

Designing the Green Supply Chain of the Future for a Luxury Fashion Platform

Francisca Baía Antunes

Master's Dissertation

FEUP Advisor: Prof^ª Maria Antónia da Silva Lopes e Carravilla



Master in Industrial Engineering and Management

2022-07-11

Abstract

E-commerce has bridged the gap between consumers and products, leading to a spiral of unhealthy consumption culture. This behavior has pressured supply chains to deliver a fast response to this steady rise of online products demand, at the expense of the increase of the environmental footprint of operations. Farfetch, as a luxury fashion platform, is committed to restraining its footprint growth, focusing on its supply chain.

The project aims to identify all strategies, as well as analyze different network designs to minimize Farfetch's supply chain footprint, and to develop a 3-year road map of initiatives to lay the foundation to create the green supply chain of the future. Three different configurations of the supply chain were tested resorting to an agent-based digital twin simulator, Anylogic. The simulation models output metrics in three dimensions - sustainability, cost, and service - to understand the benefits and challenges of the proposed strategies. All metrics are automatically exported to an Excel file, where the conclusions can be drawn.

The three tested configurations for developing a green delivery system, to achieve the green supply chain of the future, were: investing in an electrical vehicle to collect boutique orders for the first leg, transport orders by rail freight, and lastly, to deliver last leg orders by cargo bikes. Additionally, a sustainability reporting dashboard was created to bring more visibility to Farfetch's supply chain environmental performance.

The proposed network design initiatives confirm an overall reduction of carbon emissions, between 15% to 99%, varying with the scenarios of each initiative. This emissions cut was also accompanied by a decrease in cost, without compromising the service level of Farfetch. After understanding the potential impact and effort of each strategy, the sustainability reporting initiative was set to be implemented first, then the first leg strategy, followed by the rail freight, and lastly, the last leg initiative. The 3-year road map was developed considering all the analyzed initiatives and the results obtained to structure the green supply chain of the future.

Resumo

Modelação da Cadeia de Abastecimento Sustentável do Futuro de uma Plataforma de Moda de Luxo

E-commerce estabeleceu uma ponte entre os consumidores e produtos online, o que conduziu a uma espiral de consumo não saudável. Este comportamento pressionou as cadeias de abastecimento a responder rapidamente ao aumento da demanda, de forma a assegurar a entrega dos produtos online, às custas do aumento da pegada ambiental. A Farfetch, como plataforma de moda de luxo, comprometeu-se a conter este crescimento da pegada ambiental, mitigando o problema ao focar-se na cadeia de abastecimento.

O projeto tem como âmbito identificar todas as estratégias, bem como analisar as configurações da cadeia de abastecimento com maior potencial para minimizar a pegada de carbono da Farfetch e, finalmente, desenvolver um plano de três anos com iniciativas para estabelecer as bases para criar a cadeia de abastecimento verde do futuro. Três configurações da cadeia de abastecimento foram testadas, com recurso a um simulador *digital twin*, no Anylogic, da cadeia de abastecimento da Farfetch. Os modelos de simulação calculam métricas em três dimensões - sustentabilidade, custo e serviço - para melhor compreender os benefícios e desafios das estratégias propostas. As métricas são exportadas, automaticamente, para um ficheiro Excel, onde as conclusões são tiradas.

As três configurações testadas para o sistema de entregas verde foram: investir num veículo elétrico para recolher encomendas de lojas, transporte das encomendas por comboio e, por último, entregar encomendas aos consumidores finais por bicicletas elétricas. Além disso, também foi criado um painel com métricas de sustentabilidade da empresa, para dar mais visibilidade ao desempenho ambiental da cadeia de abastecimento da Farfetch.

Os resultados das iniciativas simuladas confirmaram uma redução de carbono entre 15% a 99%, variando com os cenários de cada iniciativa. Esta redução de emissões também foi acompanhada por uma redução de custo, sem comprometer o nível de serviço da Farfetch. Após compreender o potencial impacto e o esforço para executar cada estratégia, foi estabelecido que a empresa devia começar por implementar a criação de métricas de sustentabilidade em logística, seguida da estratégia para recolher encomendas com veículos elétricos, depois a entrega de encomendas por transporte ferroviário e, por último, a estratégia de entregas aos consumidores das encomendas por bicicletas elétricas. A definição do plano estratégico de 3 anos foi desenvolvido considerando os resultados obtidos e todas as iniciativas que foram analisadas para estruturar a cadeia de abastecimento verde do futuro.

Acknowledgements

In this section, it is not possible to acknowledge everyone part of my academic journey, which led me to this moment. Firstly, I would like to thank my family, who were my constant rock of support, and without them none of my work was achievable. A special thanks to my mother, who always pushed me to be my best self and to never give up.

To my friends, who were always there for me during the fun times and during stressful exam seasons, and that made college years go by so fast. A special appreciation to Sebastião, your way of looking at the positive side of things and calmness is an inspiration.

I would also like to thank my advisor, Prof^a. Maria Antónia Carravilla, for the constant support and guidance during this project. And to thank Farfetch people who make the company so special and never hesitate to help me.

Lastly, a special thanks to Kathleen and António, from the supply chain design team, for their tireless efforts to make me feel welcome, for always finding the time to guide me and answer my questions, and for sharing their experiences.

"The climate crisis has already been solved. We already have the facts and solutions. All we have to do is wake up and change."

Greta Thunberg

Contents

1	Introduction	1
1.1	Project Context and Motivation	1
1.2	Company overview	2
1.3	Project Goals	3
1.4	Methodology	3
1.5	Dissertation Structure	4
2	Literature Review	5
2.1	Fashion Industry Sustainability	5
2.2	Green Supply Chain Network	7
2.3	Digital Twin Tool	10
2.4	Sustainability KPIs for Supply Chains	11
3	Problem Statement	13
3.1	Supply Chain Overview	13
3.1.1	Operations Workflow	14
3.1.2	Delivery Service Characterization	17
3.1.3	Shipping Cost Structure	19
3.2	Distribution Environmental Footprint Analysis	19
3.2.1	Line-Haul Footprint	20
3.2.2	First Leg Pick-ups	22
3.2.3	Last Leg Delivery	22
3.3	Sustainability Commitment & Reporting	22
3.4	Benchmark Analysis on Green Practices	24
3.4.1	Green Delivery Initiatives	24
3.4.2	Supply Chain Transparency Initiatives	24
4	Proposed Solution	25
4.1	Green Delivery System	25
4.2	First Leg Green Optimization	26
4.2.1	Model Conceptualization	27
4.2.2	Model Translation	28
4.2.3	Output Metrics	31
4.3	Rail Freight	33
4.3.1	Model Conceptualization	34
4.3.2	Model Translation	34
4.3.3	Output Metrics	36
4.4	Last Leg Green Optimization	36
4.4.1	Model Conceptualization	36
4.4.2	Model Translation	37
4.4.3	Output Metrics	38
4.5	Sustainability KPIs Reporting	39

5	Results	41
5.1	First Leg Model	41
5.2	Rail Freight	42
5.3	Last Leg Model	43
5.4	Results Discussion	45
6	Conclusions and future work perspectives	48
A	GHG Protocol Emissions Calculation	57
B	Models Validation	59
B.1	First Leg Model Validation	59
B.2	Rail Freight Model Validation	60
B.3	Last Leg Model Validation	60
C	Ship Stock Movement	61
D	Sustainability KPIs Dashboard	63

