Zero Air Packaging

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Abstract

During and after the COVID-19 pandemic, most businesses start having an online presence. Along with those who already depended on this channel, there was a strong adherence and request for home deliveries, especially with regard to essential goods. Once this is not the case for luxury fashion, companies in this sector suffered an abrupt sales drop during 2020, with a full recovery estimated for 2021. As these witness the slow return on their investments to improve the service level of delivery, companies such as Farfetch have been dedicated to cost efficiency, mainly related to the transport of parcels, executed by third-party carriers. Additionally, given that the amount of greenhouse gases (GHG) released by the activity of these partners is accounted for in the company's carbon footprint, the sector has made an effort to approach the "Net-Zero Emissions" concept.

Based on these priorities, "Zero Air Packaging" proposes to minimize the amount of unused space in packages, as the reduction in volume will also be followed by a proportional reduction in the transportation costs and the reduction of CO_2 released during the shipping routes.

The solutions proposed to solve this problem are (1) upgrading the sizes of the largest boxes in Farfetch's packaging portfolio, (2) moving from double to single packaging in shoe purchases and (3) investing in an automatic packaging machine capable of making custom right-sized boxes.

Together, these 3 initiatives will, theoretically , provide the company with annual savings in transport costs around 4.53% and avoid the emission of almost 5,148 tons of carbon dioxide, while maintaining the same delivery routes. As Farfetch monetarily compensates for all CO_2 emissions released by its activity, the company will save 3.36% annually on offsetting costs. Since all initiatives prioritize the use of smaller and, therefore, cheaper packages, it will also be possible to save around 6.00% on the supply of Farfetch boxes and around 67.21% on Stadium Goods boxes.

Although these results are quite satisfactory, the concept of "Zero Air Packaging" is far from being achieved and should be addressed with the utmost urgency, allowing the company to positively contribute to climate change.

Resumo

Durante e após a pandemia de COVID-19, a maioria dos negócios passou a ter presença *online*. Juntamente com os que já dependiam desta vertente, assistiu-se a uma forte aderência e solicitação de entregas ao domicílio, principalmente no que tocava a bens essenciais. Não sendo este o caso da moda de luxo, as empresas deste setor sofreram uma queda abrupta nas suas vendas durante 2020, estando a recuperação total estimada para 2021. Enquanto assistem ao lento retorno dos seus investimentos para melhorar o nível de serviço de entregas *online*, empresas como a Farfetch têm-se dedicado à eficiência de custos, principalmente relativos ao transporte de encomendas, executado por operadoras de terceiros. Adicionalmente, dado que a quantidade de gases com efeito de estufa libertada pela atividade destes parceiros é contabilizada na pegada de carbono da empresa, a generalidade das empresas do setor têm-se esforçado para se aproximarem do conceito "Net-Zero Emissions".

Tendo por base estas prioridades, o "Zero Air Packaging" propõe-se a diminuir ao máximo a quantidade de espaço inutilizado das embalagens, visto que a redução de volume será também acompanhada de uma redução proporcional no custo de transporte e da redução da CO_2 libertado durante o percurso de entrega.

As soluções propostas para resolver este problema são (1) a otimização dos tamanhos das caixas maiores do portfólio de *packaging* da Farfetch, (2) transitar da embalagem dupla para uma única caixa em compras de sapatos e (3) o investimento numa máquina de embalagem automática capaz de fazer caixas à medida.

Em conjunto, as 3 iniciativas serão teoricamente capazes de proporcionar à empresa cerca de 4.53% de poupanças anuais nos custos de transporte e evitar a emissão de quase 5,148 toneladas de dióxido de carbono, mantendo as mesmas trajetórias de entrega ao domicílio. Visto que a Farfetch se compromete a compensar monetariamente todas as emissões de CO_2 libertadas pela sua atividade, a empresa será capaz de poupar anualmente 3.36% em custos de *offsetting*. Uma vez que todas as iniciativas priorizam o uso de embalagens mais pequenas e, por sinal, mais baratas, será ainda possível poupar cerca de 6.00% no fornecimento das caixas da Farfetch e cerca de 67.21% nas caixas da Stadium Goods.

Ainda que estes resultados sejam bastante satisfatórios, o conceito de "Zero Air Packaging" continua longe de ser atingido e deverá ser encarado com a máxima urgência, permitindo que a empresa contribua positivamente para as alterações climáticas.

Acknowledgements

"It was love at first sight" was my response to the question “Why Farfetch?” during my recruitment pitch to the Plug-in program. In 2019, I visited one of the Farfetch offices and instantly fell in love with the company: the colourful furniture, the beautiful pieces of art spread throughout the office, the natural light, the informality between people and the company’s values that were visible to the naked eye. Two years and a pandemic later, when researching the proposed thesis for the fifth year of my master’s program, I saw the ten internships available at Farfetch. The opportunity to join this organisation came sooner than expected, and I eagerly applied to 8 of the 10 proposals. After being accepted into my first choice, “ Zero Air Packaging”, my expectations were the highest, and during these 4 months, Farfetch never disappointed me. In that sense, I want to thank the company for seeing value in me and giving me this incredible opportunity. This internship was my first professional experience and made me believe that it is possible to love Mondays and leave home to work with a smile on my face.

Every company is made by its people and I was able to testify how Farfetch employees are the true soul of the organisation. I owe a special “Thank you” to all my team members, Carla, Carlos, Diana, Graça, Henrique, Marcela and mainly to José Adriano Moreira, my supervisor at the company. His dedication, patience and support outlined the course of this project, boosting its success and value for the company.

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Last but not least, I want to thank my family and friends for supporting me during this 5-year course, for constantly motivating me to achieve things for myself and for boosting my confidence in difficult times. And to Francisca Baía, my “Work Bestie”, who was a plus during my time at Farfetch. Your help, positiveness and friendship were substantial to this extraordinary experience.

"Só queria ser feliz... Ser feliz como o Dalai Lama... ou o João Baião."

Madalena Bourbon de Linhaça

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Acronyms and Symbols

AIB	Air Waybill
ATV	Average Transaction Value
FF	Farfetch
FFP	Frustration-Free Packaging
FPS	Farfetch Platform Solutions
FSC	Forest Stewardship Council
GHG	Greenhouse Gas
GTV	Gross Transaction Value
KPI	Key Performance Indicator
NC	NanoCellulose
NGG	New Guards Group
SG	Stadium Goods
VW	Volumetric Weight

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Chapter 1

Introduction

The current project was developed at Farfetch, a multi-brand luxury fashion marketplace based in London and founded in 2007 by the portuguese entrepreneur José Neves. Farfetch's mission is "*to be the global platform for luxury fashion, connecting creators, curators and consumers*" and, by reference, today, its marketplace integrates customers from over 210 countries with products supplied by over 1700 boutiques and brands located in more than 50 countries (Farfetch, 2022g). The company's unique blend of fashion and technology enables it to offer the most comprehensive selection of luxury fashion, resulting in a truly remarkable shopping experience.

In recent years, the company's mission was expanded towards sustainability, after the launch of "Positively Farfetch". In December 2020, this strategy was updated with long-term sustainability goals, including the intention of achieving Net Zero emissions by 2030 (Farfetch, 2020).

The title of this dissertation, "Zero Air Packaging", immediately reveals its main objective: to reduce the amount of empty space in the packages, shipping each product in the smallest possible box or envelope. Being integrated into Farfetch's packaging team, this project grew out of past efforts to improve the packaging portfolio, which has proven to be very beneficial, given its direct decreasing effect on delivery expenses and carbon emissions. Packaging is part of the supply chain department, which is integrated into the logistics department. In order to promote conscious business through the company's carbon footprint, logistics has set the goal of reducing carbon dioxide (CO_2) emissions by 4.6% per unit sold by the end of 2022, essentially implementing delivery initiatives. Considering the proportionality between package volume and its delivery carbon footprint, "Zero Air Packaging" is projected to significantly assist the organisation in achieving this target and becoming more "Climate Positive".

Using proper packaging is a concern for most e-commerce businesses, including luxury marketplaces like Farfetch and its competitors. Instinctively, the development of this project will consider the observed strategies implemented in similar companies as well as Farfetch's approach regarding packaging sustainability.

Facing numerous improvement opportunities regarding the use of inappropriately sized packaging, this thesis will focus on the implementation of three initiatives, with distinct potential and barriers to implementation: (1) The size optimisation of the larger boxes; (2) the optional removal

of the brand box in shoe orders by shipping it inside a single e-commerce Farfetch box; (3) and the installation of an Automatic packaging machine in a high volume warehouse.

1.1 Farfetch Presentation

Farfetch is a digital platform designed to support direct-to-customer luxury e-commerce for brands and boutiques around the world, making them accessible 24/7 to a growing elite client base. Beyond this, Farfetch provides its partners with a set of e-commerce tools, including all kinds of logistic services and order processing support, without any significant investments.

Given that the biggest amount of stock is not owned or held by Farfetch, which avoids considerable holding costs and risk, the company generates its revenue by charging a commission on sales processed on its platform, ranging from 25 to 33% (McKinnon and McCullough, 2021). Every time an order is placed on farfetch.com, one of the third-party couriers will collect the package at the boutique and deliver it to the customer's address, charging Farfetch for the transportation costs (Farfetch, 2022e). Farfetch's unique business model allows it to have more control over marketing, pricing, and the customer experience, which has been translated into continuous growth, in both sales and the number of employees. In 2021, Farfetch employed 6,464 people, which is practically 2 times the number of employees in 2017 (macrotrends, 2022).

Farfetch is structured into seven departments, including Operations, which are subdivided into several teams. The current project is integrated into the packaging team, which is part of the supply chain team, which belongs to a wider team, logistics. The logistics team is under the Operations department.

The company is based in London, United Kingdom and, in the past 15 years of its existence, it has opened a total of 28 offices in many different cities around the world, such as Porto, Guimarães, Lisbon, New York, Los Angeles, São Paulo, Shanghai, Hong Kong, Tokyo, and Moscow. With the purpose of increasing the service level of order fulfilment, Farfetch has been acquiring a few warehouses around the globe, which are strategically placed to support its' large scale demand.

The Farfetch Group consists of multiple different business units besides the marketplace. In 2015, Farfetch acquired Browns, the iconic British luxury boutique, hoping to gain a better understanding of the luxury fashion environment through the perspective of a physical store. Since then, Browns has been the pioneer for most technological innovations conducting Farfetch to revolutionize luxury retail (Farfetch, 2022a). Additionally, in 2018, Stadium Goods, a trainers and streetwear marketplace founded in 2015, joined the Farfetch group after recognizing the platform's potential for sales growth (Farfetch, 2022f). One year after, Farfetch also acquired The New Guards Group (NGG), which is the representative platform for 9 international world-renowned brands, such as Off-White c/o Virgil Abloh, Marcelo Burlon County of Milan, Palm Angels, Ambush, Unravel Project, Heron, Alanui, Kirin by Peggy Gou and Opening Ceremony. The combination of NGG's disruptive mindset, creativity and innovation and Farfetch's expertise in technology, data and logistics has successfully strengthened the group's strategy (Farfetch, 2022d). Likewise, in December 2021, LUXCLUSIF, a B2B luxury resale platform, joined Farfetch, after working closely with the

group for a few years. Since its foundation in 2013, LUXCLUSIF has been providing a custom service for the purchase, authentication and resale of second-hand luxury items, and as part of the Farfetch group, it aims to transition both marketplaces to be the worldwide platforms for pre-owned luxury fashion (Farfetch, 2021). More recently, in January 2022, Farfetch announced the acquisition of a beauty retailer, Violet Grey, which was followed by the launch of Beauty on the marketplace (Farfetch, 2022c).

Farfetch's ambitions go far beyond serving just as a mediator between partners and luxury customers, having founded Farfetch Platform Solutions (FPS) in 2015. This white label service is currently developing and managing online marketplaces and apps for more than 18 brands, including Harrods, Browns, Stadium Goods, Off-white, Palm Angels and Ambush (Solutions, 2022).

In 2015, Farfetch became the first Portuguese company to achieve the Unicorn status after being valued at over US$1 billion (DiChristopher, 2015), having only become a public company in September 2018 (Shen, 2018).

1.2 Motivation of the Project

The "Zero Air Packaging" project has emerged from the continuous development of increasingly sustainable packaging. For instance, in 2021, the packaging team noticed a gap in their portfolio and proceeded to optimize the size of the 3 existing shoe boxes, resulting in 3 smaller boxes and an extra box size in between. Taking into account that shoes is the second best-selling category in Farfetch's Marketplace, these 4 optimized (smaller) boxes are expected to bring annual savings of 2.4% in transportation costs and avoid the emission of more than 10 200 tons of CO_2.

Regarding the inclusion of new sustainable packaging options, since 2021, the packaging team has been introducing padded envelopes corresponding to specific box sizes that can be used as an alternative to those boxes while reducing the package volume in 33%. Despite the poor feedback regarding its appearance and arrival condition, the team is still developing new envelope sizes and, for example, in 2022 a new padded envelope for large clothing is due to be included in the portfolio, hoping to generate annual delivery savings of more than 0.52%.

Even facing such positive outcomes, there was still room for improvement and the team needed someone fully committed to these causes, giving rise to this dissertation.

1.3 Project Goals

As briefly mentioned above, the main goal of "Zero Air Packaging" is to continue developing the packaging portfolio to offer more optimized and flexible packaging options to all fulfilment locations (boutiques and warehouses).

Given that shipping costs are strongly influenced by the volume and weight of the package, decreasing the unnecessary amount of air inside the box by reducing its dimensions to fit the product can make the company avoid millions of dollars in transportation expenses. By shipping

less volume packages, more orders can be placed and delivered in the same truck and/or airplane, meaning a fewer number of trips, less fuel burnt and, consequently, a lower carbon footprint.

In that respect, the present project proposes to optimise the size of the larger boxes from the packaging portfolio, to offer customers the option of discarding the brand shoe box in case of trainers' purchase and to invest in an automatic boxing machine to produce the packaging for Stadium Goods Orders.

Besides moving the company towards sustainability and bringing considerable delivery savings, these initiatives are also expected to decrease the packaging supply costs and improve the operations workflow.

1.4 Methodology

The execution of this project implied a good level of integration, given the need for communication and agreement with other teams outside Packaging, such as Delivery, Sustainability and Supply Chain Design. In that sense, the student's On-Boarding lasted for 3 weeks, including a range of business inductions, digital learning, and a set of meetings with people within logistics. Regarding the inductions, these were group sessions directed to new joiners to help them understand the business and, in this case, the functions performed under the operations department, while also introducing them to Farfetch's culture and values. The Digital Learning was an individual learning path that included subjects like "Ethics & Compliance", "Health & Safety", Data Protection and training in the programming languages SQL and Google Big Query and in the software Looker. The individual meetings with Logistics' managers and analysts were crucial to understand their routines, the team structure, as well, to collect a few insights about "Zero Air Packaging" from people that have been in the company for a few years.

Afterwards, a set of visits to the packaging suppliers, warehouses and carrier facilities were immediately scheduled in other to meet the stakeholders involved, explore the problem closely to the source and identify its possible causes. This initial phase was also focused on research and, as expected, led to the development of the literature review.

The next step consisted in gathering the observations collected in the previous phase, mapping the current packaging portfolio, its gaps and define the core problem. A few brainstorm sessions came next, with the intention of finding alternative ways to act towards this issue and identifying innovative solutions to overcome it. Three key challenges were elected and, for each, it was necessary to define the requirements, design and prototype a methodology to test the potential of each idea and, when possible, to implement them in practice.

The last stage was dedicated to trying out these solutions, which involved collecting data, building the respective models, updating them regularly and, according to its results, raising new conclusions.

During the 4-month period, it was important to adopt an iterative approach, by re-visiting the planning phase during execution, questioning the agreed procedures or even rejecting ideas without enough potential.

The methodology described above can also be identified as the "5-Stage Design Thinking", which is articulated in five steps: empathize, define, idealize, prototype and test (Dam, 2022).

1.5 Dissertation Structure

This dissertation is structured as follows: After presenting the company and the motivation for the project in section 1, the next chapter, containing the literature review, is responsible for contextualizing the reader on packaging sustainability trends that currently surround the luxury fashion e-commerce industry. Chapter 3 outlines the problem, considering topics such as the ordering process, Farfetch's approach to sustainability, the current packaging portfolio, its environmental impact and the gaps that still need to be covered. In Chapter 4, all the initiatives and respective methodologies will be explained, from data collection, data cleansing, the main assumptions, how the models were built, what are the possible scenarios and what is the main classification criteria to distinguish them. Chapter 5 presents the results, their interpretation and the most favourable scenarios for all initiatives. Finally, Chapter 6 consolidates all the subjects covered in the previous chapters, the main conclusions, and future lines of action.

Chapter 2

Literature Review

This chapter aims to provide an overview of the many subjects related to "Zero Air Packaging", more specifically, to grant a clear image of the current theories, practices and gaps surrounding the choice of packaging by luxury e-commerce brands. Regardless of being focused on the online retail of personal luxury goods, the “Zero Air Packaging” project is a transversal trend to all the e-commerce businesses, as it allows companies to decrease their operational and delivery expenses and their carbon footprint. Beyond benchmarking Farfetch with its direct competitors in issues such as eco-packaging, this chapter will also explore the market evolution in the previous years, the main sustainability trends in Luxury fashion e-commerce, including packaging, how these influence consumer experience and anticipate what could be the future of packaging.

