Leveraging a business solution to enhance last mile deliveries

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Abstract

E-commerce businesses are experiencing accelerated growth (Clement, 2020) leveraged by a shift in purchasing habits. Luxury fashion e-commerce, the industry where the present company competes, is no exception. With the increasing customer demand regarding shopping experience and the number of marketplaces available online, providing a quality service becomes even more imperative. From that perspective, last mile delivery plays an important role, since it is the final link of the supply chain before products arrive to their destination. Assessing its performance and constantly seeking improvements is therefore a vital requirement for those who wish to remain competitive.

In consequence, this project studies the impact of business solutions based on multi-leg, namely working with other carriers or owning a ground fleet to enhance last mile, with the primary goal of uplifting clients' satisfaction. In a first stage, a method to appraise which regions could be subject to last mile restructuring is developed, considering strategic and operational KPIs. To assist decision making, a DEA model is used to measure operational performance. Given the output, the territory's last mile processes are scrutinized and relevant information withdrawn. Consequently, a tool is developed using *Python* software to estimate the resources necessary to convey operations, without detailing the routes. Crossing the simulator's results with the other alternatives presented and the AS-IS situation, the total yearly costs and customer experience enhancement for several scenarios are evaluated and presented in a user-friendly interface.

Findings suggest that in-sourcing transportation improves customer experience and provides savings when order volume is high or time between consecutive customers is low. For one of the cities being evaluated, C3, owning a ground fleet to fulfill a limited amount of shipments proves to be the best overall solution. On the other hand, in C2, using carrier T4 to serve VIPs is a better alternative. Results also indicate that, in the long term, in-sourcing transportation is a feasible option if there is enough order volume and resources are used efficiently.

Globally, this dissertation provides a framework to assess the effect of multi-leg initiatives in last mile. Using the simulator built and following the guidelines here provided allows to analyse different scenarios, change inputs accordingly and assist decision making. The flexibility of the framework enables this structure to be replicated to any city.

Resumo

Os negócios *e-commerce* estão a atravessar forte crescimento (Clement, 2020) alavancado por uma mudança nos hábitos de consumo. O *e-commerce* da moda de luxo, indústria onde a presente empresa opera, não é exceção à regra. Com um aumento da exigência do consumidor relativa à experiência do cliente e do número de *marketplaces online*, oferecer um serviço de qualidade ganha ainda mais relevância. Assim sendo, a *last mile*, como elo final entre o cliente e a cadeia de abastecimento, toma um papel de destaque. Monitorizar a sua performance e explorar oportunidades de melhoria é vital para as empresas se manterem competitivas.

Consequentemente, este projeto estuda o impacto de soluções de negócio baseadas em *multi-leg*, nomeadamente trabalhar com outras transportadoras ou realizar o transporte internamente, com o objetivo de aprimorar a satisfação do consumidor. Numa primeira fase, é desenvolvido um método para avaliar cujas cidades devem ser analisadas, com base em indicadores estratégicos e operacionais. Para auxiliar a decisão, um modelo DEA é usado para medir a performance operacional. De seguida, os processos *last mile* nas regiões em questão são minuciosamente investigados. A informação obtida é usada num simulador em *Python* que determina os recursos necessários para satisfazer a procura, desenvolvido para o efeito. Os resultados obtidos, aliados às outras soluções propostas, permitem comprarar os custos anuais e a variação de experiência do cliente e sumarizar a informação numa interface.

Os resultados obtidos sugerem que realizar internamente o transporte melhora a experiência do cliente e pode levar a *savings* quando o volume de encomendas é elevado ou o tempo entre clientes consecutivos baixo. Para uma das cidades estudadas, C3, usar esta solução para entregar um número limitado de encomendas é a melhor alternativa. Por outro lado, em C2, contratar o carrier T4 para servir os VIPs é a hipótese mais adequada. A longo prazo, operar um *carrier* próprio é uma opção adequada se houver volume de encomendas suficiente e os recursos forem utilizados de forma eficiente.

De um modo geral, a dissertação consiste numa *framework* que permite avaliar o efeito de soluções *multi-leg* na *last mile*. O simulador construído e a estrutura proposta permitem analisar diferentes cenários, variar parâmetros e auxiliar a tomada de decisão. A flexibilidade da estrutura proposta permite que a mesma seja replicada para outras cidades para além das analisadas.

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"The secret of getting ahead is getting started"

Mark Twain

Contents

Acronyms and Symbols

3PL	Third Party Logistics
AGV	Automated Guided Vehicle
ATV	Actual Transaction Value
CI	Composite Indicator
DAP	Delivered At Place
DDP	Delivered Duties Payed
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
GMV	Gross Merchandise Value
KPI	Key Performance Indicator
NYSE	New York Stock Exchange
TSP	Travelling Salesman Problem
TT	Transit Time
TTALF	Transit Time After Last Facility
VRP	Vehicle Routing Problem

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Chapter 1

Introduction

In today's world, people are strongly dependent on digital applications when performing most of their daily tasks. From using the computer to execute trivial calculations and edit text documents, to being constantly connected to a network of people through social media. The most recent generations, known as 'millennials', are familiar with the digital environment and were the main drivers of this mindset change, using new technologies to shape and improve quality of life. This tendency has impacted many industries worldwide, including the fashion industry. As expected, 'millennials' amount to more than 40% of online traffic in some fashion websites, and are sensitive to marketing campaigns and social media awareness (Bailis, 2017). Therefore, e-commerce has become a vital requirement for most of the players competing within the industry, in order not to fall behind the competition. In fact, e-commerce retail sales amounted to $3.5 trillion in 2019, and are expected to almost double by 2023 (Clement, 2020). Figures that definitely highlight the weight this kind of trading gained over recent years, and the importance and resources that should be allocated by companies to remain competitive.

This dissertation was conducted in a technological company operating in the luxury fashion industry and whose primary source of revenue is an online marketplace. In this industry, keeping up-to-date and granting customers the best experience possible is even more critical, given that clients are usually market experts and competition is fierce. They can easily place their orders through other marketplace, if not satisfied with the service provided. This easiness to reach global markets with e-commerce has also presented an opportunity for smaller companies to grow and earn a market share in their environment, contrarily to traditional commerce where those who benefit from economies of scale have a clear advantage (Barns, 2016). However, online marketplaces pose a new challenge regarding the perception of value from the customer point of view. Unlike physical shopping, where clients usually appraise customer service or aesthetic appeal, online shoppers mainly treasure online trust, convenience and price (Liu et al., 2013). Factors that should be considered to enhance customer satisfaction.

In general, most luxury companies are from Europe and the United States (Global, 2019). When talking specifically about luxury fashion, Europe is a major supplier, with many notorious brands and boutiques in Italy. Nonetheless, the geographic distribution of consumption does not match this supply pattern. United States, China and Japan are the three biggest markets for 2020, followed by Italy and France (Statista, 2019). The gap tends to increase, as in 2018 China sales grew above 30%, and the rest of Asia grew above the market rate of 5%. On the other hand, Europe grew slower than the average market rate (D'Arpizio et al., 2019). This comes as a logistic challenge for retailers who are placed in Europe and must place their products in distant geographic locations.

Taking this into consideration, last-mile delivery planning and assessing multi-leg opportunities, by enabling more than one carrier to participate in the delivery process, becomes important not only to drive down costs of a complex logistic operation, but also to award customers a meaningful experience. After all, delivery is the final link between complex supply chains and the final clients.

1.1 Farfetch

The company, based in London, was created in 2007 by a tenacious entrepreneur with love for high-end fashion and drive to revolutionize the industry. With more than a thousand partners, the organization's goal is to be the global platform for this fast-growing market, by connection boutiques and brands to customers from over 190 countries.

Up until 2015, the only distribution channel and source of revenue was the online marketplace, where thousands of products belonging to different partners are displayed and made available to customers worldwide. Later that year, Farfetch launched an innovating initiative originally known as Black & White (meanwhile renamed to Farfetch Platform Solutions). This white-label solution enables brands and retailers to take advantage of Farfetch's marketplace capabilities and scale, while focusing on the creative aspects of their business. Furthermore, they can choose from a set of packages, where each package represents a specific service, or opt to outsource their full end-to-end e-commerce experience (Farfetch, 2018). Additionally, in 2017, "Fashion Concierge" was acquired as a solution to supply the needs of VIP customers and improve the experience with Farfetch.

Experiencing a fast growth, the company ultimately filed an Initial Public Offering in the New York Stock Exchange in 2018. At the first day in NYSE, shares rose from \$15 to \$20 and the company raised 885 million dollars (News, 2018). From then onwards, relevant investments were settled, such as the acquisition of the New Guards Group, with exclusive brands like Off-White and Palm Angels (Singh-Kurtz, 2019), or the partnership with Harrods as the exclusive global e-commerce partner.

Farfetch's business model is particularly interesting in the sense that the items exhibited in the marketplace do not actually belong to the company. Instead, the stock is held by the partner boutiques and brands which also carry the costs related to stock management and warehousing. In a way, this strategy mitigates risks and offers a wider range of options to customers. On the other hand, there is a strong operational dependency on partner boutiques not only to supply the products, but also to choose the correct package, work with other third-party logistics providers and maintain a constant flow of information. Carriers are also important partners due to the responsibility transportation carries in the company's operation. Their integration and the information that is bilaterally shared allows to monitor tracking events and manage billing information, among others.

Considering the geographical mismatch between luxury fashion supply and "consumption" markets, most routes are intercontinental. In these cases, packages are sent by plane in a first stage, and then delivered using ground fleet. Also when only ground vehicles are used, namely on some domestic shipments, there is evidently a clear division between the first and last miles, usually connected through a distribution center/delivery facility. Currently, both these legs are generally done using the same courier.

1.2 The project

In a company where transportation is one of the key operational tasks, and "Amaze customers" an instilled value, last mile achieves more relevance as it is the final contact between client and company. The present dissertation is an initiative launched by the Delivery team, responsible for streamlining and optimizing processes, as well as pinpointing problems and suggesting improvements from the moment products leave the partner boutiques and brands until they reach their destination. This includes consulting invoices shared by carriers, tackling customs issues that might occur or analysing data available in the database to identify business opportunities, among others. Delivery is inserted in the Logistics department, which consequently is part of the Operations division. Assessing multi-leg opportunities in last mile poses as an interesting option to evaluate if whether the current last mile setting is the most fitting to provide customers a great experience and adequate shipping costs for the organization. Additionally, the present project provides guidelines to evaluate multi-leg solutions that can be adapted and replicated to different cities. More than a recommendation, the outcome of the dissertation is a framework to assist decision making concerning last mile.

1.2.1 Motivation and goals

Having experienced rapid growth over the company's lifetime, Farfetch's environment and planning is fast-paced and quickly changing. Concerning strategic planning, a trade-off between quality, cost and lead-time must be incurred, since excelling in the three axes is not possible. The strategy of capturing a big percentage of market share, by means of aggressive expansion and substantial investments, has “forced” to focus primarily on enhancing customer experience and decreasing product lead times'. Prioritizing these two dimensions (lead time and customer experience, that reflects the quality of the service) rose cost of operations, leading to negative profit & loss statements in the past. Now that Farfetch has generated $1.8 billion of Digital Platform GMV and established itself as the first in-season luxury player online (Farfetch, 2019), attention is also being directed towards operational cost reduction. Subsequently, shipping costs have a significant weight of these expenses, in consequence of the company's business model.

The present project focus on the last mile of delivery. At the moment, the courier who picks the product in the boutiques delivers it to the final customer as well. Using the same third-party logistics to perform both the first and last miles might not be the best alternative in terms of customer experience and costs. In consequence, this dissertation aims to determine the impact in operations of two distinct alternatives: working with other carriers in the last mile, and owning a ground fleet. The central objective is to enhance customer experience, aligned with the company's vision. In addition, and taking into account the will of having profitable income statements, shipping costs will also be considered. Globally, a flexible framework to assess multi-leg opportunities in last mile, adaptable in every city, will be developed.

1.2.2 Methodology

From the start, the project was divided in three major stages. Firstly, it was fundamental to understand the business as a whole and the scope of the dissertation inside the organization. In addition, the definition of objectives, deadlines and main deliverables in each stage allowed to get a broader overview of the project. Consequently, in stage two, a city selection was conducted, limiting the regions where the study would be assessed. Lastly, based on the choice previously made, multi-leg solutions would be analysed and compared to the AS-IS situation, in order to determine the best option in a company's perspective. The different stages, deadlines and deliverables are depicted in Table 1. Logically, each stage is further divided in smaller duration sub-stages that ensure the execution of the project. This segmentation is present along the dissertation and can easily be identified.

Table 1: Project stages, deadlines and main deliverables

Stage	Deadline	Main Deliverable
#1 Business overview and objective definition	10/02 - 15/03	Project guideline
#2 City selection	01/03 - 31/03	Cities filtered
#3 Study multi-leg solutions	01/04 - 15/05	Best fitting solution

Due to the short time-frame available to develop the present project, a strict planning had to be conducted at first. This range of requirements suggests a *Waterfall* methodology, where a plan is delineated from the start and rigidly followed. In this case, conceiving detailed guidelines from the beginning without enabling some flexibility would be unwise, since the solutions to analyse in stage 3 can depend on the decision taken in the precedent stage. Even within stage 2, the final sub-stage is dependent on the results previously obtained. Therefore, an hybrid approach was followed instead, providing the structure and requirements of *Waterfall*, with an increase in flexibility and the possibility to make changes as requested, characteristic of *Agile* (Cohen, 2019).

Throughout this report, due to confidentiality reasons, names of cities or carriers will be encoded, and information regarding Farfetch and its partners will either be altered or omitted. The values presented are, therefore, not the real values used during the project. Even so, conclusions drawn still apply.

1.3 Thesis structure

The structure of the following chapters was adopted to portray the course of work taken along this dissertation and to justify all the decisions taken. Starting by Chapter 2, a literature review of the most relevant aspects regarding the project is made. Firstly, luxury e-commerce is described to properly position the company on its environment; additionally, a decision making model used in a mid-project stage is defined, as well as last mile delivery concepts and relevant planning costs. Chapter 3 provides a fair description of general processes and delivery configurations available in last mile. Consequently, Chapter 4 details the steps followed along the project. In a primary phase, a geographic filtering is conducted based on different KPIs. Afterwards, the solutions to enhance last mile are meticulously delineated, especially a model developed to estimate the impact of in-sourcing the last mile. The results obtained are discussed in Chapter 5. Lastly, Chapter 6 sums up the work developed during this dissertation by summarizing the most relevant findings, recommending a solution for the company and acknowledging aspects that should be reviewed and considered in future work.

Chapter 2

Background literature

Across this chapter, topics that are relevant to the dissertation and justify decisions taken afterwards will be discussed. Firstly, the luxury industry where the company operates is described, along with their customers that are demanding by nature, in Sections 2.1 and 2.2. In the city selection stage, a considerable amount of data was used to choose the areas where last mile restructuring was useful. With the purpose of assisting the decision process, the data envelopment analysis method was employed. Section 2.3 details this technique. When designing multi-leg solutions, in-sourcing transportation was one of the options considered. To estimate the resources required to convey such an operation, an high level tool was developed instead of a vehicle routing problem defining the routes. On the other hand, to calculate a parameter to input in the high level tool, a nearest neighbour heuristic was chosen. The definition of vehicle routing problem and factors to consider when analysing last mile scenarios are depicted in Section 2.4.

2.1 Luxury goods e-commerce

Luxury is a concept that has constantly changed over the course of history (Okonkwo, 2007). In business, it is seen as a strategy to differentiate from competition and build a unique value proposition, based on: 1) Original product conceptualization; 2) Craftmanship and precision in production; 3) Enhanced brand recognition; 4) Exclusive access and 5) High quality products, focusing on a market niche (Okonkwo, 2009). Although the main goal is often to maximize shareholder value, organizations are confronted with a trade-off between standardization and profit (Dall et al., 2003). This business model provides control over the supply chain by vertical integration, guaranteeing product quality upstream and directly contacting customers downstream, upgrading their experience. However, the concept is broad and subject to interpretation, since two customers might disagree in categorizing an item as luxurious. In consequence, its definition varies from region to region (Kapferer, 2015).

With the proliferation of the internet, and the usage of mobile devices and online shopping, a dilemma emerged (Ashill et al., 2018). Should luxury fashion companies sell online, losing its aura of exclusivity, or be limited to the physical store? At first sight, Internet's features like global reach or lack of human contact seem to be opposite of luxury's core elements (Okonkwo, 2009). Nonetheless, the author also states that organizations managed to overcome that problem and selling products through the web maximizes profits. Afterall, a web domain captures customers who do not have access to nearby stores, feel intimidated by the physical store environment (Kapferer, 2000), or prefer shopping using a computer, tablet or even a mobile phone. The latter has originated a segment of e-commerce called mobile commerce, or m-commerce, defined as the ability to purchase goods anywhere through a wireless Internet-enabled device (Clarke III, 2008). The same author also states that mobile phones offer superior value in areas such as ubiquity, localization or personalization, when comparing to e-commerce, and companies will have to adapt their value proposition in order to reach a competitive advantage. This particular way of shopping has gained popularity over recent years, and studies have been conducted to understand what factors influence the usage of m-commerce, in both males and females (Esmaeili and Eydgahi, 2016). Others, such as Al-Khalaf and Choe (2020), analyzed what aspects prevented citizens from trusting m-commerce. Findings suggested that perceived security and social media influencers increased respondents' trust in shopping using the mobile phone.