Acronyms and Symbols

1P	Products owned by Farfetch
3P	Products owned by external parties
3PL	Third-party Logistics
AI	Artificial intelligence
CROPS	Creative operations
ESG	Environmental Social and Governance Report
EV	Electric Vans
FPS	Farfetch Platform Solutions
FxFF	Fulfillment by Farfetch
GHG	Greenhouse Gasses
KPI	Key Performance Indicator
NGG	New Guards Group
NS	No Stock
NY	New York
NYC	New York City
LCU	Load Capacity Utilization
PA	Packaging Accuracy
SBTs	Science-based Targets
SoS	Speed of Sending
SSCM	Sustainable Supply Chain Management
US	United States
WI	Wrong Item

Glossary

Carbon Offsetting Cost	Fee paid by companies per CO2 tonne released to fund organizations focused on reducing emissions by, for example, planting trees or investing in sustainable energy (Fuels, 2022).
CROPS	Farfetch's department responsible for creating the content in the platform, such as the image, description, and size of the clothing item, until it is ready to go online.
Depot	Central warehouse located outside the city where orders are sorted and shipped to the end customer.
Hub	Local auxiliary facility that assists carriers with order collection and deliveries.
Rate Card	Cost of moving items from the origin to their destination. The carriers charge the rate card by route, volumetric weight category, and shipping type of service (express or standard).
Volumetric Weight	Common pricing technique for commercial freight transport adopted by carriers, which estimates the weight of the package measured by its volume and divided by a constant defined by the carrier. The delivery cost fee is based on the actual weight or the volumetric weight, whichever is greater. The charges are made by categories volumetric weight categories 0.5 by 0.5 kg/cm ³ , meaning if an order has 0.7 kg/cm ³ , it will be charged as 1 kg/cm ³ (ParcelBroker, 2022).

List of Figures

1.1	Gantt Chart of work load distribution	4
3.1	Percentage of total volume of orders supplied from partners per country	14
3.2	Percentage of total volume of orders supplied to consumers per country	14
3.3	The three types of orders generated by a customer, when placing an order	15
3.4	Order delivery steps	16
3.5	Brief illustration of 1P (NGG and Browns) and 3P supply chain	17
3.6	Percentage of volume distributed per carrier	18
3.7	Percentage of volume shipped by standard and express services	18
3.8	Comparison between standard and express of routes with both services	18
3.9	Farfetch's carbon footprint per emissions scope and respective category, adapted from Simonnin et al. (2021)	20
3.10	Total CO2 emissions per delivery service type and respective route type	21
3.11	Offsetting cost projections until 2029 per tonne of CO2	23
4.1	Framework for assessing each opportunity	25
4.2	Green delivery system to lay the foundation to create the green supply chain of the future	26
4.3	First leg green optimization model general overview	27
4.4	First leg model flowchart for model conceptualization	28
4.5	First leg as-is model flowchart for model conceptualization	29
4.6	Boutiques clustering groups using K-means algorithm	30
4.7	First leg green optimization model simulation running	31
4.8	Rail freight model general overview	34
4.9	Rail freight flowchart for model conceptualization	34
4.10	Rail freight model simulation running	35
4.11	Last leg green optimization model general overview	37
4.12	Last leg flowchart for model conceptualization	37
4.13	Last leg green optimization simulation running	38
4.14	Workshop sustainability KPIs dashboard results	40
5.1	Percentage difference of the first leg model's results with the as-is model's outcome for sustainability, cost, and service	42
5.2	Percentage difference of the rail freight model's results with the as-is model's outcome for sustainability, cost, and service	43
5.3	Last leg model parameter variation results for obtaining the optimal number of cargo bikes	44
5.4	Percentage difference of the last leg model's results with the as-is model's outcome for sustainability, cost, and service	45
5.5	Sustainability and cost impact comparison of absolute values between models	45
5.6	Effort-Impact Matrix of Initiatives	47

6.1	3-year roadmap of sustainability initiatives to create the green supply chain of the future	50
6.2	Carbon tax mock-up at checkout for 3-year roadmap	50
A.1	Flowchart for selecting a calculation method for emissions from upstream transportation, adapted from GHG Protocol	58
B.1	First leg green optimization model total orders comparison for the model validation . .	59
B.2	Rail freight model total orders comparison for the model validation	60
B.3	Last leg green optimization model total orders comparison for the model validation . .	60
C.1	Ocean freight overview	61
C.2	Ocean freight analysis results in terms of sustainability and cost comparison	62
D.1	Emission Deliveries section	63
D.2	Emission Returns section	64
D.3	Emission Partners section	65
D.4	Waste & Recycling Products section	66

List of Tables

3.1	Percentage of total orders supplied from partners’ country to consumers’ country . . .	14
3.2	Top five routes with the greatest carbon contribution	22
4.1	Simulation parameters for the first leg model	31
4.2	Output metrics of the first leg model for comparing results	32
4.3	Cost components of the cost output metric for the first leg model	33
4.4	Sustainability KPIs obtained from the workshop	40
5.1	Total EV yearly investment for Farfetch	41
5.2	Sustainability impact of the first leg model	42
5.3	Sustainability impact of the rail freight model	43
5.4	Sustainability impact of the last leg model	44

Chapter 1

Introduction

The planet is getting dangerously hotter through the accumulation of Greenhouse Gasses (GHG). Climate change has become an existential emergency for the human species, with devastating consequences. The consumption culture fed by corporations is at the heart of the global ecological crisis. A collective effort needs to be secured to assure the vitality of the planet and the quality of life.

The chapter starts by giving a short context, then it characterizes the company where this project was held, followed by an overview of main goals expected to be achieved. Then the chapter finalizes with a description of the methodology and the structure of this project.

1.1 Project Context and Motivation

The rising concern towards sustainability has affected how companies are conducting their businesses and strategies. A recent survey indicated that there is rising pressure to act from a wide spectrum of stakeholders. Customers take the lead of those who pressure corporations to act, but employees, regulators, and investors are right behind them. As of 2018, there was a 34% rise in investments towards sustainability, with a total value of \$30 trillion (Coppola and Blohmke, 2019). This tendency demonstrates the global shift of behavior towards a more environmental approach, making the climate crisis central to all stakeholders' agendas.

Consumers' global awareness of environmental issues pushes firms to assess their sustainability performance and actively address the situation (Mastercard, 2021). Corporations are increasingly recognizing the importance of including sustainability strategies, aiming for a balance between financial and environmental performance to generate value sustainably, without compromising the future of the next generations (Eitelwein, 2021).

The fashion industry, in 2018, was estimated to be responsible for 2% to 10% of the global GHG emissions due to the extensive activities involved in the manufacturing and shipping of the millions of apparel bought each year (UNECE, 2018). Although the fashion industry committed to reach net-zero emissions by 2050, pledging to keep the global temperature rise under 1.5°C, there is a lack of dedication. Currently, the industry is on a trajectory that will surpass the target to mitigate climate change, established by the Paris Agreement, and COP26 (Fashion Charter, 2018). Additionally, it was set to reduce GHG emissions by 2030 to 1.1 billion metric tons of CO₂ equivalent, but a McKinsey study revealed that the industry is set to release almost double of the target by 2030 (Berg et al., 2020).

Farfetch, as a global platform for the luxury fashion industry, is committed to assessing the company's impact on the environment and becoming a leader in sustainability, as stated by José Neves, chief executive officer, *"We are building and growing our business model to have a positive impact, where sustainability is at the heart of our culture and how we prosper"*. This commitment was prompted by Farfetch pledging to become climate positive by 2030 (Farfetch, 2020).