2.1 Luxury E-commerce Market

Since the very first COVID-19 lockdown, many luxury brands and wholesalers were forced to close doors, prioritizing the safety of their own staff, clients, and business partners. Given the extreme trade restrictions at the time, the predisposition to adapt in the short term could determine the survival of the business. A month into the first lockdown, luxury retailers were advised to address a set of priorities in both tactical and strategic planning to help them quickly restore sales volumes and reach customers all around the world: if not done yet, retailers should transit to a vertically integrated distribution model, develop an omnichannel strategy, enhance digital presence through online platforms and social media, reshape the operations model by consistently pushing e-commerce to the centre and consider partnerships with online multi-brand retailers (Achille and Zipser, 2020). Traditionally, luxury brands rely on the offline shopping experience, fearing to dilute brand exclusivity and luxury experience once transitioned to online marketplaces. Nonetheless, multi-brand online retailers are able to provide luxury customers with a wide range of premium brands and items, improving brand visibility and creating new opportunities for both existing partners and entrants. Farfetch is one of the most prominent and fastest-growing marketplaces for luxury goods with over 10 million active clients by 2020.

"*E-retail sites are opening the doors to the world's best luxury boutiques — boutiques that are open 24/7, without geographical borders. So this channel is both the next big challenge and a big opportunity for luxury brands.*" (Florine Eppe Beauloye, n.d.)

Despite the fact that COVID-19 may have hastened the rate of e-commerce growth, the trend toward this sales channel had already been verified and labelled as "Digital Darwinism". This concept symbolizes the evolution of consumer behaviour, comparing natural selection to companies' struggle to survive and do better than their competitors when technology and society evolve faster than firms' ability to adapt (Schwartz, 2002).

The integration of digital commerce has been more recognized and consolidated over the years and as a result, in 2018, online sales already corresponded to 8% of the global luxury market and roughly 80% of luxury sales were "digital influenced" (Achille et al., 2018). In comparison, according to Bain's Luxury Goods Worldwide Market Study, in 2021, online sales accounted for 22% of the luxury market and are expected to reach 30% by 2025 (BAIN & COMPANY, 2020). Additionally, the popularity of E-commerce has been heavily boosted by the younger customer demographic: together, Generation Z and Millennials will be accountable for 70% of the luxury market by 2025, contributing for a 130% overall market growth (D'Arpizio et al., 2020).

Even facing such positive perspectives, a fast supply chain response did not prevent the 22% decline in the global luxury market between 2019 and 2020 (D'Arpizio et al., 2021). Almost 2 years into the pandemic and considering the industry's efforts to restore its business operations and service levels, D'Arpizio and Levato (2021b) forecasted that, in 2021, the global luxury market would reach a total value of €1.14 trillion, which is 13% above 2020 but still 9% below 2019 (D'Arpizio and Levato, 2021b).

Moving specifically into personal luxury goods retail, which includes clothing, watches, jewellery, cosmetics, bags and other fashion accessories, the 2021 Bain & Company's annual study from the same authors predicted that, in the same year, this sub-market would be able to fully recover from the pandemic: between 2019 and 2020, the global personal luxury goods market value decreased from 281 to 220 billion euros (-22%) but, between 2020 and 2021, it was expected to reach 283 billion euros (+ 29% than 2020 and +1% than 2019) (D'Arpizio and Levato, 2021c). In what concerns e-retail of personal luxury goods, in 2021, the worldwide online luxury goods industry was worth 62 billion euros (Sabanoglu, 2022).

The personal luxury goods e-commerce market is co-shared by many multi-brand retailers besides Farfetch and, based on the degree of similarity, the main competitors are Mytheresa, Net-a-Porter and Matchesfashion (similarweb, 2022). Besides not being fully comparable to Farfetch, e-retailers, such as Amazon, ASOS and the brand Nike will be mentioned given their strong e-commerce presence and sustainability efforts.

2.2 Sustainability trends in e-commerce

"*Where once it was all about status, logos and exclusivity, luxury brands are now actors in social conversations, driven by a renewed sense of purpose and responsibility.*" (D'Arpizio and Levato,

2021a).

The percentage of luxury buyers looking for brands who are genuinely committed to sustainability, inclusive fashion and social responsibility, is expected to increase continuously and, for reference, in 2021 already 43% of Generation Z consumers preferred to purchase from companies with a good reputation for sustainability (Amed et al., 2021). Recognizing this business opportunity, many fast-fashion brands use "Greenwashing" to give the false impression of being environmentally friendly, providing misleading information about the materials and processes used to obtain its final products. By comparison, luxury brands are often more sustainable, given that high-quality products are built to last, which represents an environmental benefit. Even so, these companies continue to feature sustainability measures in their long-term strategies, promoting circular, ethical, slow, and conscious fashion and recognizing their individual potential to make a difference.

Regarding circular fashion, second-hand luxury resale is the most widespread practice: beyond reinforcing the timelessness, durability and enduring desirability of luxurious items, the luxury resale industry aims to increase items' life cycle, promote conscious consumerism and build demand for clients drawn by these topics (D'Arpizio and Levato, 2021a). Luxury resale appeals, in particular, to Millennials and Generation Z since it is a convenient and sustainable alternative to fast fashion and is often more affordable than first-hand luxury products. For instance, when purchasing luxury items, at least 50% of Millennials and 57% of Gen Z take into account its resale value (Boston Consulting Group and Altagamma, 2019). Additionally, given that most fashion trends are seasonal and that some objects gain value over time, many retailers see second-hand as a prosperous form of investment (Woodworth, 2019).

Furthermore, luxury brands are accountable for operating with ethical responsibility, regarding the source and fair trade of materials, the production methods, and the working conditions of its employees. Given that quality is inherent to luxury, these companies are very demanding about the quality of raw materials, directly threatening the preservation and regeneration of rich ecosystems. Nonetheless, since resources are the foundation of the supply chain, each manufacturer should prioritize the responsible and sustainable management of natural reservations and plantations (Vallejo, 2018).

In that sense, for example, Chanel, a French luxury fashion house, has purchased a minority share in Nature, a Boston-based firm focused on the manufacture of sustainable silk. The patented Activated Silk is made from silkworm cocoons and may be used in textiles, cosmetics, and medicinal items (Bhasin and Bloomberg, 2019). Another practice aligned with the circular economy approach and sustainable sourcing is using recycled pre-manufactured products and waste from other industries. For example, Salvatore Ferragamo, an Italian luxury goods company, has used a silk-like twill fabric produced from the leftovers of citrus juice manufacture (Ferragamo, 2017).

In addition, luxury manufactures are exploring the adoption of biotechnology to boost the sustainability of their methods, relying less on farming, extraction, and fishing (Faccioli and Sheehan, 2021). Conceptually, Biotechnology can be defined as the use of organisms, cells, components thereof, and molecular equivalents in product manufacturing through the combination of natural

and engineering sciences (Chemistry (IUPAC), 2014). For instance, Estée Lauder Companies, the global leader in prestige beauty, partnered with a biotech company, and both have been exploring the potential of anti-aging molecules extracted from botanical materials (Wray, 2020). Likewise, in 2018, Stella McCartney launched a bag made with lab-grown Mylo mushroom leather, potentiating the discontinuation of the use of leathers, furs and skins and their transition to a vegan brand (Stella Mccartney, 2021).

Besides production, luxury brands' operations also include design, distribution, and communication, extending its range of potential improvements regarding sustainability. In what concerns product design, apart from selecting environment-friendly textiles and dyes, fashion brands are pressured to minimize waste in their pattern creations, by reusing offcuts and end-of-roll and selecting fabrics with a repeated pattern, maximizing the usage of the entire roll. Furthermore, as the shape and measurements of the finished product directly influence the amount of packaging used, the product design should consider the avoidable waste by creating compact products. Directly, less bulky packages optimise shipping container space, allowing the transportation of more goods at the same time, decreasing the number of travels, the amount of fuel burned and the carbon dioxide (CO_2) emissions (Victoria Business, 2021).

During the COVID-19 pandemic, to manage the short-term economic crisis, many luxury brands and retailers have slowed down their transition to sustainability. However, prioritizing the selection of environmentally friendly materials and packaging to reduce carbon emissions can also be considered a competitive move in the post-pandemic economy. In this sense, it is suggested that sellers structure a strategy that incorporates environmental, social and ethical concerns, proposing collaborations, partnerships and shared responsibility within the luxury fashion sector (Fuxman et al., 2022).

2.3 Sustainable E-commerce Packaging

Even though most companies and retailers recognize the importance of sustainability, there are no universal guidelines on how to achieve it across all supply chains. To elevate the urgency of this global responsibility, major corporations have been collaborating and committing to similar ambitious targets regarding greenhouse gas (GHG) emissions (Feber et al., 2021).

Given the scale of its online marketplace, Amazon is the greatest example of a global corporation with a strong position to influence and spread market trends toward sustainability beyond its ecosystem. Since the co-foundation of "The Climate Pledge" in 2019 by Amazon, 313 public and private-sector brands have subscribed to this initiative, committing to achieve net-zero carbon emissions throughout their businesses by 2040, a decade ahead of the Paris Agreement 2050 deadline. To achieve such goal, these organizations agreed to regularly measure and report GHG emissions, implement decarbonization strategies through change and innovation, and take action to neutralize any remaining emissions (The Climate Pledge, 2022).

Considering the end-to-end view of the value chain, the direct and indirect impacts of packaging materials and a science-based method to calculate its GHG emissions, packaging is one of

most underrated subjects regarding e-commerce sustainability. Conceptually, the three basic elements of packaging sustainability are: minimizing non-recycled material leakage into the environment, enhancing circularity by incorporating recycled content (read section A.1) and developing recyclable packages, and dropping GHG emissions and carbon footprint across the value chain. Before deciding which path to follow, it is important to understand the connection between these three factors and the key trade-offs surrounding packaging sustainability. For instance, the highest recyclability and usage of recycled materials does not always imply the lowest carbon footprint. Beyond being prepared to quickly respond and adapt to such sustainability trends, every company should incorporate a proactive and transparent approach and educate all stakeholders involved in the packaging value chain (Feber et al., 2021).

Being the biggest reference in e-commerce and simultaneously committed to decrease its overall carbon footprint, Amazon has been developing a set of initiatives that together allow the providence of recyclable, protective and right-sized packaging to all its customers.

Beyond implementing packaging certifications to improve box recommendation and selection (read section A.2), Amazon Web Services (AWS) and the customer packaging experience team have been collaborating in the development of a Machine Learning Algorithm, that uses data from product descriptions, historical orders, and customer feedback from multiple channels, to accurately predict the correct packaging while producing the least amount of waste. Besides identifying items that do not need packaging at all (e.g., diapers) and pointing out those whose original box needs to be extra-protective, the model predicts what products might leak or what are the ones that can be shipped in paper bags, considering all category exceptions, and ensuring that all products are packed in the right-size box or mailer (AWS Retail Editorial Team, 2021).

Amazon started introducing flexible paper-based mailers (fully recyclable padded envelopes) in their 2019 packaging portfolio and given that these are made by sandwiching a water-based cushioning material between 2 layers of lightweight paper, mailers are reported to be 75% lighter than boxes and take up to 40% less shipping space (Figure 2.1). The cushioning effect that protects customer orders is triggered by the expansion of the recyclable adhesive holding the 2 sheets of paper after contacting with heat (Quigg, 2019; Sperber, 2020). By replacing bulkier boxes with mailers, more orders can be loaded and departed simultaneously, representing a smaller individual carbon footprint. In 2020, after incorporating the padded mailers in the packaging portfolio, the Machine Learning Algorithm shifted the usage of boxes from 69% to 42% (AWS Retail Editorial Team, 2021).

In short, the adoption of this science-based approach that combines lab testing, machine learning, and materials science has enabled Amazon to succeed in both scaling sustainability across its packaging supply chain and boosting customer experience (Amazon, 2022b).

Aligned with Amazon's 'Net-Zero Carbon by 2040' challenge, Nike has also established a similar journey towards zero carbon and zero waste, called 'Move to Zero'. This environmental approach is constantly updated and detailed in its annual reports, and every year it employs lower use of materials, water, and energy. In what concerns circular fashion and recyclability, customers can drop off their worn shoes and clothing at any Nike Store, where an expert will evaluate its

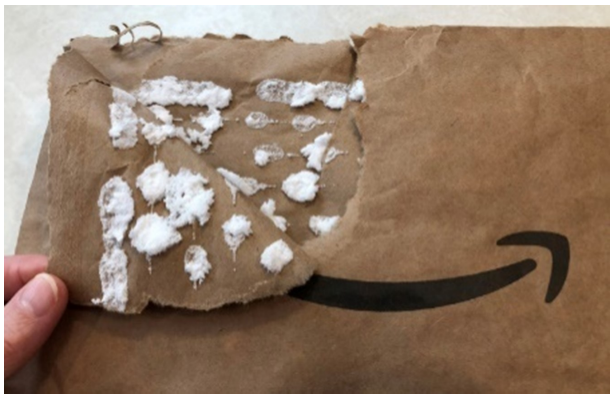

Figure 2.1: Amazon's Padded Envelope

condition and decide which items are recyclable, donatable or able to be re-sold after being refurbished. Any shoes and apparel labelled with the "Sustainable materials" tag is made with at least 20% and 50% recycled content by weight, respectively (Nike, 2022a). For instance, in 2020, Nike launched the 'Space Hippie' footwear collection in which all designs were made with varying percentages of recycled materials, as well as being shipped in alternative packaging that leveraged waste reduction. More specifically, instead of delivering a pair of shoes in the original box surrounded by another carton box, the packaging team opted to send these in a single functional and right-sized box adapted for e-commerce (Figure 2.2, on the right). Given the success of the line and the negative feedback regarding the durability of the box, the packaging team was pressured to improve it in terms of resistance. The updated box model is logo-free, has no external designs, has easy-to-open and return strips, and is reported to avoid 51% wastage when compared to the traditional e-commerce double box solution. In the short term, Nike hopes to implement 'One Box' in more products, but also to reduce the amount of paper used to stuff shoes and discard plastic bags used to package individual apparel items (Nike, 2022b).

Figure 2.2: Before and after of Nike's e-commerce packaging

Across many supply chains, packaging serves a big part of the customers' purchasing experience and, mainly in the footwear retail, it has been used as an asset to promote brand's sales and reinforce its values. In that sense, including the selection of packaging (between more or less sustainable options) in the buyer's decision-making process should help prevent any damage caused

by the lack of attractive packaging and improve its overall satisfaction (de Faultrier and Towers, 2011).

Similarly, ASOS, a fashion and cosmetics online retailer has devoted a significant amount of resources to provide its customers with the most ecologically friendly packaging possible, considering the pros and cons of recycled, recyclable, biodegradable, and compostable materials (ASOS, 2022a). Besides offering either recyclable or reusable options, the brand is committed to reduce the amount of packaging used for order protection during transportation, by discarding unnecessary material and optimising the size of boxes and bags to fit products more efficiently and carry less air. As a result, between 2018 and 2019, ASOS has raised the overall number of dispatched parcels by 17% while only increasing the total weight by 3%, demonstrating the direct benefits of improving packages efficiency. Currently, ASOS uses both carton boxes and plastic bags, despite the continual efforts to increase the bag's recycled content (already between 80-90%) or even to switch to fully recyclable plastics. In that sense, customers are sensitized to return their plastic bags so that they can be reused or transformed into new recycled bags (ASOS, 2022d).

Along with these initiatives, ASOS has also considered the adoption of compostable packaging, in spite of not being fully convinced of its environmental benefits. For instance, to guarantee that only carbon dioxide, water, and biomass remain from their degradation, compostable bags must be subject to strict conditions, such as being exposed to 58ºC for 12 weeks in a row, under a controlled environment. The most expectable scenario for these bags is to end up in a landfill, where they will probably fail to decompose correctly, resulting in even bigger waste and the production of methane, a gas 25 times more polluting than CO2. In addition, these packages are not either suitable for home composting facilities or recyclable as common plastics (ASOS, 2022c). Likewise, the inclusion of Biodegradable packaging was once over the table, but again neglected by ASOS, given the requirements of sunlight and oxygen exposure to break down safely into nature. These solutions are also not recyclable nor degradable in landfills or home composting bins (ASOS, 2022b).

Aside from environmental concerns, many businesses have been updating their packaging options as a cost-efficiency strategy. In order to meet heterogeneous demand, fashion vendors typically include many variations of packaging sizes for the same generic type of product. Because packaging is involved in many logistical activities (storing, picking, transportation, etc.), its size, shape, and structure have a significant impact on supply chain costs. In this regard, packaging optimisation models have proven to be very effective in cost reduction (Gámez Albán et al., 2015).

2.4 Luxurious vs. eco-packaging

When compared to the examples above, luxury retailers typically incorporate sustainable packaging at a slower pace due to the negative impacts it could have on the customer unwrapping experience. Even so, in recent years, players such as Farfetch, Matchesfashion, Mytheresa and Net-a-Porter have been integrating several sustainability performance indicators to minimize their overall carbon footprint and extending their environmental responsibility towards packaging.