Within the luxury fashion e-commerce, multibrand retailers act as partners for brands and boutiques to showcase their products and increase their customer base, and as a source of information for the visitors. According to Dauriz et al. (2014), some research is usually made by the client before making a purchase, either physically or online. In fact, multibrand websites are the preferred source of information, ahead of luxury blogs or official brand sites. The easiness to compare characteristics and prices is the differentiating factor. This acts as a strong motivator for brands to display their product in these platforms, since their "audience" will increase. For multibrand retailers, selling luxury brands makes customers believe their privacy and payment details are protected (Al-Khalaf and Choe, 2020). All in all, synergies are achieved when partnerships are established between both parties. This link ultimately benefits the consumer because competition increases as well as product availability worldwide.

2.2 Luxury customers

Clients who buy luxury products are usually thought to belong to a high social status, at least when talking about income. Therefore, they are demanding by nature and expect to have a superior customer experience. Lemke et al. (2011) defined customer experience as the subjective response to the direct and indirect contact with the firm, and customer experience quality as its perceived superiority. In a time where 'the experience is replacing quality as the competitive battleground for marketing' (Gupta, 2016), an urgent need to understand the target client has arisen. Only then companies can upgrade the quality of the service they are providing.

According to Kim (2019), the expectation the consumer builds towards the shopping experience can differ from an online setting to a physical environment. In-store shoppers' value friendly interactions with the employees and an upscale background, being also more averse to risk. E-shoppers, on the other hand, trust customer reviews, are more price conscious and feel safe performing online transactions (Liu et al., 2013). For that matter, it is essential to host an appealing and secure website, placing visual cues that ensure security of data and always protecting the user's privacy (Srinivasan and Barker, 2012).

Moreover, gender is also a factor that conditions customer expectation. For men, order and delivery management are indicators that relate closely to e-satisfaction, which is apprehensible taking into consideration the price of the items being delivered. Women, besides these indicators, also value customer service and trust, processing more information and evaluating a wider range of service attributes than men, which are goal-oriented and focus on the information that directly assists their purchase. On the other hand, a lack of personalization on luxury websites, so characteristic of the physical environment, negatively influenced females' experience (Kim, 2019).

Online consumers are getting increasingly more informed, and using different sources of information to compare products on their wish list (Dauriz et al., 2014). Consequently, in a customer centric business strategy, hosting a secure website and providing quality information is imperative to enhance consumer satisfaction, especially since information quality is valued in every region of the globe (Ghasemaghaei and Hassanein, 2015). In addition, granting superior service by improving last mile delivery can help attain customers, whose repurchase rate is even more important given the order values of the luxury fashion industry, and maintain a competitive advantage.

2.3 Data Envelopment Analysis

Problems companies face and the decisions they need to make are complex and most of the times subject to different interpretation. Several factors must be taken into account to estimate the pros & cons of a particular strategy. This multi criteria decision making can be assisted by analytic models, but the decision maker has the final word, since there are other variables difficult to include in these models. Nevertheless, their use is helpful when treated as a decision support system.

The performance of a system depends on different individual indicators that affect the final output. Normally, a system's efficiency is compared to others', so windows of improvement are pinpointed and corrective action taken. When the number of systems or indicators is large, or the systems' comparison is not straightforward, a composite indicator can be built. A composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model, and should ideally measure multidimensional concepts which cannot be captured by a single indicator (OECD, 2008). Its construction comprises a number of stages, amongst which the theoretical framework, data selection, multivariate analysis, normalisation or weighting and aggregation. According to OECD (2008), the first steps of selecting a theoretical framework, clearly defining what is being evaluated, and filtering data, by deciding which sub-indicators fit the framework, are the basis for the rest of the analysis and should be carefully outlined. Upon that, several methods can be used in each of the stages, depending on the purpose of the composite indicator and the type of variables used. A widely known composite indicator is the Human Development Index, compiled by the United Nations to measure the level of economic and social development of countries (Roser, 2020).

Weighting techniques are derived from statistical methods, such as data envelopment analysis and factor analysis, or participatory models like analytic hierarchy processes and budget allocation processes (OECD, 2008). Many composite indicators adopt a fixed weighting scheme, assigning each sub-indicator the same weight and then using the simple additive weighted method to perform comparisons between units (Stumbriene et al., 2019). Assigning weights, however, is a challenging task since a consensus must be reached between the experts, whose verdict is subject to their own interpretation. To avoid this subjective process, data envelopments analysis (DEA) can be used. This technique, introduced by Charnes et al. (1978), employs linear programming tools to estimate an efficiency frontier used as a benchmark to measure the performance of a set of decision-making units (DMUs). One of the method's advantages is the possibility to set efficient targets and identify peers as by-products of the optimization analysis. While traditional methods are appropriate for the construction of rankings, DEA pinpoints possible improvements for a particular DMU (Stumbriene et al., 2019). Unlike fixed weighting systems, a model is solved for each DMU, enabling the estimation of sub indicators' weights that are DMU-specific. The value of the composite indicator ranges between 0 (worst) and 1 (best). This flexible weighting system, named by Cherchye et al. (2007) as 'benefit of the doubt' approach, selects the weights that maximize the composite indicator value for a particular DMU. Supposing that the units under assessment are countries, the flexibility mitigates the effect of having different strategic programs from country to country, usually prioritizing and investing in different areas. This way, the model will attribute more weight to education or healthcare in regions where educational or healthcare performance is good, and less weight where these sub-indicators have less satisfactory figures, since this difference can be explained by the importance given to the indicators by each region. Nevertheless, full flexibility can lead to assigning null weights in many (if not all) of the sub-indicators and classifying several DMUs as efficient (Stumbriene et al., 2019). When it is desired to take all factors into account, weight restrictions can be imposed to the sub-indicators, to guarantee that they remain within certain boundaries. These restrictions can be imposed to the pure weights, being dependent on the units of measurement of the indicators, or to the virtual weights, as explained by Wong and Beasley (1990).

2.4 Last-mile delivery

2.4.1 Overview

Last-mile is a trending topic amongst researchers that gained importance as supply's chain complexity increased. Since competition between firms rose, and globalization settled, it became impracticable to replenish stores directly from the suppliers, as initially occurred. Therefore, intermediate facilities and operations were added to facilitate this replenishment of products and to partner with suppliers from other countries. A diagram of supply chain's evolution is depicted in Figure 1.

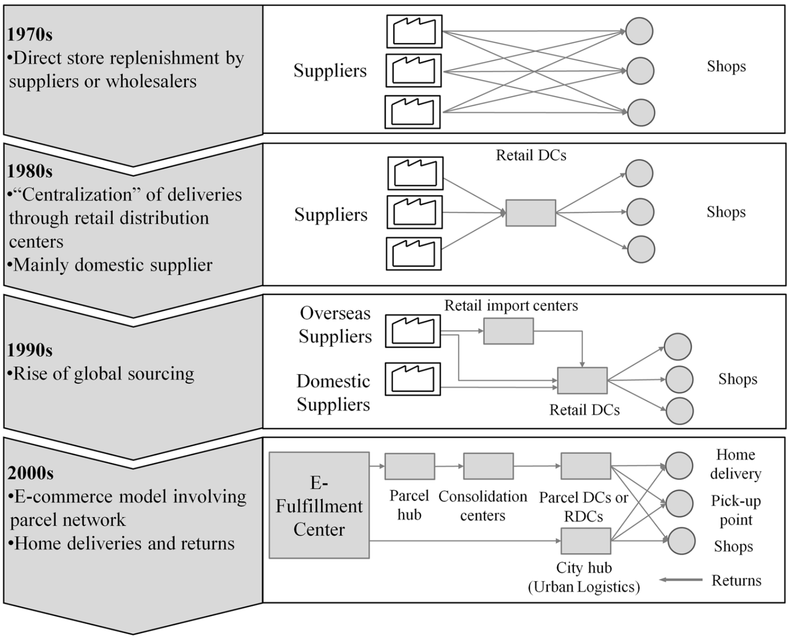


Figure 1: Supply chain evolution. Source: Kayikci (2018)

E-commerce changed not only the physical flow of goods, but also the financial and informational flow. Retailers are eager to achieve real time access to data across the supply chain, as well as an insight of the inventory management (Kayikci, 2018). In addition, the variety of sales channels available (stores, website, mobile app) might provide the customer with different shopping experiences with the same retailer. In most cases, the goal is to offer a seamless experience, regardless of the channel used. In consequence, many organizations are turning to a omni-channel strategy, managing their channels in an integrated way.

Last-mile refers to the transport of goods between the last facility where it is stored or processed, and the end customer. Due to the fact that several households/pick-up points/stores must be visited, the last leg usually is the costliest segment of a supply chain (Tiwapat et al., 2018; Vakulenko et al., 2019; Liu et al., 2019). Furthermore, in markets where it is difficult to sustain a competitive advantage through the product itself, delivery services have become determinant for success. A need has emerged to differentiate these services based on consumers' buying and returning behaviour (Hjort et al., 2016). Understanding customers has an impact on defining a value proposition as well as designing supply chains. The heterogeneous behaviour of customers, acknowledged by Hjort et al. (2016), has invalidated the "one size fits all" vision, especially when companies aim to deliver a superior customer experience.

Regarding last-mile logistics models and services, several papers have been published in literature. According to Lim et al. (2018), in broad terms, last-mile distribution structure can adapt three basic forms. When it is push-centric, the item is sent directly to the customer's home or workplace. In pull-centric systems, the client participates in the order transportation process, by visiting a local store and shopping the traditional way, performing the last-mile. Despite the popularity of e-commerce, some customers still prefer offline shopping, not worrying about product returns or inspecting digital products. Another option is to use hybrid systems, where the product is delivered to agreed stores or collection points, from where the client picks the product. This solution is particularly helpful to avoid "not-at-home" situations, and it is less challenging to perform the transport due to the fewer addresses are visited. It is important to point out that the delivery can be executed by a third-party logistics, an in-source fleet or crowdsourced using independent contractors. The system used has an impact not only on transportation costs, but also inventory levels, product availability and responsiveness (Lim et al., 2018).

For push-centric systems, Macioszek (2018) distinguishes three last-mile methods. The first is the pragmatic performance method, where orders are accepted by a central unit, passed to the closest branch and delivered according to a waiting list. The second accepts a number of orders for a particular region and period of time. That way, the resources do not become overloaded. Lastly, milk-runs are considered, pre-scheduling a route and delivering according to the defined order. On the other side, Tiwapat et al. (2018) details different hybrid system solutions from where clients can pick their orders, amongst which the reception box, collection point, post office and unnatended home delivery.

Considering the volume of orders placed in urban areas, last-mile faces operational challenges that are complex to overcome. Carriers state that traffic congestion and parking difficulty are factors that highly influence their productivity, besides having the right address or finding someone to pick the order (Manzano and Sánchez-díaz, 2016). Bad organisation of parcel facilities, lack of access roads to the receiver or accidents, among others, also pose as additional problems (Macioszek, 2018). To tackle them, several initiatives have been tested and implemented in the past, such as off-hour deliveries or vehicle parking reservation systems (Manzano and Sánchez-díaz, 2016; Macioszek, 2018). More recently, a more disruptive alternative as emerged as a credible option: using autonomated guided vehicles. According to Joerss et al. (2016), these AGV's will deliver 80% of parcels in the future, with a special emphasis on parcel lockers. Drones are also an alternative (Yoo and Chankov, 2018), but its weight limit and space required to land make it difficult to apply in urban areas (Joerss et al., 2016), being nevertheless a good fulfillment option in rural areas.

2.4.2 Planning costs

Given the parcel of costs associated with last mile, and the complexity inherent to these operations, its planning becomes increasingly important. Nocera et al. (2020) propose a set of guidelines that managers should consider when outlining their operations, aiming to diminish the negative consequences of transport. According to the author, defining last mile's geographical scope, schematizing the problem and analysing the costs, identifying relevant stakeholders to be involved, detecting critical aspects and choosing the best cost reduction strategies are key stages to meet the objective stated above. When analysing costs, which include exogenous factors like noise pollution or congestion, internal elements that have direct impact on expenses such as vehicle type or time of transport are likewise evidently considered.

Regarding external components, its cost is most of times harder to estimate, specifically when the negative outcome is not directly measured monetarily, as in the case of noise pollution. Notwithstanding, studies in literature (Cárdenas et al., 2017) developed external costs indexes by taking into account metrics like congestion, accidents, air pollution, noise or climate change. More commonly, internal costs, which are easier to predict and represent a bigger fraction, are used to compare different last mile scenarios. Gevaers et al. (2014) selected the number of stops, cost of returns, time windows, customer density, among others to develop an instrument that estimates a total transportation cost and compares several scenarios with different inputs. Obviously, this value is affected by a number of strategic decisions. For instance, suggesting time delivery windows impacts route efficiency, since the delivery company is offered less flexibility in routing. In addition, a higher customer density is desirable to efficient routing (K. Boyer et al., 2009). On the other hand, loosening the window increases the number of situations where a client is not home at the moment of delivery, forcing a new attempt or a drop-off at collection point. The usage of inadequate vehicle types, or not fully loaded, also leads to a cost increase (Gevaers et al., 2014). To mitigate the effect of operating under-capacitated vehicles, collaborations are being established between service providers who operate in coincident areas. This team-work, named 4th Party Milk Run, is based on pay-per-use and intends to take full advantage of the resources at a company's disposal, with proven savings (De Souza et al., 2019).

Many studies in literature concerning last mile analysis consist on the development of a analytical linear programming model/heuristic to define the routes of a particular operation. The action of defining vehicle routes at a minimal cost is called vehicle routing problem (Sharma et al., 2018). Given the variety of constraints that can be applied and specific to a certain situation, such as time windows, multiple depots or fleet restrictions, a huge amount of formulations are available in literature (Vidal et al., 2019). The author states that over the last two decades, research regarding this topic has evolved rapidly, and vehicle routing is now being used to support strategic and tactical decisions, besides solely outlining routes. The standard model of VRP is the travelling salesman problem (TSP), where the goal is to minimize the distance a salesman must travel in order to visit several cities (Cherif-Khettaf et al., 2015). According to Sharma et al. (2018), these problems can be tackled using exact methods, heuristics and metaheuristics. The first computes every solution possible, and the best is retrieved. Due to finite computational resources, this approach is only reasonable for small sized instances. On the other hand, heuristics build a solution based on a set of rules initially defined. The result obtained is not necessarily the best, but the time required to reach it is lower. Metaheuristics generally yield better solutions than heuristics, but computational time is also higher. Having said that, to estimate a parameter used further, on Chapter 4 - time between consecutive customers - a nearest neighbour heuristic will be used, taking advantage of its low computational time that is sufficient to provide good results.

In a different manner, routing is not always vital to perform last mile analysis. Gevaers et al. (2014) based on previous studies' data and interviews to estimate the costs per unit of delivery in different settings. The goal was to assess the effect of strategic decisions, such as using collection points or only serving certain areas, on delivery's unit cost. Alternately, K. Boyer et al. (2009) exploited powerful enterprise software to solve a vehicle routing problem for different scenario configurations, determining the impact of customer density and time window lengths on transportation cost. Given the software and resources available, and the scope of the project, the model developed during this dissertation does not detail routing. Instead, similarly to the studies presented by Gevaers et al. (2014) and K. Boyer et al. (2009), a more high level tool is built, where its flexibility and speed to reach a solution compensates for possible less accurate results.

Chapter 3

Problem description

Throughout the chapter, company's current processes and relevant general information to be used afterwards is depicted, providing a good starting point for the analysis conducted further. Although the project's scope is solely the last leg of delivery, presenting an overview of events since a client buys a product online until it arrives allows to comprehend the role of last mile on delivery. Having said that, the first section specifies how orders are processed across their journey to the final customer.

3.1 Order processing

In order to fully understand the ordering process, it is important, first of all, to distinguish between three different levels of granularity concerning orders: portal, boutique and product. In Farfetch's marketplace, in order to complete a purchase, the customer adds one or more products to a virtual basket, and then proceeds to checkout. The group of items in the user's basket is called a portal order.

In case a portal order is made of several products, they can have origin in different boutiques. A boutique order is the group of items that are supplied by the same boutique. Therefore, each portal order can have more than one boutique order, which consequently can be broken down into different products. Figure 2 captures these degrees of segmentation. In case a product is available in more than one boutique, an algorithm which takes several elements into account is used to choose which partner will supply the customer.

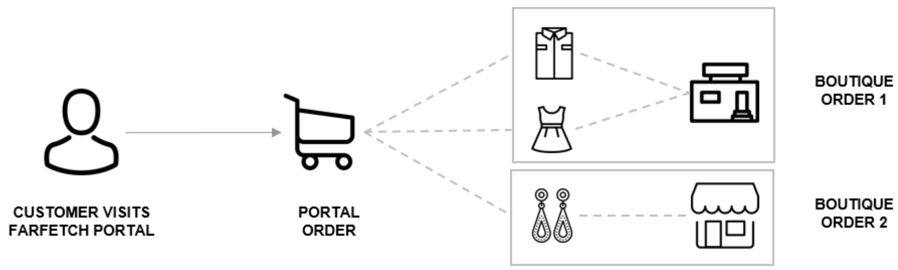


Figure 2: Distinction between portal orders, boutique order and product

After the order is placed until it reaches its destination, a sequence of six steps is followed. Each of these stages is depicted below.

Step 1 - Check stock

At first, the boutique stock level needs to be verified. Since there is no real time inventory synchronization between Farfetch and every partner, a misreport from the boutique's side or a simultaneous sale in their brick-and-mortar environment can cause a stock-out before expected. If the item is available in other partners, one of these is selected again according to the algorithm. Else, the client is refunded or suggested a similar product.