Supply chain network design has a significant influence on the environmental impact of Farfetch's supply chain. As supply chains become more complex, strategic decisions on facility location and delivery channels are becoming more demanding. To add to that, the traditional focus on cost minimization is no longer viable and GHG emissions need to be weighed in decisions.

Bearing in mind the importance of reducing GHG emissions and given that Farfetch's supply chain is at the heart of the company's sustainability strategy, the project will be integrated into Farfetch's Supply Chain Design team.

1.2 Company overview

Farfetch exists for the love of fashion and since it was founded in 2007 by José Neves, it has been bridging the gap between luxury fashion brands and boutiques with clients from all over the world. The company's mission is to be the global platform for luxury fashion (Farfetch, 2022).

Farfetch has come a long way since the launch of the e-commerce marketplace for luxury fashion in 2008. The company is currently present in over 210 countries and counts the partnership with over 1700 brands, boutiques, and department stores, providing a one-of-a-kind purchasing experience to clients all over the world (Farfetch, 2022). Currently, the company has 14 offices and has been growing the number of employees, reaching over 5000 employees (Craft.Co, 2022).

Farfetch's business model allows boutiques and brands, known as 3P partners, to reach millions of customers, while the company secures the distribution and shipping of the items to the clients, earning a commission on the sale. The inventory is held and packaged by the boutiques and brands, whereas the shipping is fulfilled by third-party logistics (3PL) through the drop-shipping method. Most of the deliveries are held by DHL partners, but it is done by other carriers, such as FedEx and UPS. In addition, Farfetch grew the business by acquiring Browns, a fashion boutique; Stadium Goods, a retailer focused on the resale of sneakers; Violet Grey, a beauty retailer, and New Guards Group (NGG), a luxury fashion producer holding 9 brands. The acquisition of these partners, known as 1P partners, allowed Farfetch to enter the retail industry and to own stock, broadening the company's offer of luxury to customers.

Farfetch has also been searching for strategic opportunities to secure a strong position in the luxury fashion market, expanding its portfolio by developing Fulfillment by Farfetch (FxFF). FxFF is a network of fulfillment centers responsible for managing inventory. For this purpose, the company made a joint venture with Clipper Logistics, a retail logistics company offering logistics services. The company currently has warehouses distributed in Hong Kong, Italy, the Netherlands, the UK, and the USA, managing mostly stock from 1P partners and a small percentage from 3P partners, allowing greater control over the business.

Farfetch has also launched Farfetch Platform Solutions (FPS), offering luxury companies the possibility to benefit from the company's e-commerce and digital expertise, enabling corporate clients to integrate their in-store experience with their online.

Since Farfetch is responsible for the entire order process, from the online content, and the payments, to securing the order shipping and delivery of the items, it is imperative to monitor Farfetch's operations and supply chain performance, to deliver an operational excellent service. Part of the operations team, the department of Logistics Optimization and Strategic Planning, is in charge of providing strategic design, tactical optimization, and operational intelligence to Farfetch logistics. The supply chain design team is part of this department, where the project is integrated.

1.3 Project Goals

As previously stated, Farfetch is committed to becoming a sustainability leader. Downstream transportation and distribution account for 55% of the total carbon emissions, therefore, Farfetch's supply chain is crucial to the firm's sustainability strategy and success (Farfetch, 2020).

As Farfetch has set the ambitious target to be climate positive by 2030, the project aims to design the green supply chain of the future that will result in the reduction of the company's carbon footprint, focusing on network design to reduce Farfetch's carbon footprint for the next 3 years.

For this purpose, firstly, it is important to continuously track Farfetch sustainability by the development of Key Performance Indicators (KPIs) of sustainability to evaluate and capture the performance of Farfetch's supply chain. Secondly, all the strategies, that should minimize the footprint, need to be identified from the assessment of Farfetch's supply chain and benchmark analysis. Afterwards, the impact of the most promising strategies are analyzed, resourcing to a digital twin simulator of Farfetch's supply chain. The simulating tool will allow for computing alternative scenarios and designs, while assessing and comparing the performance of each scenario to identify the most impactful ones.

The final goal will be to develop a business case demonstrating the impact of the results on Farfetch's P&L and a 3-year road-map of initiatives to lay the foundation to create the green supply chain of the future.

1.4 Methodology

Aligned with the project goals, the methodology implemented had the objective to identify relevant improvement opportunities, as well as assist in the planning, organization, and monitoring of the project execution.

The methodology can be divided into five phases and respective goals:

1. Business understanding: Characterization and mapping of the supply chain network and identification of opportunities to address, according to the project scope;
2. Research: Collection, preparation, and understanding of the data and benchmark analysis;
3. Traceability & Modeling: Definition of sustainability KPIs to monitor Farfetch's supply chain performance and definition of the model structure for the different identified scenarios;
4. Evaluation: Comparison of the different scenario's performance;
5. Recommendations: Description of the initiatives to be implemented on a 3-year plan.

For the tasks involved in the projects, a Gantt chart was created to better organize the workflow and time, as presented in Figure 1.1.

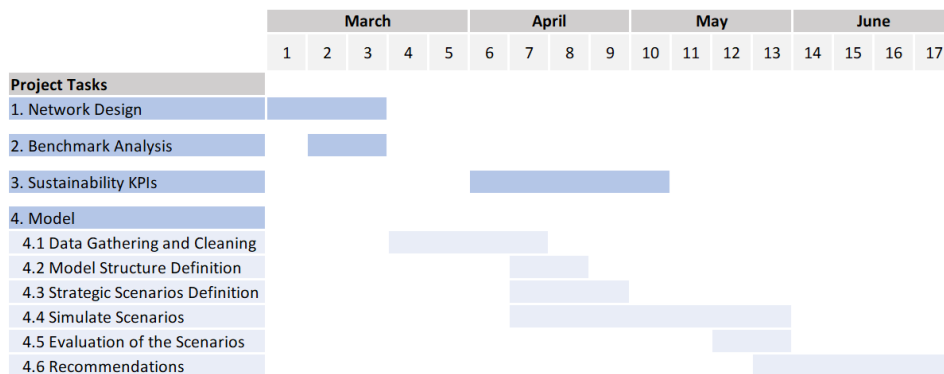


Figure 1.1: Gantt Chart of work load distribution

1.5 Dissertation Structure

The remaining content of this document is organized in five chapters.

Chapter 2 includes a literature review regarding the thesis scope. It starts with a deconstruction of the luxury fashion business and a review of its sustainability performance, as well as the industry's future and challenges. Then, is followed by an assessment of the current challenges and needs for a green supply chain network design, the importance of a digital twin tool for testing alternative scenarios, and finally an overview of KPIs in sustainability.

Chapter 3 encompasses the description of the problem of Farfetch's supply chain carbon footprint. It begins with a general overview of Farfetch's current supply chain and operational processes. Then, it includes a detailed characterization of Farfetch delivery service. Finally, it discusses the influence of the supply chain on the carbon footprint, complemented with a benchmark review of the best green initiatives of companies to minimize their carbon footprint, focused on green delivery service and transparency.

Chapter 4 describes the presentation of the proposed green network optimization scenarios, as well as the digital twin simulation models created to assess the potential of the proposed optimizations on the network, followed by the KPIs developed to secure the monitoring of Farfetch's environmental performance.

Chapter 5 examines, in-depth, the influence of each scenario on the supply chain performance from a sustainability point of view.

Chapter 6 concludes the dissertation with a roadmap of initiatives to reduce Farfetch's carbon footprint for the next 3 years.