Delta Global is the package supplier for Matchesfashion and Net-a-Porter, standing out as one of the best for combining the luxury unboxing experience with an environmentally conscious approach. Their concept emphasises brand preservation while actively conveying businesses' values, ensuring that all packaging steps are designed to decrease carbon footprint, from sourcing to manufacturing, transport, and consumption (Leona, 2021).

Matchesfashion was founded in 1987 as a physical store located in London, having only launched its online store in 2007. From the early days, packaging has served as brand identity and, for instance, the Matchesfashion luxury box is instantly recognized by the printed expressionist colourful marble designs (figure 2.3, on the right). The brand was advised to retain this design but to reconsider the magnetic closing system, which compromises the box's recyclability. In that sense, in 2021, Matchesfashion boxes started featuring perforation points around the magnet, making it removable and, indirectly, turning boxes recyclable. The aesthetic of the luxury box is already achieved with sustainable materials, given that the paper is ethically sourced and FSC certified, and the marble designs are printed using a water-based painting technique (Lockyer, 2021).

Figure 2.3: Matchesfashion's Eco-Box vs. Marble print Box

Besides the discussion of maintaining the brand's image, Matchesfashion is currently offering two packaging options (Figure 2.3), both free, but different in terms of ecology: the eco-box, which is a single carton box suitable for e-commerce, that uses less wrapping paper and is fully recyclable, and the Luxury box, with its iconic marble print, ideal for gifts and only recyclable after the removal of the magnets. In reality, selecting the luxury box implies double packaging, given that it will be shipped inside a protective and size-adjusted carton box (MATCHESFASHION, 2022).

Similarly, Net-a-Porter is operating in online retail of women luxury fashion since June 2000, as part of Yoox Net-a-Porter Group. Together, this group pledges to protect natural ecosystems by becoming a zero-waste company by 2023, ensuring that all operational waste is reused, recycled, or composted. This commitment is part of the infinity Strategy, which was launched in 2009 following Yoox's first e-commerce sustainable packaging, the ECOBOX. This low-impact packaging is made from a mixture of recycled and virgin paper that has been sourced sustainably in accordance with the Forest Stewardship Council certification, resulting in a high-quality and

durable material that is functional for long-distance deliveries, reusable for returns, and 100% recyclable. Once again, the choice between sustainable and signature packaging (Figure 2.4) depends on the customers' awareness of environmental issues and their willingness to give up the luxury unwrapping experience (YOOX NET-A-PORTER GROUP, 2022).

Figure 2.4: Net-a-Porter's Eco-Box vs. Signature Black Box

Mytheresa, a comparable brand to the previous examples, was founded in 2006 and based in Munich, offers two free packaging options (Figure 2.5): the signature yellow box and their environmentally friendly packaging (Mytheresa, 2022). Not being fully satisfied with this contribution, since July 2021 (beginning of fiscal year 2022), the brand has committed to drastically reducing its GHG footprint by scope (1,2, and partly 3), per order shipped and in total, intending to become climate-neutral in their operations but also in packaging, shipments and returns. Conceptually, Scope 1 covers direct GHG emissions from owned controlled sources, while scope 2 covers indirect GHG emissions from purchased electricity, heating, and cooling. Scope 3 is typically the most critical and hard to minimize, given that it covers all the other indirect emissions caused by the company's value chain.

Figure 2.5: MyTheresa's Eco-box vs. Signature Yellow Box

Until the end of June 2023 (the end of the fiscal year 2023), Mytheresa also hopes to a become zero-waste company, following KPI's such as total amount of operational waste and the disposal procedures from logistics, offices and stores per order shipped and in total. Lastly, the company aims to be transparent and inform its customers about their own orders' GHG emissions, by integrating the responsibility into their purchase (Mytheresa, 2021). In that sense, when

choosing shipping method and the type of packaging intended, any customer can donate 0,25€ to ClimatePartner, to help offset the non-avoidable carbon emissions of packaging, delivery, and potential returns from their own purchase. Taking into account the GHG emissions of the previous fiscal year, ClimatePartner, an expert for corporate climate action solutions, conducts the carbon footprint analysis as a baseline for Mytheresa while also supporting its website with future improvements to maintain carbon neutrality (ClimatePartner, 2021).

The main raw material for cardboard production is cellulose, which has have proven to be very low environmental impact, relative to other choices, like plastics. This raw material is very abundant and renewable, being found in plants (grass, algae), bacteria and in waste from forestry, agriculture and paper industries. The macro structure of Cellulosem make it very interesting to disposable packages: For instance, given its antimicrobial properties and permeability to water and oxygen, nanocellulose (NC) is very attractive for Food packaging, which is supposed to be made out of a strong, lightweight bio-based material. However, several studies have been conducted in order to develop new approaches for the future, namely by improving the humidity stability and the reuse of cellulose-based packages (Escursell et al., 2021).

2.5 Future of packaging

As a result of the pandemic, many luxury consumers have shifted their shopping habits to e-commerce. This trend is pushing online retailers to reconsider the unboxing experience in order to recreate the sense of excitement provided by luxury offline shopping, as well as its level of personal service. For instance, personalization on packaging, offering gift box/wrapping with messages unscripted or attaching QR codes to packages that lead to style tutorials and live-stream shopping events are examples of how to make unwrapping memorable (Leona, 2021).

Some brands selling though Amazon marketplace have been collaborating with the Amazon Packaging Support and Supplier (APASS) network to develop printed reversible packaging, reinventing the boxes to be reusable and informing customers about the environmental benefits of the new packaging. When received in good condition, the reversible print can be used as a typical store box, gift wrap (Figure2.6) or as a complement to the product (toy packaging may serve as an accessory) (Pierce, 2022).

Figure 2.6: Reversible Packaging transforming the initial box into a reusable gift box

Similarly, luxury brands should also educate all their stakeholders across the value chain according to the environmental impacts of packaging, making the transition to more sustainable

solutions less questionable to luxury consumers and less damaging to their unboxing experience. Besides updating their own websites and incorporating tabs specifically dedicated to their sustainability efforts, luxury brands must place recycle logos on their packages or even send cards inside gently communicating the importance of choosing responsible packaging (Leona, 2021).

Additionally, it is inconceivable to imagine the industry's future without increasing levels of automation and technology dependence. For instance, by incorporating intelligence systems across the entire supply chain, brands and retailers can reduce their overall waste, given that artificial intelligence and automatic data tracking can help them understand purchasing trends, improve forecasting, and control the waste production in real-time. In the last 50 years, packaging automation has been a topic of interest for many industries, especially the food and pharmaceutical industries, considering the long list of benefits, such as improved quality control, increased productivity and throughput, packaging standardization, reduced packaging material waste, reduced product damage, reduced labour costs and lower risk of employee injury (Nichols, 2020).

Considering the previous topics inducing the proportionality between the box size and its carbon footprint, the e-commerce industry is also evolving towards customized packaging automation at the smallest level, ideally shipping each item inside a fully optimised box according to its dimensions. Amazon has been interested in automating as many segments of its value chain as possible, such as product pricing, packaging or even transportation between warehouses. Considering the increasing number of orders processed by Amazon's fulfilment centres in the United States of America, in 2019, the company has decided to strategically install automatic packaging machines to box up customers' orders. This technology is supplied by CMC, an Italian machinery manufacturer, which produces a range of automatic wrapping systems, that had evolved from the original 1980's model suitable for food and confectionery industries. The "Carton Wrap 1000" machine firstly developed in 2014 and capable of producing nearly 1000 customized boxes per hour was the chosen model to be installed in dozens of U.S warehouses, constituting one of the largest Amazon's steps towards automation and sustainability. Conceptually, the products placed in the machine's initial conveyor belt are dimensionally scanned and enveloped second later in a custom-built box. Beyond avoiding millions of dollars in delivery and operational expenses, these solutions prevent the emission of millions of tonnes of CO_2, being the considerable investment totally covered by the "The Climate Pledge" fund. Conscious of the number of employees that might be replaced by these machines, Amazon expects to re-invest the efficiency savings in new and more valuable jobs (Dastin, 2019).

For the same reasons, some fashion retailers have also implemented automatic packaging solutions, which is the case of Macy's Inc, an American omnichannel retailer that comprises three retail brands: Macy's, Bluemercury and Bloomindale's. By 2020, the company was already using auto-boxer and auto-bagger machines, capable of building perfectly fitting packages. In the 2020's sustainability report, Macy's group reported that this "fit-to-size auto-boxing technology" was reducing their box volume up to 50% (Inc, 2021). Given that Bloomingdales is specialized in luxury multi-brand retail, both through its 50 department stores chain but also through its online platform, it is safe to assumed that packaging automation has arrived at luxury online retail.

More recently, technologies such as additive manufacturing and 3D printing have also been tested in the development of packages that fit perfectly the shape and volume of the inner item. Beyond reducing the package volume, these procedures use less raw material (wasted paper material), boosting the sustainability of packaging production and reducing the resulting carbon emissions (Escursell et al., 2021).

Chapter 3

Problem Statement

The current section illustrates the purpose of the dissertation by addressing issues such as the entire order processing workflow, the current Packaging portfolio, how it is being adjusted to "Zero Air Packaging" and what discrepancies still need to be covered. Based on these points of improvement, a set of initiatives will be suggested, promoting cost efficiency and a positive impact on the environment.

3.1 Operations Overview

In 2021, more than 8.7 million orders were placed and fulfilled across all Farfetch platforms (marketplace and FPS), generating over US$ 5.3 Billion in gross transaction value (GTV). Farfetch's business is supported by the luxury fashion life cycle, which starts with the moment where the boutique products come to life in one of the Farfetch Platforms.

Every season, luxury brands showcase their new collections to boutiques, which may purchase a selection of those. If these boutiques are Farfetch partners, they will send an example of each new product to one of the five Farfetch production centres, so that these items can be created in the Marketplace. Creative Operations (CROPS) is the team responsible for planning the production, photographing the items received, creating product descriptions in the greatest detail, translating them into 16 languages, pricing, uploading this content to the website and managing the whole catalogue. Since this is the only moment that Farfetch staff has physical access to the product, CROPS is also accountable for making a packaging recommendation according to the product's perceived volume and shape. After this, the products are returned to the partner.

Regarding Operations, the employees working under this department support the full length of the order processing workflow, enhancing the organization's overall performance. As can be seen in the scheme in Figure 3.1, this process is composed of 6 steps: (1) stock validation; (2) fraud check; (3) product packaging; (4) shipping preparation; (5) parcel pickup; and (6) order delivery. Whenever a boutique order is placed, the partners or warehouses holding the requested products will be supported by a partner team during this process, especially in steps 1, 3, 4 and 5. Besides

solving daily issues, the partner team helps partners reach success, by improving their main KPIs and following strategic projects.

Figure 3.1: Order Processing Workflow

In the first step, partners need to physically check if they have the product requested online by the customer. If the boutique has no stock available, the workflow will check for an alternative partner to fulfil this order. Otherwise, the order is cancelled, and the customer is refunded.

Next, comes the fraud check, in which more than 94% of transactions are processed automatically. However, when an order is suspicious, the fraud team will manually verify personal details before approving it as a legitimate order or cancel it for fraudulent behaviour.

The third step is product packaging, where the partner selects the box or envelope in which they will be shipping the item to the customer. This choice should be based on the box recommendation provided by Farfetch. The Logistics Planning & Intelligence team provides partners with packaging forecasts that evaluates if its current packaging stock is enough for the forecasted sales in the next 2 weeks, specifically advising them on the quantity and sizes they should purchase from Farfetch. Even after being pressured to pack items inside the smallest box possible, partners do not always select the best size since they perceive it as the opposite of a luxury experience. Given that the dispatched volume has a huge environmental impact, this disagreement is one of the main sustainability challenges.

At this stage, the package is not ready to be shipped yet: the partner needs to create the shipping label and print the Air Waybill (AWB) and attached them to the box. The AWB carries the details of the carrier and the address of the customer and, if any issues appear, the Customer operations team will be accountable for solving them. Currently, due to a sustainable initiative aiming to minimize the use of paper (“Paperless”), the invoice and the return instructions are sent to the customer by email.

The fifth step is the parcel pickup, in which the package is handover to the carrier for delivery. Carriers are third-party logistic partners, and currently, Farfetch has established partnerships with over 15 global companies, such as DHL, UPS and FedEx. When partners face any problem with the carrier or the shipping, they can create an "exception" and the delivery support team will be automatically notified.

Regarding the last step, order delivery, this is fully supported by the delivery team, which is constantly developing new services and managing carriers and custom relationships.

3.2 AS-IS Packaging Portfolio

According to the order processing workflow, whenever an order is placed, the partners holding the requested products are responsible for the packaging step, which should be based on the recommendation attached to each item. Depending on the packaging forecast and the expected volume of sales, partners may order varying quantities of Farfetch branded packaging at their convenience.

3.2.1 Corrugated Boxes

Since June 2022, the box portfolio has been composed of 13 different sized corrugated boxes (see Figure 3.2). This range covers most product categories sold through the Farfetch marketplace, offering both small and large solutions for accessories, clothing, shoes, boots, bags and coats.

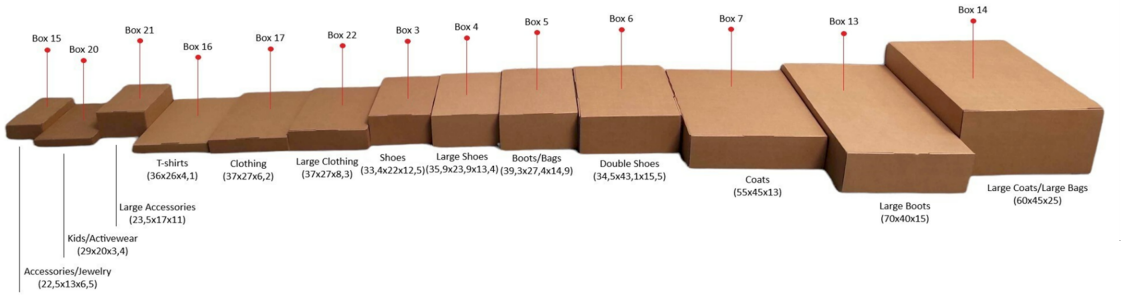

Figure 3.2: Corrugated Boxes Portfolio

Since these boxes were designed to pack different categories of products, their interior dimensions are not directly proportional either, as can be deducted by columns 3, 4 and 5 from table 3.1. Regardless of the box category label, if a box is the smallest suitable option, it can be used to pack any other product category. Considering the historic percentage of utilisation (in the 7th column), the most requested boxes are box 17 (19.1%), box 16 (17.1%), box 3 and 5 (10.4%, each).

As previously stated, delivery costs are influenced by a few variables and their combination, including the route trajectory, distance travelled, transportation mode (road, ship, or aeroplane), duties and taxes for importation, and the weight and/or volume of the freight. Currently, regarding the package features, all carriers are charging Farfetch for the highest value between dead weight (in kg) and volumetric weight. As the name suggests, the volumetric weight is a variable similar to volume (D1 * D2 * D3), which is shown in the equation 3.1:

$$Volumetric\,Weight = \frac{Length(cm) * Width(cm) * Height(cm)}{Dimensional\,Constant} = \frac{Volume(cm3)}{M} \tag{3.1}$$

Even though Farfetch is working with different box suppliers around the globe, the main characteristics of the box are standardised within all sources. For instance, the paper used as raw material is 100% recyclable and FSC certified, and the final product is a corrugated Fiberboard featuring a single wall and type E flute (see figure C.1).

Table 3.1: Boxes' internal dimensions, volumetric weight and expected demand (based on historical data)

Box	Label	Length (cm)	Width (cm)	Height (cm)	Volumetric Weight	Historic Volume Shipped
3	Shoes	32.2	21.2	12.1	2	10.39%
4	Large shoes	34.7	23.1	13	2.5	7.62%
5	Boots / Bags	38.1	26.6	14.5	3.5	10.39%
6	Double Shoes	33.3	42.3	15.1	4.5	6.23%
7	Coats	55	45	13	6.5	2.71%
13	Large Boots	70	40	15	8.5	1.34%
14	Large Coats / Bags	60	45	25	13.5	1.07%
15	Accessories / Jewelry	22.5	13	6.5	0.5	6.41%
16	T-shirts	36	26	4.1	1	17.07%
17	Clothing	37	27	6.2	1.5	19.09%
20	Kids / Activewear	29	20	3.4	0.5	6.03%
21	Large Accessories	23.5	17	11	1	4.74%
22	Large Clothing	37	27	8.3	2	6.92%

In what concerns the box design, this is also standardised, independently of the size or the supplier. As can be seen in figure C.2, this design has minimal branding, only in the interior, and features an easy-to-open strip and a return tape. These two last details improve, respectively, the customer unboxing experience and the life cycle of the box, in case of return.

3.2.2 Padded Envelopes

Since July 2021, the packaging team has been introducing 100% paper envelopes into their portfolio, with the same identification number as the equivalent replacement box. In the first year, three envelopes were simultaneously developed with the areas of 270*330 mm^2 , 330*350 mm^2 and 370*445 mm^2, as an alternative to boxes 20, 16 and 17, respectively (figure 3.3). Besides being made out of 100% recyclable and FSC sourced paper, one of the 3 sheets that comprise the envelope is the padding, which is responsible for creating a damping effect and offering a minimal protection to the items inside (figure C.3).

