data processing techniques.

Farfetch has a global order management platform, called *Sales*, in which all Farfetch logistics are based on. It can output all kinds of data like specific order details, partner information or even returning process details.

Although *Sales* (Figure 4.1) is a very powerful tool and definitely a big data source of this project, Farfetch has all data stored in multiple *Microsoft SQL Server* databases which feed the *Sales* platform. These big and complex databases are utterly the major data source of this work.

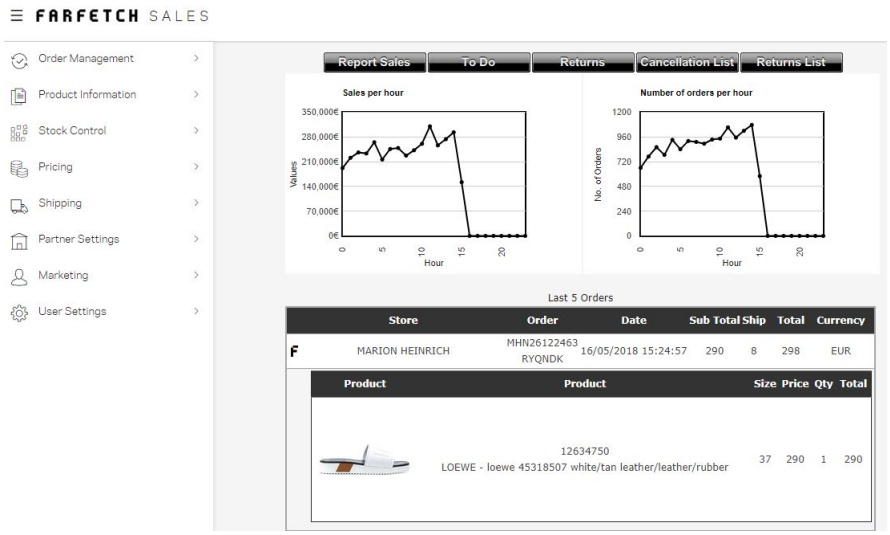

Figure 4.1: *Sales* platform

4.1.1 Data entry, storage and management processes

As stated before, most of the data used to build this algorithm comes directly from Farfetch databases. Order details, customer addresses, delivery schedules and time references are all provided through this data channel. There are a vast number of databases (some with hundreds of tables) which makes the scheme of how they were engineered a very complex topic that falls out of this work objective.

Besides that and in the specific case of f90, order details get registered in a shared spreadsheet managed by delivery support teams. This spreadsheet contains all the times, from the beginning until delivery, related with f90 orders. It is also in this document that all f90 details such as delay reasons and other important informations are registered. This is a key document since it represents the starting point of data analysis and project development.

Data entry and register is also a very complex part of the Farfetch business caused not only by the company's exponential growth, but also by the volume of daily orders. Farfetch teams work forcefully in maintaining this process the most clear and organized but this is not an easy task. Eventually, when a fast solution is needed, documentation and structure are deprioritized, inserting entropy into the organization structure.

4.1.2 Data quality

Data quality refers to the veracity and accuracy of the available data. During this project development, a lot of data initially considered reliable ended up being the opposite. Farfetch databases and data registering is a process that grew too fast and some of the data does not match what happened in reality.

The overall data available is sufficient to develop a solid algorithm ,but a big part of the process needs to be restructured in order to allow scalability. When dealing with low order numbers,

some solutions are totally acceptable but, when the goal is to scale the solution, some adjustments become mandatory. This is the case with both f90 and same-day delivery services: some parts of the process (like manually booking a courier service) need to be restructured and a more formal and exact method of processing and registering data is required.

Additionally, and since f90 is a barely new service, a lot of the data sets are small. This fact does not imply direct unreliability, but more data usually entails more robust algorithms and predictions. In specific cases, some assumptions were made in order to cover this lack of data. In other scenarios, and for the same reasons, instead of data categorizing, all the available data since launch (April 2017) were taken in consideration.

4.2 The main algorithm

This is the part where the main algorithm is described and the crucial parts are explained. When first starting developing it, a lot of approaches came to the table but it was decided the best one was to divide and independently study each part of the process.

4.2.1 Stock ok, fraud detection and courier booking

As mentioned in section 3.2, the first processes of the order flow are stock check, payment approval and courier booking, which happen simultaneously.

With respect to stock availability, the approach consisted in dividing the orders by stores since their agility can be different. Some stores are fast at processing orders, while others are slow. The first approach of modeling this time consists on an arithmetic mean of the stock availability times.

The order cannot proceed without the payment being approved which means that, while the payment does not get approved, the order processing is stopped. The approach was to separate the orders per city and try to model the correspondent time slot. It is safe to say that this process can usually output a fast answer. An approximation by an arithmetic mean provided the best results.

Lastly, regarding the courier booking time, a close study of the process was made, together with the delivery support team. After full analysis, the separation of orders should occur by city and an arithmetic mean provided the best results. In opposition to the approval time, payment approval time correlates the fraud team assigned and the country of the payment.

These two last steps have an important aspect in common: they are both Farfetch team dependent, which means the process should be fairly equal for all orders and easily controlled and monitored. It is important to note that events like lunch time or high order volume can provide outliers who influence this time negatively.

4.2.2 Courier reach time

Courier reach time is the time that, after being booked, the courier takes to reach the store and pick up the package. Recalling subsection 3.2.3 and the analogy made with *Uber*, it is a big challenge

to determine this time. There is no platform integration so the exact location of the driver upon booking has a big level of randomness.

In this situation, the approach was to model the traffic in the city and try to guess how much time a driver would take to reach the store. Estimating traffic conditions in a city throughout the day is a very complex calculation that overcomes the time available for this project. A simpler computation was designed to try and estimate this time with some precision.

Starting off with London (due to order volume) the estimation consists:

1. Identify f90 partners;
2. Convert store addresses into Global Position System (GPS) coordinates;
3. Draw a convex polygon delineated by the GPS coordinate set;
4. Compute the previously drawn polygon centroid;
5. Spread out 10 GPS points in a circumference around centroid with a specific radius;
6. Run real-time transit time from those 10 points towards centroid during a full week simulation (half hour intervals, 24 hours, 5 days).

Figure 4.2 helps visualizing this part of the algorithm. Pinned in black are stores locations that delimit the convex polygon colored in gray. The centroid and the spread GPS points are pinned in red.