Step 2 - Approve payment

Simultaneously, users' purchase history is checked automatically to detect potential frauds. In most cases, the payment is accepted. More rarely, the process stops in this step, or a more thorough investigation is conducted.

Step 3 - Decide packaging

Afterwards, the boutique chooses the box in which the product will be sent. Farfetch recommends the box that best fits the product, but the partner can opt for another. To prevent this from happening, there is an incentive plan that rewards those who more often follow Farfetch's recommendation.

Step 4 - Create shipping label

Once the packaging is complete, the paperwork required for the carrier and the client is printed by the boutique. In case the customer fills the shipping information incorrectly, or if the data is not recognized by the system, the Delivery Support team must manually identify the erroneous information and adjust it.

Step 5 - Send Parcel

After concluding the previous stages, the carriers are notified that the package is ready to be sent. Based on the order volume of the boutique, the products are picked with a certain frequency.

Step 6 - In Transit

Finally, the packages are collected and proceed to be delivered to the final customer. This is usually the most time-consuming step of the process. If the client is not pleased with the product, he can trigger a return which will take the package back to the boutique. The refund will depend on the condition of the item. Farfetch adopts a free return policy, aligned with its value proposition, meaning that no additional shipping costs are incurred by the customer when a return is deployed.

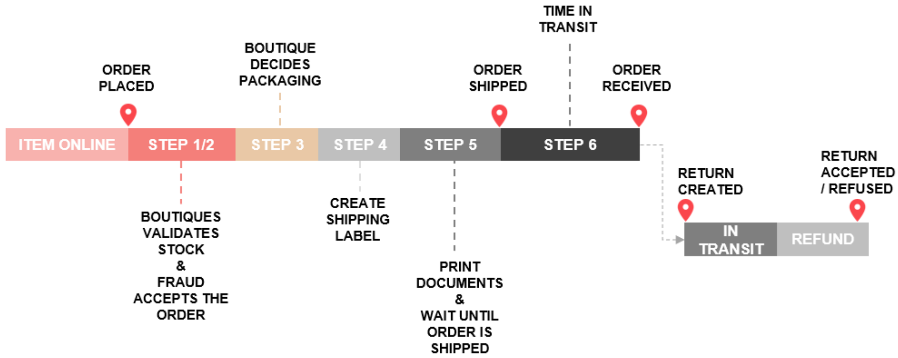


Figure 3: Order processing overview

3.2 Tracking events

Step six encompasses the transport from the store to the ending address. In other words, the duration of this step corresponds to the transit time. At this stage, the customer can check the location of the package based on information provided by the third-party logistics. This data is also shared with Farfetch, in case the carrier is integrated. Different events are registered, namely when a parcel enters a facility or is processed in customs. When a package is lost, for instance, it becomes particularly useful to find the last known location of a certain product. A boutique order's tracking log is shown in Table 2.

Table 2: Step 6 detailed view

Date	Event	Location
2019-07-29 17:09	Shipment picked up	Brescia
2019-07-29 20:10	Departed Facility	Brescia
2019-07-29 20:26	Processed	Brescia
2019-07-29 20:46	Arrived at Sort Facility	Brescia
2019-07-29 22:57	Departed Facility	Brescia
2019-07-30 00:49	Arrived at Sort Facility	Leipzig
2019-07-30 01:32	Processed	Leipzig
2019-07-30 03:36	Departed Facility	Leipzig
2019-07-30 02:33	Customs status updated	New York City Gateway
2019-07-30 05:40	Arrived at Sort Facility	New York City Gateway
2019-07-30 06:45	Clearance processing complete	New York City Gateway
2019-07-30 07:02	Processed	New York City Gateway
2019-07-30 07:02	Departed Facility	New York City Gateway
2019-07-30 08:51	Arrived at Delivery Facility	New York
2019-07-30 11:35	With delivery courier	New York
2019-07-30 16:33	Delivered - Signed for by	New York

In this example, the package was collected in Brescia-Italy, to be delivered to a client in New York City. In fact, the Italy-United States connection has a big parcel volume, explained by the concentration of suppliers in Italy and the utter demand in the US. After the pickup, the order travelled to Leipzig so it could be shipped to the destination country. Since this shipment is not domestic, nor inside the European Union, duties & taxes must be payed when arriving at the United States. When this clearance process is complete, the parcel can continue to the customer's shipping address. For this order, the time spent between customs clearance and delivery was less than 10 hours. The present project focus specifically on the final segment of step six: from the arrival to the delivery facility to the customer. Therefore, these events will be useful to aid the analysis conducted further on.

Even though trackings provide useful information to isolate last mile, there are underlying operational aspects that are not mentioned. The way packages are transported from a sort facility to the last delivery facility depends on the carrier and region. In some cases, the carriers responsible for the first mile also grant the distribution across the various delivery facilities. On the other hand, a 3PL is sometimes recruited to convey this transport, even if the first and last miles are conducted by the same carrier. All in all, different configurations can be adopted in this segment. Since last mile is considered to be after the last delivery facility, these aspects do not impact the present project.

3.3 Carriers

Farfetch's business model relies on the performance of both boutiques/brands and carriers. The first group is responsible for supplying and stocking products that will eventually be sold on the online marketplace, whereas the second has the task of ensuring the parcels arrive at the final clients as soon as possible, in line with the 'Amaze Customers' motto. For confidentiality purposes, specific carriers will from here onwards be referred to as T1, T2, ..., Tn.

In general, carriers handle the end-to-end process without collaborating with others 3PLs, performing all the necessary legs. Nevertheless, in particular cases, a multi-leg approach is being adopted in collaboration with local carriers. In specific environments, such partners pose as important assets who are familiar with the region's geography and address coding, factors that might cause mistakes in the shipping information and delays.

Currently, the company works with more than a dozen carriers, from which only a few are integrated. Therefore, information such as tracking events is only available for orders processed by one of these. Although it seems an inconvenient, at first glance, these carriers combined carry over 96% of shipments. Hence, there is access to data concerning most of the shipments made by Farfetch. However, those carriers' 'monopoly' inside the company's operations has both pros & cons. On one side, economies of scale are developed by the order volume directed to them, and the integration and condensing of information is easier since there are less partners to communicate with. On the other hand, these third-party logistics acquire great power and can leave the company in a difficult situation, under some circumstances. Assessing multi-leg opportunities allows not only to improve the quality of the service and decrease costs, but also to mitigate this risk of being over reliant on specific partners.

3.4 Multi-leg

Broadly, multi-leg occurs when two or more carriers are responsible for the transportation of goods on distinct stages of the journey. Therefore, it can not only be applied in last mile, but also in the first mile. Given the plurality of parties, collaboration is required so the goods are transferred to the next stage without compromising the service. The increasing complexity resulting from this cooperative process is one of its major challenges. Still, and especially in territories where only a few 3PLs attain the necessary conditions to convey a first/last mile operation, multi-leg gains even more importance. In addition, partnering with different carriers in separate legs of the route can lead to savings or a customer experience enhancement, by reducing transit time, for instance.

When adopting multi-leg in last mile, the solution chosen acquires even more importance in Farfetch environment, given the importance of the service presented to the customer. Also, goods can be transferred to the next carrier in different points of the supply chain. In this project, as mentioned, the focus is on the journey after the last delivery facility. Thereafter, multi-leg operations in these conditions are performed as follows:

- One carrier is responsible for picking the parcels in the brands/boutiques and shipping to the destination country, in case of international purchases, or to a sort facility close to the customer, for domestic orders;
- The parcel is collected in the gateway/sort facility and further distributed to a delivery facility, from where the last mile will be conveyed. This step is performed by one of the carriers or a broker;
- Finally, the last carrier manages the last mile from the delivery facility.

Further on, when analysing the hypothesis of internally conveying last mile, it is considered that the vans pick the parcels on the first carriers' delivery facilities, since Farfetch does not own such infrastructure, and the second step enumerated is responsibility of the first carrier or a broker. On the other hand, in case other carriers perform the last mile, that step can be negotiated between them, since each has its own network of warehouses and schedules.

3.5 Delivery settings

3.5.1 Express vs Standard

A shipment can be classified as cross-border (international), domestic or intra-EU (inside the European Union). The type of shipment depends on the country of the boutique fulfilling the order and the customer's. As acknowledged in Chapter 1, the supply and demand patterns do not match, with the majority of the customer base residing in the United States or China Region, whereas boutiques and brands are more present in Europe. Consequently, most of the orders are cross-border and subject to customs processing.

Besides, a client usually has the option to choose from a range of delivery modes, depending on the carrier providing the service. Primarily, shipments can be classified as Express or Standard. When the predefined express shipment is selected, the customer is indicated a time window to receive the package at home. Normally, that window ranges between 2 to 4 days in Europe and USA, and 3 to 7 days for the rest of the world. Only in Europe and USA, the standard transportation is available for domestic and intra-eu orders, usually taking 5 to 7 days to be delivered, but at a lower cost. The majority of the orders are assigned the Express configuration. In Section 3.5.3, further options besides standard and express are explained. Moreover, within the previously mentioned classifications, carriers present solutions that best fit customers' needs. Those alternatives are detailed below.

3.5.2 Carriers' alternatives

Carriers offer different choices in order to provide the customers more flexibility, mainly when it is not possible to receive the orders at the agreed delivery date, and decrease the number of packages returned to sender. Although these alternatives differ among companies, most of them are similar.

A recurrent solution is to collect the items from a pickup point instead of receiving them at home. Third-party logistics often own or partner with hundreds of businesses, where products are stocked for a period of time and clients can pick them. This way, the customer can choose a convenient hour to do so. Furthermore, there is a possibility of delivering the order to a trusting neighbor, to avoid being at home during the estimated interval. Similarly, an alternative shipping address can be given to the carrier, or even the permission to complete the service without requiring any signature, transferring the responsibility to the client. In case none of these is a viable option, the original delivery day can also be changed, to find a more convenient date. If the customer is on vacation, the package is put on hold for a number of days (depending on the carrier) until it is returned to sender.

These are the most commonly adopted measures, even though it is possible that some carriers provide other alternatives. In spite of the wide range of options presented, these services are not widely used, and the regular settings are frequently preferred. For illustrative purposes, the frequency each option was selected, for a particular carrier, is depicted in Figure 4. The information used is from 2019. It is important to bear in mind, however, that roughly 20% of total shipments include any of the aforementioned alternatives. In that year, signature dismissing represented over 50% of these orders, followed by delivery scheduling with 25% and collecting from a pickup point with 10%. Leaving the package with a neighbour and changing shipping address were rarely used. Although these numbers are global, the use of different solutions varies greatly from country to country, depending on regional habits.

3.5.3 Farfetch initiatives

Adding to the carrier options mentioned above, Farfetch also performs deliveries in the same day of the order, or even in 90 minutes. Due to the complexity of these operations, and the need to have a supply source close to the customer, these options are solely open in a number of cities. Same day delivery is available in Berlin, London, Manchester, Paris, Hong Kong SAR, Shanghai, Los

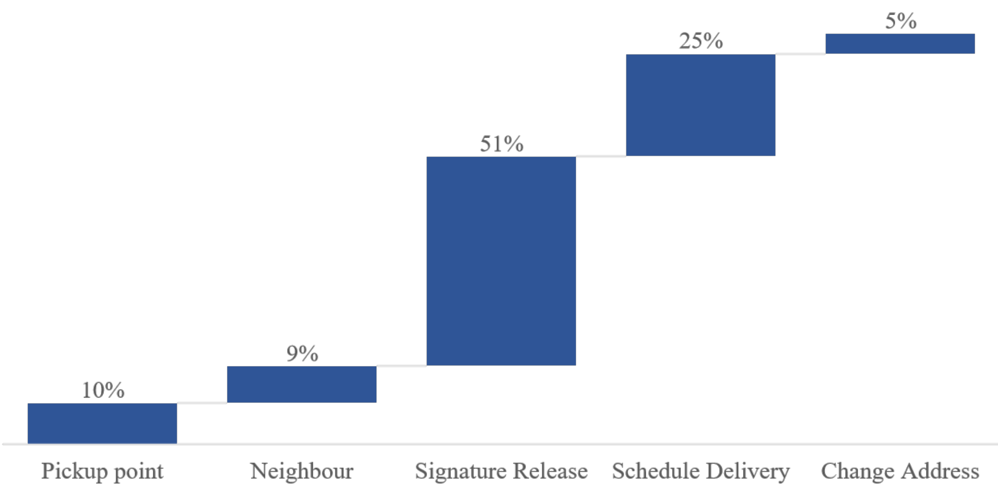


Figure 4: Selection frequency of delivery options for a particular carrier in 2019

Angeles, New York, Chicago, Dallas, Miami, Seattle, Milan, Rome, Barcelona and Madrid. For F90 store to door, the cities are Berlin, Dubai, Hong Kong SAR, Los Angeles, London, Madrid, Milan, New York, Paris and São Paulo.

Although these initiatives were launched in 2015 and 2017, respectively, their order volume is residual. Globally, for 2019, only a fraction of total orders were either same day delivery or F90. One can argue that the low percentage is explained by the limited geographic coverage of the initiatives. However, even in the above mentioned cities, the results are similar. The exception is a european city, C3, where these initiatives are embraced and carry a more significant weight of city's total orders. One of Farfetch's major boutique partners is based there, making the region a supply center and facilitating the development of new strategies.

More recently, the company considered the possibility of placing warehouses in strategic locations, where stock could be held. For the items there stored, the journey from the boutique/brand to the storage facility would be anticipated, leading to savings in transit time. The usage of warehouses means an increase in fixed costs and a change in Farfetch's business model, whose no stock policy has leveraged a competitive advantage over its short lifespan. For the time being, Fulfillment by Farfetch is still in pilot testing, with facilities in two countries. If this strategy achieves greater importance and spreads to other locations, synergies can be obtained by merging Fulfillment by Farfetch with last mile initiatives.

3.6 Granularity level of data

Conducting a last mile analysis to evaluate multi-leg opportunities requires delimiting a geographical boundary where this final step can be completed without impairing the service. As far as the current project is concerned, a country-level study would not bring the necessary results to draw accurate conclusions, since significant discrepancies are often raised inside the same country. In addition, implementing a last-mile initiative to an entire country would not be reasonable, as there are areas with low order concentration. The ideal geographical delimiter would be a circular shape, where a trip between the center and the frontier would take one to two hours. Nonetheless, this level of granularity is difficult to delineate. Instead, metropolitan city areas with big volume are a good approximation, where carriers are capable of visiting customers without compromising the steady flow of operations by taking an inadequate amount of time.

Therefore, customer city was chosen as the starting point to conduct a initial last mile analysis. Namely at the start of Chapter 4, in Section 4.1, getting a city-level broader view is useful and suits the purpose of the research, pinpointing regions with more deliveries and operational inefficiencies. However, this level of segmentation was not sufficient to undertake some of the procedures adopted further in this project. When scrutinizing regional operations, in Section 4.2, global demand is inadequate to assist the analysis performed, since vehicles usually depart from different warehouses to deliver, depending on customer location and carrier, and information exhibited per warehouse is required. Consequently, tracking information shared by the carriers was consulted, more precisely the last departing delivery facilities' location, whose level of detail is greater than that provided by the cities. Still, this location can include more than one facility, especially when regions with big volume are being taken into account. When this happens, and using information available online in the carriers' websites, the location's demand was distributed across the existing facilities.

All in all, along the present project, the granularity level steadily increases. Firstly, entire cities are regarded, in order to pick those where multi-leg opportunities should be studied. Afterwards, and aligned with the deep-dive required to map operations within the regions, city-level demand is further divided, first per last departing facility location (also called destination service area), and inside each location, per delivery facility, in case more than one exists.

Chapter 4

Methodology

The present dissertation aims to evaluate potential multi-leg solutions within last mile and boost the delivery process. Primarily, understanding Farfetch's business model and organizational structure allowed to specify the project's scope inside the organization. Additionally, as explained in Section 1.2.2, this first stage set the milestones to be achieved in the following steps, and outlined a structure as in a *Waterfall* methodology. Thereupon, the second and third stages are detailed below. Firstly, a city selection process will be conducted to infer the regions where to study multi-leg solutions to enhance last mile. Only then, alternatives will be proposed and studied to choose the one which will bring more benefits to the company, in customer experience and shipping costs. The advantages of *Structured Agile*, namely increased flexibility, will be exploited by allowing mid-project planning as more information relevant to the project unveils, such as the cities selected in the second stage.

4.1 City Selection

Farfetch is a worldwide spread company that registers sales in thousands of cities. A large amount of information must be treated in order to choose a small number of cities to study. In addition, selecting what information to retrieve regarding each city is also a critical requirement of this process. It soon became evident that the necessary information to characterize each region could be divided in two sets: strategic and operational metrics. Therefore, the filtering of the cities was also divided in two steps. At first, a primary and broader selection based on their strategic figures was conducted. Afterwards, further operational KPIs were calculated to describe the customer experience. Places where this experience is more deteriorated, or where there are opportunities to improve last mile, would be good options to implement multi-leg solutions. However, this operational part must also be tied to the strategic impact the city has in operations.

4.1.1 Strategic filtering

This strategic stage selects the cities that have the most impact on the company's operations. From a business perspective, these are important territories where there is usually high demand and consequently a solid source of revenue. To describe the cities in terms of their strategic relevance, three factors were pinpointed:

- Number of boutique orders;
- Actual Transaction Value (ATV) in dollars;
- Percentage of Farfetch VIP Users.