Figure 3.3: Envelopes 20,16 and 17

These solutions are reported to pack less 33% of air while also being able to ship the same items that would be sent in a box, except for heavy and sharp products or those who need to be shipped inside the original branded box. In this sense, it is easier to implement padded envelopes for the transport of clothing and activewear, where there is no need for impact support.

Given that, together, boxes 20, 16 and 17 have a demand of 42.19%, the benefits of this strategy began to appear in the following months: when checking the carriers' reports, the team realised that the average cost per shipment charged by volumetric weight decreased, while the average cost per shipment charged by dead weight increased significantly: most envelopes were being measured by dead weight and the remaining ones were being measured at a lower volumetric weight than the corresponding boxes. According to the team's projections, in 2022, the outbound shipping savings coming from this initiative will exceed 1.4% of total delivery expenses until the end of the year.

Furthermore, envelopes bring considerable environmental benefits, once delivery containers are able to carry more packages at the same time, optimising the use of space and fuel consumption. For instante, regarding 2021, DHL revealed that, in contrast to 2020, the average emissions per shipment were reduced by 13.5%, and the emissions per kilogram decreased by 7.7%. Despite the fact that this is the product of several initiatives, these 3 envelopes were the primary reason for the carbon footprint decline.

3.2.3 Supply, Stock Management and Distribution

Recognizing the boost that Farfetch Marketplace can provide to their sales, a growing number of boutiques all across the world have become partners with Farfetch, reaching 1700 recently. In addition, in 2021, Farfetch fulfilled more than 8.7 million orders from more than 3.2 million customers spread across 210 countries. Along with increasing network complexity, there has been a substantial push to enhance and standardise service levels globally.

Likewise forecasting and stock management, packaging is also a logistic service provided to Farfetch partners. In that sense, there is also the need for a packaging network composed of several suppliers, stock facilities and distributors.

Regarding the boxes, Farfetch is currently being supplied by 3 main corrugated packaging companies, separately based in London, Dublin and Guimaraes. These suppliers operate many facilities in Europe, implying that all continents, including Europe, are supplied from these locations. Likewise, the production of envelopes is handled by 2 British suppliers.

After production, packaging pallets are transported and held in one of the 11 packaging warehouses, located in Portugal, England, Italy, The Netherlands and The United States of America. The range and quantities of packaging transported to each warehouse depends on which boutiques it will fulfil.

Most contracts established between Farfetch and its Packaging Suppliers are Delivered Duty Paid (DDP), which means that the seller is responsible for managing the transportation and delivery of the merchandise to the specified locations, after paying for all applicable taxes and fees and obtaining import authorization. The main transportation modes used by these companies are air

and land, but recently water started to be used to ship packaging from Europe to the The United States of America. The replacement of air transport with waterway or even road transport has a significant decreasing impact on CO^2 emissions, which are accounted for in the company's scope 3 emissions calculation.

3.3 Packaging Recommendation and Selection

3.3.1 Packaging Recommendation

As previously mentioned, when brands and boutiques intend to sell a selection of their products in the Farfetch marketplace, they have to send them to a CROPS facility, which will be responsible for uploading the items in the platform. This part of the operations workflow is called production because, since the arrival of the products until being returned to the partner, these products go through a standardised sequence of steps, including packaging recommendation. Despite the fact that the staff has a limited amount of time to perform this task, this is the only chance to propose a packing size based on the product' shape and gross volume. Besides recommending by looking at the different boxes placed in a distant wall, the staff faces other limitations that can lead them to the wrong recommendation. For instance, the partner only sends one product size and, in case of shoes, sometimes, only one shoe is sent and without the original branded box, which should also fit into the recommended box.

In that sense, since 2019, Farfetch has been developing Machine learning algorithms to recommend the best packaging solution given the product characteristics and historical data regarding the packaging size used in similar products. Given the recommendation initially provided by CROPS, the algorithm revises it and may correct it if a better one exists.

Nonetheless, without accessing the true dimensions of an item, these algorithms will always imply considerable errors. Simultaneous to the development of "Zero Air Packaging", there is also another project trying to take the measurements of all products' dimensions and weight at CROPS before sending them back to the partners. This data will directly feed a new algorithm that will be capable of returning a packaging solution with the smallest error possible.

3.3.2 Packaging Accuracy

To control partner behaviour concerning the selection of packaging, Logistics created a new KPI, Packaging Accuracy, that essentially traduces the percentage of orders placed to a certain partner in which the packaging recommendation was followed. However, if a partner chooses to pack the item into a smaller box, this choice is positively recognized to the calculus of this KPI (equation 3.2). On the other hand, if the recommendation is too small to pack the order, it will be unreadable for the packaging accuracy and the partner will not be penalised if a bigger but more appropriate package is used.

$$Packaging\,Accuracy = \frac{No.\,orders\,sent\,in\,the\,recommended\,box\,(or\,smaller)}{No.\,boutique\,orders} \tag{3.2}$$

In order to motivate partners to enhance their overall performance, Farfetch created an incentive program, frequently updated, featuring conditional benefits according to their KPIs values. For instance, regarding Packaging Accuracy, if the partner follows Farfetch box recommendation or uses a more appropriate box in 85% of their orders, they will receive 0.04% of their monthly average transaction value (ATV), which is the value from all orders that they sent, including what was eventually returned.

3.4 Packaging Initiatives

Zero Air Packaging can be achieved through three parallel streams: by recommending the right packaging through an algorithm fed with as much information about the product as possible; by selecting the right packaging, which is dependent on the partners; and by offering the right packaging, which is the primary role of the packaging team.

Over the previous year, this team was involved in many projects that include the optimisation and expansion of their portfolio, the inclusion of new suppliers and warehouses, and the adoption of technology to improve operations and data collection. For instance, regarding the boxes portfolio, there was a recent update in the shoe boxes 3,5 and 6. Taking into account the category's potential to lower delivery expenses and the company's carbon footprint, the team created an optimisation model that proposed new sizes for the old shoe boxes and returned a new box between 3 and 5 (see table 3.2). As a result, this adjustment is estimated to save roughly 2.4% of transportation costs per year and prevent the emission of more than 10 200 tonnes of CO_2.

Table 3.2: Old and New Shoe Boxes

Shoe Boxes					
Until June 2022			After June 2022		
Box	Label	Dimensions	Box	Label	Dimensions
3	Shoes	35 x 23 x 14	3	Shoes	32.2 x 21.2 x12.1
5	Boots / Bags	38 x 30 x 14	4	Large shoes	34.7 x 23.1 x13
6	Double Shoes	37 x 45 x 15	5	Boots / Bags	38.1 x 26.6 x14.5
			6	Double Shoes	33.3 x 42.3 x15.1

Concerning the padded envelopes, a new one comparable to box 22 is set to be launched, with the dimensions of 500x460mm^2, which is expected to represent a total delivery savings of 0.52% at the end of a full year. The benefits of using envelopes instead of boxes are indisputable, both in cost efficiency and environmental impact. However, taking into account the quality and price range of the items sold through the marketplace, some clients complain about the conditions of envelopes when they arrive at their destination, which is clearly damaging their luxury experience. In that sense, the team is constantly exploring new solutions to balance the interests of both parts.

The use of technology to increase the efficiency of packaging is also being analysed. For instance, in collaboration with one of the Farfetch warehouses, the packaging team is investigating

the feasibility of implementing an automatic packaging machine. By scanning the item's measurements in the entry conveyor, this technology can manufacture right-sized boxes at very high output rates, decreasing the cost and carbon footprint of each box, while also improving overall productivity.

Despite the fact that the team has already identified and addressed the major flaws in its services, the "Zero Air Packaging" should continue to enhance the packaging portfolio, in order to offer better options to partners and customers and to decrease expenses associated with packaging supply and delivery. In addition, this approach will help the Logistics department meet its 2022 sustainability target of reducing 4.6% of carbon emissions per box delivered, which should indirectly contribute to the company's commitment to achieving Net-Zero emissions by 2030 (see Appendix B).

3.4.1 Size Optimisation of Large Boxes: 7,13 and 14

Despite the fact that large item's category have the lowest utilisation rate (5.1%, table 3.1), the boxes 7, 13 and 14 correspond to volumetric weights of 6.5, 8.5 and 13.5, respectively, which are the highest values within the whole portfolio. Moreover, according to table E.1, displaying the percentage of shipments and the amount spend per weight threshold, it is possible to observe that the cumulative amount spent in the packages measured from 6.5 (inclusive) is around 9.4%, inferring that the (cumulative) transportation cost of larger boxes is higher than its (cumulative) demand.

It is important to clarify that the labelled volumetric weight may not be the same measured and charged by the carrier. If a box is heavier than it is bulky, it will be charged by its dead weight instead of volumetric weight, falling into a different threshold than originally expected.

One of the project's goals is to optimise the size of boxes 7, 13 and 14, so that they fall into smaller weight thresholds, while continuing to cover the same product categories and sizes.

As mentioned in the appendix B, Farfetch Boutique is an integrated partner responsible for reselling customer returns when they arrive in good condition. In one of the visits to its facilities, the staff suggested the incorporation of a box with a size between box 7 and 13. Attending to this request, two different scenarios will be considered: (A) The optimisation of boxes 7, 13 and 14, without adding any other box; (B) The optimisation of boxes 7,13 and 14 and the proposal of a new box (between 7 and 14).

3.4.2 "2 Shoes 1 Box"

Following last year's optimisation of boxes 3, 5 and 6, significant delivery savings are expected once the newer sizes are supplied to the majority of partners. However, this effort does not cover every possible improvement in the footwear category. For example, shoe orders always requires double packing, as seen on the left of Figure 3.4, implying the transport of unnecessary amounts of air and the use of a larger Farfetch box for delivery, according to the proportions of the brand box. Despite the fact that certain partners are the brands themselves, Farfetch cannot dictate

the dimensions of their boxes, which directly impact the purchase's delivery costs and carbon footprint.

Considering the Nike's example in section 2.3, this project will propose the optional disposal of the branded box in the case of trainers, so that these type of items can be shipped within a single, suitably sized box, as shown on the right of figure 3.4. This sub-category is populated with the less exclusive products within the marketplace, implying that the (optional) removal of its label box will have little influence on the customer's luxury experience.

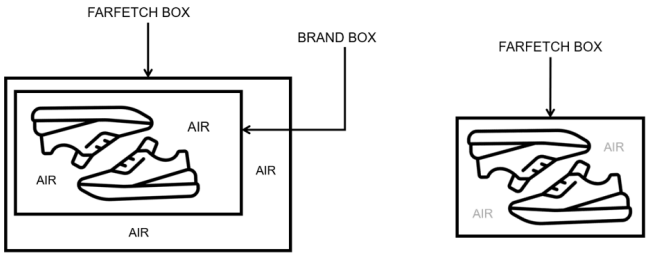

Figure 3.4: AS-IS and TO-BE Trainers Packaging

3.4.3 Boxing Machine at Stadium Goods Warehouse

As stated in the Introduction chapter, Stadium Goods is an online marketplace focused on the retail of trainers and streetwear. As part of Farfetch Group, this integrated partner sells through farfetch.com, although it continues to sell on its own platform (managed by FPS) and others such as Amazon and Ebay.

Whenever a Stadium Goods product is requested through Farfetch marketplace, it is wrapped using the Farfetch branded packaging (usually boxes 3,5 and 6). Otherwise, Stadium Goods uses their own branded packaging featuring the dimensions presented in table 3.3. Regarding the latter, boxes I and II are reported to be used 95% of the time, corresponding to the two smallest boxes in the Stadium Goods packaging portfolio, in terms of volumetric weight. Compared to Farfetch's shoe boxes (3,4,5 and 6), Stadium Goods' packaging options seem far from optimal, even though these are focused on a single product category, trainers.

Table 3.3: Stadium Goods Branded Boxes

Box	Length (cm)	Width (cm)	Height (cm)	Volumetric Weight
I	38.10	25.4	15.24	2.95
II	40.64	30.48	15.24	3.78
III	38.10	25.4	25.4	4.92
IV	40.64	30.48	30.48	7.55
V	38.10	38.10	38.10	11.06
VI	60.96	60.96	66.04	49.08

Considering the volume of SG orders shipped in 2021, which was very significant within the Farfetch Group, the project suggests investing in an automatic packaging machine, from which it

will be possible to obtain ideal size boxes for the transport of Stadium Goods products. Besides increasing productivity, this proposal will increase automation during order fulfillment and the overall service level.

Followed by a series of meetings with the major packaging machine suppliers, "CMC Genesys - Tote system" was the chosen technology to power this initiative (figure C.4), which is capable of producing 680 cardboard boxes per hour, with the maximum dimensions of 58cm*38 cm*32cm and minimum dimensions of 26cm*20cm*6cm. Regarding box design, this technology is able to reproduce any template using a plotter to cut and crease the exact drawing. In the case of a multi-item order, scraps are not discarded but folded to act as barriers between the different products. The boxes produced by the CMC Genesys, like the ones used by Farfetch, include an "easy open" and a return strip, boosting the consumer experience (CMC, 2020). By default, the machine is fed with 2 fan folds, implying that it can be supplied with 2 different cardboard materials (with different logos, for example).

Unlike any other model from the same supplier, this auto packaging system is linked to the warehouse, automatically picking and consolidating orders before conveying them to the feeding station, where items are dimensionally scanned and weighted.

Aside from decreasing labour expenses, the machine's ability to manufacture right-sized boxes can generate considerable savings in cardboard consumption, transportation costs and carbon footprint.

Chapter 4

Methodology

The current chapter is responsible for revealing the practices followed for the three proposed initiatives, allowing the reader to understand the sequence of steps taken and to reach the same results and conclusions. After restating the three problems and the approaches chosen for each one, it is necessary to explain how the data was collected and processed, enumerate and justify the assumptions adopted and how these limit the feasibility of the method, which tools were used and how the model was designed and built.

4.1 Optimisation of boxes 7, 13 and 14

As stated in the Chapter 3, the larger boxes within the portfolio (7,13,14) are accountable for 9.4% of delivery expenses, while only representing 5.1% of the total number of boxes used. By default, larger boxes are more expensive to ship and are associated with a heavier carbon footprint. Additionally, taking into account that these were designed to ship "exceptional" volumes, these end up being used more times than expected, transporting an unnecessary amount of air. These significant insights lead to the identification of an opportunity: Boxes 7, 13, and 14 require a dimensional optimisation.

4.1.1 Sample Collection

Given its strong analytical approach, Farfetch provides a comprehensive Cloud that stores all types of data associated with its business. For example, regarding product information, it is possible to obtain its brand, category, colour, size, season and many other attributes. However, when the brand does not provide product dimensions, Farfetch also does not have to access this level of detail.

Taking this into account and in order to understand if the larger boxes are accurately satisfying its main purpose, it was mandatory to collect a sample containing the length, width and height of voluminous items and what box was used to ship such product (out of the three boxes in study). As expected, this task ended up being one of the main challenges of the project, given the low usage of the boxes 7,13 and 14, the fact that large items are typically sold during Fall-Winter seasons and the project's deadline.

In that sense, the sample was gathered using two independent stock and order processing locations: Farfetch Boutique and the Venray warehouse. In both facilities, the packaging staff was asked to search for large items in-stock, measure them and simulate in what box these items would be sent to a customer. Regardless of the proportion of large item orders being conditioned by its seasonality, if an order was actually prepared to be shipped inside one of the boxes 7, 13 or 14, the corresponding measurements could also be attached to the sample.

Once this sample would more likely gather large clothing, accessories and footwear, it was important to outline a few guidelines. For instance, regarding coats, jackets, knitwear and other voluminous clothing, these needed to be folded before being measured, according to the Nordstrom folding Guidelines (figure D.1). Moreover, in the case of products that come inside the original brand box, such as shoes, the registered measurements must be from that same box.

As previously stated, Farfetch Boutique was established to store and resell "Refused Returns", which are generated when Boutiques reject returns from earlier orders placed on the Marketplace. The method used by this partner to measure the length, width and height in this experiment consisted in attaching measuring tapes to two intersecting edges of a table and a third tape perpendicular to the table plane fixed on the same corner (figure D.2). After 4 weeks, Farfetch Boutique was able to deliver the measurements and the corresponding Farfetch box of 114 items.

When comparing all fulfilment centres, the Venray warehouse is the dominant in order processing, accounting for 70% of total warehouse shipments annually. Recently, this facility acquired a Cubiscan 325 (figure D.3), which is a measuring and weighing technology that allows users to rapidly and accurately assess the dimensions and weight of large and irregular-shaped products. Conceptually, products must be placed on top of the device and their dimensional data will be collected by the infrared sensing technology, with a resolution of 0.05". Aside from facilitating the job and reducing human error, this reliable information is promptly recorded and made available to the company. Despite incorporating a weighing scale, the weight attribute provided by the Cubiscan was disregarded once most boxes are charged by volumetric weight rather than dead-weight. Given that this technology is very intuitive and features an user-friendly touch display, no extra training was provided to the staff. After a 3 week period, the sample collected in Venray gathered 2007 SKUs, precisely.

Regardless of the fact that the two sub-samples differed in both quantity and quality, they were merged into one containing 2,121 items and their 5 corresponding attributes: product ID, product's length, width and height, and the "used box" for shipping.