Chapter 2

Literature Review

This chapter begins by introducing the theoretical background review on the sustainability performance of the fashion industry, starting by explaining why the fashion industry is unsustainable. Then, it continues by comparing the luxury and fast fashion environmental impact. The chapter is then followed by the characterization of the market shift towards sustainability and how luxury fashion companies can seize this opportunity to broaden their approach to sustainability, alongside a review of how the fashion industry is addressing the sustainability challenges.

The chapter proceeds to deep dive into the influence of supply chains on the e-commerce environmental performance, focusing on the different aspects of the online retailing delivery system and its impact. Then, it is given a short overview of how to take advantage of the digital twin tool to assess supply chain design strategies. Finally, a summary of sustainability KPIs importance and found in different studies is characterized.

2.1 Fashion Industry Sustainability

The fashion industry has become one of the most wasteful global industries. In the last 15 years, clothing production has doubled, due to the rising demand for new fashion items, coupled with a decrease in the number of times a product is worn. In fact, in the United States, clothes are worn for just a quarter of their life span (Magnin and Hedrich, 2019). In fashion, trends rapidly change, and consumers want to wear the latest style, which shortens the life cycle of clothes. This behavior results in 73% of clothing ending in landfills and only 1% being recycled, estimating that \$140 million worth of clothing is wasted, just in the UK (Moorhouse, 2020). The clothing industry is also characterized by overproduction, where 40% of the items manufactured are sold at a markdown. This is due to faster product drops, longer lead times, and multinational supply networks (Brydges, 2021). The unsold stock is sometimes donated or even destroyed, generating even greater waste (Gabardi, 2022).

The liberation of trade and the globalization of markets allowed the fashion industry to scale globally, overcoming boundaries and relying on outsourcing of the final production and delivery channels. This business model results in companies having an opaque and complex supply chain, where there is a lack of control of where the raw materials are coming from, how the textiles and clothing are being produced, and how the items are being delivered (P.Pucker, 2022). This lack of transparency in the

supply chains of fashion companies translates into the lack of ability to extensively analyze their environmental impact and assess ways to improve it. In fact, a recent report comparing fashion companies' sustainability performance, highlighted how there is an urgent need to disclose quality data to enable key decisions driving environmental change, as sustainability goals are falling short (Kent, 2021). Increasing collaboration between stakeholders would allow fashion companies to align strategies and share best practices across the whole network, to improve their sustainability (Berg et al., 2020). The shortage of transparency limits traceability and results in the industry footprint ranging from 2% to 10% of overall global carbon emissions (UNECE, 2018).

The fashion market can be deconstructed into three fashion verticals – luxury, high-street, and sportswear. The high-street and sportswear can be identified as fast fashion. When looking into the sustainability performance of each vertical, it would be expected for luxury to be more sustainable than fast fashion, as luxury products are more durable and with better high-end materials. However, when comparing the environmental performance of the verticals there is little difference between them (Kent, 2021). In fact, the luxury fashion is becoming increasingly similar to the fast fashion business model.

According to Balchandani et al. (2022), Covid-19 hit luxury fashion sales hard, resulting in a 20% decline. To adapt and avoid further collapse, luxury fashion firms are adopting the cycles of fast fashion, by targeting millions of consumers (Choufan, 2020). The tremendous market built by brands such as Zara, incentivize luxury fashion labels to do partnerships, resulting in a 'high-low' collaboration to appeal to the masses with luxury styles, closing the gap between fast and luxury fashion. The luxury brands even shifted from 2 seasons to now introducing new collections every month, being in sync with the consumer demand. Luxury companies have also adopted the fast-fashion direct-to-consumer business model by creating their retail channels and further increasing the consumption of clothing (Choufan, 2020).

Although the fashion industry still has a long way to go, the market demands for sustainability are rapidly shifting the business mindset. Consumers are increasingly demanding fashion companies to be sustainable and to offer more environmentally friendly options. According to the latest study by Business of Fashion, a third of the millennial and gen-z generation are willing to spend more money on less harmful products (Kent, 2021). According to a poll by Granskog et al. (2020), 65% of respondents want to buy more durable fashion garments, and 71% want to retain the clothes for a longer period. Another interesting research found that when consumers were confronted that the purchased item was unsustainable, they felt more guilty if it was a luxury item than a mass-market product. Additionally, green items were found to be seen as a mark of the status of luxury goods, as consumers of luxury can publicly communicate their concern for the environment and also expect luxury brands to be more sustainable.

These customers' behaviors constitute a significant opportunity for fashion firms to examine and reaffirm their commitment to the environment. However, the consumption culture is the main force that drives companies to engage dangerously, leading to the devastation of the environment (Amatulli et al., 2020). Therefore, the typical business model of the fashion sector is no longer viable, and sustainability can no longer be ignored, as luxury brands are facing pressure, not only from consumers but also from legislation and investors, who are targeting companies monitoring sustainability, increasing in 2020 by 73% (Winston, 2016).

Luxury fashion companies are aware of the environmental concerns arising and are tackling the

situation by focusing on more sustainable design and production (Faccioli and Sheehan, 2021). Bringing sustainability into the luxury market could also help brands improve their reputation, increase the customer retention rate, and gain a competitive advantage over other companies that do not tackle environmental issues (Yang et al., 2017). However, other studies state that the principles of sustainability are incompatible with luxury, because it focuses on providing consumers with unique, valuable, and rare materials that make them feel prestigious (Karaosman et al., 2020). The challenge lies in delivering the same value to the consumer, but with more sustainable materials and fabrics. The complexity of this challenge leads to companies losing motivation to implement sustainable practices, especially when it comes to production (Yang et al., 2017). In fact, for luxury fashion companies, the main motivation lies in reducing the environmental impact resulting from their operations, but sustainability actions must tackle the entire network (Karaosman et al., 2020).

Nevertheless, the luxury industry is entering a new era, and a redesign of the fashion business is imperative. An extensive analysis by McKinsey (Berg et al., 2020) identified key areas of improvement to reduce the industry's carbon footprint and assure a sustainable future by 2030. Reducing the emissions, from upstream operations, by improving energy usage and transitioning to renewable energy sources, could result in 61% of the necessary reduction to achieve the 2030 goals, previously mentioned. Second, by enhancing recycled material utilization, making smarter production decisions, increasing sustainable transportation of goods, improving packaging with lighter and recyclable materials, minimizing returns, and eliminating overproduction, the fashion industry will cut emissions from operations. Finally, by motivating responsible consumer behavior to overcome the over-consumption issue. This could lead to the implementation of new business models, such as circular businesses that promote apparel repair, resale, rental, and refurbishment, increasing recycling, and reducing textile waste, moving the industry toward a closed-loop recycling operating model. This business model has the potential to overcome the current damaging environmental impact of the fashion industry, which can only be possible if it becomes transparent for traceability (The Sustainable Fashion Forum, 2022).

2.2 Green Supply Chain Network

The e-commerce fashion industry relies heavily on the efficiency and flexibility of its supply chain, which are elaborate networks, crucial for companies to remain competitive, involving several stakeholders. One of the most vital decisions for a company is the architecture of its supply chain, as designing and planning its network is key to an organization's efficiency and sustainability (Kelly and Marchese, 2015). Additionally, researchers, in different studies, confirm the potential to reduce carbon emissions through supply chain activities, playing a vital role in the environmental performance of companies (Gunasekaran et al., 2015).