Only the purchases made by customers in 2019 were considered. Using data related to previous years would increase even more the data set to be analysed and their usefulness would be inferior, knowing that Farfetch's environment is quickly-changing. Moreover, shipments that were cancelled before being sent (in other words, before reaching step 6), that represent a fraction of total orders in 2019, were also ignored, since this project has no influence over those cases. Similarly, actual transaction value only considers the purchases that were not cancelled. In that year, 5 million boutique orders were processed, amounting to $2.2 billion in ATV, from which 40k users were VIP. Choosing number of boutique orders instead of portal orders or products is explained by the fact that each boutique order equals one package to be shipped. For the last mile, it is more useful to know the number of packages sent than the number of products or portal orders placed. The actual transaction value is defined by the amount, in dollars, transacted by the company's marketplace or other services (Farfetch Platform Solutions). Cancelled orders are not included in this metric. Normally, cities where more packages are sent to will also generate a bigger ATV. However, there are some territories where a lower number of boutique orders translates into a higher ATV, simply because the average order value (AOV) is greater. For that particular reason, both metrics were included in this strategic filtering. Regarding the percentage of Farfetch VIP users in the city, it evidences the number of VIPs that can be affected by alternatives implemented in the region. A customer attaining such a status has to spend over $ 12k in a year. Reaching a larger number of these clients is also a positive strategic outcome.

Taking this metrics into account, and the assumptions aforementioned, *Microsoft SQL Server* was used to retrieve information from the company's database. The first 20 cities, ordered by ATV, are shown in Table 3.

Table 3: General overview of the the top 20 cities, ordered by ATV

City	ATV ($M)	Orders (k)	%VIP	City	ATV ($M)	Orders (k)	%VIP
C1	167	377	9.95%	C11	33	70	1.35%
C2	113	235	7.60%	C12	31	79	1.09%
C3	70	128	4.06%	C13	28	71	0.65%
C4	68	142	4.83%	C14	26	64	1.01%
C5	51	104	2.28%	C15	24	74	0.53%
C6	50	178	1.80%	C16	23	50	1.55%
C7	48	100	1.30%	C17	20	50	0.54%
C8	43	98	3.11%	C18	20	46	1.93%
C9	36	92	1.05%	C19	20	45	0.49%
C10	34	76	2.18%	C20	19	41	0.14%

C1 and C2 are clearly detached from the rest, leading in the three factors with a significant difference. C8 and C10, although in the top 10 when ordering by ATV, will not be selected in this first stage because other multi-leg initiatives are already being implemented there. For the remaining cases, the choice was made based on the values obtained. Therefore, cities C1 to C16 (excluding C8 and C10) are filtered in this first step and will be further analysed in the next section.

4.1.2 Operational filtering

Solely assessing the impact regions have on the company's operations is not sufficient to choose the locations where to study multi-leg solutions. Territories with more improvement opportunities, derived from operational inefficiencies, and where customer experience is being affected should be prioritized over those with no evident problems in their operations. Following this train of thought, a need to describe the operational behaviour of the regions has emerged. Knowing that this project focus on the last mile, only KPIs affected by it should be considered. Therefore the six following factors were chosen:

- Percentage of boutique orders with returned products;
- Transit time after customs;
- Transit time after last facility;
- First attempt rate;
- Percentage of boutique orders with customer contacts;
- Lost parcels.

As explained in Section 3.1, a boutique order can have more than one product. When one of these is returned, the boutique order is said to have returned items. Although a return might be deployed due to customer dissatisfaction with the service, in most cases cultural habits are a key factor. There are countries, such as Germany or Lithuania, where the return rate is clearly higher than the rest, probably due to a higher familiarity with shopping online and trust in e-commerce. In some cases, the customers purchase different sizes of the same piece to check which one fits best, returning the rest. Hence, jumping to conclusions regarding last mile operational performance based on returns can be misleading. Ideally, this KPI should only consider returns triggered by last mile issues that led to a bad delivery service. Still, data to perform such classification was not available. The inclusion of return rate brings a different advantage in the future: the possibility of achieving synergies by using the last mile to collect returns as well.

Transit time after customs is the time elapsed since the order is cleared in customs until it is delivered. It was selected instead of total transit time (duration of step 6) or even total lead time because it is only affected by last mile, unlike the others. To compute it, carriers' trackings events (revisit Section 3.2) were consulted, namely the time difference, in days, between the customs clearance and the delivery. This KPI, besides containing the time spent in last mile (from the last facility to the customer), also includes the time the package is awaiting to be picked up by the carrier. However, it is important to bear in mind that only international flights are subject to a customs clearance process. Notwithstanding, cross-border shipments represent over 90% of order volume in most cities. Even so, namely in European cities where the demand for intra-eu and domestic shipments with no customs processing is large, cross-border shipments' weight decreases significantly. Therefore, a new transit time was computed: transit time after leaving last facility. This metric includes the time, in days, since the vehicle first leaves the last warehouse until it reaches the customer. If, for example, the customer was not home and the package has to be delivered in the following day, this KPI value will be greater than one day, since only the first departure is taken into account. Unlike transit time after customs, the amount of time a product spends in the warehouse waiting to be sent is not included.

To measure the number of times a package was delivered in one try, first attempt rate was used. Low figures might indicate a carrier difficulty to find the correct addresses or contact customers if needed. Even though this rate depends on carriers' policies, such as waiting 5 minutes for a customer response or calling to a mobile phone, the fact that over 70% of global shipments is performed by the same 3PL mitigates the chance of having differences in first attempt between cities due to carrier characteristics. When Farfetch's Customer Service department is contacted by a customer regarding a particular boutique order, it is included in the percentage of orders with customer contacts. From there, a ticket is created and can be delegated to different departments inside the company, such as Delivery Support, depending on the type of problem. Preferably, only the contacts due to last mile issues should be accounted for, but this level of data granularity is not available. Once again, similarly to returns, jumping to conclusions about last mile operational performance based on customer contacts can be misleading. Nevertheless, in many cases, it identifies difficulties that can be diminished adopting last mile solutions, and indicates customer dissatisfaction. At last, the number of lost parcels in the last mile was retrieved. Although these values are generally low, losing a parcel deeply affects the customer experience, and decreasing its number definitely improves the quality of the service provided.

Having collected all the information required, and calculated the aforementioned KPIs, the data can be summarized in Table 4. Graphic content regarding each of the factors is found in Figure A.1 of Appendix A. Average values of Farfetch in 2019 were used to compare the values obtained, except for lost parcels, since most cities with purchases in 2019 did not register any.

Regarding returns, there are five cities above average (C1, C2, C3, C4, C11), from which three of them belong to the same country, highlighting the cultural effect. Similarly, C2, C3, C4 and C11 also have a high number of customer contacts, with the remaining cities performing well below the average of 8%. Concerning transit time after customs, C5 and C6 separate from the rest. The latter belongs to a non-DDP country. DDP stands for delivered duties payed and is adopted in most countries. With DDP, the duties and taxes are included in the products' price, and the client does not have to pay them in customs. In this case, the country is DAP (delivered at place), and the fact that duties & taxes are payed in the destination country can explain the time spent after customs in this city. With regard to the transit time after last facility, C1, C7, C15 and C16 have satisfying figures, whereas C11 and C14 are facing some issues. In general, all the regions have similar values, especially when considering that this time is only a small percentage of total transit

Table 4: Performance KPIs for the 14 previously filtered cities

City	Returns	TT after C	TTALF	First Attempt	Lost Parcels	Contacts
C1	18%	1.17	0.26	91.4%	$ 14k	4.5%
C2	26%	0.98	0.32	93.7%	$ 62k	11.3%
C3	23%	1.60	0.42	90.1%	$ 40k	11.1%
C4	23%	1.46	0.33	93.8%	$ 34k	8.6%
C5	11%	1.95	0.39	83.7%	$ -	6.0%
C6	9%	2.15	0.36	91.4%	$ 28k	4.9%
C7	13%	1.23	0.19	95.5%	$ -	5.1%
C9	15%	1.26	0.42	88.6%	$ 8k	5.9%
C11	24%	1.62	0.46	90.0%	$ 40k	9.3%
C12	6%	1.07	0.31	93.3%	$ 2k	3.0%
C13	15%	1.35	0.42	88.6%	$ 50k	5.9%
C14	8%	1.22	0.45	92.7%	$ 3k	3.3%
C15	13%	1.02	0.25	93.8%	$ 37k	3.5%
C16	9%	1.27	0.29	91.7%	$ -	3.1%
Farfetch average	16%	1.50	0.36	91%	-	8%

time. The first attempt rate is also fairly similar in the analysed cities, except for C5 that only delivers 84% of boutique orders at first try. Finally, most parcels are lost in C2, C3, C11 and C13.

With the amount of information available, it is difficult to perform comparisons between cities and make a reasoned decision about which are performing better and worse taking all the factors into account. Therefore, a data envelopment analysis model was used to analytically assess the best performing regions and support the decision regarding where should multi-leg solutions be implemented.

4.1.3 DEA Model

Firstly, and according to OECD (2008), it is important to define what is being evaluated, and which sub-indicators should be included in the model. The model measures the level of performance of the cities under analysis. Consequently, all the metrics mentioned in Subsection 4.1.2 will be included. The sub-indicators can be desirable or undesirable, depending if a higher level of the indicator leads to a better or worse performance. In this particular case, all the indicators are undesirable (the lower, the better) except for the first attempt rate. The software used to run the model, *PIM-DEA*, only accepts indicators of the same type. Hence, a data treatment was conducted, turning the first attempt values into their symmetric by subtracting it to 100%. In addition, the lost parcels column was also subject to change. All the other factors are either percentage or time in days. It is desired to have all the metrics with the same units of measure whenever possible. Consequently, the individual lost parcel values were divided by the sum of lost parcels of the 14 cities and turned to percentage.

A constant returns to scale input-oriented model was implemented, having all sub indicators treated as inputs and a dummy output created. The generic formulation, originally applied by Charnes et al. (1978), can be adapted to other contexts such as output-oriented forms, and has been widely used in literature.

$$h_{j_0} = min \sum_{i=1}^{m} v_i \cdot x_{ij_0} \tag{4.1}$$

$$s.t. \sum_{r=1}^{s} u_r \cdot y_{rj_0} = 1 \tag{4.2}$$

$$\sum_{r=1}^{s} u_r \cdot y_{rj_0} - \sum_{i=1}^{m} v_i \cdot x_{ij_0} \leq 0, \qquad j = 1, ..., n \tag{4.3}$$

$$u_r \geq 0, \qquad r = 1, \ldots, s \tag{4.4}$$

$$v_i \geq 0, \qquad i = 1, \ldots, m \tag{4.5}$$

This linear programming will estimate a composite indicator for each city by solving the model for each DMU j_0 under assessment. x_{ij} are the inputs ($i = 1, \ldots, m$) consumed by DMU j ($j = 1, \ldots, n$) to produce the outputs y_{rj} ($r = 1, \ldots, s$). As mentioned above, only a dummy output is considered for every DMU j_0. u_r and v_i are the weights attached to the outputs and inputs, respectively, and are the variables which the model will optimize. The objective function set in Equation (4.1) is equivalent to $\sum_{i=1}^{m} v_i \cdot x_{ij0}$ / $\sum_{r=1}^{s} u_r \cdot y_{rj0}$, being the denominator equal to 1 as imposed in the first restriction. The efficiency score is given by $1/h_{j_0}$.

Let S_{j_0} be a dimensionless measure of total output of DMU j_0, $S_{j_0} = \sum_{r=1}^{s} u_r \cdot y_{rj_0}$. Accordingly, $u_r \cdot y_{rj_0}$ / S_{j_0} represents the proportion of total output for DMU j_0 devoted to output measure r (Wong and Beasley, 1990). In parallel, similar reasoning can be applied to inputs. Limits can be imposed on those virtual weight proportions, so that the efficiency score of a DMU does not over or under-rely on certain inputs. With this being said, the ratios were bounded between 10% and 25% of total input for DMU j_0, as shown,

$$a_i \leq v_i \cdot x_{ij_0}/S_{j_0} \leq b_i \tag{4.6}$$

maintaining a balance amongst the weights attributed to the different inputs in play. Lastly, the model was run, with the efficiencies displayed in Figure 5.

A lower value of the CI is originated by operational inefficiencies which translate in customer dissatisfaction. On the other hand, an efficiency close to 100% indicates strong performance. In this regard, C7, C12 and C15 have remarkable figures, followed by C16, C14, C1 and C2. In contrast, C6, C5 and C3 have considerable room for improvement. To condense the information gathered so far regarding the cities, strategic information must be crossed with the operational KPIs. Thereupon, the chart exhibited in Figure 6 was created, having the operational efficiency in the horizontal axis and the strategic importance (represented by the number of boutique orders) in the vertical axis. A visual representation of the results allows to understand the trade-off to be made between operational impact and performance, as well as assist the decision making process. For that matter, the most appealing cities to choose from would be those closer to the top left corner, which have a relevant number of orders and more operational inefficiencies. In this case, C1 and C2 benefit from their strategic importance, but show acceptable performance

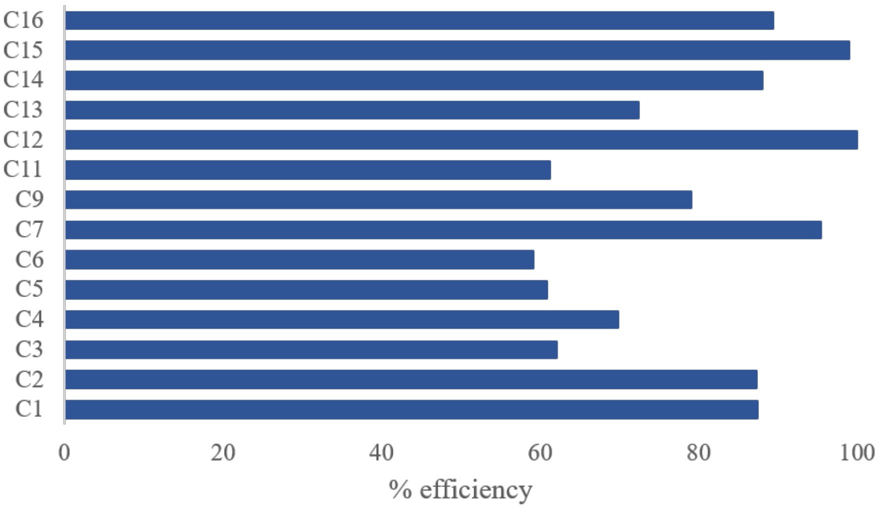


Figure 5: DEA efficiencies obtained using PIM-DEA software, per city

levels. On the contrary, C3, C4, C5, C6 and C11 have comparably low volume and exhibit poor levels of efficiency. The cluster made by C7, C12, C14, C15 and C16 is excluded from the final decision since they are the furthest from the top left corner. Ultimately, other factors which were not included in the model, and the company's knowledge regarding each of the cities will also be considered when making a decision. The most appealing regions to choose from are C1, C2, C3, C5 and C6, closer to the top left region of the chart. After discussing the results inside the organization, it was decided that C2 and C3 were the cities where multi-leg solutions could be leveraged to improve last mile delivery.

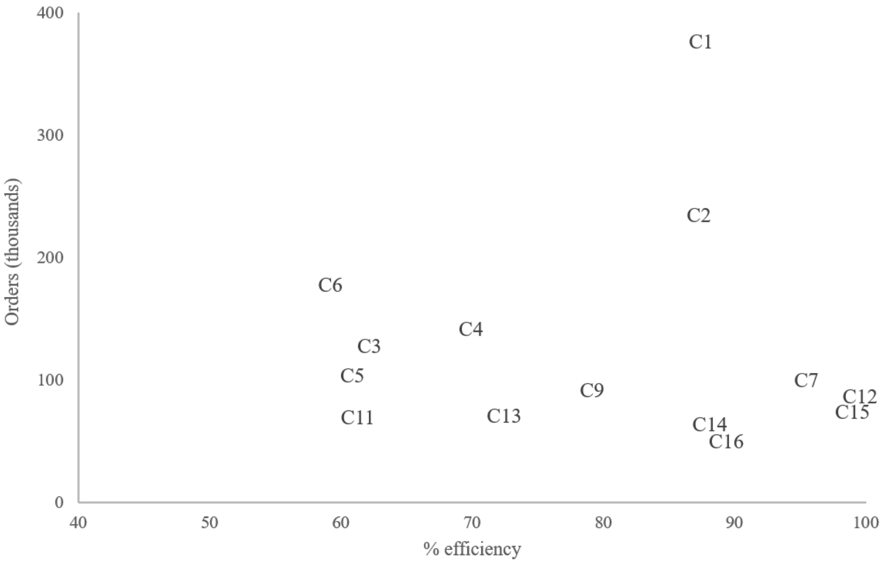


Figure 6: Cities' strategic and operational trade-off

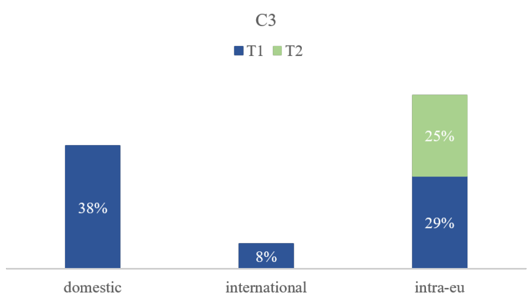
4.2 Cities operations' deep dive

The metrics calculated in Section 4.1 are a good indicator to whether the cities are operationally efficient or not, but obviously are not sufficient to describe the day-to-day processes. Therefore, now that only two cities have been chosen, detailed data that will be used further on in the solution design was gathered. This includes the carriers operating in the cities, type of shipments, warehouse geographical distribution and arrival and departures scheduling.