4.1.2 Data Cleaning and Preparation

The current section is focused on explaining the activities carried out to correct inaccurate, incomplete, and duplicate data, allowing the preparation of the data-set before submitting it to an algorithm. By modifying, updating or eliminating misleading data, it is possible to prevent inflated conclusions that distance the project from reality.

As mentioned in section B, a few returns that end up in Farfetch Boutique arrive without the original brand box. In these cases, the staff stores the items inside one of the two white standard

boxes that are only used by Farfetch Boutique: a smaller box measuring 34 cm*24cm*12 cm and a larger one measuring 50cm*33 cm*11 cm. After realizing that these specific combinations were very prevalent in the sub sample and that these proportions do not represent the Farfetch universe, it was decided to remove such records from the sample.

Furthermore, regarding the product dimensions, it was important to distinguish which one of the three values was the length, width and height. Presumably, this sort of human error occurred solely in the Farfetch Boutique sample, as well as duplicates, outliers and empty cells, which were attentively removed.

Thirdly, the "used box" attribute was disassembled into the corresponding length, width and height of the Farfetch branded box. Considering that a product gently folded and compressed inside one of the shipping boxes may have its volume "reduced", the number of items whose height was greater than its box height, for example, was rather common. In this case, all product measurements were fixed using the minimum dimensions of the two objects.

After this correction, it was decided to also dismiss the "used box" attribute. Like any other partner, Farfetch Boutique and the Venray Fulfilment Centre have individual packaging accuracies that differ from 100%. In that sense, this column was replaced by the values returned by the "ideal AS-IS box" function, which was specifically created to compare the 3 product dimensions with the current packaging portfolio, indicating the smallest fitting box that should be used initially. After filtering out all the products whose "ideal AS-IS box" was 7, 13 and 14, it was safe to assume that the model would not be accounting for the benefits of not recommending and actually selecting the right package in the AS-IS scenario.

Table 4.1: Expected vs. Verified proportions of Boxes 7, 13 and 14

Box	No. of clean records within the sample	Proportion of boxes within the sample	Expected proportion	Shorten sample with corrected proportions
7	210	15.50%	52.95%	210
13	618	45.61%	26.12%	104
14	527	38.89%	20.93%	83
Total	1355	100%	100%	397

Lastly, while checking the box proportions captured by the resulting sample (table 4.1 - column 3), it is noticeable that these do not match the expected proportions (column 4). In that sense, the 210 lines associated with box 7 were maintained, while the items associated with box 13 and 14 were radically and randomly shortened in order to correspond to 26% and 21%, respectively. As a direct consequence, the final sample only features 397 items, which might lead to over fitting and compromise the model's accuracy against unknown data.

4.1.3 To-Be Scenarios and Assumptions

Taking into consideration the large dimensional gap between the boxes 7, 13 and 14, its optimisation had to consider two possible scenarios:

- Scenario A: Boxes 7,13 and 14 are optimised and no extra box is added to the portfolio.

- Scenario B: Boxes 7,13 and 14 are optimised and an extra box is added to the portfolio.

Taking into account the historical demand for boxes 7, 13 and 14, it is considered that the new optimized boxes will continue to represent 5.11% of the total volume of boxes distributed to partners.

Furthermore, the delivery costs calculated in the AS-IS and TO-BE scenarios are based on historical costs by weight, whose proportionality can be represented through a linear regression, as shown in the plot below:

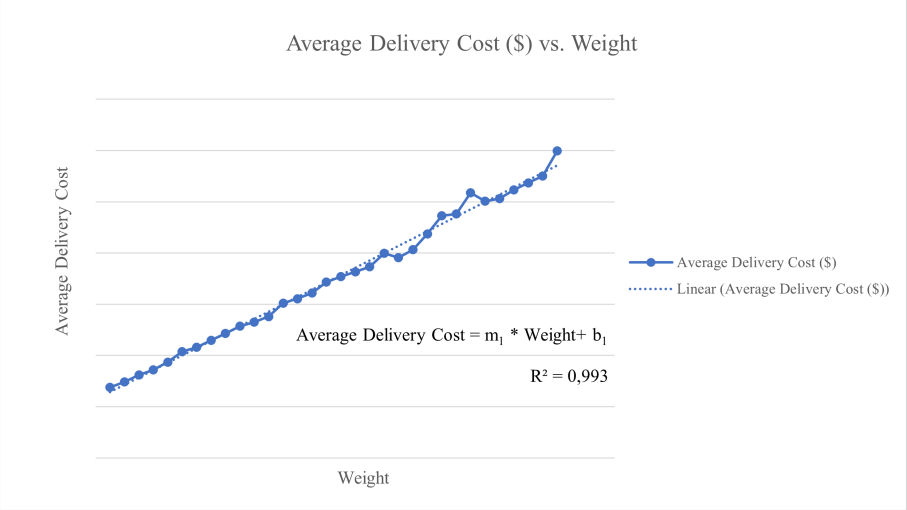

Figure 4.1: Plot of the Average transportation cost per weight threshold

The trendline drawn on the top of the graph has a coefficient of determination of 0.993, indicating that 99.3% of the cost variation is accurately explained by the weight variance.

Moreover, with the optimisation of the boxes 7,13 and 14, it is likely that the corresponding manufacturing costs will suffer a variation. Presumably, if one or more box dimensions are reduced, the cardboard area required to produce the box design will also be reduced, as well its cost. Looking at figure C.2, it is possible to estimate the minimum cardboard sheet area required to produce each box (equation 4.1).

$$Cardboard\ Area\ to\ produce\ a\ box = (Length + 4 * Height) * (2 * Width + 4 * Height) \quad (4.1)$$

Taking into account the average cost per box area, whose correlation is plotted in figure 4.2, it is possible to obtain a linear regression with a R^2 of 99.7%. This expression will be used to estimate the packaging supply costs for the new boxes, considering its dimensions and corresponding cardboard area.

Incremental Inventory costs will be disregarded in this model given that, in the AS-IS and TO-BE scenarios, the number of larger boxes required should be the same.

Furthermore, the volumetric weights considered in this study differ from those shown in table 3.1, which were calculated using equation 3.1. To approach the model to reality, the volumetric weight calculus should consider the external dimensions of the box (rather than the internal) as

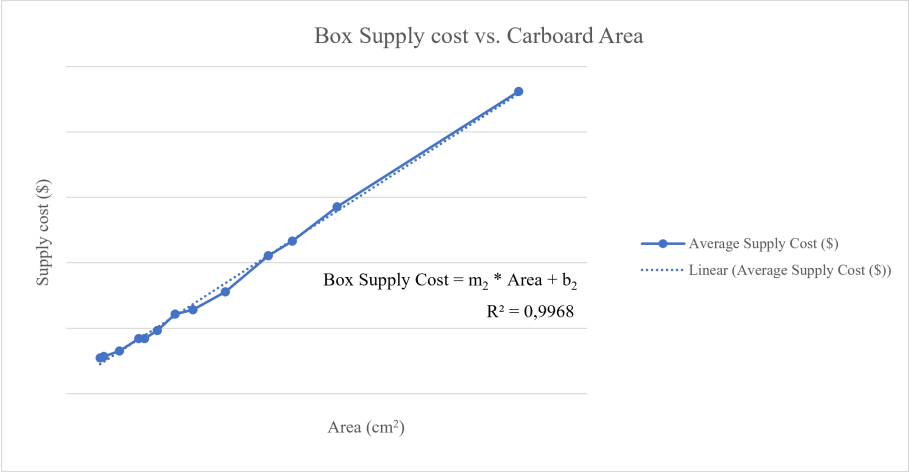

Figure 4.2: Plot of Supply costs per cardboard area

well as a 5% safety margin. This percentage is the average difference between the estimated volumetric weight of boxes 7, 13, and 14 and the actual volumetric weight charged by the carriers. In that sense, the volumetric weight of old and new boxes is calculated using equation 4.2:

$$Volumetric\ Weight = \frac{(Length + 1.2) * (Width + 0.8) * (Height + 0.4)}{(1 - 0.05) * M} \tag{4.2}$$

From this point, the volumetric weights returned for both scenarios will be directly compared to the 5th column of the table 4.2.

Table 4.2: Actual Volumetric Weights of boxes 7,13 and 14

Box	Lenght	Width	Height	VW
7	55	45	13	7.5
13	70	40	15	9.5
14	60	45	25	15

Lastly, the environmental effect of this approach will be compared against the total downstream transportation and distribution emissions reported in 2021 (153,200 tonnes of CO_2) and the logistic department's sustainability goal for 2022 (a 4.6% reduction in CO_2 emissions per unit sold). Given that Farfetch is committed to paying a certain amount for each tonne of CO_2 produced by its operations, the more carbon emissions that are avoided, the more savings there are in relation to upfront offsetting expenses. Furthermore, to help the reader visualize the benefits of this initiative, it is assumed that each tonne of CO_2 can be naturally offset by 60 trees after a full year of photosynthetic activity.

4.1.4 Model Building

The model focused on improving boxes 7, 13 and 14 was built using the Microsoft Office application Excel, more specifically, the add-in program "Solver". This tool runs an optimisation

algorithm, allowing to find an optimal value (minimum or maximum) for the objective cell, subject to the fulfilment of a set of restrictions.

Following the cleansing of the data sample, it was required to build the mathematical model to solve the problem, namely by defining the objective function, the decision variables and specifying what restrictions will be affecting the final solution.

Initially, each of the 397 sample records contained 5 attributes: product ID, product length, width and height, and the AS-IS "used box" for transport. Using these 3 dimensions, it was possible to calculate the volume of the product, which can be subtracted from the volume of the "used box" to obtain the percentage of empty space, i.e., the percentage of air inside the box. By estimating the volumetric weight of the "used box" (via equation 4.2), and subjecting this value as the independent variable in the expression displayed in plot 4.1, it is possible to obtain the AS-IS delivery cost for each record. The sum of the 397 delivery costs represents the total AS-IS delivery cost.

Regarding the TO-BE scenarios, it was necessary to structure the optimisation model, namely by defining the most relevant indexes (table 4.3), parameters (table 4.4) and the auxiliary variables (table 4.5).

Table 4.3: Relevant indexes

Notation	Definition	Range
b (Scenario A)	new box	b={7', 13', 14'}
b (Scenario B)	new box	b={7', ad, 13', 14'}
p	product	p={1,....,397}

Table 4.4: Decision Variables and Relevant Parameters

Decision Variables		Parameters	
Notation	Definition	Notation	Definition
L_b	Length of box b	l_p	Length of product p
W_b	Width of box b	w_p	Width of product p
H_b	Height of box b	h_p	Height of product p

Table 4.5: Auxiliary Variables

Notation	Variable Type	Definition
X_{bp}	Binary	If box b is used to ship product p, 1, otherwise, 0
VW_b	Continuous	Volumetric weight of box b
C_b	Continuous	Cost of shipping box b

The model's decision variables correspond to the Lenght (L_b), Width (W_b) and Height (H_b) of the new box, b = 7', 13', 14', which, when considering Scenario B, also includes an additional box, b = ad, between boxes 7' and 13'. The objective function aims to minimize the sum of the transportation costs C, that results from using the new boxes to ship the products incorporated in the final sample, whose count, as described in section 4.1.2, ranges from p = 1,2 ..., 397.

The model can be written as:

$$\text{Min} \quad \sum_{p}\sum_{b} C_{\text{b}}(VW_{\text{b}}) * X_{\text{bp}} \tag{1}$$

$$\text{s.t} \quad VW_{\text{b}} = \frac{(L_{\text{b}} + 1.2) * (W_{\text{b}} + 0.8) * (H_{\text{b}} + 0.4)}{(1 - 0.05) * M}, \ \forall_b \tag{2}$$

$$L_{\text{b}} \geqslant l_{\text{p}} * X_{\text{bp}}, \ \forall_{b,p} \tag{3}$$

$$W_{\text{b}} \geqslant w_{\text{p}} * X_{\text{bp}}, \ \forall_{b,p} \tag{4}$$

$$H_{\text{b}} \geqslant h_{\text{p}} * X_{\text{bp}}, \ \forall_{b,p} \tag{5}$$

$$L_{\text{b}} \geqslant W_{\text{b}} \geqslant H_{\text{b}}, \ \forall_b \tag{6}$$

$$40 \leqslant L_{\text{b}} \leqslant 80, \ \forall_b \tag{7}$$

$$30 \leqslant W_{\text{b}} \leqslant 50, \ \forall_b \tag{8}$$

$$13 \leqslant H_{\text{b}} \leqslant 30, \ \forall_b \tag{9}$$

$$15 \geqslant VW_{14'} \geqslant VW_{13'} \geqslant VW_{7'} \geqslant VW_{6} \ \text{(for Scenario A)} \tag{10}$$

$$15 \geqslant VW_{14'} \geqslant VW_{13'} \geqslant VW_{\text{ad}} \geqslant VW_{7'} \geqslant VW_{6} \ \text{(for Scenario B)} \tag{11}$$

Although "Zero Air Packaging" aims to decrease the amount of air inside the boxes, the objective function for both scenarios (equation (1)) is the sum of the transportation costs of the box assigned to each product p (C_b). Since this cost and the amount of air are positively proportional, if the model manages to minimise transport costs, the percentage of air inside the boxes will also be minimised.

The volumetric weights of the new boxes (VW_b) are obtained through constraint (2), which will be then used to determine the corresponding delivery costs. However, since the regression displayed in plot 4.1 must remain confidential, it is not possible to display an additional constraint representing the correlation between the C_b and VW_b.

Constraints (3), (4) and (5) ensure that each product fits correctly inside the box to which it was assigned, while constraint (6) distinguishes the boxes' proportions into Length, Width and Height. In addition, restrictions (7), (8) and (9) represent the dimensional ranges, within which the length, width and height of the new boxes can vary.

Constraint (10) applies to Scenario A only, imposing that, in terms of volumetric weight, all new boxes are smaller that the original box 14 and bigger than box 6, as well that, box 7' must be smaller than box 13', which must be smaller that 14'. Likewise, for Scenario B, constraint (11) imposes the same order within the new boxes, with the exception of having an additional box (b=ad), which should be bigger than box 7, but smaller than box 13.

After modeling the problem, it was necessary to choose one of the optimisation algorithms available: GRG Nonlinear (Generalised Reduced Gradient), LP Simplex (Linear Programming) or Evolutionary. Given the nonlinear nature of the current problem, LP Simplex was instantly

discarded. Regarding the other options, the Evolutionary algorithm was chosen above the GRG Nonlinear once it has a higher probability of finding a globally optimal solution (Fylstra, 2022). However, it is important to understand the major limits of the Evolutionary Solving method and how to overcome them in order to achieve the best solution possible.

For instance, this method does not guarantee that the optimal solution was reached: the algorithm stops after trying a number of iterations without any improvement, which can consume a lot of time, or by reaching the predefined time limit. When the Solver keeps converging to the current solution, this can mean that it has found a local optimal solution or that the population has lost diversity. In this case it is recommended to increase the mutation rate or the size of the population. For example, by default, the method uses a mutation rate of 0.075, which was gradually increased to 0.9 during the improvement phase. Starting with different initial values can also help to escape local optima. Additionally, there is another parameter limiting the capacity of the Evolutionary method, the "Maximum time without improvement". During this interval, Solver will keep searching for alternative solutions as long as it is making decent progress; otherwise, if it is unable to make significant advancements within the time selected, it will quit and present the best solution identified. For reference, the maximum time without improvement selected in the final run was 3000 seconds (FrontLineSolvers, 2022).

After the user decides to adopt the last results as the optimal, a "TO-BE ideal Box" function is responsible for returning the smallest fitting box for all products within the new box sizes. The corresponding packaging supply costs can be calculated using the linear function displayed in figure 4.2. Given the initial and final proportions of the new and old boxes, respectively, it is possible to predict the savings regarding packaging supply.

Considering the environmental impact expected from this initiative, the approach was complemented with the calculus of the carbon dioxide emissions avoided by replacing the old boxes with the new ones, for both scenarios. After accessing the total number of shipments sent per box (7, 13 and 14) per route (store country - customer country) and matching it with a table containing the CO_2 factor per route, it is possible to estimate the amount the CO_2 emitted during transportation in the AS-IS and TO-BE situations. However, these CO_2 factors are related to air transportation, which is not the case of the deliveries done by Farfetch carriers. In that case, it was also needed to separate the number of shipments regarding their shipping service (Standard or Express) and order type (International, domestic or Intra-europe).

According to the delivery team, it is possible to predict the transportation mode depending on the combinations between the variables above: if the shipping service is Standard and the Order type is Domestic or Intra-Europe, the transportation mode is probably Road. Additionally, if the store country is the same as the customer country and these are both located in Europe, road transportation will also be used. The remaining combinations are more likely to be associated with air transport. The sustainability team has stated that replacing air with road can reduce Carbon emissions by 93.35%. With this in mind, for a certain route, the CO_2 factor associated can be the tabled one or 6.65% of that amount.

4.2 "2 Shoes 1 Box"

According to the problem statement, all shoe orders imply double packaging: the interior box (or the brand box) and the exterior box (the Farfetch box suitable for E-commerce). The “2 Shoes 1 Box” initiative is suggesting customers to discard the interior box, which would reduce the size of the exterior box required for transportation. To minimise the impact on customer experience, it was decided to only offer this option for trainers, which are very resistant and flexible and do not require extra protection.