Therefore, there is a need to incorporate sustainable supply chain management (SSCM) for the implementation of responsible practices, throughout the network, focusing on two crucial areas: upstream and downstream flows and apparel production (Saeed and Kersten, 2019). The goal of a green supply chain is a balanced break-even point between efficiency and sustainability (Martí et al., 2015).

To reassure an effective environmental strategy, companies need a clear understanding of their GHG emissions and other sustainability metrics to track their supply chain environmental performance. Although GHG emissions calculation is very important for sustainability reporting, it can be a very com-

plex and challenging task. According to Barrow et al. (2013), there are three scopes for calculating GHG emissions:

- **Scope 1:** Direct GHG emissions from sources controlled by the company;
- **Scope 2:** Indirect GHG emissions from the purchase of electricity for the company use;
- **Scope 3:** All other indirect GHG emissions from the company activities from sources not controlled by the company.

While many corporations have focused their efforts to mitigate scope 1 and 2 emissions of the GHG protocol; neglecting scope 3 emissions is a critical mistake (Barrow et al., 2013). In fact, Wren (2022) argues that sustainability reports from fashion companies still lack transparency when it comes to the disclosure of their environmental impact of scope 3 emissions. As e-commerce supply chains become more complex and demanding, social and environmental costs are far greater than operational costs (Swartz and Bove, 2016). More than 80% of the total GHG emissions, in most consumer-goods categories, are in supply chains and only 25% of companies engage with their stakeholders to address scope 3 emissions. Primarily in the fashion industry, where subcontracts are very common, it becomes difficult to control and assess the environmental impact of the entire supply chain. This behavior makes it difficult to fully commit to SSCM strategies.

The rise of e-commerce demand has pressured supply chains to deliver a fast response, which increased the number of trips of distribution channels, especially across short-haul and last-mile (Hooper and Murray, 2019), at the expense of the environment. In fact, according to Logistics City (2021), in New York, home deliveries have tripled from 2009 to 2017 to more than 1.1 million deliveries. This trend was further heightened by the Covid-19 pandemic, in 2020, where in Europe, 73% of consumers shopped online, accounting for the steepest increase observed (Lone et al., 2021), reaching \$4.2 trillion (Coppola, 2022).

The sales increase of online shopping is also due to the success of fast delivery services. Amazon was one of the first companies to offer such service and led consumers to always expect fast delivery from other companies, pressuring them to also adopt this strategy (Grosman, 2018). Today, consumers expect their orders to arrive within two days maximum, whereas before one to three weeks delivery time was expected (sendcloud, 2021). With 78% of consumers pressuring companies to deliver products within one day, organizations turn to more expensive and faster modes of transportation, such as airplanes, which are environmentally more damaging (Bertram and Chi, 2018). Additionally, fast delivery was found to increase costs by 68% and emissions by 15%, in a study comparing road freight with fast delivery, standard delivery, and green delivery with a slower delivery window (Muñoz-Villamizar et al., 2021). This pressure on the supply chains distribution led to a difficulty in consolidating orders and fully loading airplanes and vehicles, as well as planning and optimizing delivery routes, incurring in high spending, pollution, and an increase in the number of deliveries (Logistics City, 2021).

However, according to Rai (2019), consumers are willing to choose a wider delivery window and reveal a lack of awareness of the damaging impact fast delivery has on the environment. An interesting study conducted by MIT (Fu and Fu, 2018) concluded that companies have the power to influence consumers to engage in greener shopping behavior. The researchers found that when the consumer had the choice to save a hundred trees or opt for fast shipping, 40% opt for slower delivery. Using trees as

a way to explain the environmental impact of fast delivery was more effective than financial incentives. Another study concluded that 80% of online consumers are unaware that fast delivery has a greater impact on sustainability than slower delivery, and when explained, only 10% preferred fast delivery, while 43% preferred green delivery (Logistics City, 2021). These studies show how consumer behavior is changing towards sustainability and that other factors, besides price, are considered on opting for green deliveries.

As e-commerce sales keep rising, the transport demand will continuously grow. Looking into the global CO₂ emissions from transportation, airplanes emit the greatest emissions, followed by trucks, rails, and ships. The International Energy Agency's scenario for 2070, predicts the electrification and hydrogen of transport modes, expecting the decarbonization of motorcycles, rail, and small trucks. But aviation and road freight with large trucks is a challenge to decarbonize (Ritchie, 2020). The potential of rail freight network in Europe could save a substantial amount of CO₂ emissions. If 62% of road freight were replaced by rail, it would lead to a reduction of 200t of CO₂ per day (Boehm et al., 2021). When it comes to ocean freight, an interesting study conducted by Lagoudis and Shakri (2015), concluded that by leveling the cargo transported by ocean freight and air freight, companies could take advantage of ship routes, reducing emissions by 30% with a marginal increase in cost and, if done before peak season, assure delivery on time. However, there is still a need to use non-decarbonized transport modes, and to reach net-zero by 2070, the emissions need to be offset (Ritchie, 2020). Nevertheless, new modes of transportation for the last mile are resurging, such as electric cargo bikes, a more flexible and environmentally friendly option (Logistics City, 2021).

Home-delivery of goods is also a major contributor to the environmental impact of e-commerce. The vans used for the last-mile delivery account for the release of excessive amounts of CO₂, because of their size and the frequency of transit between cities. Although last-mile deliveries only represent a small percentage of the distance traveled, last mile emissions correspond to 36.4% of the overall transportation emissions (Mommens et al., 2021). Similar research reaffirmed that last mile delivery is responsible for 32% of the total energy usage of e-commerce distribution (Bertram and Chi, 2018).

Another problematic factor for e-commerce is failed deliveries, when the delivery of a package does not take place, because the customer is not at home. On average, consumers miss 12% of deliveries. This leads carriers to try to deliver the package on another day, or consumers must drive to the collection point to pick up their package. In Bertram and Chi (2018), failed deliveries were found to potentially increase emissions by 25%.

Basket size, in Loon et al. (2015) study, was also found to impact the e-commerce footprint. The researchers conclude that the emissions per item increase steeply in smaller basket size. This is verified as the items from different suppliers, in fulfillment centers, are distributed into different parcels, instead of maximizing the space within the same package. Motivating consumers to increase the number of items delivered per order attenuates the environmental effect of e-commerce. Load capacity utilization (LCU) is also a crucial factor linked with the release of CO₂ emissions. A review on the third-party logistics (3PL), in Hong Kong, of truckload optimization against truck capacity found there is an increasing concern among companies to measure this factor. However, there are no structured methodologies to map it (Wong et al., 2018).

As returns play a significant role in the e-commerce fashion industry, it also greatly affects the environmental impact of online sales, which is determined by how it is returned, with the least damaging

approach being for the carrier to divert their usual delivery route to pick up parcels. However, when a consumer returns an item to a store location, their carbon emissions rise. As well as, when a consumer returns an item via post-office, since it cannot be bundled with other goods (Bertram and Chi, 2018).

Although store retailing could be more environmentally damaging, when considering all factors that contribute to the e-commerce industry's footprint, it rapidly loses the benefit over traditional retailing (Loon et al., 2015).

However, re-adjusting the supply chain network to optimize its environmental performance might reduce the overall footprint. For example, when looking into the possibility of adapting collection points, studies conclude its benefit depends on the density of the delivery areas. For rural areas, home delivery is the best option, in terms of sustainability. However, when it comes to urban areas, with a high density, collection points are the most viable option, in terms of sustainability (Mommens et al., 2021). Another simulation research on groceries e-commerce networks compared home deliveries, collection points, and crowd logistics. The last is a new potential concept that encourages the use of passenger space capacity in vehicles such as automobiles, motorcycles, buses, and aircraft to transport goods (Rai et al., 2017). The study found the most sustainable design of last-mile delivery is crowd logistics, followed by collection points and lastly home deliveries. When it comes to costs, the least expensive option was click and collect, followed by crowd logistics (Melkonyan et al., 2020).