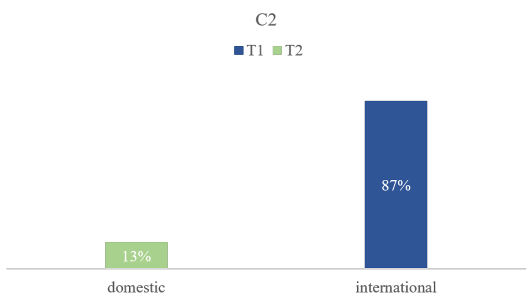
4.2.1 Type of shipments

Normally, shipment types can be divided in cross-border or domestic, depending on the location of the supplying boutique. European Union countries represent an exception, since intra-eu shipments must also be considered: although the brand/boutique is located in a different country, no border is surpassed due to the free movement of goods policy, avoiding the payment of duties and customs processing. To some extent, its characteristics are similar to those of domestic purchases. C3 is located inside the European Union, and intra-eu order volume represents more than half the total purchases in 2019, for that city. Curiously, cross-border orders only amount to 8% of total yearly figures, unlike other cities where domestic (and intra-eu) shipments have little relevance. The fact that the country in question is home to important store partners and the top supplying state belongs to the European Union are elements that disclose the low number of cross-border shipments. On the other hand, C2 had only 13% of domestic purchases, similarly to what happens in most cities. Since the country does not belong to the European Union, the remaining orders are international and subject to the payment of duties.

In these cities, carriers T1 and T2 are responsible for all the shipments, except for the small percentage of same day deliveries and F90 minutes. In the European city, the standard service of T2 conducted nearly half of intra-eu orders, while the remainder were assigned the express option of T1. The latter also conveyed domestic and cross-border volume. Likewise, C2's internal deliveries are assigned with T2 standard service, whereas T1 handles international shipments. Figure 7 illustrates the percentage of purchases each carrier treats, per type of shipment, for each city.



(a) Number of orders per type of shipments, for C3

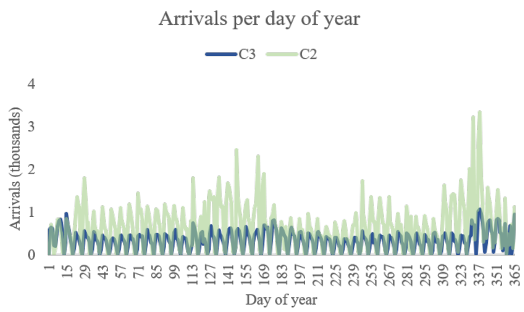


(b) Number of orders per type of shipments, for C2

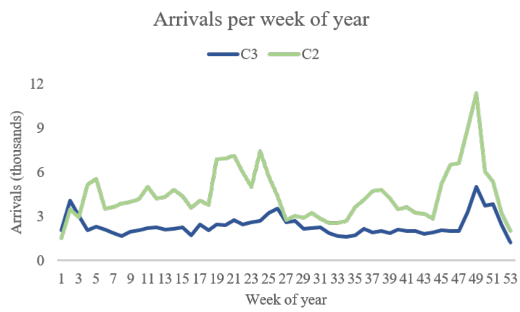
Figure 7: Orders each carrier conveys, per type of shipment

4.2.2 Weekly, daily and hourly demand

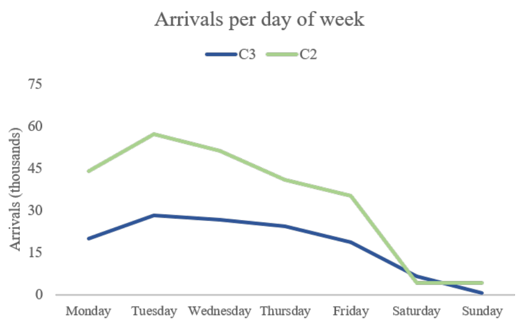
Ideally, when planning a last mile operation, the number of orders to be shipped per day should be known in order to manage resources and fulfill demand. Accordingly, the number of arrivals and departures from the last facility in C2 and C3 in 2019 were segmented by weekday, to detect patterns between arrivals and departures to the warehouse. Data per day and week of the year was only retrieved for arrivals, since the charts are similar to those obtained for the departures, and having both would be redundant. First of all, it is essential to remember that there is a higher number of departures than actual orders, because some packages are not delivered at first attempt. In those cases, parcels normally return to the warehouse and are loaded onto the vans again the next day, increasing the number of departures in relation to total orders. For the entire year 2019, 141k tries were recorded in C3, while in C2 the value amounts to 250.8k. Figure 8 exhibits the arrivals per day of the year, week and weekday, as well as the departures per weekday as aforementioned.



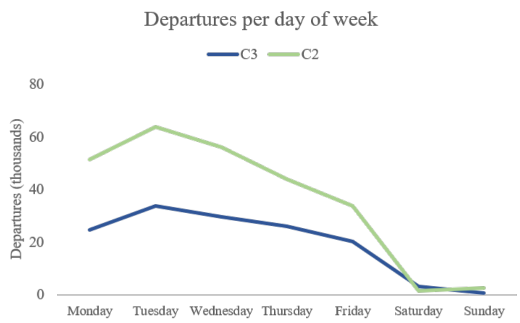
(a) Arrivals per day of the year



(b) Arrivals per week of the year



(c) Arrivals per weekday

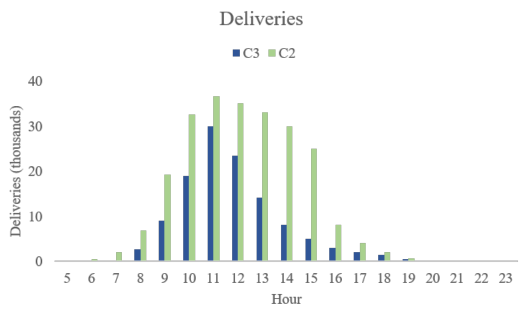


(d) Departures per weekday

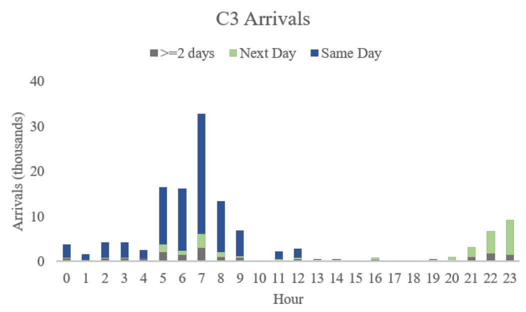
Figure 8: Time distribution of last facility's arrivals and departures

It is evident from the arrivals per day of the year that, although in different orders of magnitude, there is a strong match between weekly demand spike patterns of both cities, explained by periods with high purchasing activity such as Christmas or summer start. In addition, when shortening the time-frame under analysis, it is also possible to identify weekly seasonality. Corroborating this hypothesis is the fact that almost no departures are registered in Saturday and Sunday, even though some orders still arrive at the warehouses on Saturday, in C3, to be delivered on Monday. On the contrary, Tuesday distinguishes itself by registering the highest number of arrivals and departures. In general terms, there is more warehouse activity at the start of the week, which gradually decreases as the weekend approaches. No great differences are found when separately analysing T1 and T2, as both follow similar behaviour.

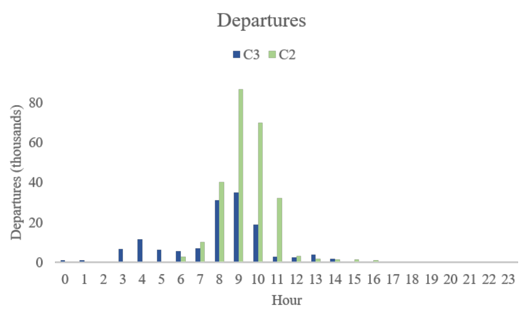
Further scaling down the level of detail, the arrivals, departures and deliveries from last facility were partitioned per hour of the day. Furthermore, for the arrivals, a division was made to assess if whether the package was delivered in the same day, the next day or in two or more days. Like so, a general picture can be drawn regarding transportation activity, by detecting in which intervals of the day more vans enter and leave the warehouses, as well as the window for delivering to the end customer. Figure 9 reveals that in both cities, packages are delivered between 8 a.m. and 18 p.m., achieving the peak near the lunch hour.



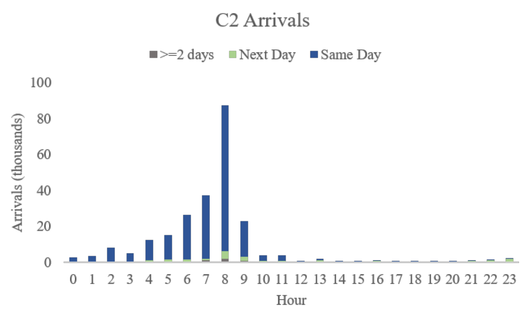
(a) Delivery distribution per hour of the day



(b) Departure distribution per hour of the day, in C3



(c) Departure distribution per hour of the day



(d) Departure distribution per hour of the day, in C2

Figure 9: Hour distribution of last facility's deliveries, departures and arrivals

Concerning departures, a slight discrepancy is detected between the regions under assessment. While in C2 most orders depart at 9 a.m. and 10 a.m., in C3 the maximum is 1 hour prior. After 12 p.m. almost no departures are recorded. This difference can result from a range of factors such as flight schedules of international shipments that delay the order processing. Similarly, arrivals have a 1 to 2 hour offset between the two cities. T2's weight in each state can also have an impact on this offset, since its orders usually arrive and depart from last facility sooner. Given that 25% of packages in C3 are conveyed by T2, against only 13% in C2, a slight decrease in the average arrival and departure hour is expected. For the European region, the majority of orders arriving before 21 p.m. are delivered in the same day, even though others take 2 or more days.

Those records between 22 p.m. and 0 a.m. are obviously delivered in the following day. On the other hand, C2 has a residual amount of orders arriving after 22 p.m., given the low weight T2 has in the region, and therefore the greater share of packages are delivered in the same day.

4.2.3 Warehouse distribution

The existing facilities in each city are evidently dependent of the network developed by each carrier. Since Farfetch does not own warehouses to stock their products, the distribution centers from where the last mile is performed are carrier property. Although no stock and fixed costs are incurred, it leads to a lack of flexibility by adapting to the 3PL operations. Analysing the tracking events, the last departure facility's location was extracted as explained in Section 3.6. Solely the biggest service areas were considered for every region, representing in both cases over 90% of total orders.

With respect to C3, five areas were considered, which will from here onwards be referred to as SA1, SA2, SA3, SA4 and SA5. The first four belong to T1, while SA5 is operated by T2. In fact, SA5 and SA4 are virtually the same area which is more city central, but fulfilled by different 3PL. The other service areas are 5 to 20 km from the city center and serve the customers closer to the designated delivery facility. While the remainder is served by only one facility, SA1 has three supplying delivery facilities: WH1.1, WH1.2 and WH1.3. Since the number of orders that travel through each facility is not known, the demand in SA1 was divided equally by the three delivery facilities. In regards to C2, four service areas were pinpointed: SA6, SA7, SA8 and SA9, with the initial three belonging to T1 and SA9 to T2. Once again, SA6 and SA9 are actually coincident areas, in the city center, operated by the different carriers. In this context, the other service areas are farther apart - up to almost 30 km - in relation to the city center. SA6 and SA9 are fulfilled by two warehouses each, named WH6.1, WH6.2, WH9.1 and WH9.2. Similarly, the demand was evenly distributed between the existing warehouses in the same area. The number of boutique orders processed by each warehouse in 2019 is depicted in Table 5.

Table 5: Volume of orders processed by each warehouse in C1 and C2

City	Area	Warehouse	Orders (k)	City	Area	Warehouse	Orders (k)
C3	SA1	WH1.1	11	C2	SA6	WH6.1	57.5
C3	SA1	WH1.2	11	C2	SA6	WH6.2	57.5
C3	SA1	WH1.3	11	C2	SA7	WH7	56
C3	SA2	WH2	18	C2	SA8	WH8	35
C3	SA3	WH3	27	C2	SA9	WH9.1	6
C3	SA4	WH4	14	C2	SA9	WH9.2	6
C3	SA5	WH5	25				

4.2.4 Shipping costs

The shipping cost paid by the company to the carriers who provide transportation is based on agreed rates that depend, among other factors, of the region under assessment or the order volume.

These rates are most commonly presented per package, and dependent of its weight. Evidently, a heavier parcel will be charged a higher price, as well as longer shipments. For the current company configuration, where a carrier is responsible for picking the orders at the stores and delivering to the end customer, performing the first and last miles, prices are negotiated to the entire operation, and not segmented by first and last mile. Thereafter, an alternative estimator for the last mile cost has been used: the domestic rates in the countries being analysed.

Before consulting the rates, the average package weight must be calculated. The weight billed by the carriers, in kilograms, is the greatest between actual weight and volumetric weight, related to the space a parcel occupies. Since apparel goods are usually light, the volumetric weight is most often billed. In C3, the average parcel weight for 2019 was 1.5 kg, compared to 2.1 kg in C2.

The shipping costs were partitioned by carrier, since each will charge different rates and is responsible for distinct types of shipments. These costs include the arranged rates and a small surcharge percentage to mitigate variable costs such as fuel expenses. When possible, historical data regarding domestic shipping cost was used. Otherwise, carriers' pricing tables were browsed, considering the average parcel weight for 2019 mentioned above. In both cities, T1 presents more competitive prices, with the difference being minimal in C2 and significant in C3. The last mile rates considered for both carriers in C2 and C3 are summarized in Table 6.

Table 6: Last mile rates for carriers T1 and T2

City	T1 last mile rate	T2 last mile rate
C2	$ 6.49	$ 6.63
C3	$ 5.80	$ 6.52

4.3 Multi-leg solutions

To enhance last mile deliveries, two approaches based on multi-leg will be studied: using alternative carriers to perform the last mile, or owning a ground fleet capable of fulfilling demand. If, for the first option, comparing alternatives requires a benchmark exercise as a means to gather carriers rates, for the latter there is not information regarding the cost of managing transport operations in-house. Thereby, a tool was developed for that purpose, by taking several parameters into account and providing as output the resources necessary to smoothly serve the customers. This instrument is further detailed in the next subsection.

It is important beforehand to define what will be evaluated from these multi-leg solutions. The cost structure will be compared to the AS-IS situation (and between alternatives) unveiling the carriers with the most competitive prices. This quantitative analysis is straight-forward. On the contrary, assessing customer experience variation is more complex. Concerning transit time after customs and last facility, although they are being computed in the own fleet model, a carrier will hardly deliver time rates exclusively for last-mile, and directly comparing options becomes groundless. However, these times represent only a fraction of total transit time, that ranges between 2 to 7 days. Consequently, the client perceives no difference in receiving the package at 11 a.m. or 16 p.m., if the delivery is conveyed on the same day. If no evident problems are detected in transit time after customs, as in the present case, the packages will most likely arrive to the final destination within the same day, independently of the solution chosen. Therefore, comparing transit times after last facility is dispensable, as long as the packages are received by the customer in the same day it leaves the last facility. A transit time difference of two or three hours has little to no impact on total transit time and customer experience. As for KPIs such as first attempt rate, customer contacts or lost parcels, the impact each alternative would have could only be measured if pilot tests were made in each city. Since the time-frame available to complete the present project does not allow pilot testing, measuring these outcomes will stand as future work. In the end, the customer experience improvement will be evaluated more subjectively, along the description of the solutions analysed.

4.3.1 Own fleet simulation model

To assess the impact of operating a ground fleet, a simulator was built. The program's output indicates the number of vehicles required to deliver a number of orders in the same day, total distance travelled and time spent since the start of the shift, rather than suggesting routes. A vehicle routing problem was discarded due to two main reasons. Firstly, the level of detail of a VRP did not match the scope of this project. A more high level analysis is sufficient in order to only retrieve the number of vans needed, and not the specific routes. Secondly, although a VRP would certainly provide the number of vehicles as well, the size of the instances and the restrictions imposed would hinder the search for a solution. All things considered, building a simulator under the terms described further in the present section instead of a VRP was a reasoned decision. Before diving into the functioning of the simulator, it is relevant to enumerate the parameters that serve as input for the model.

Service level allows to specify the percentage of orders that the fleet size is able to fulfill. For instance, a service level of 0.99 forces the vans to cover demand in 99% of the days of the year.

Time in client defines how long a driver spends, on average, on the destination address delivering the package to the customer.

Maximum shift limits the time window when it is possible to complete the transportation without compromising the customer well being. Normally, acceptable bounds are 8 a.m. and 19 p.m., but those can vary according to local habits or restrictions.

Fill time indicates the duration of loading the vans in the warehouse.

Van load specifies the amount of packages put in each vehicle. All vehicles are assumed to carry the same load.

These parameters are defined by the user and can be changed, especially when different scenarios are being analysed. Three parameters, the time between consecutive customers, time between warehouses and time required to return to the warehouse, essential to the proper functioning of the model, need to be computed due to its importance and difficulty in establishing a plausable value. The method used to estimate the parameters is depicted below.