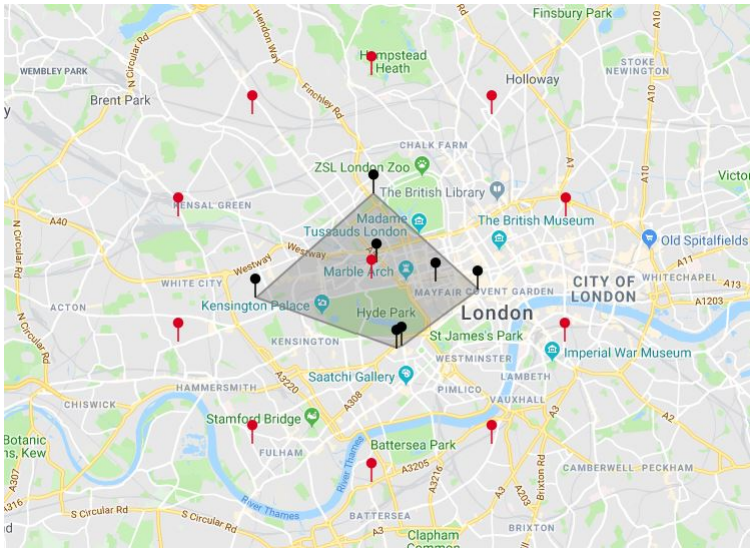

Figure 4.2: Courier reach time estimation

The radius chosen for this circular distribution is not random. In London, the average time a courier takes to reach a store is around 25 minutes. Assuming that in the city the average speed is around 12 kilometers per hour (km/h) the radius should be around 5 kilometers (km). After data separation by time of the day and day of the week, the simulation should provide enough criteria

to make a reliable estimation which will be discussed and presented on chapter 5. This approach is far from perfect but it showed to be a reliable way of getting an accurate measurement. This same logic can also be applied to all other cities that support f90 delivery but error margins might differ from London.

4.2.3 Store performance: packaging

Usually, the time it takes to pack an f90 order and make it available for transport is shorter than the time for the courier to reach the store, but packaging times are still an important metric.

Store performance helps modeling the behavior and partner agility. Similarly to the time partners take to announce product stock, package times are associated to a partner and computed by arithmetic means. The analysis of this time can be important to understand what is the probability of a partner to accomplish specific time goals.

4.2.4 Actual delivery time

Followed by these preparation processes, the actual delivery time represents the time the courier takes to get the order from the store to the final customer. In this situation randomness does not exist: the location of the physical store and customer address are both known. After translating both addresses into GPS coordinates, transit times can easily be computed with precision.

4.2.5 Algorithm synopsis

In order to clarify the process, the following table describes the different parts and how they are computed:

Table 4.1: Time estimation algorithm tear down

Time slot	Computation method	Responsible
Stock OK and package OK	Arithmetic mean by store	Sales partner
Payment approval	Arithmetic mean by city	Fraud team
Courier booking	Arithmetic mean	Delivery support team
Courier reach	Random transit time estimation	Courier
Courier delivery	Transit time estimation	Courier

Looking to table 4.1, it is pertinent to explain why, in this case, arithmetic means work the best. As explained in the final part of subsection 4.1.2, to create a more robust model it is more convenient to look at data as a whole than to categorize it. This means that, for now, the best and most robust approach is to consider the average results rather than look at smaller data patterns.

For example, lets consider the stock OK times. It is simple to understand that this time is dependent on the time of the day: in the early morning a shop can have few clients making this time shorter, while in the middle of a busy afternoon it could become substantially larger. It would make sense to consider this fact and make it a variable of the model but, unfortunately, some stores

do not have enough orders to allow a valid assumption. This makes averaging a more robust and less erratic estimation.

4.3 Dynamic isochrones algorithm

While focusing on trying to estimate delivery times, an idea arose: omit final customer addresses and draw possible delivery areas. These areas will represent possible delivery regions with a specific time window. This quickly became the most powerful algorithm of this project because it would not only provide a quick method to find if a customer address can receive an order in 90 minutes without any external dependency (such as zip-codes), but also serve as a tool to understand and to plan a more dynamic approach to the whole f90 delivery service.

4.3.1 Computing isochrones

Isochrones are lines that connect points with equal values, in this case travel times.

The main goal is to draw isochrones given an origin GPS coordinate and a time frame in minutes. Besides that, the isochrones must be travel method and traffic dependent. The main algorithm structure goes as described:

1. Identify the origin of the isochrone map and convert it into GPS coordinates;
2. Map N number of points around the origin;
3. Iteratively compute transit time from origin to mapped points until isochrone time is met.

This is the simplest way of describing the isochrone algorithm but in the next sections full algorithm details will be given.

4.3.2 GPS coordinates on planet Earth

Earth is approximately a sphere and GPS coordinates were created to identify and locate subjects on its surface with simplicity. GPS coordinates consist on pairs of two angles called latitude and longitude. These angles are spread based on two perpendicular axis that divide the planet in two equal halves: the Greenwich meridian and the equator.

The fact that planet Earth is approximately spherical means point mapping described in subsection 4.3.1 cannot be simplified into a regular Cartesian plan. For this reason a study on spherical trigonometry is mandatory.

Taking a GPS point, a bearing angle and a radius as input, the following formulas can output the location of the second point. These will be crucial when iterating over the points to find transit times.

$$lat_2 = \arcsin\left[\sin(lat_1)\cdot\cos\left(\frac{r}{R}\right) + \cos(lat_1)\cdot\sin\left(\frac{r}{R}\right)\cdot\cos(b)\right] \tag{4.1}$$

$$lng_2 = lng_1 + \arctan\left[\frac{\sin(b)\cdot\sin\left(\frac{r}{R}\right)\cdot\cos(lat_1)}{\cos\left(\frac{r}{R}\right)-\sin(lat_1)\cdot\sin(lat_2)}\right] \tag{4.2}$$

where (lat_1, lng_1) is the origin GPS point, $R(\approx 6371km)$ the Earth radius in km, r the arch length in km from origin point and b the bearing angle from the origin point.

These equations are not trivial to understand and to dig into mathematical proofness would require a lot of effort and fall out of this thesis purpose and time frame. Basically, they derive from Haversine formula and an application of the cosine law on spherical trigonometry. The theoretical principles of this calculus can be found in the book of Brummelen (2013) entitled Heavenly Mathematics: The Forgotten Art of Spherical Trigonometry; the mathematical deductions can be found in the report of Gardiner, Ahmad, Cooper, Haveard (2011) entitled Collision Avoidance Techniques for Unmanned Aerial Vehicles [18, 19].