Another example is the surge of micro-fulfillment hubs close to urban areas and, therefore, closer to the customer, allowing for faster and more flexible deliveries with fewer trips and pollution, solving problems with urban delivery. Additionally, it could also be used for collection or return points. This design could potentially reduce emissions by 16% to 26% (Pharand, 2021).

The rising concern with sustainability needs to be considered in the redesign of the supply chain of the future, which needs to be transparent, providing real-time data used to trace and measure environmental performance and identify disruptions. Blockchain can be a useful technology to mitigate the transparency issue of supply chains, improving traceability and observability. This technology is an enabler to keep data updated and accessible (Agi and Jha, 2022). Additionally, blockchain technology could be applied to trace the materials used in clothing and help manage complex circular supply chains (Wang et al., 2020). In this sense, collaborative operations and information have a considerable potential to reduce environmental impact (Verlinde, 2015).

2.3 Digital Twin Tool

Supply chain network design plays a fundamental role in a company's sustainability and cost-efficiency, critical to materializing companies' value proposition (Altıparmak et al., 2006). Ensuring the efficiency of the network can be quite challenging as supply chains are very complex networks with multiple variables, where uncertainty is a constant (Barrow et al., 2013). Therefore, decision enablers are crucial to support strategic decision-making on the architecture of the supply chain. A holistic hybrid simulation-optimization approach might be the key to overcoming this problem (Tordecilla et al., 2021).

A digital twin is a scenario-based virtual model characterized by the integration between physical and virtual space, capable of predicting the impact of potential changes to the network (anyLogistix, 2022). The tool enables multiple experiments in a risk-free and cost-efficient environment, without

the need to modify the actual network, providing support in complex decision-making. This technology, capable of dynamically representing real-life situations, is being increasingly applied in different industries, as it enables stakeholders to make more accurate predictions and, therefore, to make more valuable decisions (Tao et al., 2019).

In complex industry processes, such as fashion supply chains, simulation with data analytics combined with artificial intelligence (AI) has a limitation when it comes to developing a credible model, as it is based on historical data, making it hard to forecast the impact of decisions (Bruzzone et al., 2022). Digital twin receives real-time data to make predictions, indicating not only what might happen in the future, but also now in the real world (Raghunathan, 2019). Given these considerations, combining historical data analysis with digital twin simulation, capable of forecasting the impact of scenarios changes, allows reproducing actions of the various agents during the simulation, as it is considered one of the best techniques for simulating complicated systems (Terzi and Cavalieri, 2004). AI, data analytics, and optimization can be part of the digital twin, where it will be used to predict and perform decision-making (anyLogistix, 2022).

Digital twin models involve virtual, physical, connections, and data modeling. Physical modeling is effective for extracting, defining, and describing essential physical entity properties. Virtual modeling creates a replica of the real entity that includes the same characteristics and behaviors (Tao et al., 2019). The connection is established between the physical to the virtual environment, where the metrics are measured in the physical space and updated in the virtual space. While the connection between the virtual to the physical, updates the physical space with the optimal set of parameter values measured in the virtual environment. This action is called twinning (Jones et al., 2020). Another important stage is data fusion, as data collection from the physical entity can be a complex phase and there is an empirical need to extract valuable data. This state involves three steps: data preprocessing, data mining, and data optimization (Tao et al., 2019).

Modeling an e-commerce fashion supply chain enables companies to better understand properties and identify improvement opportunities. At present, digital twin are mostly used for manufacturing models. However, it has a potential to analyze different network scenarios for sustainability purposes, as it enables dynamic supply chain optimization and performance improvement. The tool is able to identify potential improvements and give insights on particular events occurring in the supply chain, enabling its transformation (Kamble et al., 2022).

2.4 Sustainability KPIs for Supply Chains

Organizations need to track the environmental impact of their supply chains to be able to identify opportunities to improve sustainability. This makes it imperative for supply chain teams to define relevant KPIs to monitor and control the network sustainability (Chorfi et al., 2015). KPIs allow businesses to more effectively monitor their performance, maintain tighter control over operations, and ensure the company is going in the right direction (Ammara et al., 2016).

Hristov and Chirico (2019) study addressing sustainability KPIs for the three sustainability pillars - environmental, social, and economic, defined four goals for the environmental dimension. The first is to reduce gas emissions, focusing on tracking the percentage of released emissions, such as GHG. The second goal is to improve the use of renewable, addressing KPIs for monitoring the waste generated per

unit and the percentage of recyclable material. The third is focused on the reduction of natural resources consumption, such as controlling the amount of energy, gas, and water consumed. Finally, the fourth goal is to reduce waste and to improve the efforts to address “greenness”, tracking the renewable energy, reusable material, and sustainable water rates.

Regarding GHG emissions KPIs, delivery is responsible for a great amount of emissions released. However, a study found that most companies using 3PL do not ask distribution companies to report their CO₂ emissions, which is vital to assessing supply chain environmental impact (Laura et al., 2019).

Another relevant sustainability reporting suggested by Swallow (2022) is to track the companies’ social impact disclosed in the Environmental Social and Governance reporting (ESG) on relevant sustainability metrics. This reporting allows for companies to advertise their efforts in addressing social problems, helping to keep track of the initiatives being implemented to mitigate such issues. However, P.Pucker (2022) reminds that even with ESG reporting increasing, in the past few years, environmental damage is still rising, and this report lacks an external audit to confirm the veracity of the document.

As governments are pushing forward to be carbon-neutral by 2050, carbon emission reduction has become one of the primary purposes of supply networks (UN, 2021). A study, reviewing the effect of companies adopting carbon policies to mitigate supply chains’ footprint, found that by adopting carbon policies, such as carbon tax or carbon offsetting, where a small fee is paid per gram of CO₂ released, significant reductions, in emissions, might be accomplished with minor cost increases (Waltho et al., 2019). The main difference between carbon tax and carbon offsetting lies in the fact that the offsetting fee is used to fund organizations focused on reducing emissions by, for example, planting trees or investing in sustainable energy (Fuels, 2022). These carbon policies might be a way forward to bring more attention to sustainability, as they make sustainability KPIs monetizable.

Chapter 3

Problem Statement

This chapter starts with a general overview of Farfetch's supply chain, aiming to fully understand how the company's operational processes work. Then, as the distribution of goods plays a critical role in Farfetch's environmental footprint, the chapter deep-dives into the company's delivery service and corresponding cost structure.

After the introduction of Farfetch operations, the chapter continues with a description of the company's sustainability reporting and commitments, followed by an analysis of Farfetch's network footprint.

Finally, the chapter is concluded with a brief benchmark analysis of green practices and transparency of the supply chain network of relevant companies in the industry.

3.1 Supply Chain Overview

Farfetch has a dynamic and complex network, covering customers in over 210 countries. In 2021, Farfetch was responsible for fulfilling over 8.7 million orders from 3.2 million customers, partnering up with more than 1700 boutiques from 55 countries worldwide.

Farfetch partners are mostly located in Italy, where it accounts for almost 40% of the total supply. The volume of the orders fulfilled per partners' countries are represented in Figure 3.1. The volume supplied is divided between the two Farfetch partners: 3P is responsible for delivering 85% of orders and 1P for 15%. Farfetch still has five warehouses in a global network in four distinct countries to assist the fulfillment of orders directly from the warehouses to customers worldwide and to hold stock, mostly from 1P partners.