Time between consecutive customers

The carriers responsible for delivering in those cities serve not only Farfetch but many different companies. Nonetheless, it is not uncommon for vans to departure facilities with only a handful of orders placed by Farfetch customers, together with dozens of other packages. Accordingly, since only data regarding the company's parcels is available, and they are not distributed consecutively, analysing historical data would not allow to estimate how much time it takes, on average, to travel between two consecutive customers. Instead, another methodology was followed. Depending on the scenario under analysis, a sample of customers was drawn, along with the zip code or street name. For this purpose, a simple and low restricted vehicle routing problem was developed to solve a travelling salesman problem without returning to the original depot. The heuristic employed was one of the first algorithms used in these type of problems - nearest neighbor - which although it is known to not give the shortest routes, fits the scope of the project. This way, areas with more customer proximity will have a lower time between consecutive customer, and consequently more parcels are delivered in a day. Having said that, Algorithm B.1 of Appendix B was used. Initially, the clients were separated by clusters, depending on their service area. If a segmentation was not conveyed, users placed in different areas would be compared and their time distance measured, erroneously increasing average time, since two customers placed on opposite sides of the city will unlikely be fulfilled by the same warehouse and vehicle. Afterwards, for each cluster, the nearest customer was consecutively selected as well as its time distance, allowing to compute the average duration between two consecutive customers. The duration and distance of the journeys were computed using specialized software.

Time between warehouses

To incorporate the chance of a vehicle departing from a warehouse picking parcels in other facility, the time between warehouses must be calculated. Especially when the number of orders in the facilities is low and the van load relatively high, using a single vehicle to handle multiple distribution centers can be beneficial. As a result, the time between warehouses was computed and summarized in a distance matrix.

Time to return to warehouse

Estimating the time required for vehicles to return to the designated warehouse is useful when the same ground unit can refill. Such trip is sometimes time-consuming and influences the number of deliverable orders within the maximum shift. Taking into account the reasoning followed for the previous parameter, the length of the return journey to the warehouse can be computed by registering the time distance between each customer and the origin warehouse. In case a service area has multiple warehouses, the nearest one is selected. Algorithm B.2 of Appendix B details the code used to estimate the parameter.

Simulator description

Having set the parameters, the functioning of the model can now be outlined. The first pertinent aspect to mention is the fact that vehicles can return to the warehouse to refill, but only one time. As previously noted, Farfetch does not own delivery facilities. Therefore, the last mile operation has to be conducted from the partners infrastructure. Given that warehouses are run under tight schedules, and carriers usually have multiple vans departing per hour, overloading staff and the loading area is not an option. Therefore, the limit of returns was set to one, meaning that vans can be loaded twice: at the start of the day, and after the first round of packages is delivered.

Initially, the number of orders to consider in a day, different for each scenario, must be calculated. To do so, a target service level for the operation must be defined. Pairing the departures per day of 2019 with the established service level allows to find the supplying capacity vehicles must have to meet the user defined parameter. Thereafter, this amount is distributed by the service areas based on their demand weight. If an area explains 50% of departures for a particular scenario, and the departures to consider in a day are 1000, half of those will be assigned to that area.

After specifying how many departures every warehouse should plan, the algorithm treats each facility individually, solving clusters independently. Hence, to incorporate the possibility of vehicles picking packages from other warehouses, in case the amount of parcels in that facility does not justify the departure of a single vehicle, a warehouse order balancing was adopted beforehand. Starting from the initial distribution, the algorithm adapts the amount of orders in the facilities to minimize the under-utilization of van capacity and, consequently, the number of vehicles needed. The pseudocode used is available in Algorithm B.3 of Appendix B.

Now that the demand per warehouse is defined, along with van load and the rest of the parameters, the initialization is complete and the minimum number of vehicles needed to operate a last mile operation can be computed. Instead of requesting the program to minimize the number of vehicles required to carry the departures, an inverse rationale was implemented: given the van load determined by the user, for a particular number of vehicles available, the model reveals if all orders were delivered; the average time a customer waited since the start of the shift; the total time elapsed since the start of the shift and total distance travelled. Assuming that maximum shift is 10 hours, time to return to warehouse is 1 hour, filling time 30 minutes and time between customers 15 minutes, a van only has 8.5 hours of operating time (10 hours minus one hour and a half) and the maximum amount of shipments it can convey in a day is 34. Considering this threshold, any vehicle capacity surpassing it will evidently only perform as good. If, for instance, 100 orders were to be delivered in a day, and each vehicle had capacity for 20 packages, the lowest number of vans covering the 100 shipments is 3. A lower quantity is not feasible since the demand, already with the service level ratio applied, is not fulfilled. On the other hand, more than 3 vehicles decreases the average delivery time per package. It is important to note that, although returns to the warehouse are limited to one, the model does not force the refill to be held within a specific interval. So, if a van finishes the first round at 15 p.m., nothing prevents it from returning to replenish, and leaving again at 16:30 p.m. to deliver the remaining orders, never surpassing nonetheless the maximum shift limit.

Table 7: Algorithm rationale with the maximum shift restriction

Orders	Van load	Vans	Deliveries
100	20	1	34
100	20	2	68
100	20	3	100
100	20	4	100
100	20	5	100

The model is executed for the several existing facilities, and the minimum number of vehicles required to fulfill demand in each facility is selected. However, the result depends on the van load inputted by the user. Consequently, the simulator is run for capacities ranging between an acceptable lower bound and upper bound. In the end, the best combination van load - number of vans is preferred. Pseudocode of the model is depicted in Algorithm 1.

Result: Resources required to perform last mile in a city

```
Initialize parameters;
for Van capacity = LB, ..., UB do
    for Warehouse = 1,2, ..., N do
        Max vans = Warehouse orders / Van capacity;
        Vans = 1;
        while Vans < Max vans do
            Compute orders delivered;
            Compute average time, total time and total distance;
            Vans = Vans + 1;
        end
        Select minimum vans that fulfill demand;
    end
    Sum minimum vans of all warehouses;
end
Select best overall solution;
```

Algorithm 1: Choosing the minimum number of vehicles to conduct last mile operations

Thereafter, it is possible to obtain the significant expenses attached to the operation that are directly associated with the number of vans, total time and total distance. To do so, the daily cost of renting a van, the price of fuel and the average delivery drivers' salary in each city was obtained by performing an online search. These values are shown in Table C.1 of Appendix C. Besides, other costs like additional expenses per kilometer were not considered, since reaching a plausible value proved to be unfruitful.

4.3.2 Alternative carriers

In a different manner, other carriers' domestic rates were consulted to estimate last mile shipping costs in both cities. Direct comparison between options is possible by simple observation of the various rates. Regarding customer experience, carriers offer distinct capabilities and characteristics that can be beneficial for the company. For each city, the 3PLs presenting more interesting rates/capabilities on the particular environment were selected.

In C2, two options were highlighted: using T2 or T1 to convey the entire order volume; or contracting T4 to be responsible for the total orders. T2 and T4, along with T1, are the main players in C2's country and consequently represent the most viable options. While there is not a visible difference between Standard and Express in last mile, the type of service will not be taken into account. Unlike the current situation, T4 delivers packages on Saturday and Sunday, which poses as a great advantage since total transit time can be significantly decreased.

Concerning C3, two alternatives will also be studied: T1 or T2 managing all the shipments; or resorting to T5 to conduct all orders. Given the relevant same day/F90 order volume in the city, using T3 (the main same day delivery player) could be a possibility, but it was taken out of the equation due to its tremendously high rate, unsuitable for conveying mass volume. T5 is a popular carrier in C3's country which also has some of the most competitive rates in the region, besides T1 and T2, and its expertise on the area can be an advantage.

The rates and main feature of each carrier discussed are depicted in Table 8. They will be further used in Chapter 5, to estimate the costs of every scenario under assessment. The rates include additional surcharges.

Table 8: Carriers' rates for each city and main feature

City	Carrier	Rate	Feature
C2	T1	$ 6.49	Pricing
C2	T2	$ 6.63	Scale
C2	T4	$ 6.52	Weekend delivery
C3	T1	$ 5.80	Pricing
C3	T2	$ 6.52	Scale
C3	T5	$ 5.92	Local knowledge

Chapter 5

Results

This chapter presents and interprets the results drawn from the model developed and carriers analysed. In the end, in order to facilitate decision making, an interface is created with a comparison between the different alternatives available in each scenario and their outcomes. Firstly, however, the scenarios studied are going to be defined.

5.1 Scenario formulation

A set of scenarios, transverse to both cities, was designed with the purpose of targeting different service areas or groups of customers, together with a variation in order volume. As previously seen in Figure 8b, greater demand is found in certain weeks of the year, which requires increasing resources to deliver parcels in the same day. Therefore, a distinction is made between peak and off peak weeks, where a different number of vans will be used. A week is considered peak when the sum of its departures is 50% above weekly average.

In the first scenario, all orders in each city will be considered. Although it is unreasonable to firstly adopt a solution that delivers all orders, analysing its results is useful especially to assess the effectiveness of this solution for a large number of purchases, and can also provide hints to long term success. Scenario 2 only examines orders placed by VIP customers. In this case, delivering superior service is even more imperative, since these clients are great spenders in Farfetch and expect to be given proper appreciation. Contrarily to the first hypothesis, a very limited number of parcels are regarded, which is preferred in a pilot testing stage. At last, only the most city central service area of one of the carriers will be served. Once again, it represents only a percentage of total city orders. In C2, area SA9 was selected, given that the other city central area SA6 had a huge quantity of orders. In C3, SA4, operated by T1, was preferred. Each of these scenarios is then divided into peak and off peak, and the total cost for the year 2019 calculated. To sum up, three scenarios will be considered in each city. Within, a division is made between peak and off peak. Table 9 summarizes this information. Given the huge volume in week 49 of the year, which corresponds to the first week of December when Black Friday purchases are delivered, those days were not considered in the model. Moreover, last mile shipments can only be conveyed during weekdays, since T1 and T2's warehouses rarely dispatch on the weekends.

Table 9: Scenarios considered in both cities

	All orders		VIP orders		Central orders	
City	Off peak	Peak	Off peak	Peak	Off peak	Peak
C2	-	-	-	-	-	-
C3	-	-	-	-	-	-

5.2 Model output

Initially, the time between consecutive customers, between warehouses and time to return to warehouse was obtained for each service area, in every scenario. Not only the time was retrieved, but also the distance in kilometers, to compute total distance. If the time between warehouses is constant across scenarios, the same cannot be said for the other two parameters. So, before jumping into the model's results, the values obtained for these parameters (and the definition of other parameters) will be discussed. Software *Python* was used to implement the algorithms.

5.2.1 Parameters

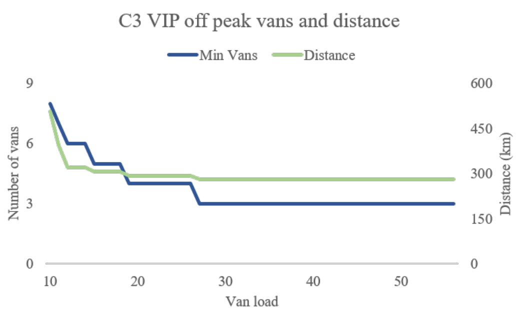
For the VIP orders scenario, all VIP clients in each city were considered, due to the limited size of the instance (800 in C3, 1000 in C2). The same was not followed for the All orders scenario, since the number of customers in 2019 was 35k in C3 and 45k in C2, and software limitations did not allow to analyse all users. In this case, a sample representing 10% of total customers served by each service area was drawn, and Algorithms B.1 and B.2 applied. Although ideally the entire population should be examined, because in general average distance between costumers decreases when increasing sample size, more than 500 clients were considered in all services areas, representing a reasonable sized instance.

Tables C.2, C.3 and C.4 from Appendix C exhibit the various times and distances obtained for the different scenarios. Time and distance to return to warehouse is greater in All Orders Scenario in relation to the VIP. Such fact can be related to the fact that VIP customers are probably concentrated in and around the city center, closer to carriers' warehouses. On the other hand, the time and distance between consecutive customers is lower in All Orders scenario, since there is more customer density. Even though only a 10% sample was retrieved, the amount of users analysed is greater than the number of VIP users. For the Central scenario, where only SA4 and SA9 are considered, the values used are those of All Orders, in these areas.

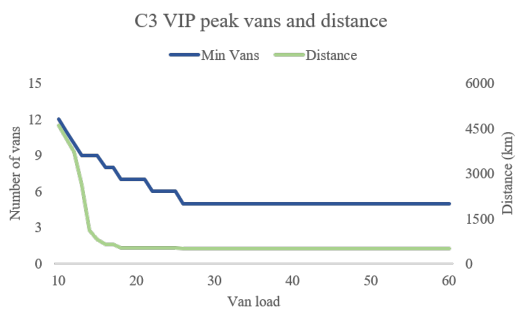
Concerning the remaining parameters, in every scenario, service level was set to 99%, time in client 5 minutes and fill time 30 minutes. However, maximum shift differs between cities. As seen in Figure 9, orders in C2 actually arrive slightly later than in C3. Therefore, in C3 maximum shift is 11 hours, while in C2 the limit is 10 hours. The van load will not be inputted by the user, since the model considers all feasible capacities. Additionally, in order to estimate van cost, the price of renting a vehicle must be known. The selection obviously depends on the number of parcels each unit will carry. Given that Farfetch's packages occupy little volume, and feasible van loads in the model never surpass 100, the cost of renting a small commercial van was obtained. Furthermore, to calculate fuel cost and drivers' wages, the average diesel fuel price and average delivery driver's salary in both cities for 2019 were also collected. This information is available in Table C.1 of Appendix C.

5.2.2 Minimum number of vans

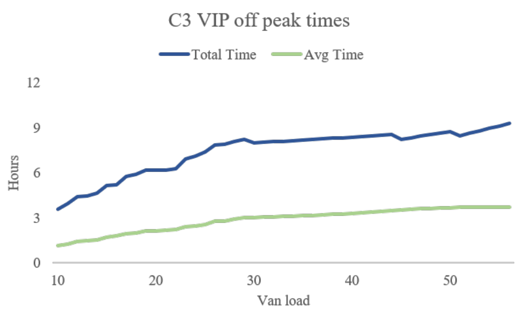
After defining the parameters, the minimum number of vans in each scenario is found by running Algorithm 1. When analysing lower van capacities, the quantity of vehicles needed is higher, similarly to total distance travelled. On the other hand, total time and average time a customer waits for the package since the beginning of the shift start with low value, but gradually increase with van load. To understand this behaviour, C3's VIP scenario will be used as an example. The reasoning followed is equally applied to other scenarios. Figure 10 presents the results of the selected scenario. Considering the 50% peak parameter, four weeks were given such status.



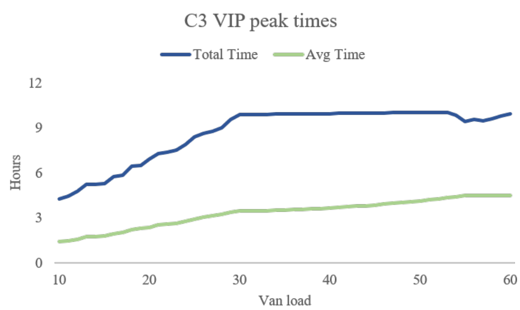
(a) Minimum vans and total distance, in km, of C3 VIP scenario in off peak season



(b) Minimum vans and total distance, in km, of C3 VIP scenario in peak season



(c) Total and average time, in hours, of C3 VIP scenario in off peak season



(d) Total and average time, in hours, of C3 VIP scenario in peak season

Figure 10: Evolution of minimum number of vans, total distance, total time spent and average customer waiting time with increasing van load, for C3 VIP scenario

For each van load, the solution that required the minimum number of vans was selected. Therefore, all the alternatives presented are feasible, meaning that demand is always fulfilled in the same day. Once again, highlighting that the most crucial KPI is to deliver package within the time window, the ideal combination van load - number of vans should be the one with less vehicles required. In this case, there are several options where that occurs. In the off peak season, the optimal fleet size is 3, but the van load ranges from 27 to 57. Since total time and total distance have an impact on operational costs, given their influence on the amount paid to drivers and the expenses in fuel, both these curves should be regarded and the minimum values selected, from the van load range filtered above. Although the total distance is constant, total time experiences slight variations. The lower value is found for van load equal to 28 in off peak and 27 in peak season. The same reasoning was applied for every scenario in both cities. Results are displayed in Tables D.1 and D.2 of Appendix D.

Still using the C3 VIP scenario, stipulating a 99% service level forces the 3 vehicles to be able to daily deliver 125 packages in the off peak season and 231 in peak, with 5 vehicles. If those values are compared with the real departures observed in each day, a big difference is noted, which leads to under-utilization of resources, namely vans and drivers. Ideally, to optimize resource usage, fleet size would be adjusted daily. However, in practice, that is not reasonable since the vehicles used are rented for a longer period of time. Dividing in peak and off peak mitigated under-utilization to some extent, but still in almost everyday of the year, not all vans will be used nor the drivers will be delivering parcels, as shown in Figure 11.

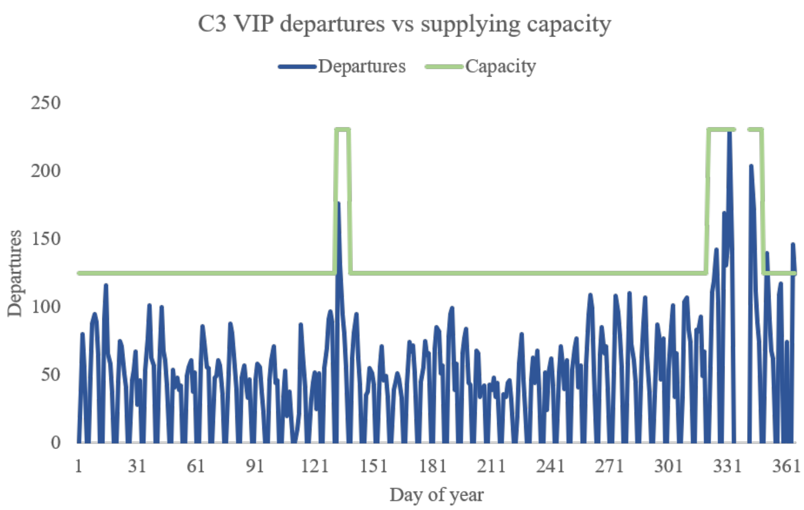


Figure 11: Departures and supplying capacity for C3 VIP scenario

Controlling the variation on demand would be a way to contour this problem, by allowing the supplying capacity curve to be fixed on a lower value. In consequence, other possibility emerged: only fulfilling a lower percentage of the orders, and outsourcing the rest to the current carriers. In this manner, the supplying capacity will decrease, while all the orders will still be delivered at the same day. The model is still used in a similar fashion, with a peak and off peak division, but now with less orders fulfilled by the own ground fleet.