4.3.3 Point iteration

After the initial point distribution around the origin, transit time iteration starts. This iteration can be compared to a classic binary search algorithm where r is the distance radius in km from the origin point and r_{max} and r_{min} represent the radius boundaries. r_{min} value starts at zero and r_{max} starts with a distance assuming a maximum speed of $120km/h$.

To simplify, figure 4.3 illustrates the two initial steps of a 5 minute isochrone example:

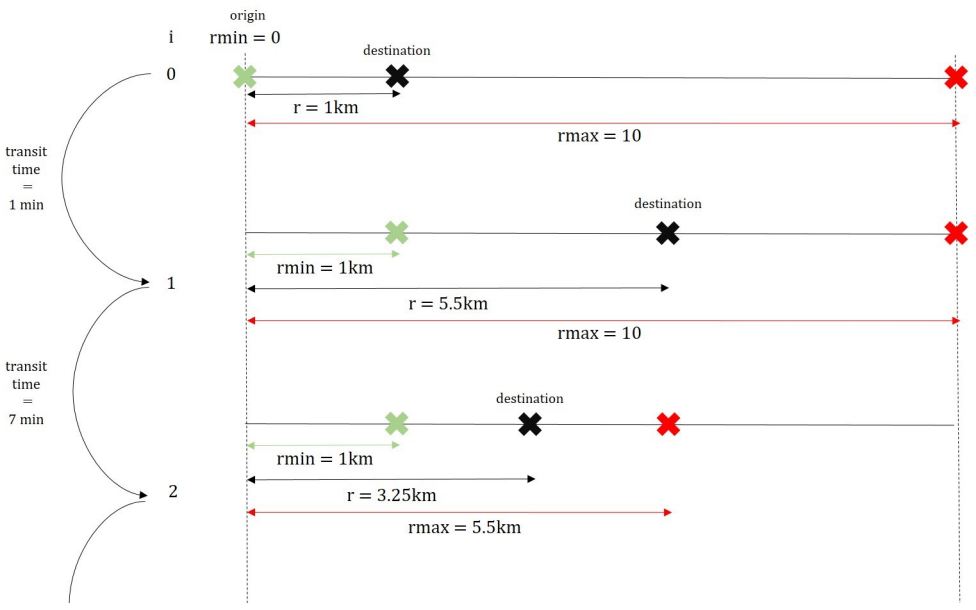

Figure 4.3: Two initial iterations of 5 minute isochrone

On the first iteration, $r = \frac{5min\cdot 12km}{60min} = 1km$, $r_{max} = \frac{5min\cdot 120km}{60min} = 10km$ and $r_{min} = 0$ and the computed transit time is 1 minute. Since it is smaller than the isochrone time, $r_{min} = r = 1km$ and $r = \frac{r+r_{max}}{2} = 5.5km$

On the contrary, in the second iteration, after acknowledging that the transit time is now bigger than 5 minutes, $r_{max} = r = 5.5km$ and $r = \frac{r+r_{min}}{2} = 3.25km$.

The algorithm would continue running until the final isochrone time is met. Also, an extra margin variable can be introduced to the algorithm in order to improve computational performance.

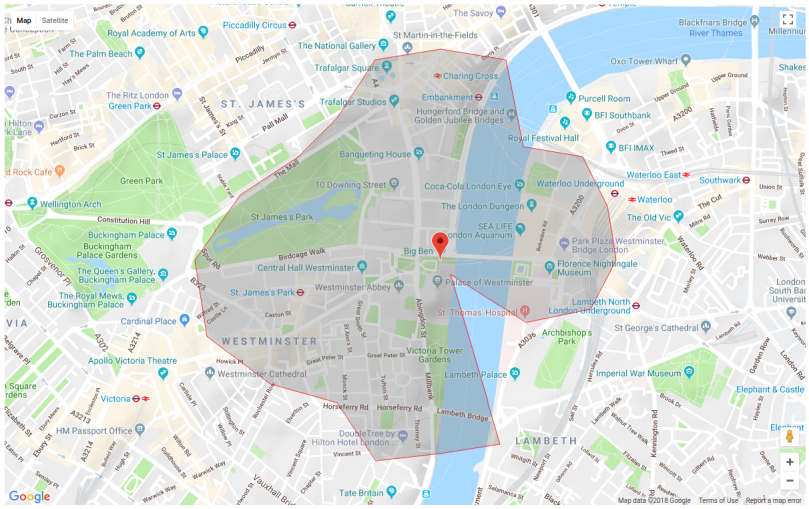

Figure 4.4: 15 minute walking isochrone from Big Ben, London

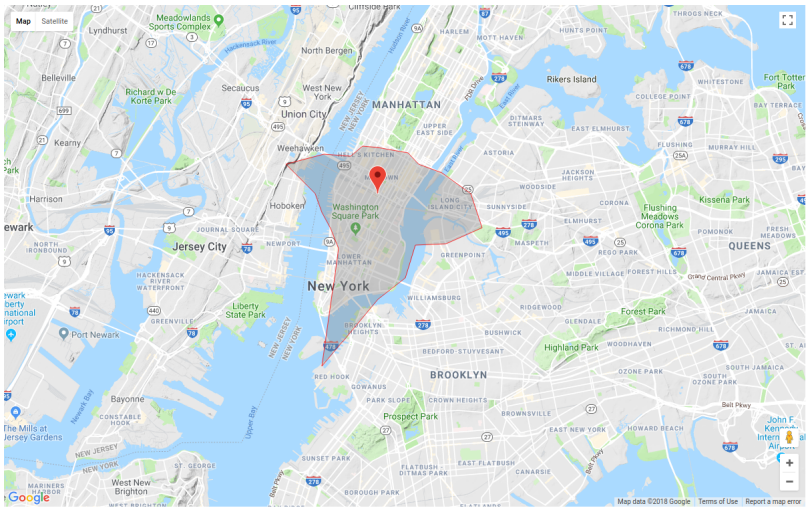

Figure 4.5: 35 minute car isochrone from Empire State Building, New York City

Taking a closer look at figure 4.4 and figure 4.5, it is remarkable that traffic isochrones tend to follow the city's infrastructure like main arterial roads and bridges.

4.3.4 Input variables and area dynamism

The result of this algorithm is a set of GPS points that delineate an area of possible reach. These areas are generated using real-time information and can provide valuable data when it comes to delivery planning and estimation.