Regarding customers, the country with the biggest demand is the United States, as revealed in Figure 3.2. The routes with the greatest volume transported are exhibited in Table 3.1, where the route with the greatest flow is between Italy and the United States. In conclusion, the supply is more centralized than the demand, which is more fragmented.

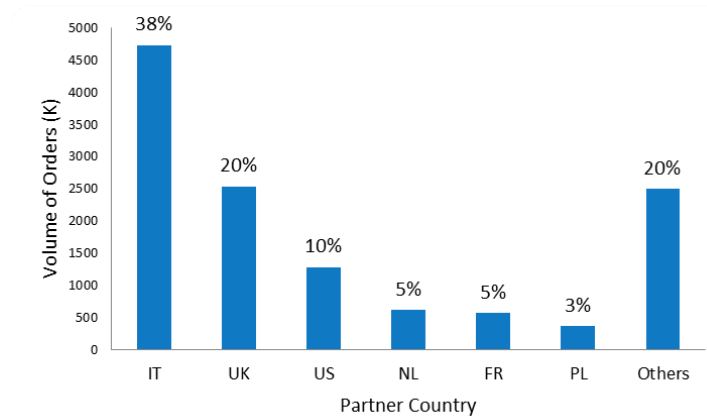


Figure 3.1: Percentage of total volume of orders supplied from partners per country

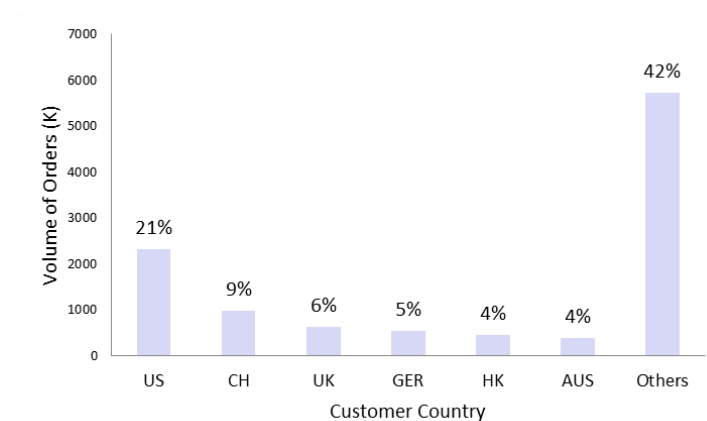


Figure 3.2: Percentage of total volume of orders supplied to consumers per country

Table 3.1: Percentage of total orders supplied from partners' country to consumers' country

Routes	% Orders per Route
Italy-United States	7.1%
United States-United States	4.7%
Italy-Russian Federation	3.8%
Italy-China	3.1%
United Kingdom-United States	2.8%
Italy-Germany	2.3%
United Kingdom-United Kingdom	2.0%

3.1.1 Operations Workflow

Farfetch operations plays a critical role in the company's success. The operation's workflow is characterized by three stages until the order is delivered: luxury fashion product life cycle, creative operations, and order processing. Following the delivery of the order, there are two additional stages: post-order service and service excellence. The description of the operation's workflow in the following only accounts for the 3P partners.

Luxury fashion product life cycle represents how products are added to Farfetch's platform, starting with the boutique partners ordering products from luxury brands. Then, the partners create, on Farfetch's platform, the item to sell, supported by Farfetch's catalog team.

Creative operations (CROPS) is responsible for creating the content in the platform, such as the image, description, and size of the clothing item, until it is ready to go online. Before the items go up on the platform, the boutiques send the item to one of the five CROPS facilities in Guimarães, Porto, Hong Kong, São Paulo, and Los Angeles, to be photographed. The content & catalog management team is then responsible for placing the product online, with the proper description and pricing. After the item is photographed, it is sent back to the boutique.

The last stage is **order processing**, where the orders are delivered to the final customer. This process starts with the customer placing an order on the platform, which creates three different types of orders: portal order, boutique orders, and product orders. Figure 3.3 exemplifies the types of orders. In the example, the customer orders three products in the platform, which constitutes the portal order. Product order 1 and 2 are supplied from a different boutique than product order 3, generating two separate boutique orders, respectively. Then, the two boutique orders are delivered separately to the customer. This means that a single portal order can have products from different boutiques in distinct countries.

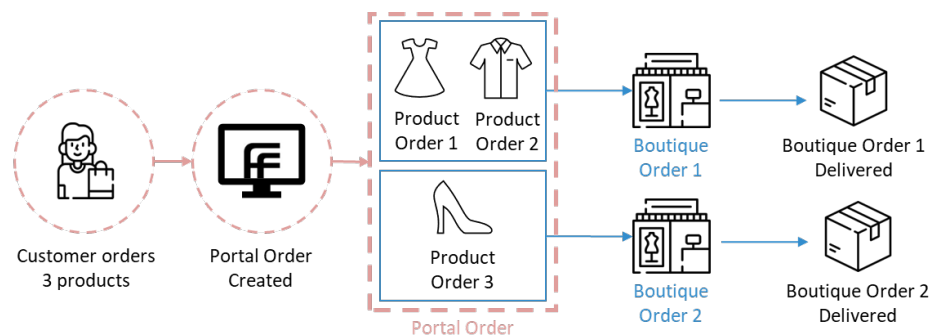


Figure 3.3: The three types of orders generated by a customer, when placing an order

Another important factor is the allocation of the boutiques to the boutique order. Several items are available in more than one boutique and when the customer places an order, the routing algorithm is responsible for selecting the boutiques where the order will be fulfilled. The algorithm's main priority is cost-saving, where it selects the route with the least impact on Farfetch cost. The second level of priority is, if the customer has a high return probability, prioritizing domestic/intra-EU supply. The third level is prioritizing suppliers with a low probability of no stock. The final level is prioritizing routes with the lowest carbon offsetting cost. This algorithm has a fundamental environmental role as it defines the distance between the boutique and the customer, directly influencing the environmental impact. After the order is placed, Farfetch order process follows six main steps, as illustrated in Figure 3.4.

The first step is **stock validation**, where the allocated boutique partner checks if it has in stock the items requested by the customer. In case of not having stock, another boutique with available stock and with the lowest price is allocated. In a situation where there is more than one boutique with the same price, the allocation considers the distance and then the rating of each partner. However, if there is not another boutique with stock, the platform may suggest an alternative item. If the client refuses the suggestion, the order is canceled and the client is refunded.

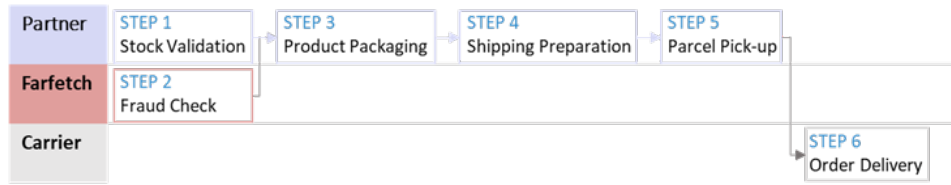


Figure 3.4: Order delivery steps

The second step is **fraud check**, where the fraud team analyzes orders to verify the legitimacy of the purchase, simultaneously with the first step. Firstly, they check the customer history. If they are on the blacklist, the order is automatically canceled. The customers on the no-black list proceed directly to step three. The no-black list customers are those who are making their first purchase.