In order to simulate the impact in terms of delivery costs, packaging supply costs and carbon footprint, it was necessary to build a model similar to the previous one, with some exceptions.

4.2.1 Sample collection

Given that shoes is the second best-selling category and one of the most returned categories at Farfetch, the sample needed to build this optimisation model was sourced entirely from Farfetch Boutique. In contrast to section 4.1.1, this task required additional characteristics related to the category under study. For shoe orders only, the staff were asked to document the product ID, the measurements of each pair of shoes (figure D.4, on the left), the measurements of the brand box (figure D.4, on the right), and which Farfetch box was used for shipping.

After 5 weeks of data collection and using the same measurement method depicted in Figure D.2, Farfetch Boutique was able to provide a representative sample with 575 pairs of shoes and 8 attributes for each: product ID, the shoes’ length, width and height, branded box length, width and height and used box for transportation.

4.2.2 Data cleaning

Similarly to the data treatment performed in section 4.1.2, the main steps executed to this sample included removing outliers, duplicates and records with empty cells. Additionally, any records associated with the standard white boxes (used to store items arriving at FF Boutique without the original box) have been discarded and the remaining items’ measurements have been corrected to the smallest length, width and height of the 3 objects (the item itself and its 2 boxes).

Once again, the attribute containing the Farfetch used Box for transportation was replaced by the values returned by an “AS-IS Ideal box”. This function compares the measurements of the shoe branded box with the packaging portfolio and returns the smallest fitting box. It is crucial to note that the shoe boxes had not yet been updated at the time the sample was obtained. However, since these would be launched in the meantime, the AS-IS used boxes already take into account the upgraded portfolio of 13 boxes. That way, this analysis will not be inflated by the impact of using the wrong box in the initial scenario. Moreover, it was decided to eliminate all records whose “AS-IS ideal box” was 7,13 and 14. When used to pack shoes, these boxes are most likely to be packing boots, which is not the focus of this initiative.

As a consequence of such radical cleaning tasks, the final sample consisted of only 238 records.

4.2.3 Assumptions

This initiative is only applicable to trainers, which are assumed to be packed inside boxes smaller than box 7. As a consequence, the sample might present products whose "AS-IS used box" is not one of shoe boxes (3,4, 5 or 6).

Despite the fact that this initiative focuses on a different product category than in the previous model, the linear functions obtained through plots 4.1 and 4.2 are also employed here, in order to estimate delivery costs and packaging supply prices, respectively. These expressions were developed using a representative set of volumetric weights and box areas, thus they are appropriate to all categories.

Nonetheless, the safety margin considered above for large boxes is not the same for the shoe boxes. For instance, the average gap between the expected volumetric weight of shoe boxes and what is in fact charged by carriers is around 8%. In that sense, the calculus of volumetric weight should consider this percentage, as well as the exterior dimensions of the box, according to equation below:

$$Volumetric\ Weight = \frac{(Length + 1.2) * (Width + 0.8) * (Height + 0.4)}{(1 - 0.08) * M} \tag{4.3}$$

Even though this option should be available for any trainers' purchase, it is possible to anticipate which are the brands whose boxes are more likely to be discarded. For instance, considering the range of trainers sold through the Marketplace in 2021, it assumed that the adoption rate scenarios should range between 10% and 44%.

Despite the fact that this initiative may accumulate many branded boxes at the partners' facilities, the respective holding costs will not be calculated. Regarding the fulfillment of e-commerce Farfetch Boxes, it is considered that the AS-IS and TO-BE inventory costs are maintained, once the number of orders processed in both scenarios is the same.

Since many boutiques reject customer returns when they arrive without the brand's original box, this proposal manages to avoid this type of inconvenience, since the brand box never left the partner. If in fact the boutique accepts the return, Farfetch does not need to refund the customer, which is a strong benefit from "2 Shoes 1 Box". However, these savings will not be calculated.

To access the impact of the initiative, the total delivery savings will be directly compared with the Delivery Budget (that already include returns). The overall impact of this initiative depends on the annual volume of trainers sold and on the level of customer engagement, in other words, the actual percentage of customers willing to discard the branded box.

Lastly, when assessing the improvements in the Logistics' carbon footprint, it is assumed that Farfetch is charged with offsetting expenses according to the amount of Carbon emissions released during its operations and that, alternatively, each tonne of CO_2 would require 60 trees to be naturally processed during 1 year.

4.2.4 Model Building

From a sample of 238 products, the "2 shoes 1 box" model was created using Excel, which is an appropriate tool to clean, analyse and transform data. The initial sample contained 8 attributes for each item: Product's ID, length, width and height, the Brand Box length, width and height, and the AS-IS "used Box" for transportation.

Considering the given attributes, it is possible to calculate the volumes of the product, the brand box and the Farfetch box. By subtracting the first volume from the last and ignoring the thickness of the inner box, it is possible to obtain the amount of air transported in the AS-IS scenario. After submitting the "used box" dimensions to equation 4.3 and redirecting the volumetric weight returned to the linear function expression derived from plot 4.1, it is possible to obtain the AS-IS delivery costs.

Regarding the TO-BE situation, where the second box between the product and the transport box will be discarded, 5 new attributes were created: the ideal TO-BE box, the corresponding volume, the new amount of air, the corresponding volumetric weight and delivery costs (per record and in total).

The TO-BE ideal box is returned by a conditional function that compares the dimensions of the product with the dimensions of the boxes 15, 21,17, 3, 22, 4, 5 and 6, returning the smallest suitable box. Once again, the new amount of air within the box is the difference between the new box volume and the product's volume. Since the size of the portfolio boxes was maintained during this model, the packaging supply costs per box type are exactly the same as in the original scenario. However, given that the model favours the allocation of smaller (and cheaper) boxes in the TO-BE scenario, considerable savings in packaging supply are expected.

Following the same methodology described in section 4.1.4, this model is also complemented with the calculation of avoided carbon emissions. This outcome, as well as the savings in delivery and packaging supply, depends on the customers' percentage of adoption towards this initiative.

4.3 Automated Packaging Machine at Stadium Goods

Considering the suggestion of installing a CMC Genesys - Tote system in one of the Stadium Goods fulfillment centres, the current section presents the methodology used to predict the impact of such decision.

4.3.1 Sample Collection

To anticipate the effect of shipping Stadium Goods products in appropriately sized boxes rather than in their own packaging or Farfetch boxes, it would be necessary to obtain a sample of Stadium goods products, primarily containing trainers. However, given the project's deadline, it was decided to reuse the shoe sample collected in October 2021 for the optimisation of boxes 3, 5 and 6. At the time, this task was employed to Farfetch Boutique and the Venray warehouse, which

were able to deliver a sample of 2936 shoes, including the following arguments: product ID, the length, width, and height of the brand box and the Farfetch Box used for transportation.

4.3.2 Data Cleaning and Preparation

The data cleaning procedures applied to this sample were very similar to those performed in the two previous samples, including the removal of duplicates, outliers and incomplete records. Likewise, regarding the data coming from the Farfetch Boutique, it was necessary to exclude items whose "brand box" was one of the standard white boxes and not the original brand box. Additionally, the attribute "used box" was also removed, given that it is influenced by the partner's packaging accuracy and associated with the old Farfetch portfolio. Lastly, since Stadium Goods mainly sells trainers, it was necessary to discard any other type of footwear from the sample.

After such drastic cuts, the final sample featured 2,158 items and corresponding arguments.

4.3.3 Assumptions

The automatic packaging machine chosen to power this initiative is the CMC Genesys - Tote system, which is able to produce ideal size boxes at a rate of 680 units per hour. The investment cost considered was proposed by the supplier itself, which already includes the installation cost and a few other optionals. During this study, it is considered that the machine is accountable for fulfilling 100% of Stadium Goods orders, which would imply the consolidation of all warehouses in a single one.

Given the nature of the sample, the current study will only simulate the production of custom right-sized packaging for shoes, neglecting other product categories such as streetwear. It is also assumed that the shoe sample collected by Farfetch Boutique and Venray's warehouse is representative of the range of brands and sizes provided by Stadium Goods.´

To predict the impact of using the CMC Genesys, this study will take into account last year's volume of stadium goods orders to determine the necessary number of custom boxes per marketplace (fareftch.com and stadiumgoods.com).

Taking into account that this packaging machine is able to produce boxes between the minimum dimensions of 26cm*20cm*6cm and the maximum dimensions of 58 cm*38cm*32cm and assuming that the difference between the lengths, widths and heights of the custom box and the inner item will be around 1 cm, 1 cm and 0.7 cm, respectively, the following conditions were inflicted:

$$\text{Length}_{\text{Custom box}} = \begin{cases} 26, & \text{if } Length_{\text{brand box}} + 1 < 26, \\ \text{"}Out\ Of\ Specifications\text{"}, & \text{if } Length_{\text{brand box}} + 1 > 58, \\ Length_{\text{brand box}} + 1, & \text{otherwise.} \end{cases}$$

$$\text{Width}_{\text{Custom box}} = \begin{cases} 20, & \text{if } Length_{\text{brand box}} + 1 < 20, \\ \text{"}Out\ Of\ Specifications\text{"}, & \text{if } Width_{\text{brand box}} + 1 > 38, \\ Width_{\text{brand box}} + 1, & \text{otherwise.} \end{cases}$$

$$\text{Height}_{\text{Custom box}} = \begin{cases} 6, & \text{if } Height_{\text{brand box}} + 0.7 < 6, \\ \text{"}Out\ Of\ Specifications\text{"}, & \text{if } Width_{\text{brand box}} + 0.7 > 32, \\ Height_{\text{brand box}} + 0.7, & \text{otherwise.} \end{cases}$$

If a custom box has at least one dimension classified as "Out of Machine Specifications", the whole record will be disregarded.

Regarding the delivery costs, which were again determined using regression models, as shown in figure 4.3. Since FF marketplace orders are typically international while Stadium Goods marketplace orders are usually shipped within the same country, the transportation costs were determined separately: The delivery costs for Stadium Goods products sold through Farfetch and Stadium Goods Marketplaces are based on the trendlines derived from the Blue and Orange series, respectively.

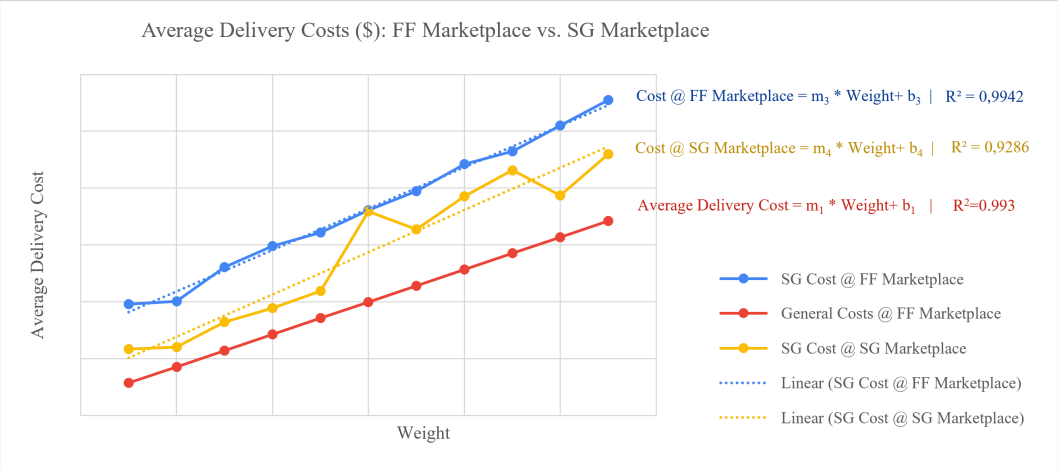

Figure 4.3: Delivery costs at Farfetch Marketplace vs. at Stadium Goods marketplace

Taking into account the production cost per box provided by the machine supplier and by comparing it with the current box prices for both marketplaces, it is possible to estimate what should be the resulting packaging supply savings.

The true cost of the CMC Genesys machine is confidential, but the recovery of investment will be evaluated using metrics such as break-even production and the payback period.

Even though the sustainability impact from this initiative would be concentrated in Stadium Goods orders, it still affects the overall progress of the company towards its Climate Positive mission. Again, with regard to offsetting carbon emissions, it is assumed that Farfetch is charged a certain amount for each ton of CO_2 emitted, which is also equivalent to the amount of CO_2 consumed by 60 trees during 1 year.

Lastly, given that the machine will be replacing human labour, it is considered that the affected employees will be allocated to new jobs with greater value to the business. In that sense, salary savings will not be calculated.

4.3.4 Model Building

Taking into account the differences in delivery costs per sales channel outlined above, the impact of producing custom boxes for Stadium Goods orders were modelled separately, simulating if these were coming from Farfetch Marketplace or from Stadium Goods Marketplace itself. To facilitate the understanding of the methodologies followed in each model, they will be distinguished as:

- **Model A:** Replacing Farfetch branded boxes with custom right-sized boxes (Farfetch marketplace orders)
- **Model B:** Replacing Stadium goods boxes with custom right-sized boxes (Stadium Goods marketplace orders)

In the model A, there is an AS-IS "used box" function that checks the Farfetch portfolio displayed in table 3.1 and returns the smallest fitting box to ship the shoe brand box. Likewise, model B contains a similar function, which compares the brand box proportions with the Stadium Goods portfolio laid-out in table 3.3. This procedure ensures that the initiative earnings are not accounting for the benefits of "recommending the right box" and following that "suggestion" in the TO-BE scenario. In fact, once the auto packaging machine starts operating, terms like "Packaging Accuracy" and "Box recommendation" will not be applicable to the Stadium Goods partner.

Since the sample contains only products from the shoe category, the safety margin considered is 8%, meaning that, in both models, the volumetric weights of the AS-IS "used box" and Custom boxes will be calculated using equation 4.3.

As stated in the section above, the size of the custom boxes will be determined by adding 1 cm to the length and width of the branded box and 0.7 cm to the height. However, taking into account that the minimum and maximum dimensions of the boxes produced by the machine are 26 cm * 20 cm * 6 cm and 58 cm * 38 cm * 32 cm, respectively, customised boxes outside of these specifications would not be approved for production.

After obtaining the volumetric weights for the AS-IS and TO-BE situations, the corresponding delivery costs can be acquired using the trendline expression derived from the blue series (in model A) and from the orange series (in Model B), represented in plot 4.3.

By multiplying the expected annual number of orders for both sales channels with the average delivery savings per box (which is returned by the corresponding models) and summing both products, the total delivery savings are obtained.

In addition, comparing the current packaging supply costs (for both portfolios) and the TO-BE production cost per box provided by the machine supplier and assuming the same order volume, it is also possible to predict the savings from packaging supply.

Lastly, after filtering the number of Stadium Goods orders sent per weight threshold per route and per transportation mode (air or road) in 2021, it is possible to estimate the AS-IS and TO-BE carbon emissions before and after implementing the Boxing Machine, which will be distinct because the average volumetric weight per order shipped will surely decrease.

Chapter 5

Results

The current chapter aims to expose the results obtained for each one of the three initiatives described in chapter 4. Despite being focus on different improvement points, the criteria used to measure the success of the three approaches is the same: annual impact on delivery costs, packaging supply costs, offsetting costs and carbon footprint.

5.1 Optimisation of boxes 7, 13 and 14

The size optimisation of boxes 7,13, and 14 assumed two separate scenarios: keeping the number of larger boxes while also revising their sizes (scenario A) and adding a new larger box and obtain the best size for the four boxes (scenario B).

Given the restrictions of the Evolutionary method, the final results are not proven to be optimal. Nevertheless, the sizes and volumetric weights disposed in table 5.1 represent the best solution obtained after a long improvement phase.

Table 5.1: New Box Sizes returned for scenarios A and B

Scenario A					Scenario B				
Box	Length	Width	Height	VW	Box	Length	Width	Height	VW
7'	61.6 cm	38.1 cm	13.2 cm	7.0	7'	60.2 cm	36.6 cm	13 cm	6.5
13'	70 cm	41.9 cm	16 cm	10.5	ad	47.7 cm	41.8 cm	18.9 cm	8.5
14'	57.3 cm	45.2 cm	24.9 cm	14.5	13'	70.2 cm	40 cm	15 cm	9.5
					14'	57.2 cm	45.3 cm	25 cm	14.5

Regarding Scenario A, and comparing the returned volumetric weight with the originals (in table 4.2), it is visible that boxes 7' and 13' are actually bigger than 7 and 13, respectively, and that only box 14' is smaller. On the other hand, Scenario B was able to provide 4 boxes generally smaller than the original, except for box 13', which is a bit longer than box 13. The additional box was returned with a volumetric weight of 8.5, meaning that it is bigger than the original 7 and smaller than 13.

By consulting tables F.1 and F.2 in Appendix F, it is possible to follow the initial and final distributions of boxes sizes for both Scenarios, which might suggest the actual behaviour after implementing one of scenarios.

As stated earlier, the sample used to feed this model was massively cut to be representative of its population, which could lead to overfitting. To verify if the model was succeeding against the unseen data, the dimensions of the new boxes were applied to 1355 clean records (table 4.1, 2nd column): in scenario A, only 1 item did not fit inside the new 3 boxes, indicating a test error of 0.07%, while in Scenario B, 20 items did not fit into the new 4 boxes, representing a test error of 1.44%.