It is important to explain all input variables of this algorithm:

- Origin: origin point in GPS coordinates;
- Duration: isochrone duration in minutes;
- Number of angles: number of spread points around the origin;
- Margin: margin limit in minutes;
- Travel mode: three modes provided by Google Maps Distance Matrix API: walking, bicycle or driving;
- Traffic: boolean to indicate real-time traffic consideration;
- Traffic model: three models provided by Google Maps Distance Matrix API: pessimistic, best guess or optimistic;
- Departure time: the departure time in seconds since January 1st 1970 (UTC) or "now" for run-time simulation.

Also, since they are represented by a set of GPS coordinates, operations like region overlapping, withdrawal or point checking are all possible. For example, an unreachable area (like a big city park) can be withdrawn from a previously calculated isochrone.

In order to do this computations, a small toolkit was also developed. In this case, Cartesian system approximation provides error margins totally acceptable since it deals with mainly small distances. This could be helpful since it increases the planning dynamism.

4.4 Algorithm caveats and main problems

Identifying the caveats of any possible solution is a mandatory step. Understanding the flaws of a solution is the first step before scaling it. This section will go over the algorithm caveats and the main problems encountered when developing the presented solution.

4.4.1 External transit data dependency

To estimate a transit time between two points is a very hard computation. Variables like weather, time of the day, day of the week, transit route, road works, among others, are few of the many possible variables that can influence transit times. Due to this high level of complexity, it would be unfeasible to try and make a model to estimate transit times.

To overcome this drawback, an external data source dependency was mandatory. For this project purpose, Google Maps Application Programming Interfaces (API) showed to be the most suitable. Google Maps API's are simple to use, provide high quality results and, for this initial scale are free of charge.

This project uses the Google Maps Geocoding API to translate addresses into GPS coordinates and the Google Maps Distance Matrix API that computes transit time between fixed locations.

This last allows the computation of real-time transit times in various transportation methods (car, walking or motorbike). It also features different traffic models which are useful since they can provide a result closer to reality.

These API's are the only tools used beyond the ones available at Farfetch. They represent a crucial element in this project development; for future and bigger implementations, a study on the cost of mass using these services should be done.

Also, it is important to note that a system without errors does not exit. This means that external data dependencies, such as Google Maps API's, introduce uncontrolled errors. In this case, and due to Google's data precision, it should not be relevant but it is an important fact to point out.

4.4.2 Process simultaneity

Stock OK, fraud detection and courier booking all happen simultaneously and are all related with each other. This means that the order they have in the order flow can vary a lot. For example, a store can be busy taking longer time to announce stock, the courier delivery services can be all booked or even the payment approval can take more time than usual.

Out of these three, the longest time is the one that characterizes this step, but this simultaneity means it is difficult to understand or predict which one is it.

In this case, the approach was to sum up the payment approval time and the courier booking time. This would guarantee that this time is always inside the real time frame providing an acceptable error margin. Not considering stock OK time is also linked with the order volumes of stores. In most of the cases, stores do not have enough orders to make a valid and accurate estimation.

4.4.3 Courier location randomness

In section 4.2.2 an efficient way of estimating an approximate time of courier reachability was presented. This small algorithm is a simple way of dealing with the lack of knowledge on the courier initial location. To this scale and with the objectives set, the error margin provided by this approximation is acceptable but, in a bigger scale, this error can become a major problem.

The other problem with this estimation is the fact that it is city dependent. This means that the study that was done for London needs to be repeated for all cities that support f90 deliveries. This can be time consuming and, at the end, provide worse estimation models since traffic modeling varies a lot from city to city and from country to country.

The problem of courier randomness will eventually be solved by integrating Farfetch platform with the courier's. This can occur in a near future for the cities with higher service demand.

4.5 Chapter conclusion: from algorithm to a service

At this point, the general algorithms are explained in detail. Firstly, a more concrete algorithm that estimates the time an order takes since creation until delivery. Secondly, the isochrone algorithm which computes reach areas given time windows. Both of them are related with each other but

they represent distinct calculations: the first is more related with the initial part of the project, while the second is more related with the planning tool that is being projected.

It is undeniable that the most important part of this project is to come up with a functional algorithm with working proof attached but, after this step, there is a vast list of possible ways of using the technology behind it.

One of the possible implementation ideas is to build a *Web* service in the form of an API. This would be the most universal and easy way of providing a tool that, in the future, could be used with ease by different Farfetch departments and teams. Possible applications of this project within the Farfetch business will be explained with more criteria in chapter 6.

Chapter 5

Algorithm simulation and results

In this chapter the algorithm results and test environment will be described. This is an important part of this work, since it validates the algorithm presented on chapter 4.

Initially, this chapter will go over on how simulation was implemented during the development of this project as well, as how it was adapted to provide more accurate results.

Furthermore, results and error minimization will be subject of a deep analysis. This should allow to classify the algorithm results and to identify error sources. It is important to identify these to future correction and to help the continuous improvement of this algorithm.

Finally, last section will classify the error margin and frame it in this project expectancy and development time window.

5.1 Simulation conditions

When starting a project with less than 5 month time span, it is important to start simulation testing the earliest. This allows early error detection and helps providing the most accurate results at the end. This specific project is not an exception to that rule: as soon as the first algorithm instances were developed, they were immediately put to test.

In section 3.2.1 some numbers on f90 orders were presented. Again, f90 has a low order volume when compared to any other delivery method available at Farfetch. This reinforces the fact that algorithm simulation needs to happen as soon as possible but, due to this order volume, sometimes generated data is not enough. Basically, there is a quick data necessity to prove algorithm veracity but, due to low order volume, this process can take substantial amounts of time. Regarding data used to create time estimations, it will always be considered the whole f90 order history, unless indicated otherwise (without obvious process outliers).

Since it is impossible to compute past traffic conditions, all simulations happened with real-time orders. This means that once an f90 order is placed, the different transit times get computed and the total delivery time calculated. Afterwards, it gets registered on a spreadsheet and later confronted with what happen in reality.

5.2 Simulation results

The best way to show the achieved results is to separate the various estimations and evaluate them individually. This allows identifying and classifying error sources quickly and more accurately. All results are presented in 'minutes:seconds' format.

5.2.1 Payment approval and courier booking times

To estimate both of these times, all f90 orders since launch were considered. All the orders were separated by city and arithmetic averages computed. Average timings are presented in table 5.1.