5.2.3 Redefining service level

A new service level should be defined that allows both to deliver most of the orders, maintaining control over the majority of last mile operation, and avoiding a huge gap between supplying capacity and actual departures. To meet both these requirements, new results will be calculated with a service level of 80%, comparing its costs with the 99% baseline. Similarly, the results are presented in Tables D.3 and D.4 of Appendix D.

As expected, the fleet size required to deliver the daily orders is shorter, together with total distance, in nearly all scenarios. Exceptions are C3 Central (off peak and peak) and C2 Central off peak, where two vehicles are always needed. When the number of orders considered increases, such as in All Orders, the difference observed in quantity of vans between both service levels is obviously greater. One curious aspect when scrutinizing the 99% service level results is the supplying capacity in C3 All Orders, where the off peak's is actually larger than the peak's capacity, resulting in a larger daily cost. The root cause for this particular behaviour is the distribution of departures (or arrivals, since both curves are similar) per day of the year. A week is considered peak if its sum of orders is 50% higher than the average weekly demand. However, some isolated days in the off peak season actually register more orders than the peak days. The weeks where these isolated days are inserted do not have enough demand to reach a peak status, provoking this inconsistency in C3 All Orders scenario, for a 99% service level.

Resuming the C3 VIP scenario, the offset between supplying capacities is evident for both service levels, decreasing renting, fuel and wage expenses. Nevertheless, the cost of assigning the unfulfilled orders to current carriers should be taken into account. The cost analysis is detailed in the next section, by comparing the AS-IS pricing with model costs and alternative carriers rates.

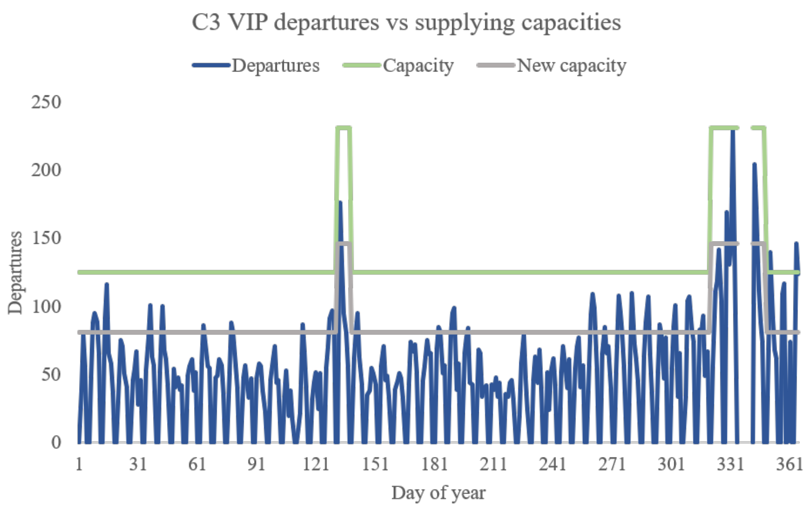


Figure 12: Departures and supplying capacity for C3 VIP scenario, using a 80% and 99% service level

5.3 Cost analysis

Firstly, the actual value paid for last mile shipments in each city should be computed. Accordingly, the current rates, extracted in Section 4.2.4, are multiplied by the volume each carrier conveys in every scenario. Regarding the model, estimating total costs for the entire year relies on three parameters, depicted in Table C.1 of Appendix C: daily van rental, average drivers' wage and diesel fuel price. The first is multiplied by the fleet size; the second by the number of vans and the wage per hour; and the third by total distance travelled, resulting in operation's daily cost. Consequently, that proxy is used to get total year cost. While the van rental fee is applied for the whole year, including weekends and week 49, the same is not said for wages and fuel expenses. In these cases, weekends were disregarded, because operations will not be conveyed during those days, as well as week 49. When testing the model, not all orders are served by the own ground fleet. In the 80% service level case, 20% of days will have a demand greater than the fleet's supplying capacity, and some packages will be delivered by the current carrier. This outsourcing cost is also considered in total yearly cost. In this case, the solution is actually a mix: in 20% of days, a number of orders will not be delivered by the own ground fleet, but by the partner carrier instead. Moreover, in some cases, parcels will still not be delivered in first attempt. Even so, no additional costs will be incurred. In these cities, Farfetch can use warehouses from purchased/partner brands that are sufficient to store the low volume of packages not delivered at first and park the vans during the night, avoiding renting a space for the effect. Alternative carriers' yearly cost was computed likewise the AS-IS situation, using the rates obtained in Section 4.3.2 and multiplying by order volume. Values obtained are shown in Table 10.

Table 10: Yearly costs for the different scenarios, using the studied solutions

City	Scenario	AS-IS	All T1	All T2	All T4/T5	Model 80%	Model 99%
C2	All	$ 1.68M	$ 1.68M	$ 1.72M	$ 1.69M	$ 1.44M	$ 2.73M
C2	VIP	$ 262k	$ 262k	$ 267k	$ 263k	$ 268k	$ 479k
C2	Central	$ 94k	$ 92k	$ 94k	$ 93k	$ 92k	$ 107k
C3	All	$ 829k	$ 808k	$ 908k	$ 825k	$ 681k	$ 1.16M
C3	VIP	$ 92k	$ 90k	$ 101k	$ 92k	$ 107k	$ 166k
C3	Central	$ 98k	$ 98k	$ 110k	$ 100k	$ 83k	$ 105k

Naturally, the yearly cost is higher when more orders are assigned to a scenario. In C2, the disparity between All and VIP is notorious, with Central occupying the position where less shipments are conveyed. In parallel, C3's All scenario has the greater cost, with Central and VIP assuming similar figures. From all the carriers presented, T1 assumes the best rates in all cases, resulting in a lower total cost. In C2, T1 is followed by T4 and then by T2, whereas in C3, T5 is more competitive in terms of price than T2. Regarding the model, the discrepancy between the results for both service levels are quite evident: yearly costs almost double when applying a 99% parameter. That is the price to pay in order to totally control operations. On the other hand, the customer experience advantages from having a own ground fleet, discussed in the next section, will certainly target more clients when more shipments are conveyed in-house. Therefore, in terms of expenses, the 80% case will always perform better than the 99%. In C2, the model yields a better result, when compared to the AS-IS situation, for the Central and All scenarios. In the first case, the positive outcome is related with the low time between consecutive customers and short distance to the warehouse, demonstrating proximity between clients and allowing more addresses to be visited in a single day. For the latter, the savings are caused by a good utilization of resources. Since the warehouses have a big number of parcels to deliver, less journeys between facilities are needed, increasing the time vans are actually delivering orders. Identical conclusions can be withdrawn for C3. The VIP scenario does not enable any savings, since the time between consecutive clients is higher than the Central's, given that all warehouses are being considered, and the limited number of orders does not facilitate a good utilization of resources, as in All scenario. Still, the figures are not unpleasant, since only a 2.3% cost increase is verified in C2, and a 16% increase in C3.

The price of renting a van was not subject to negotiation by the company. In reality, an agreement could be achieved at a lower value, resulting in additional savings. For C3 VIP, decreasing daily renting price to $30, for instance, grants 7% of savings in yearly costs. Therefore, the original rate used is the worst case scenario. Contrarily, other operational costs like vehicle maintenance were not regarded, since quantifying them is quite subjective.

5.4 Assessing customer experience

The present project is focused on enhancing last mile deliveries, primarily by boosting the customers' experience when buying with Farfetch. Consequently, it is essential to evaluate the impact of the aforementioned solutions. In every scenario, owning a ground fleet has the same advantages, whereas different carriers offer different abilities.

Having control over the operation lowers dependency on partners, which play such an important role at the moment. The information flow becomes total responsibility of the company, and operational day-to-day adjustments can be accomplished with ease. Other relevant aspect is the visibility the brand will have if personalized branded vehicles daily travel through busy city streets, which can have favourable outcomes as a marketing strategy and to enhance company's image. Quantifying this effect is not trivial, but it definitely favors the company by spreading the brand and potentially reaching more customers. Also, this solution enables to aggregate orders directed to the same user. If a portal order includes two items from distinct boutiques, they are currently not delivered simultaneously, prejudicing the experience. Aggregating packages both decreases the number of travels needed to the destination address, and prevents the client from receiving parcels twice. In 2019, 10k portal orders in C3 and 20k in C2 included more than one boutique order. Apart from that, synergies can be achieved with other Farfetch initiatives. Instead of depending on the network of carriers' facilities, the last mile could be leveraged by Fulfillment by Farfetch, providing infrastructure to stock and ship packages. However, the initiative is currently in an embryonic state, and coupling both projects is not possible. In addition, the last mile could also be utilized to pick up returns from clients, speeding the current process and possibly resulting in savings. In comparative terms, the 99% service level model serves more customers and, therefore, provides a superior customer experience overall. Still, when compared to the AS-IS situation, the 80% alternative also yields superlative experience.

Regarding the carriers, T1 and T2 are currently used and offer similar features: weekday deliveries and a worldwide network, benefiting from economies of scale. Opting to continue with one of these carriers is advantageous because less changes are sustained, and the challenges with carrier integration or information flow are minimal. In C3, T5 has the advantage of working mainly with companies in the region, being up to date with local policies and procedures. From a client's perspective, being served by a carrier which is popular in the region might be a point in favour. Adding other carrier to the range of partners also mitigates the risk of over depending on specific 3PLs. All in all, in terms of customer experience, T5 outperforms T1 and T2, but the own fleet still brings more advantages. In C2, T4's weekend deliveries are an extremely strong aspect. Orders placed on Thursday or Friday are usually delivered on the next week, adding two days to transit time. Therefore, and assuming that half the orders would be delivered on Saturday and the other half on Sunday, using T4 could decrease transit time in 1.5 days, for the purchases processed by the end of the week. As an example, the transit time variation for the All Orders scenario in C2 is analysed. For the affected orders, as previously mentioned, a decrease of 1.5 days is detected. Overall, the transit time for all orders in the city lowered, on average, from 2.83 to 2.58 days. In this city, both T4 and the own ground fleet solutions provide substantial advantages to enhance customer experience.

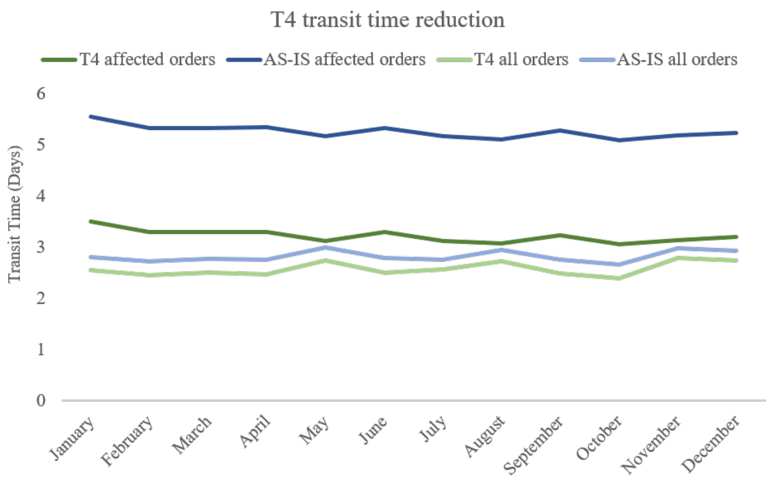


Figure 13: Variation in transit time when using T4, in C2

5.5 Decision Interface

With the main purpose of assisting decision making, an interface was created to display the results obtained, both for costs and customer experience, and permit a easy comparison of values between solutions and scenarios within the same city. One of its main advantages is the possibility of easily incorporating different carriers' rates or model configurations in the analysis, gifting the interface with a useful flexibility that allows it to adapt to several situations. An example is shown in Figure 14 for scenario C3 VIP.

C3 VIP

Scenario Description	
Service Level	80%
Delivery window	11 hours
Total Orders	10129
Peak weeks	20, 47, 48, 50

Rates	Cost/parcel	Feature
T1	$ 5,80	Pricing
T2	$ 6,52	Scale
T5	$ 5,92	Local Knowledge

Model Output	Off peak	Peak
Number of vans	2	3
Total distance	179	318
Total time	8	10
Outsourced orders	672	205

Van Daily Cost	Off peak	Peak
Van Rental	$ 77,50	$ 116,25
Drivers	$ 246,00	$ 461,25
Distance	$ 18,42	$ 32,72

	AS-IS	Own Vans	T1	T2	T5
Yearly Cost	$ 91 955	$ 106 851	$ 90 010	$ 101 184	$ 91 872
Savings	$ -	$ -14 896	$ 1 945	$ -9 229	$ 82

Solution	Saving	Customer experience
Own Van	$ -14 896	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 1 945	Current partner, minimal effort with integration and information flow
T2	$ -9 229	Current partner, minimal effort with integration and information flow
T5	$ 82	Localized company, mitigating partner dependency

Figure 14: Decision Interface for scenario VIP in C3

On the top left corner, general information such as service level or total yearly orders is provided. Carriers' rates are displayed on the right. Highlighted in yellow is the simulator's output, namely the number of vans needed, total time elapsed and distance travelled, essential to compute total cost. The outsourced orders are also made available. The daily cost of operating a own ground fleet is partitioned per category, so the biggest parcel is detected. At the bottom, yearly expenses and customer experience are compared to the AS-IS situation, summarizing vital information necessary to assist decision making. This design is repeated for the three C3 and C2 scenarios, as displayed in Tables E.1 and E.2 of Appendix E. When examining the simulator's values, only the 80% service level case will be considered, due to the disproportional cost obtained for the 99% service level which would immediately rule out that hypothesis.

In C3 All scenario, the own ground fleet yields $ 149k of savings per year due to the good utilization of resources mentioned in Section 5.3. T1 and T5 result in residual savings, and solely using T2 is costlier than the AS-IS situation. In terms of customer experience, the in-house alternative and T5 are the best options. For the VIP, the simulator does not provide any savings, because the order volume is low. The remaining aspects are similar to All Scenario. On the other hand, the model is the only solution with savings in Central hypothesis.

Regarding C2 All, the own fleet again presents the best results, with $ 244k in savings, comparing to the rest nearly neutral solutions. In terms of customer experience, the model and T4 both enable a experience enhancement. For the VIP, all the alternatives are close to the AS-IS in terms of expenses, with the simulator yielding the worse solution. On the other hand, all solutions are better than the AS-IS in Central scenario.

All in all, in C3, although the All scenario provides superior savings, applying a new initiative to such a wide range of orders is risky, and a lower scale should be chosen to start with. On those conditions, it is recommended to use the 80% own ground fleet setting from the Central warehouse considered, enhancing customer satisfaction and resulting in savings as well. In C2, the reason for not choosing the All scenario is parallel. In order to reduce risk, the own van model will not be suggested, since implementing such operation in C3 firstly to evaluate the solution's feasibility is more rational. Instead, in C2, and as a means to gift VIP users, the suggestion is to contract T4 for the VIP scenario, since costs are identical and customer experience is improved with a transit time decrease. If the own fleet hypothesis meets expectations, it should be extended to situations where more orders are considered. As displayed in the All scenarios, the model performs better when more volume is handled in the operation. Therefore, the long term tendency is to enlarge the scope of the model, always depending on starting trials in C3.

Chapter 6

Conclusion

With the clear intention of presenting a business solution to upgrade last mile in terms of customer experience and potentially incur in savings, multi-leg initiatives and their effect on operations represented appealing options. In consequence, two alternatives were studied: working with others carriers or taking control over processes by in-sourcing transportation. Given last mile's scope, it soon became evident that a city level analysis was more fitting to the project. Understanding the current delivery process and relevant KPIs to evaluate last mile performance was the first step to assess and compare city performance and determine where multi-leg solutions would create the most impact. This resulted in the first value-adding element of the thesis: a structure to pinpoint where multi-leg initiatives should be studied. In this particular case, the result was C2 and C3.

Thereafter, those territories were scrutinized with further detail: warehouse distribution, arrivals and departures from last facility, or types of shipments incurred. Such investigation enabled to deeply understand the particular last mile activity in these cities, and obtain the necessary inputs to the model that estimates the resources needed to conduct a last mile operation in-doors. This is the second main contribution of the thesis: a high level tool that does not detail routing, but instead provides a broader view as to how many vans, drivers and fuel is required to deliver a number of daily orders.

At last, an interface was created to aid decision making and easily compare total yearly costs and customer experience improvements amongst alternatives and scenarios. Required information such as carriers' rates or the model's output is also presented, to provide a deeper understanding of the solutions being analysed. This project's suggestion is to implement the model with a service level of 80% in C3 Central and outsource the remaining orders, as well as contract T4 in C2 to serve VIP customers. Given the figures obtained for both All scenarios, and depending on the performance of initial trials in C3 Central, the tendency is to increase the volume conveyed by the own ground fleet. It should be bear in mind, however, that these results are only valid when last mile is conducted from the carriers' last facilities, and their contribution to perform the last mile and work closely with Farfetch vans is essential.