5.1.1 Delivery Savings and Space Optimisation

Given that the model was designed to reduce transportation costs for larger boxes, regardless of what the dimensions listed above might suggest, both scenarios resulted in significant delivery savings. Actually, in Scenario A, it was verified a reduction of 3.82% in delivery costs for boxes 7', 13' and 14', representing an overall impact of 0.37%, considering the whole portfolio and the historical return rate. Likewise, comparing the delivery costs before and after the optimisation in Scenario B, a reduction of 9.59% was verified for this box category, symbolizing a 0.90% improvement in overall delivery expenses.

Given the proportional behaviour between volumetric weight and delivery costs suggested by plot 4.1, these savings can only be achieved after a significant decrease of the volumetric weight and the air inside the box. In fact, the new boxes returned by scenarios A and B allow an average reduction of 5.43% and 13.76% in volumetric weight, respectively. Given that the air inside the box is approximately the difference between the volumes of the box and the item, Scenarios A and B grant a reduction of 8.86% and 27.03% of empty space, respectively.

5.1.2 Carbon Dioxide Emissions Avoided

One of the main goals of this project is to help the company transition to a more environmental friendly organization, more specifically to help the logistics department reaching the 4.6% reduction of carbon footprint per box sent in 2022. Given that this metric is proportional to the volumetric weight of boxes used, it is possible to avoid considerable carbon dioxide emissions adopting any of the scenarios.

According to the side calculations, Scenario A is able to avoid the release of 625.5 tonnes of CO_2, which, by reference, represents 0.41% of the total delivery carbon footprint verified in 2021. Given the direct proportionality between the quantity of carbon dioxide produced and its offsetting cost, the 0.41% overall improvement in the delivery carbon footprint also represents an 0.41% reduction in the total offsetting expenses. On top of that, to process 625.51 tonnes of this chemical compound in one year, around 37,531 trees would be needed.

Likewise, Scenario B can avoid the payment of 1.39% of the original offsetting expenses, as it avoids the emission of more than 2,133 tonnes of carbon dioxide, which represents a 1.39%

improvement in the 2021 delivery carbon footprint. As, naturally, a tonne of CO_2 requires the photosynthetic activity of 60 trees during 1 year to be entirely offset, the 2,133.23 tonnes avoided prevent the need of having 127,994 trees for this purpose.

5.1.3 Packaging Supply Savings

As verified in table 5.1, not all boxes returned for both scenarios are smaller than the original. Considering the cardboard area required to build each one of the new boxes and their expected percentage of utilisation (tables F.1 and F.2, it was possible to predict that scenario A implies extra packaging supply costs of 0.40% while Scenario B allows savings of 0.40%.

5.1.4 Total savings and scenario comparison

After combining all the results in the summary table 5.2, it is perceivable that Scenario B is, by far, the best choice: Beyond generating greater savings, it avert the emission of over 2.1 thousand tonnes of carbon dioxide in one year (3.4 times more than Scenario A). As stated in section 4.1.3, it is considered that the inventory costs in the AS-IS and TO-BE scenarios are the same, since the same number of large boxes should be requested by the partners.

Table 5.2: Total Savings after the optimisation of larger boxes

Scenario	Delivery Expenses	Offsetting Expenses	Packaging Supply Expenses	CO_2 tonnes avoided
A	-0.37%	-0.41%	+0.45%	625.51
B	-0.90%	-1.39%	-0.40%	2,133.23

5.2 "2 Shoes 1 Box"

Regarding the "2 Shoes 1 Box" initiative, the model built to simulate the impact of customers abandoning the brand's box in the case of trainers purchases showed positive results both in terms of savings (Delivery, Offsetting and Packaging Supply) and carbon footprint. However, the magnitude of these outcomes are grossly dependent on the level of customer engagement, which is expected to be between 10% and 44%.

5.2.1 Delivery Savings and Space Optimisation

By focusing on the trainers' dimensions rather than its branded box dimensions to attribute the best Farfetch Box for transportation, the algorithm predicted that these units would be 12% cheaper to ship. If the actual adoption rate occurs between 10% and 44%, delivery savings within 0.29% and 1.21% can be expected.

Regarding the space optimisation, when customers discard the brand box in case of trainers, the volumetric weight and Air inside the box is reduced by 26.3% and 46.1%, respectively. These

values are a consequence of the algorithm favoring the allocation of smaller boxes, as shown in the table F.3.

5.2.2 Carbon Dioxide Emissions Avoided

Once again, the outcomes related to the carbon Footprint are subjected to the adoption rate verified once this initiative is implemented. For instance, if at least 44% of the purchases discard the brand box, the company is able to avoid the emissions of 1,024 tonnes of carbon dioxide, representing an overall improvement of 0.67% in the Delivery carbon Footprint and offsetting costs. For the same adoption rate, this initiative avoids the requirement of 61,433 trees to naturally process this quantity of CO_2.

On the other hand, if the adoption rate takes the value of 10%, only 353.07 tonnes of CO_2 would be prevented into the environment, which would represent a decrease of 0.23% in the Delivery emissions and in offsetting costs. Alternatively, such amount of CO_2 would be annually offset by 21,184 trees.

5.2.3 Packaging Supply Savings

Even though this model does not generate new boxes, it still attributes the smallest fitting box to ship the same item (after discarding the original brand box). Once smaller boxes are cheaper to obtain from packaging suppliers, this initiative may return savings between 0.66% and 2.86%, if the adoption rate verified is between 10 and 44%.

5.2.4 Total savings from "2 Shoes 1 Box"

As in the previous model, all contributions from "2 Shoes 1 Box" were aggregated into a summary table (table 5.3), from which it is clear that the higher the adoption rate, the better the outcomes, both in terms of savings and environmental impact.

Table 5.3: Total Savings from "2 Shoes 1 Box"

Adoption Rate	Delivery Expenses	Offsetting Expenses	Packaging Supply Expenses	CO_2 tonnes avoided
44%	-1.21%	-0.67%	-2.86%	1,023.91
10%	-0.29%	-0.23%	-0.66%	353.07

5.3 Automated Packaging Machines at Stadium Goods

Despite the fact that the plan to invest in an automatic packing machine for Stadium Goods differed from the previous initiatives, the methodology employed was fairly similar, and so the criteria used to assess its viability.

5.3.1 Delivery Savings and Space optimisation

As a result of using an auto packaging machine to produce 100% of the shipping boxes for Stadium Goods orders, it is possible to obtain the overall delivery savings of 2.42%. Specifically for Stadium Goods products, switching from SG boxes to optimal custom boxes enables an average reduction of 30.86% in transportation costs, while switching from Farfetch boxes to these right-sized boxes saves only 8.62% of the total delivery expenses. It is important to highlight that the TO-BE delivery costs for both boxes are not the same given the differences outlined in plot 4.3.

Taking into account the proportionality between the package weight and delivery cost, these positive outcomes had to derive from the space optimisation induced by the technology. For instance, it was verified that the volumetric weight of SG and FF Boxes decreased by 50.90% and 21.12%, respectively, while the air proportion reduced by 88.95% and 73.88% for the same boxes. On average, the auto packaging machine decreases 36.72% of the package's volumetric weight and 81.77% of the air contained inside.

5.3.2 Carbon Dioxide Emissions Avoided

Considering that the average reduction of volumetric weight inflicted by the technology is 36.72%, it was possible to simulate the TO-BE carbon footprint and compare it directly with the AS-IS emissions. In fact, after one year, the auto packaging machine is able to avoid the emission of more than 1,900 tonnes of carbon dioxide, representing a 1.30% improvement over the 2021 delivery carbon footprint and offsetting costs. Alternatively, to process this amount of CO_2, 119,450 trees would be needed annually.

5.3.3 Packaging Supply Savings

According to the average production cost per box implied by using the CMC Genesys machine, which is much less than the current Packaging supply costs charged to Farfetch and Stadium Goods, it is possible to state that, annually, the packaging for Stadium Goods products is 65.75% cheaper, inducing a 67.21% and a 2.65% reduction in packaging supply costs for Stadium Goods Marketplace and Farfetch Marketplace, respectively.

5.3.4 Total savings from Automatic Packaging Machine

Taking into account all the benefits set out above, it is possible to conclude that the application of an automatic packaging machine in one of the Stadium Goods warehouse is beneficial both in terms of cost efficiency and environmental impact, as summarized in the table 5.4:

Table 5.4: Total Savings from using an Auto-Packaging Machine at Stadium Goods

Delivery Expenses	Offsetting Expenses	Packaging Supply Expenses For SG	Packaging Supply Expenses For FF	CO_2 Tonnes avoided
-2.42%	-1.30%	-67.21%	-2.65%	1,990.83

Given the machine's purchasing cost and the resulting annual savings, the break-even production required to recover the investment is 180,581 custom boxes, indicating that the payback period is less than 10 weeks.

5.3.5 Contributions from all initiatives combined

Once all initiatives have been evaluated using the same criteria, it is possible to add up their individual contributions to measure the potential of the entire project (see table 5.5).

Table 5.5: Total Savings from the three initiatives combined

Initiative	Delivery Expenses	Offsetting Expenses	Packaging Supply Expenses For SG	Packaging Supply Expenses For FF	CO_2 Tonnes avoided
New Boxes 7', 12, 13 and 14 (Scenario B)	-0.90%	-1.39%		-0.40%	2133.23
2 Shoes 1 Box (44% adoption)	-1.21%	-0.67%		-2.86%	1,023.81
Auto Packaging Machine	-2.42%	-1.30%	-67.21%	-2.65%	1,990.83
Total	-4.53%	-3.36%	-67.21%	-6.00%	5147.97

Regarding the Size optimisation of the larger boxes, the results considered are from Scenario B, which was revealed to be the best in all criteria, in comparison to Scenario A.

In what concerns the "2 Shoes 1 Box", the outcomes displayed in table 5.5 consider that 44% of the customers buying trainers might opt to eliminate the brand box, which is an optimistic view.

Overall, the simultaneous implementation of the 3 proposed initiatives generates delivery savings of 4.53% and restricts the emission of 5148 tonnes of carbon dioxide into the atmosphere. Once Farfetch is committed to monetarily compensating its carbon footprint, the company will be able to save 3.36% on offsetting charges. Regarding packaging supply, the current packaging expenses for the Farfetch and Stadium Goods Marketplaces orders will be reduced by 6.0% and 67.1%, respectively.

Chapter 6

Conclusion

"Zero Air Packaging" is an ideological concept transversal to all e-commerce businesses, conditioning the normal activities of different teams within the same company. Because their operations depend on third-party carriers, by decreasing the amount of air and, therefore, the volume of the package, orders become cheaper to deliver and less damaging to the environment.

Within Farfetch, "Zero Air Packaging" has been achieved through three different scopes: By recommending the right packaging, by selecting the right packaging and by offering the right packaging. The team where the project is inserted to, the packaging team, is specially focus on the last scope, being responsible for the most recent portfolio updates including the size optimisation of shoe boxes and the introduction of envelopes as an alternative to specific box sizes.

In order to help the company cut unnecessary costs and establish itself as a climate-positive organisation, the current project proposed to maintain this effort as well as to implement innovative strategies. Beyond this, the development of this project could not escape the trends observed in the Luxury Fashion e-commerce market, which were individually presented in chapter 2.

After analysing the feasibility of several initiatives, it was decided that the next steps towards "Zero Air Packaging" should be: (1) the optimisation of large boxes (7,13 and 14); (2) the optional removal of the brand box in case of a trainers purchase; and (3) the investment in an auto packaging machine to produce the packaging for Stadium goods orders.

The first initiative has emerged as a continuation of the packaging portfolio update, initiated by the team in 2021. Regarding the larger boxes 7, 13 and 14, two possible scenarios were considered: (A) To maintain the number of boxes but optimise their sizes and (B) To add a new box and obtain the optimal sizes for the four boxes. After being properly clean, the collected sample of large products was submitted to two models, each one simulating one of the two scenarios, which were responsible for returning the optimal dimensions for the number of boxes considered. After obtaining the best solutions for both approaches, it was possible to retain that Scenario B is the best choice, having returned delivery savings of 0,90% (2.5 times greater than Scenario A), preventing the release of 2133 tonnes of carbon dioxide (3.4 times greater than Scenario A), which implies a reduction of 1.39% of total offsetting costs. These outcomes are a direct consequence

of a 13.76% volumetric weight reduction induced by the new boxes 7', ad, 13' and 14'. Additionally, given that most items escape to smaller boxes, which are cheaper to obtain from suppliers, Scenario B is able to return packaging savings of 0.40%, in contrast to Scenario A that increases this expense in 0.45%. In practice, these positive results may be constrained by incorrect packaging recommendations provided by Farfetch and Partner behavior when selecting packaging for shipping orders.

The only deception associated with choosing scenario B is the increased portfolio complexity: between suppliers, partners and Farfetch employees, it is important to clarify what will be changing going from 3 to 4 large boxes boxes.

Regarding the second initiative, "2 Shoes 1 Box", it was suggested after recognizing the potential of sending trainers' orders inside a single e-commerce box, instead of using two boxes (the brand box and the Farfetch box). Even though trainers are not the most exclusive category sold through Farfetch Marketplace, it was decided that the removal of the branded box should be chosen by the customer, preventing the damage of its luxury experience. To predict the impact of switching from double to single packaging on trainers, a proper model was created, whose results directly depend on the percentage of adoption. Given that more people are becoming aware of their role in environmental preservation on a daily basis, it was decided to set this rate at 44%, which is an optimistic view. Taking this into account, the "2 Shoes 1 Box" initiative is able to reduce overall delivery expenses in 1.21% and avoids the emissions of 1024 tonnes of carbon dioxide, which decreases offsetting costs by 0.67%. In addition, the favoring of smaller boxes to ship trainers, allows packaging supply savings of 2.86%. Independently of the percentage of adoption, the model has concluded that this initiative reduces, on average, 26.3% of the package volume weight and 46.1% of the air inside the box, which is a significant step towards "Zero Air Packaging". Even though these results can be affected by inaccurate packaging recommendation and selection, the reverse might also happen: The packaging algorithm has to suggest a new (smaller) box if a customer chooses to ditch the brand box. Moreover, this proposal implies changes in the platform interface in order to include a step called "packaging options" before the purchase is completed.

In addition, the fact that the brand box remains with the partner increases the likelihood of it accepting returns, which may constitute an uncovered benefit from this initiative.

Lastly, with regard to the investment in an automatic packaging machine for Stadium goods, this proposal arose from the need to incorporate more technology in order processing and to decrease the considerable delivery costs associated with the rising volume of Stadium Goods orders. By switching from the branded Farfetch and Stadium Goods boxes to right-sized packaging, the volumetric weight is reduced by 36.72% while the amount of air inside the box is reduced by 81.77%. These improvements allow a reduction of 2.42% on delivery expenses, while also decreasing the delivery carbon footprint by 1991 tonnes of CO_2. Moreover, since the packaging will be produced instead of bought, the machine is able to reduce 2.65% and 67.21% of packaging supply costs from Stadium Goods items ordered from Farfetch Marketplace and Stadium Goods Marketplace, respectively.

Unlike the other two initiatives, these outcomes are not dependent on the packaging accuracy,

since the scanning technology incorporated in the machine allows the production of optimal sized boxes according to the items' dimensions. In that sense, Stadium Goods, as an integrated partner, will not require supervision regarding packaging selection.

Additionally, as it scans the items, this machine is able to continuously update a data set containing products' dimensions and weight, that can later be used to develop better packaging algorithms, for example.

Even though the "2 Shoes 1 Box" and the auto packaging machine have been modelled and evaluated separately, they can be correlated in practice. For example, a customer purchasing a pair of Stadium Goods trainers might choose to eliminate the branded box, implying changes in the way the item is "fed" to the packaging machine (without the original box).

Nonetheless, by summing the contributions of the three initiatives, it is possible to conclude that "Zero Air Packaging" successfully reached its objective by reducing delivery expenses on 4.537% and preventing the emission of 5148 tonnes of carbon dioxide generated during transportation activities. The latter represents a 3.36% reduction in the delivery carbon footprint and therefore a reduction in offset costs in the same proportion. Regarding Packaging Supply expenses, the overall costs of Farfetch Packaging are decreased by 6.0%, while the cost of Stadium Goods Packaging decreases by 67.21%. This last value is explained by the fact that all Stadium Goods orders will start to shipped inside custom right-sized packaging, internally supplied.

6.1 Future Projects

After the investigation phase, several improvement points emerged in relation to the empty space in the packages. However, given the project's deadline, it was necessary to select the most feasible and vigorous initiatives capable of bringing the company closer to "Zero Air Packaging". Nonetheless, it is important to ensure the continuity of the concept, by the indication of future work.

In line with the larger boxes optimisation, it is suggested to add the corresponding envelopes for large items. However, due to their lack of protection, these "XL envelopes" are best suited for less sharp and light weight products, such as oversize coats and bags. For instance, Browns recently introduced a paper envelope with the dimensions of 790 mm * 600mm, which could be used as a trial before incorporating this option in the Farfetch Packaging portfolio. This specific size is adjustable to the boxes 7, 13 and 14, once it can be folded to fit the product tightly. Beyond being cheaper to obtain, in comparison to boxes, envelopes are reported to ship a minimum amount of air and to reduce volumetric weight by 33%, which should have a positive impact on delivery, packaging supply expenses and carbon footprint. During this experience, it is important to verify if customers orders arrive intact to their destination and if the luxury experience is, somehow, damaged.