Table 5.1: Payment approval and courier call time

City	Payment approval time	Courier call
Berlin	04:37	05:12
Dubai	05:14	06:36
Hong Kong	05:50	10:23
London	05:34	06:00
Los Angeles	05:13	03:16
Madrid	06:12	04:05
Milan	06:10	08:29
NYC	06:13	05:37
Paris	05:56	06:05
Tokyo	05:00	10:00

When confronted with real information, the mean errors gave a satisfactory result since, at this stage, errors in the range of 0-5 minutes are totally acceptable. Also, the order number discrepancy between both cases is explained by the lack of some order details caused by unavailable courier information or improper data registration.

Based on the results, it can be stated that, even representing a small part of the whole delivery process, this time estimation is important and needs to be included in the final model. Results are presented in table 5.2 and table 5.3.

Table 5.2: Payment approval results

City	Mean error	Number of orders
Berlin	01:51	9
Dubai	01:57	15
Hong Kong	02:26	7
London	01:54	188
Los Angeles	02:01	14
Madrid	01:40	10
Milan	04:37	6
NYC	02:43	168
Paris	01:56	18
Tokyo	02:00	2
Total	02:16	437

Table 5.3: Courier booking results

City	Mean error	Number of orders
Berlin	01:31	8
Dubai	04:23	12
Hong Kong	05:14	5
London	03:33	218
Los Angeles	01:51	9
Madrid	01:46	6
Milan	02:14	3
NYC	03:20	117
Paris	03:20	13
Tokyo	05:00	2
Total	03:13	393

5.2.2 Courier reach time

As described in subsection 4.2.2, estimating the time a transport courier takes to reach a store has a big level of randomness.

Initially, while not aware of this fact, it was considered that drivers would be physically in the same location, but this approach generated big errors, since fixed locations are a completely false assumption.

To solve this problem, London traffic analysis was done with real-time traffic data also from Google Maps Distance Matrix API. The simulation lasted a full week (from Monday to Friday with 30 minute intervals) where traffic data from the 10 points were collected and registered on a spreadsheet. Afterwards, data were separated by time of the day and day of the week, where arithmetic means were also calculated and plotted into 5 different graphics as shown in figure 5.1.

After plotting, trendlines were computed and the results were confronted with real reach times. Regarding trendlines, second degree equations provided the best data pattern without compromising computation performance.

In the graphs there is an evident traffic evolution: transit times start to increase throughout the morning until peaking at around 8AM-9AM (London morning rush hour). After this, transit times decrease until around 5PM-7PM (evening rush hour) where a notorious transit time increase can be seen. With evening progression, transit times continue to decrease, as expected. In addition, it is interesting to note that Monday and Friday times curves are similar, also as expected. Results of this estimation are presented on table 5.4

5.2.3 Delivery time

Delivery time is the actual time between the store and the final customer. To compute this transit time the approach was to, in the same way previous transit times were computed, recur to Google Maps services.

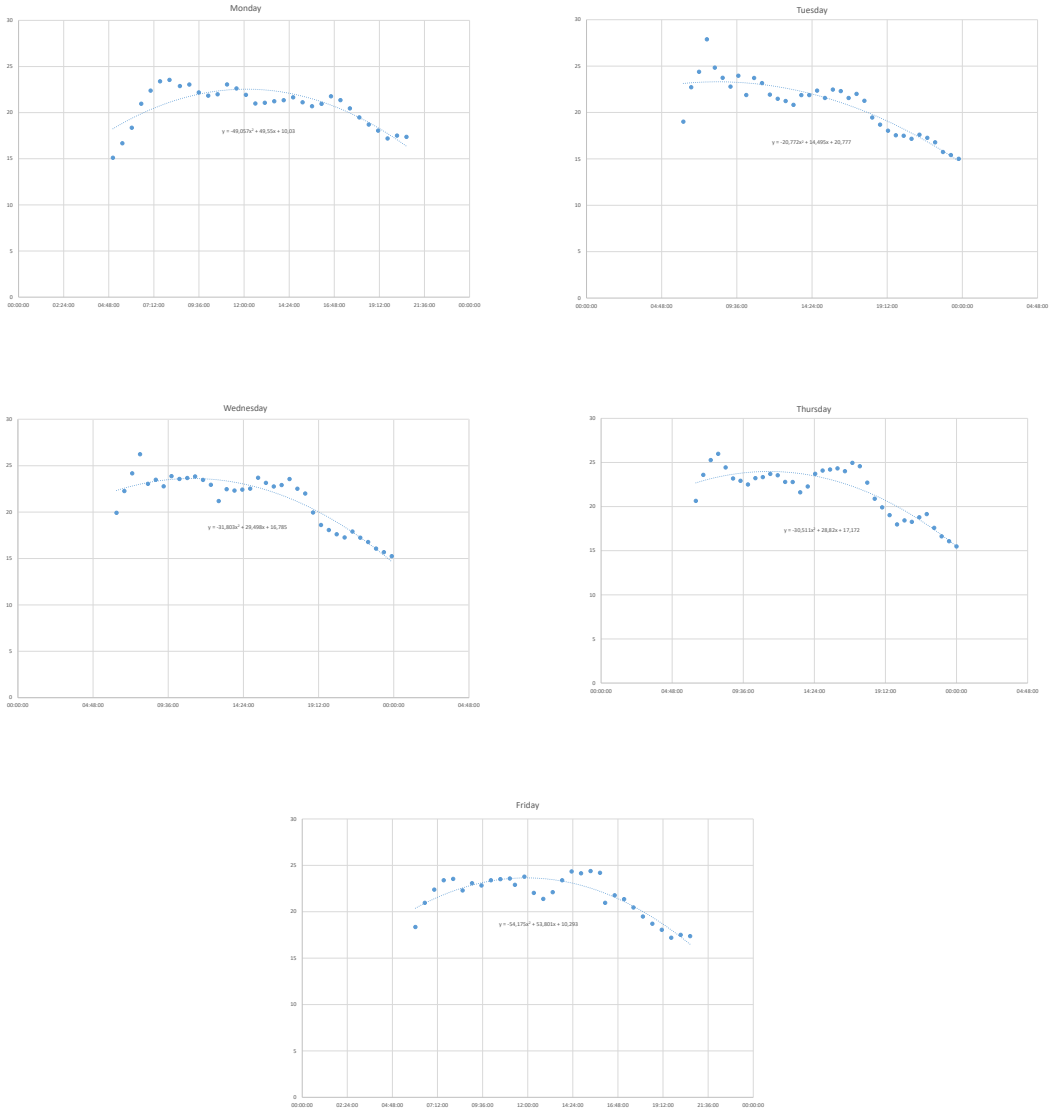

Figure 5.1: Weekly London traffic plotting

Table 5.4: London reach time results

Day of the week	Mean difference	Order count
Monday	05:24	45
Tuesday	06:17	54
Wednesday	06:40	48
Thursday	05:41	38
Friday	06:10	49
Total	06:02	234

Google Maps Distance Matrix API provides accurate information about transit time between fixed destinations. Also, it has 3 built-in transit models which are useful to help form a more

accurate estimation: pessimistic, best guess and optimistic. Results presented on figure 5.5 will consider both best guess and pessimistic models since they represent the most accurate models available.