Still, some aspects were identified along the project as subject for improvement in future work, mainly due to the short time-frame. Firstly, some of the KPIs used in the city selection, Section 4.1, namely returns and customer contacts, were not exclusively affected by last mile performance. On these cases, a further survey should be conveyed to partition the values by first mile and last mile, inputting more reliable figures in the DEA model and providing more accurate results. Regarding the simulator, the sample used to retrieve average time between consecutive customers and average time to return to warehouse in All scenario only included 10% of total users, due to software limitations. To more precisely estimate the parameters, that have impact on the final costs, a wider sample should be considered. In addition, the nearest neighbour heuristic used to compute the average time between consecutive customers is one of the simplest, and does not yield optimal results. Accordingly, a more powerful method can be used, approximating the model from reality. Concerning total yearly costs, neglected elements like van maintenance should be properly estimated and included in this model, giving the user more complete information regarding the expenses related to owning a ground fleet. By the same token, it is also important to evaluate the marketing impact of branding vans.

To validate the results obtained with the model, they should be compared to those achieved when solving a vehicle routing problem. The VRP is a more exact method that details the routing and can provide more accurate figures. Therefore, confronting both is a good way to evaluate if the simulator provides similar values, and test its accuracy. In case there is a discrepancy, the VRP can also indicate the origin of the disparity, which represents valuable information to tune the high level model developed in this dissertation.

When doing a pilot test in C2 and C3 with the new proposed configurations, the metrics considered in Section 4.1 ought to be calculated and their values compared to the current values and the solution's customer experience value proposition. The impact on such KPIs will also define the feasibility of the initiatives, since worsening clients' satisfaction when implementing them is not an option aligned with Farfetch's values, focused on amazing customers.

All things considered, this dissertation provides a framework to evaluate the impact of multi-leg initiatives. Firstly, by choosing the best locations where solutions should be presented; and afterwards, by detailing operational behaviour, estimating the cost of in-sourcing deliveries without solving a VRP, and comparing alternatives in terms of yearly costs and customer experience. The framework's flexibility and the guidelines provided along this dissertation are adequate to analyse different scenarios, with parameters defined accordingly, in territories the company finds to be suitable for restructuring last mile operations.

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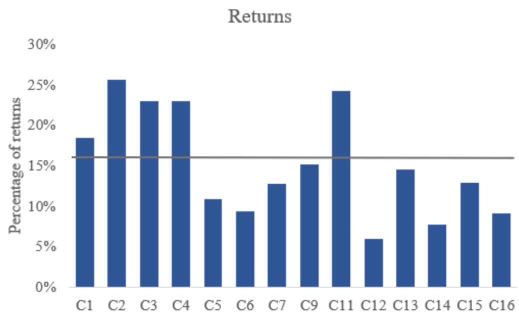
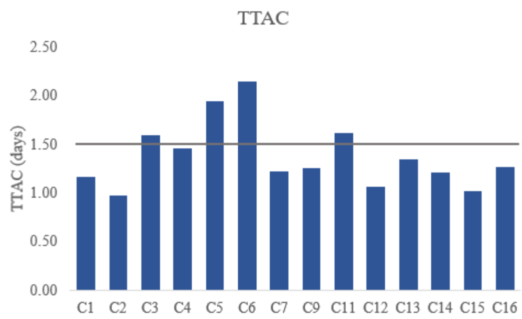
Appendix A

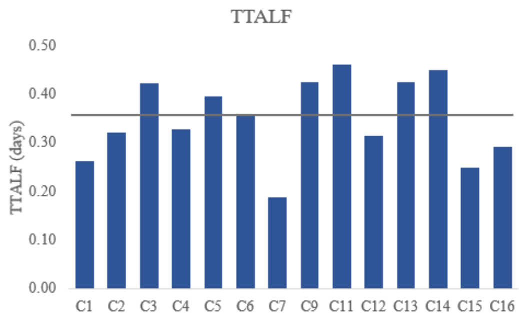
Operational KPIs graphic information



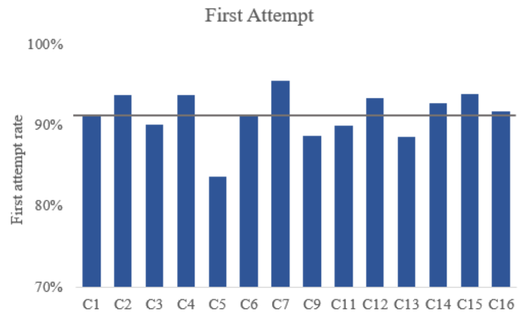
(a) Percentage of boutique order with returns



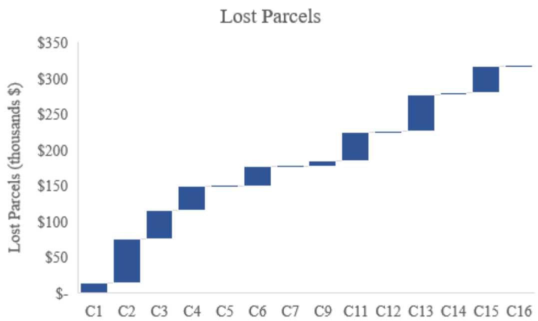
(b) Transit time after customs



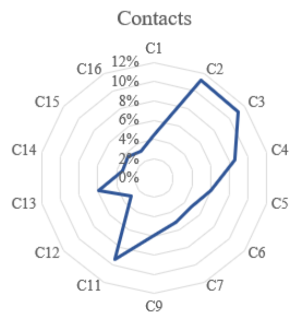
(c) Transit time after last facility



(d) First attempt rate



(e) Value of parcels lost



(f) Percentage of boutique orders with contacts

Figure A.1: Graphical display of operational KPIs for the 14 cities filtered

Appendix B

Specific algorithms included in the model

Result: Average time between customers in each service area

Divide the customers per service area;
for *Service Area = 1,2, ..., M* **do**
  initial user = first user;
  while *Service Area users not visited* **do**
    Find the closest user to initial user;
    next user = closest user to initial user;
    sum = sum + time between users;
    initial user = next user;
  end
  Avg Time = sum / Number of service area users
end

Algorithm B.1: Nearest neighbour heuristic

Result: Time to return to the warehouse

Divide the customers per service area;
for *Warehouse = 1,2, ..., N* **do**
  user = 1;
  while *Warehouse users not analysed* **do**
    Compute time between Warehouse and user;
    sum = sum + time between Warehouse and user;
    user = user + 1;
  end
  Avg Time = sum / Number of service area users
end

Algorithm B.2: Estimation of time to return to the designated warehouse

Result: Quantities in each warehouse

```
Set van load;
Set initial warehouse quantities;
for Warehouse = 1,2, ..., N do
    while Vehicle under-capacity do
        Select closest warehouse with packages;
        New quantity = min (van load, old quantity + orders in closest warehouse);
    end
end
```

Algorithm B.3: Warehouse balancing

Appendix C

Model parameters' results

Table C.1: Parameters essential to calculate last mile costs

City	Daily van rent	Average wage	Diesel fuel price
C3	39$	15.38$	1.29$/Liter
C2	50$	13.08$	0.81$/Liter

Table C.2: Time between customers and time to return to warehouse for All Orders scenario, in C2 and C3

City	Area	Time return WH	Time clients	Distance return WH	Distance clients
C3	SA1	24.08	2.84	7.96	0.79
C3	SA2	31.23	4.14	18.55	1.96
C3	SA3	30.61	3.66	28.72	1.72
C3	SA4	15.71	2.06	3.83	0.49
C3	SA5	30.17	3.55	9.24	1.12
C2	SA6	20.83	2.33	8.24	1.17
C2	SA7	25.69	3.31	22.70	1.39
C2	SA8	37.85	6.58	38.84	4.94
C2	SA9	17.88	3.05	5.32	0.66

Table C.3: Time between customers and time to return to warehouse for VIP Orders scenario, in C2 and C3

City	Area	Time return WH	Time clients	Distance return WH	Distance clients
C3	SA1	25.35	3.26	8.39	0.90
C3	SA2	29.63	9.82	17.60	4.65
C3	SA3	31.01	6.41	29.09	3.01
C3	SA4	15.32	2.48	3.73	0.59
C3	SA5	27.17	5.22	8.32	1.65
C2	SA6	17.59	2.62	6.95	1.32
C2	SA7	25.55	4.58	22.58	1.93
C2	SA8	34.21	9.34	7.02	35.10
C2	SA9	16.74	3.48	4.98	0.75

Table C.4: Time between customers and time to return to warehouse for Central Orders scenario, in C2 and C3

City	Area	Time return WH	Time clients	Distance return WH	Distance clients
C3	SA4	15.71	2.06	3.83	0.49
C2	SA9	17.88	3.05	5.32	0.66

Appendix D

Model's results

Table D.1: Model daily results in C2, for a service level of 99%

	All orders		VIP orders		Central orders	
	Off peak	Peak	Off peak	Peak	Off peak	Peak
Supplying capacity	2217	4073	338	1145	113	151
Number of vans	35	63	7	20	2	3
Van load	32	51	54	60	37	27
Total distance	31870	106988	1110	11718	84	172
Total time	11	11	10	10	10	9
Number of peak weeks	-	5	-	6	-	3

Table D.2: Model daily results in C3, for a service level of 99%

	All orders		VIP orders		Central orders	
	Off peak	Peak	Off peak	Peak	Off peak	Peak
Supplying capacity	1193	1142	125	231	136	149
Number of vans	17	17	3	5	2	2
Van load	37	36	28	27	69	76
Total distance	4566	4194	280	507	141	153
Total time	12	12	9	10	9	10
Number of peak weeks	-	4	-	4	-	2

Table D.3: Model daily results in C2, for a service level of 80%

	All orders		VIP orders		Central orders	
	Off peak	Peak	Off peak	Peak	Off peak	Peak
Supplying capacity	1267	2103	181	525	69	131
Number of vans	20	33	4	10	2	2
Van load	66	62	26	29	19	68
Total distance	10317	28032	478	2352	56	98
Total time	10	11	9	10	7	10
Number of peak weeks	-	5	-	6	-	3

Table D.4: Model daily results in C3, for a service level of 80%

	All orders		VIP orders		Central orders	
	Off peak	Peak	Off peak	Peak	Off peak	Peak
Supplying capacity	670	1042	81	146	87	149
Number of vans	10	15	2	3	2	2
Van load	73	73	44	52	45	71
Total distance	1575	3983	179	318	93	145
Total time	11	11	8	10	6	9
Number of peak weeks	-	4	-	4	-	2

Appendix E

Decision interfaces

Due to their size, the interfaces are exhibited in the next two pages.

C3 ALL

Scenario Description	
Service Level	80%
Delivery window	11 hours
Total Orders	108763
Peak weeks	2, 26, 50, 51

Rates	Cost/parcel	Feature
T1	$ 5,80	Pricing
T2	$ 6,52	Scale
T5	$ 5,92	Local Knowledge

Model Output	Off peak	Peak
Number of vans	10	15
Total distance	1575	3983
Total time	11	11
Outsourced orders	6107	210

Van Daily Cost	Off peak	Peak
Van Rental	$ 387,50	$ 581,25
Drivers	$ 1 691,25	$ 2 536,88
Distance	$ 162,05	$ 409,79

	AS-IS	Own Vans	T1	T2	T5
Yearly Cost	$ 829 277	$ 680 774	$ 808 062	$ 908 373	$ 824 780
Savings	$ -	$ 148 503	$ 21 215	$ -79 096	$ 4 496

Solution	Saving	Customer experience
Own Van	$ 148 503	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 21 215	Current partner, minimal effort with integration and information flow
T2	$ -79 096	Current partner, minimal effort with integration and information flow
T5	$ 4 496	Localized company, mitigating partner dependency

C3 VIP

Scenario Description	
Service Level	80%
Delivery window	11 hours
Total Orders	10129
Peak weeks	20, 47, 48, 50

Rates	Cost/parcel	Feature
T1	$ 5,80	Pricing
T2	$ 6,52	Scale
T5	$ 5,92	Local Knowledge

Model Output	Off peak	Peak
Number of vans	2	3
Total distance	179	318
Total time	8	10
Outsourced orders	672	205

Van Daily Cost	Off peak	Peak
Van Rental	$ 77,50	$ 116,25
Drivers	$ 246,00	$ 461,25
Distance	$ 18,42	$ 32,72

	AS-IS	Own Vans	T1	T2	T5
Yearly Cost	$ 91 955	$ 106 851	$ 90 010	$ 101 184	$ 91 872
Savings	$ -	$ -14 896	$ 1 945	$ -9 229	$ 82

Solution	Saving	Customer experience
Own Van	$ -14 896	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 1 945	Current partner, minimal effort with integration and information flow
T2	$ -9 229	Current partner, minimal effort with integration and information flow
T5	$ 82	Localized company, mitigating partner dependency

C3 CENTRAL

Scenario Description	
Service Level	80%
Delivery window	11 hours
Total Orders	13534
Peak weeks	50, 51

Rates	Cost/parcel	Feature
T1	$ 5,80	Pricing
T2	$ 6,52	Scale
T5	$ 5,92	Local Knowledge

Model Output	Off peak	Peak
Number of vans	2	2
Total distance	93	145
Total time	6	9
Outsourced orders	757	10

Van Daily Cost	Off peak	Peak
Van Rental	$ 77,50	$ 77,50
Drivers	$ 184,50	$ 276,75
Distance	$ 9,57	$ 14,92

	AS-IS	Own Vans	T1	T2	T5
Yearly Cost	$ 98 032	$ 83 394	$ 98 032	$ 110 201	$ 100 060
Savings	$ -	$ 14 638	$ -	$ -12 169	$ -2 028

Solution	Saving	Customer experience
Own Van	$ 14 638	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ -	Current partner, minimal effort with integration and information flow
T2	$ -12 169	Current partner, minimal effort with integration and information flow
T5	$ -2 028	Localized company, mitigating partner dependency

Figure E.1: Decision interface for C3

C2 ALL

Scenario Description	
Service Level	80%
Delivery window	10 hours
Total Orders	206346
Peak weeks	19, 20, 21, 24, 48

Rates	Cost/parcel	Feature
T1	$ 6,49	Pricing
T2	$ 6,63	Scale
T4	$ 6,52	Weekend delivery

Model Output	Off peak	Peak
Number of vans	20	33
Total distance	10317	28032
Total time	10	11
Outsourced orders	17997	2187

Van Daily Cost	Off peak	Peak
Van Rental	$ 1 000,00	$ 1 650,00
Drivers	$ 2 616,00	$ 4 748,04
Distance	$ 665,80	$ 1 809,01

	AS-IS	Own Vans	T1	T2	T4
Yearly Cost	$1 684 445	$1 440 921	$ 1 682 455	$1 718 748	$ 1 690 232
Savings	$ -	$ 243 525	$ 1 991	$ -34 303	$ -5 786

Solution	Saving	Customer experience
Own Van	$ 243 525	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 1 991	Current partner, minimal effort with integration and information flow
T2	$ -34 303	Current partner, minimal effort with integration and information flow
T4	$ -5 786	Developed infrastructure network, mitigating partner dependency, weekend deliveries

C2 VIP

Scenario Description	
Service Level	80%
Delivery window	10 hours
Total Orders	28761
Peak weeks	18, 19, 45, 46, 48, 50

Rates	Cost/parcel	Feature
T1	$ 6,49	Pricing
T2	$ 6,63	Scale
T4	$ 6,52	Weekend delivery

Model Output	Off peak	Peak
Number of vans	4	10
Total distance	478	2352
Total time	9	10
Outsourced orders	1999	1937

Van Daily Cost	Off peak	Peak
Van Rental	$ 200,00	$ 500,00
Drivers	$ 470,88	$ 1 308,00
Distance	$ 30,85	$ 151,78

	AS-IS	Own Vans	T1	T2	T4
Yearly Cost	$ 262 114	$ 268 356	$ 261 833	$ 267 481	$ 263 043
Savings	$ -	$ -6 242	$ 282	$ -5 366	$ -929

Solution	Saving	Customer experience
Own Van	$ -6 242	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 282	Current partner, minimal effort with integration and information flow
T2	$ -5 366	Current partner, minimal effort with integration and information flow
T4	$ -929	Developed infrastructure network, mitigating partner dependency, weekend deliveries

C2 CENTRAL

Scenario Description	
Service Level	80%
Delivery window	10 hours
Total Orders	10385
Peak weeks	24, 25, 50

Rates	Cost/parcel	Feature
T1	$ 6,49	Pricing
T2	$ 6,63	Scale
T4	$ 6,52	Weekend delivery

Model Output	Off peak	Peak
Number of vans	2	2
Total distance	56	98
Total time	7	10
Outsourced orders	948	2

Van Daily Cost	Off peak	Peak
Van Rental	$ 100,00	$ 100,00
Drivers	$ 183,12	$ 261,60
Distance	$ 3,61	$ 6,32

	AS-IS	Own Vans	T1	T2	T4
Yearly Cost	$ 94 272	$ 91 820	$ 92 281	$ 94 272	$ 92 708
Savings	$ -	$ 2 452	$ 1 991	$ -	$ 1 564

Solution	Saving	Customer experience
Own Van	$ 2 452	Company branding, control over operations, aggregate orders, synergies with returns/FxFF
T1	$ 1 991	Current partner, minimal effort with integration and information flow
T2	$ -	Current partner, minimal effort with integration and information flow
T4	$ 1 564	Developed infrastructure network, mitigating partner dependency, weekend deliveries

Figure E.2: Decision interface for C2