Additionally, the incorporation of new packaging KPIs is suggested, in addition to Packaging Accuracy. For example, Partners should be evaluated on the number of times the use of envelopes is prioritized over the option of using a box. The amount of air inside the package must also be

calculated, as soon as the company starts to have access to the items' dimensions before being displayed in the marketplace. For this, it will be necessary to invest in dimensional scanning technologies and incorporate them into the process flow.

Lastly, in other to promote circularity and preserve the world's forests, the percentage of recycled content, in both boxes and envelopes, should be increased, after being successfully tested against humidity and resistance.

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Appendix A

Literature Review Back-up

A.1 FSC Labels

Regarding sustainable wood sourcing for paper products, there is a transnational environmental certification with the name of the non-profit organization that grants it: the Forest Stewardship Council (FSC). In that sense, when choosing a package with a FSC label, the customer is helping this organization responsibly manage the world's forests. In addition to pointing its producer (Code CXXXXXX), the 3 labels available (Figure A.1) provide information about the origin of the material and the proportion of recycled paper used to manufacture the package. For example, the "FSC Recycled" label guarantees that the product is made from 100% recycled content, which has helped reduce the consumption of virgin paper sources and prevented deforestation. Secondly, the label "FSC Mix" is granted to products made from a mixture of FSC-certified forests material, recycled materials and FSC controlled wood (which is not from FSC certified forests). Lastly, the "FSC 100%" label is the biggest mark of distinction for certified products, as it guarantees that the material is supplied by an independent third party that strictly follows the social and environmental standards of the FCS (Forest Stewardship Council, 2022).

Figure A.1: The 3 FSC certified labels

A.2 Amazon's Packaging Certifications

In 2019, Amazon created "Compact by Design", a sustainability certification assignable to products to encourage its vendors to build products with efficient design and packaging. By removing the excessive air and water, packages become smaller and more efficient to ship, which, at scale, can represent considerable savings in transportation costs and carbon emissions (Amazon, 2021a).

Besides removing decorative packaging and re-structuring products into compacted shapes, when possible, producers should replace original container packaging with a lighter material and transform water-based products into a concentrated version (e.g., cleaning solutions) or even into a solid one (e.g., soaps and shampoos). Given products dimensions (in inches) and weight (in pounds), a product can be certified as "Compact by Design" if its unit efficiency (calculated using equation A.1) is lower than the established category threshold (Amazon seller central, 2022).

$$Unit\,Efficiency = \frac{Length * Width * Height}{Use}) * \frac{Weight}{Use} \tag{A.1}$$

This incentive is comparably recent to the one which it is derived from, the Frustration-Free Packaging (FFP) certification: since 2008, Amazon has granted the FFP certification to more than 2 million products, inducing brands to reduce excessive material in packages but also to offer 100% recyclable and protective packaging featuring an easy-to-open (Amazon, 2022a). To be classified as FFP, these products must have received a Ship in Own Container (SIOC) certification by passing the ISTA-6A test, that distinguishes the packages that can be shipped directly to customers, discarding extra Amazon packaging (Amazon, 2021b).

Besides improving operations in the fulfilment centres, these environmentally friendly certifications have massive sustainability outcomes: Since 2015, Amazon has reduced 36% of weight per shipment and has avoided around 1 million tons of packaging material, which corresponds to 1.6 billion shipping boxes (Amazon, 2021c).

Appendix B

Positively Farfetch

Farfetch's strategy toward sustainability is entitled "Positively FARFETCH" and its purpose is to encourage the whole luxury fashion community to think and act responsibly and to become "the platform for good in luxury fashion".

Currently, the industry faces multiple environmental, social and corporate governance (ESG) challenges such as climate change, the strong adherence to e-commerce, the violation of human rights and the urgency to reduce waste. Considering these main issues, "Positively Farfetch" is divided into 5 sub-strategies, which were recently updated with the company's objectives for 2030. These quantitative targets were set in 2020, two decades ahead of the Paris agreement deadline and, since then, these have been acting as pillars to this strategy but also to the whole business.

Regarding Climate change, Farfetch's ambition goes beyond the neutralization of its own impact. In that sense, Positively Cleaner was born, which is the sub-strategy aiming to transform Farfetch into a Climate Positive Company. In 2020, Positively Cleaner set the goal to achieve net-zero emissions by 2030, which demands the measurement of the carbon footprint in accordance with the Greenhouse Gas Protocol, collaborating with suppliers to help them reduce scope 3 emissions, using 100 per cent renewable energy (in scopes 1 and 2) and offsetting the unavoidable emissions generated by delivery and returns. With technology as its main strength, Farfetch is also investing in the development of innovative technology to accelerate the achievement of this target.

In 2019, Farfetch's total carbon footprint was 311 342 tons of Carbon Dioxide, of which 98% were scope 3 emissions generated by Logistics, procurement, packaging, waste, transportation and product manufacturing of the items sold at Browns and NGG. Regarding 2021, Positively Cleaner reported a 7.9% reduction in logistics carbon emissions per unit sold, representing a 21.6% reduction facing 2019.

In order to improve the environmental, social and animal welfare standards of the items sold through all platforms, Farfetch created "Positively Conscious", pushing the company to sell 100% conscious products until 2030. This means generating the totality of revenues from certified and sustainable brands that supply organic, recycled, pre-owned or fair-trade products. In 2021, around 7.4% of the total gross merchandise Value (GMV) was derived from conscious products, inflicting a 92% growth year-over-year.

Positively Circular is the third sub-strategy aiming to promote circularity and reduce waste production. Farfetch started to sell pre-owned items in 2010 and, along with positively conscious, has been promoting products made from recycled and upcycled materials. Additionally, Farfetch is also extending the product's life cycle through its repairing services and donations to charity.

For reference, in 2021, the number of circular units sold increased by 153%, accounting for 2.1% of the total units sold in the marketplace.

Since 2015, whenever a client intends to return a product, there are 2 possible scenarios: if the return was processed within the 14-day period and arrived intact inside the original branded box, the boutique will likely accept it and sell it to Farfetch at a considerable discount; Otherwise, when the boutique does not accept the return, it processes the order as a successful sale and Farfetch refunds the customer. In both situations, the item is physically returned to "Farfetch Boutique" where the items are revised before being re-sold or donated to charity. More recently, after the acquisition of Luxclusif at the end of 2021, the company is expecting to increase the percentage of pre-owned items in their catalogue and respective revenues. Before the 2030 deadline, products will be classified and labelled as "design for recycling", "made to order" or "designed to last" to help customers choose more responsibly.

Positively Inclusive is the name of the 4th sub-strategy, which aims to position Farfetch as the leader in conscious inclusion by 2030. In that sense, Farfetch has committed to set targets to achieve representation at all organization levels, to educate and celebrate the stakeholders' culture, to regard all farfetchers fairly, regardless of their race, gender, sexual orientation, disability or background and to battle biases and barriers in talent sourcing. As a result of this commitment, in 2021, 84% of Farfetch employees reported to feel included at the company.

Lastly, regarding Governance and Engagement, in 2020, the company elected the the ESG committee to directly assist the Directors Board in managing the environmental, social, and governance issues. For Farfetch, governance is wider than just compliance: it is about corporate ethics and values, being human, and cultivating a sustainable culture (Farfetch, 2022b).

Appendix C

Problem Statement Backup

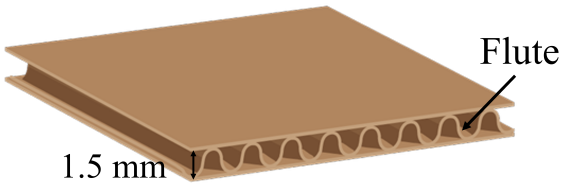

Figure C.1: Corrugated Cardboard with Single Wall and E Flute

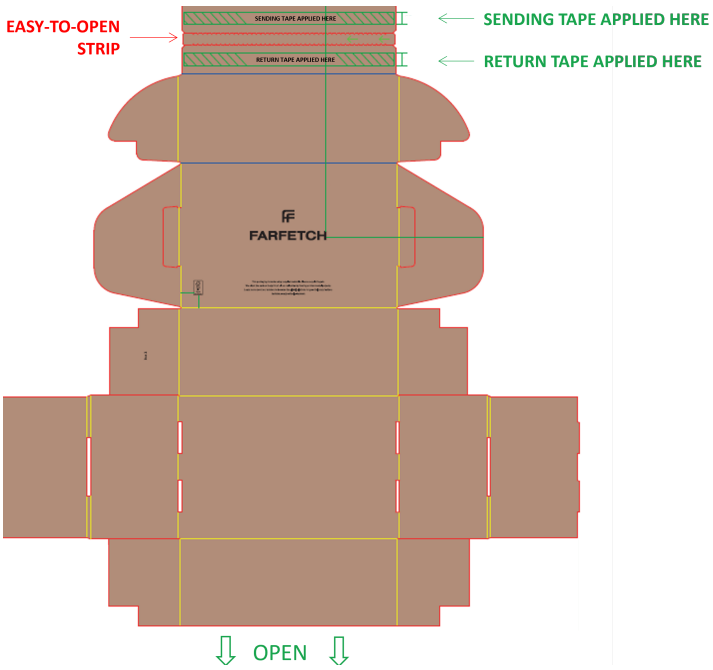

Figure C.2: Inside View of Farfetch's Box

Figure C.3: Padding Sheet

Figure C.4: CMC Genesys - Tote System

Appendix D

Sample collection procedures

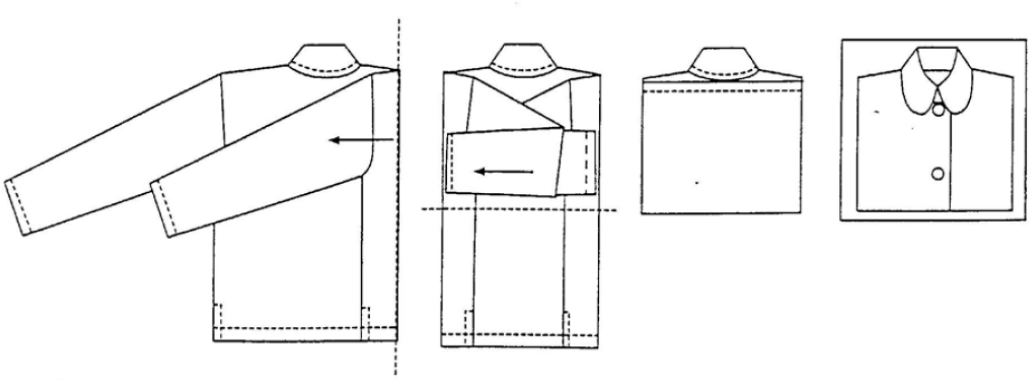

Figure D.1: How to fold Heavy Jackets, Coats, and Sweaters according to Nordstrom Folding Guidelines

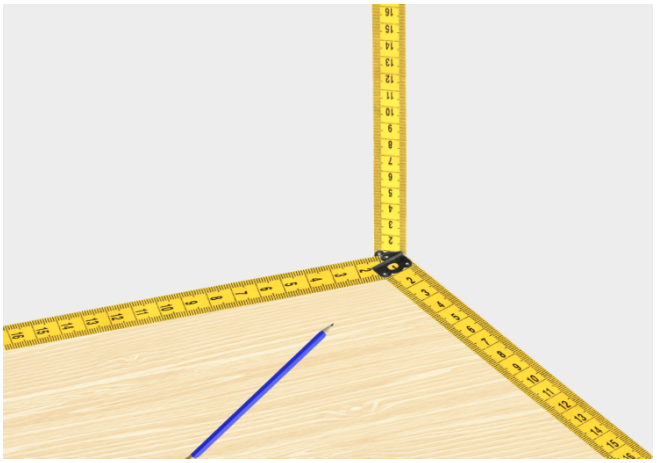

Figure D.2: Measuring method used in Farfetch Boutique

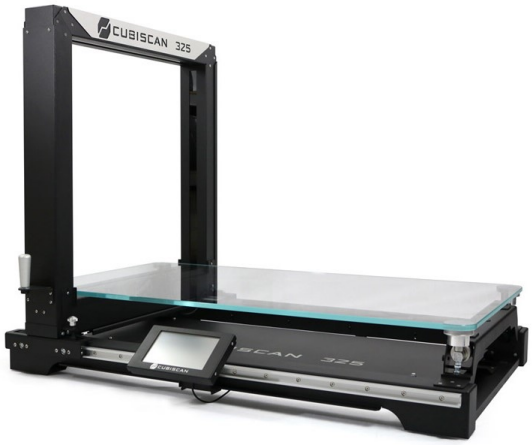

Figure D.3: Cubiscan 325

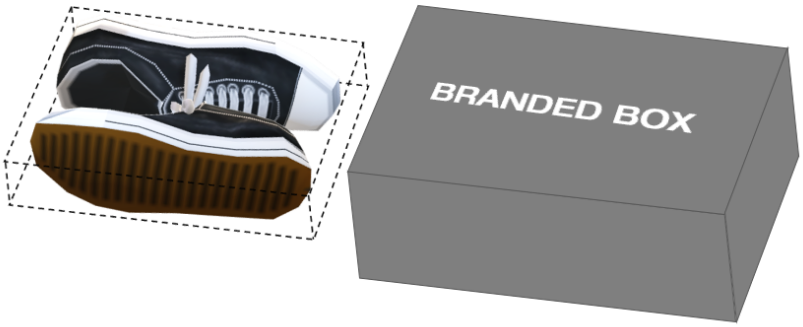

Figure D.4: Representation of a Pair of shoes (on the left) and its branded box (on the right)

Appendix E

Historical Packaging Demand and Expenses

Table E.1: Historical expenses and usage rate by weight threshold

Weight	Percentage of Shipments	Cumulative Percentage of Shipments	Percentage spend	Cumulative percentage spend
0.5	17.99%	17.99%	13.22%	13.22%
1	18.2%	36.19%	14.39%	27.61%
1.5	12.01%	48.2%	10.38%	37.99%
2	10.18%	58.37%	9.31%	47.3%
2.5	10.3%	68.67%	10.27%	57.57%
3	2.46%	71.14%	2.73%	60.3%
3.5	12.06%	83.2%	13.88%	74.17%
4	2.65%	85.85%	3.24%	77.41%
4.5	0.21%	86.05%	0.27%	77.68%
5	1.39%	87.44%	1.91%	79.59%
5.5	6.12%	93.56%	8.66%	88.25%
6	1.61%	95.18%	2.37%	90.62%
6.5	0.66%	95.84%	1.07%	91.68%
7	1.39%	97.23%	2.31%	93.99%
7.5	0.29%	97.52%	0.49%	94.48%
8	0.25%	97.77%	0.46%	94.94%
8.5	0.37%	98.14%	0.7%	95.64%
9	0.66%	98.79%	1.27%	96.91%
9.5	0.15%	98.94%	0.3%	97.21%
10	0.07%	99.01%	0.15%	97.36%
10.5	0.03%	99.05%	0.06%	97.42%
11	0.03%	99.08%	0.07%	97.49%
11.5	0.02%	99.09%	0.04%	97.53%
12	0.02%	99.11%	0.05%	97.58%
12.5	0.02%	99.13%	0.05%	97.63%
13	0.03%	99.16%	0.07%	97.7%
13.5	0.1%	99.26%	0.26%	97.96%
14	0.3%	99.56%	0.81%	98.77%
14.5	0.17%	99.73%	0.49%	99.26%
15	0.26%	99.99%	0.74%	100%
15.5	0.0%	99.99%	0%	100%
16	0.0%	99.99%	0%	100%

Appendix F

Additional Results

F.1 Optimisation of boxes 7, 13 and 14

Table F.1: Initial and Final Box Allocation from Scenario A

		Final Box			
		7’	13’	14’	
Initial Box	**VW**	7.0	10.5	14.5	**Initial Allocation**
7	7.5	43%	8%	2%	53%
13	9.5	15%	12%	0%	26%
14	15	0%	7%	14%	21%
Final Allocation		58%	27%	15%	100%

Table F.2: Initial and Final Box Allocation from Scenario B

		Final Box				
		7’	12	13’	14’	
Initial Box	**VW**	6.5	8.5	9.5	14.5	**Initial Allocation**
7	7.5	39%	8%	3%	3%	53%
13	9.5	10%	5%	11%	0%	26%
14	15	0%	14%	0%	7%	21%
Final Allocation		50%	27%	14%	10%	100%

F.2 "2 Shoes 1 Box"

Table F.3: Initial and Final Box Allocation from "2 Shoes 1 Box"

		Final Box								
		21	21	17	22	3	4	5	6	
Initial Box	**VW**	0.5	1	1.5	2	2.5	2.5	3.5	5	**Initial Allocation**
21	1.5	2%	2%	0%	0%	0%	0%	0%	0%	3%
3	2	0	1%	0%	19%	0%	0%	0%	0%	20%
22	2.5	0%	0%	1%	1%	0%	0%	0%	0%	2%
4	2.5	0%	0%	0%	14%	0%	4%	0%	0%	19%
5	3.5	0%	0%	1%	14%	1%	6%	4%	0%	27%
6	5	0%	0%	0%	8%	1%	4%	6%	9%	28%
Final Allocation		2%	4%	2%	56%	2%	15%	11%	9%	100%