There are various reasons to explain the larger mean errors in this last step:

Firstly, the order count in some cities (like Dubai, Los Angeles or Madrid) is very low, making the estimation very poor.

Secondly, using external services such as Google Maps API's means errors behind calculations are totally invisible. There is no control or knowledge on the data provided.

Thirdly, Google Maps makes its transit calculations assuming predetermined routes which can differ from the ones couriers took.

Fourthly, Google Maps does not retain traffic information from the past, meaning that it is impossible to compute transit times prior to the simulation time. This makes it impossible to simulate transit times in past orders which originates poorer estimations.

Fifthly, the transit time simulation does not take into consideration two small but important time slots: the time the courier takes since reaching the store and load the package and the time since the courier arrives at the final customer location until it delivers it. These are important times that, due to the lack of data, cannot be estimated. The transit time only computes the time it takes from the store to the final customer.

Lastly, Google Maps calculations rely on user data. Google works with users status (like speed and location) to help accuracy but, in countries where the population has not the habit of using services like these, the data quality is worse.

Table 5.5: Delivery time results

City	Delivery time error (bg)	Delivery time error (p)	Number of orders
Berlin	-	-	0
Dubai	34:19	24:48	4
Hong Kong	09:27	06:24	1
London	14:04	11:47	37
Los Angeles	05:06	01:13	1
Madrid	16:37	08:47	3
Milan	20:24	09:55	1
NYC	14:01	13:12	29
Paris	16:16	14:42	7
Tokyo	-	-	0

5.3 Error minimization and objective fulfillment

It is very important to classify error sources and to minimize them along the project development.

In this case, the major error source is data quantity: f90 is a fairly new service and its demand is still growing. The process is not automatized or optimized which implies a big general failure rate and a lot of outliers. Also, the fact of not having many orders placed makes it a bigger challenge

of estimating and making a valid model. When it was possible to use the whole f90 order data set, the results were better than when only using orders in real-time. This pattern can be seen when comparing transit times with payment approval times, for example.

Taking into consideration that this project started 5 months ago, the general results are satisfactory. These are the first steps on creating a new planning method and they point to a successful direction but still with a big room for improvement. The reach time problem will be eventually solved by integrating Farfetch order system with the different courier platforms. Big transit errors on the time from store to customer will be minimized with more data and with the introduction of new variables like explained in subsection 5.2.3.

It is certain to say that, with this service evolution, more data and more testing will imply direct algorithm improvement. This project represents the beginning of the a new approach to scale and plan new or existing short-distance delivery services.

Chapter 6

Business applicability and service scalability

This chapter will go over the possible business applications that this project can have in Farfetch.

During the execution of this project, multiple presentations were made to different business branches. This allowed colleagues with a more accurate view and professional experience in the area to give their opinions and suggestions. At the same time, these opinions constitute a very useful tool, since wider overviews support continuous development.

Besides this fact, presenting this project along its development helped understanding where it can fit and be useful to Farfetch business improvement.

This thesis was never engineered to serve a specific problem only. As a matter of fact, it should be seen as a whole, allowing multiple future approaches and applications to make use of it.

Some examples where this logic can be applied in the different branches of Farfetch business are going to be presented.

6.1 Checkout

Checkout is the shopping part where the customer, after choosing what items to purchase, inputs the delivery and payment information. Farfetch checkout is divided in three major steps:

1. Shipping: in this step the customer inputs the order details such as the full delivery address and billing information. It is also at this step that an user can choose the Click & Collect delivery service;

2. Payment: in this step the customer is prompted with the payment methods available in its region and where it should input its payment details;

3. Review: in this final step, the customer chooses the shipping method available for the previously address registered and reviews the full order details.

Figure 6.1 illustrates these steps upon Farfetch checkout.

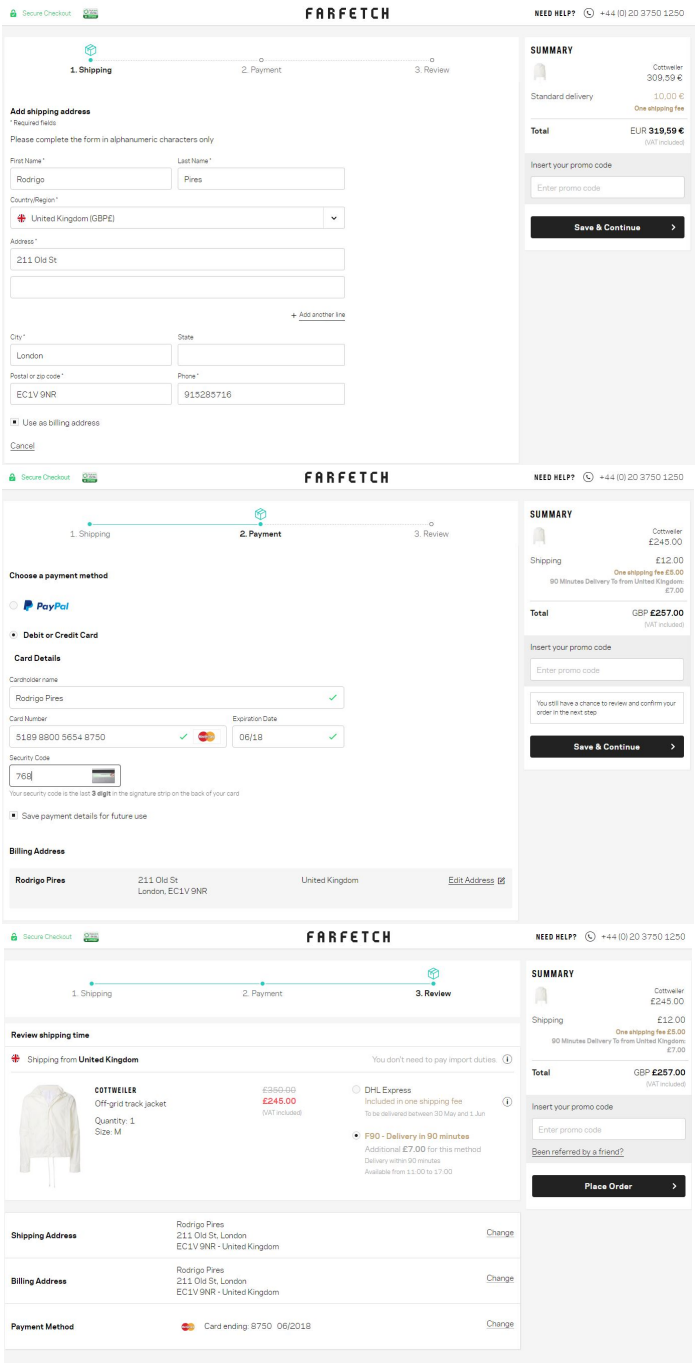

Figure 6.1: Checkout steps

In the specific case of 90 minute delivery, the customer is only prompted with the 90 minute delivery option at the last step, since it is dependent from the inputed address. This represents a big flaw, since users that want this delivery option, start shopping choosing only items that can be delivered in 90 minutes. For example, a customer chooses the f90 filter when browsing, chooses an item and proceeds to checkout, inputs shipping and payment informations and, at the last step, the previously inserted address is not eligible for 90 minute delivery. This can represent a lost order and consequently a lost customer if the customer is only buying because of the delivery time agility.

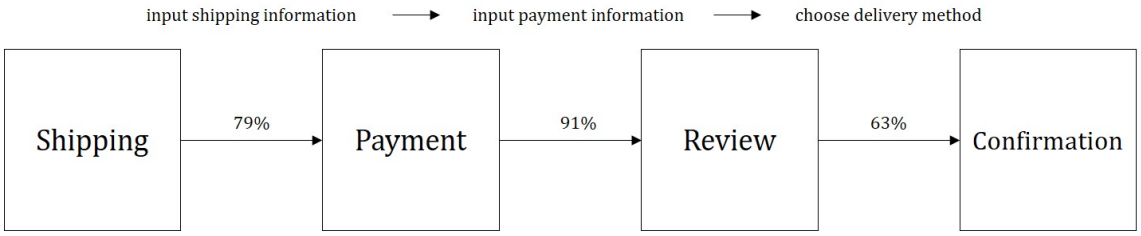

Figure 6.2: f90 checkout statistics, March 2018

On figure 6.2 the problem described before can be seen: the last step from Review to Confirmation, where the customer chooses the delivery method, the percentage of confirmations is rather low. This can be explained by multiple factors (such as service pricing), but indicates the pattern where the customer is buying the item because it can be delivered in 90 minutes. When the address is not eligible, there is a big chance of the customer canceling the order.

To avoid this possible problem, a previous address evaluation can be done while checking how much time the order is actually going to take to be delivered. With this, it would be possible to provide more accurate information while avoiding this situation.

Additionally, the 90 barrier can be ignored and checkout service can use this algorithm to provide more precise information to the customer. For example, if the order cannot be delivered in 90 minutes, checkout service can inform the customer that will take N minutes more. This allows the customer to decide if he still wants the order to proceed or the immediate cancellation.

6.1.1 Delivery Slots

Another interesting application of this project in checkout service is the implementation of delivery slots. Ideally, in checkout, having the possibility for a customer to choose when he wants the order delivered, improves the shopping experience.

To do this, the algorithm can be reversed: instead of analyzing how much time it will take for the customer to receive the order, the algorithm takes in consideration at what time the order should start being processed in order to arrive in the desired time slot.

Taking figure 6.3 in page 42 as example, the final customer wants the order to be delivery between 4PM and 5PM. After computing the different times it was concluded that everything will take an hour so, the order preparation should begin one our before, at 3PM.

In this application, the slot time (1 hour in this case) is very useful since it works as a delivery margin. The order is prepared to be delivered on the lower limit (4PM on the previous example) and, taking in consideration the multiple errors of these computations, it should arrive in the desired interval.

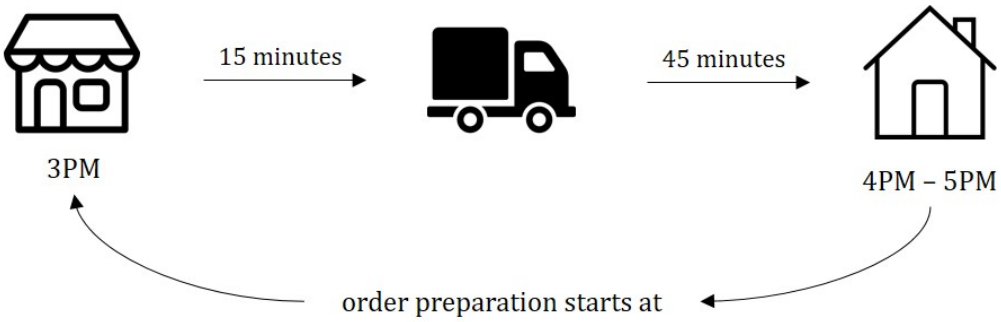

Figure 6.3: Delivery slots implementation example

6.2 Premium clients

Farfetch has groups of premium clients which consist on regular shoppers who spend more money than the average customer or celebrities that hire personal shoppers to buy their fashion items.

On the second case, the purchasing process is a little different from the normal buying process: personal shoppers contact Farfetch about their client preferences and Farfetch provides the item options. After these, Farfetch staff shops the desired items and repacks everything before sending to the final customer.

Sometimes, personal shoppers need some item with urgency. This algorithm can be useful by mapping all the stores and how much time it would take to deliver an item. The result would be a better and more accurate list of the products available.

Let's say for instance that someone famous needs a pair of shoes to attend a dinner on the same day so, his/her personal shopper gets in contact with Farfetch. After this, responsible teams can get a list of available products, how much time they would take to deliver and if they meet the customer's preferences. This process is still manual until today and applying this logic would become easier and more accurate.

In figure 6.4 the red region represents the reachability area of a customer in Knightsbridge area in London, UK. It is possible to see which stores (in black) fall inside the 15 minute reachability and are available for delivering on time. The second stage of this process would be listing the products available in the selected stores which encounter the final customer's preferences.

Since stores can have distinct speed of order preparation, it is also mandatory to design a method to evaluate if the selected stores performance meets the time schedule needed.

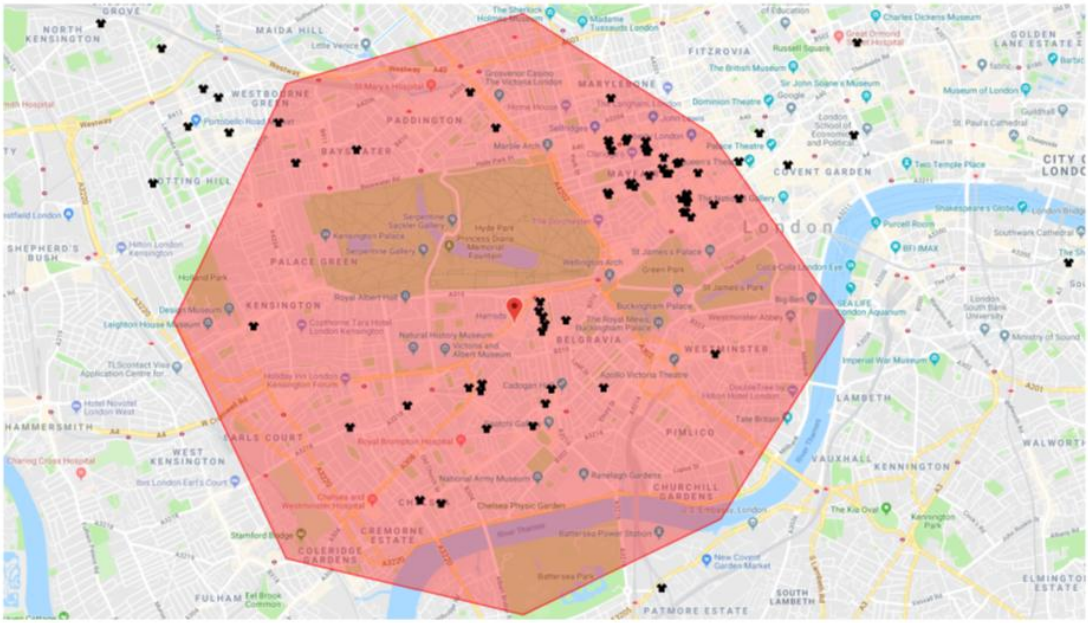

Figure 6.4: London store mapping example

Chapter 7

Conclusions and future work

This chapter presents the conclusions of this thesis. It will go back to the initial work objectives and confront them with the final results. Then, it will go over the future steps and how this work can be continued in the future.

7.1 Objective evaluation

When doing a master thesis in a corporate environment it is important that not only the thesis subject has a certain degree of scientific research but also that it represents an useful work to the company itself.

When first started, the main goal of this work was to estimate delivery times but, after a couple of weeks and some idea discussion, a need for separating long-distance and short-distance deliveries arose. Since short-distance deliveries imply better and more accurate planning, this work ended up focusing only on these and on the specific case of 90 minute delivery provided by Farfetch.

After the initial study and company acquaintance, the first stages of the algorithm started to be tested. These provided the basis on where a more concise solution was founded on.

Through the course of this project a lot of new ideas and new approaches came up. One of them was the isochrone mapping presented on chapter 4. The idea of having a dynamic region map showed to be useful not only to improve the already delivery method, but to scale it to a more efficient process.

In general, this approach can be considered a valid option to the future of these services not only at Farfetch but to any other company that needs delivery planning optimization. The results show what is expected for a project with this time span: a solid idea with some initial working proof. There is plenty of room for improvement and work to be done until this project becomes something solid enough so it can be featured on a company with Farfetch dimension. There is a big need of further testing in order to prove the final usefulness and applicability of this approach.

7.2 Future work

As stated before, this project has big room for future work.

Firstly, there is a need to keep collecting and analyzing data in order to improve the algorithm general accuracy and performance. This will make a final evaluation of the algorithm capabilities and further business incorporation. Until this point, every aspect points to a better strategy, but final results might not be enough in order to allow a future implementation project and infrastructure investment.

Secondly, it is needed to find where this project is more suitable to be incorporated in. In chapter 6 some examples were given, but a more precise fitting needs to be done. When developing a new project of this nature, a lot of different teams from various business branches need to be in accordance. This involves considerable prior testing and model validation when applied to a specific purpose. Testing on live environment can be difficult and can take some time before providing conclusive results.

Lastly, by having a rather low service demand, order analysis beyond f90 need to be part of the final model. This means including same day deliveries. These are also based on a very manual process that needs not only automation but a whole new planning base. At the moment, the booking process is being done manually which will eventually be solved by future system integration with the couriers platform. These integrations stand as one of the main tasks when proceeding with the development of the planning process of these deliveries.

Appendix A

University vs. corporate environment

University studies are a big solid base to start any professional career. In 2013 I started my 5 year degree on Electrical and Computer Engineering where I have ended up specializing in telecommunications and electronics specifically in computer networks.

These 5 years gave me a big theoretical background in very different fields: from programming and computer network design and security all the way to energy markets, automation systems, management and economics.

For this reason, when choosing a Master thesis subject, it was obvious that it needed to be inside a corporate environment. This would allow me to apply what I learned in these years while facing a real work environment and consequent problems. To me, it represented the bridge between both worlds. When the thesis options list was published, I was sure that my preference was to work in a corporate environment.

At this stage, Farfetch became my first preference for two main reasons:

Firstly, the initial theme proposed showed to be included in a different area of my previous specific studies. E-commerce logistics and delivery services is a different field from computer networks. This would allow me to widen my knowledge while still applying some of the studies from previous years. In my opinion, having a wider and less profound knowledge is more useful than a narrow and highly technical studies.

Secondly, Farfetch working methods and flow were very interesting to me. Being a growing modern company that is on the vanguard of technology, Farfetch showed to be the best contender on where to learn more. One can associate Farfetch with high-end fashion only, but its business model goes way beyond that. Besides the fashion world, Farfetch bets a lot on technological advances and research, which can be applied basically to any e-commerce business. This creates multiple academic bridges for university students like myself.

In the end, I could not be happier with my decision. Farfetch provided an interesting research problem under excellent working conditions. Since day one, all Farfetch employees showed to be highly available to introduce me to the different parts of the company and how they work together. This made this work flow seamlessly along its development while overlapping initial expectations.

In my opinion, Farfetch sets an example to all other businesses that try to reach out to university students which are ending their Master degrees.

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