The third step is **product packaging**. At this stage, the partner packs the product with a Farfetch box. There are 12 boxes of different sizes and shapes available, and the boutique is responsible for choosing the most suited box for the items. To assist partners, in choosing the right boxes, Farfetch offers a recommendation system, which is an algorithm responsible for recommending the most suited box for the boutique order. The boutiques are then responsible for accepting the recommendation. If they wish to change the box size recommended, they are required to create an exception explaining the reason for the change. If Farfetch accepts the reason, the boutique will not be penalized. As boutiques use Farfetch boxes, before the order is placed, a 3PL partner is responsible to supply to the boutiques the requested Farfetch packaging, produced by another company. Boutiques are also responsible for managing their packaging stock.

The fourth step is **shipping preparation**, where the air-way bill is generated automatically. Additionally, the shipping label and return instructions are also printed by the partner.

The fifth step is **parcel pick-up**. In this stage, the package is ready for pick-up by the carrier partner. Boutiques with high volume may have daily pick-ups. If the partner encounters a problem with the carrier, it can report the situation, which is then further analyzed by Farfetch.

The final step is **order delivery**, where the carrier scans the air-way bill, triggering an e-mail sent to the client, alerting them that their order is in transit. The deliveries are fulfilled by 3PLs, who are fully responsible for getting the boutique order to the customer. Farfetch resources to three main carriers' services, who provide different delivery capabilities, such as express or standard delivery and door-to-door or multi-leg shipping.

Once the delivery process is completed, Farfetch allows free returns, when the customer is not satisfied. The return process begins with the client placing a return, within 14 days of receiving the order. The partner needs to receive the item in a 28-day window, otherwise, it can refuse the return. The order can be picked up at a drop-off point, a partner store, or directly from the customer's house. If the return is refused, it will go to Lionesa's office, where it will go through the Farfetch boutique team. The team is responsible for performing triage on the refused items and if the items are in good condition, they are sold by the Farfetch boutique with a discount, or they can be donated, if in bad condition.

Customers can also contact customer service excellence, where they can know the status of an order or get more details about a product.

Figure 3.5 sums up Farfetch's supply chain, detailing not only the 3P, but also gives an overview of the operations process of the 1P (NGG and Browns).

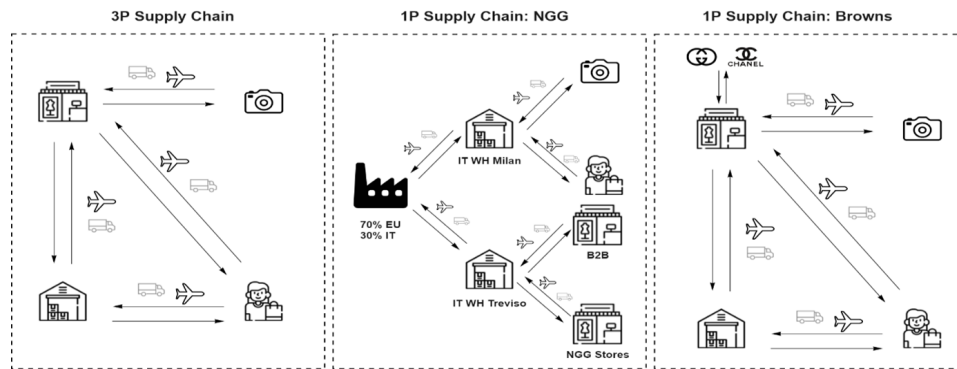


Figure 3.5: Brief illustration of 1P (NGG and Browns) and 3P supply chain

Farfetch also evaluates carriers' and partners' performance on multiple KPIs, aiming to ensure an excellent service. For the partners, the main KPIs monitored are Speed of Sending (SoS), Wrong Item (WI), No Stock (NS), and Packaging Accuracy (PA). SoS corresponds to the time between a partner receiving an order and a carrier collecting that order. Weekends and holidays are not accounted for. WI is the number of times the partner sent an incorrect item to a customer. NS is the metric with the highest penalty, and it corresponds to the number of orders that did not occur due to a lack of stock. PA is a recent metric that evaluates the partner's ability to secure the correct box for packing the items to be delivered to the customer. This metric motivates partners to choose the right packaging box, which reduces the air inside the box, contributing to less weight being shipped, and, consequently, reducing the environmental footprint.

For the carriers, the main KPIs monitored are delivery transit time, which corresponds to the time elapsed between the carrier to pick up the order and delivering it to the customer.

3.1.2 Delivery Service Characterization

After understanding the whole operations process of Farfetch, the company's delivery services is characterized to understand its environmental implications. The main 3PL partners that deliver the items from the boutiques to the customers are DHL, UPS, and FedEx. Figure 3.6 provides insights on the volume distributed by each carrier. DHL provides delivery services on most Farfetch routes, while FedEx mainly operates in the United States. UPS ships mainly in the United States and Europe. Other carriers are mostly local carriers, responsible for shipping "special" items on domestic routes, for VIP customers, for example.

Carriers provide different delivery services, differentiating in transit time and cost. Currently, Farfetch and the carriers supply two main shipping services for customers: standard shipping and express shipping. Standard shipping is on average 60% cheaper with an average delivery transit time of 4.8 days, whereas express shipping is a premium service, more expensive, with a delivery time average of 3.6 days. Figure 3.7 depicts the differential volume transported by express shipping and standard shipping.

This significant discrepancy comes from Farfetch not providing a standard delivery option on most routes. However, there is a tendency for customers to prefer standard shipping over fast shipping, when looking at the routes with the greatest volume with both delivery services available. The result of the analysis is in Figure 3.8.

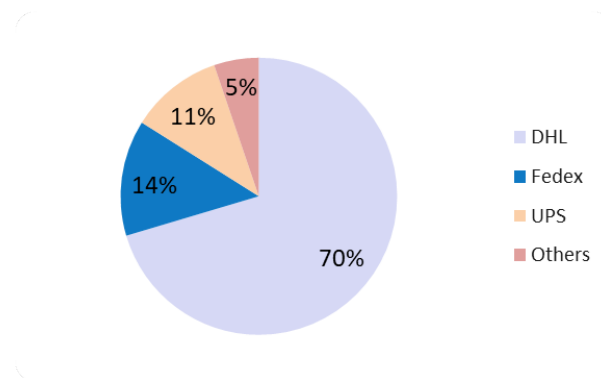


Figure 3.6: Percentage of volume distributed per carrier

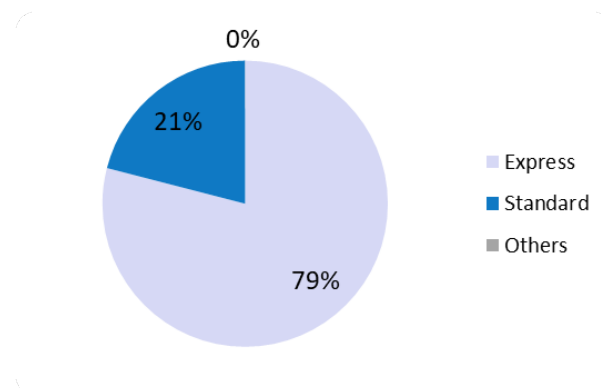


Figure 3.7: Percentage of volume shipped by standard and express services

In conclusion, Farfetch delivery service lacks standard shipping services in several countries, prompting customers across the world to choose express shipping as their preferred delivery method. This shipping service is responsible for fewer consolidated orders and for an increase in the number of trips done by carriers, to assure the service level promised.

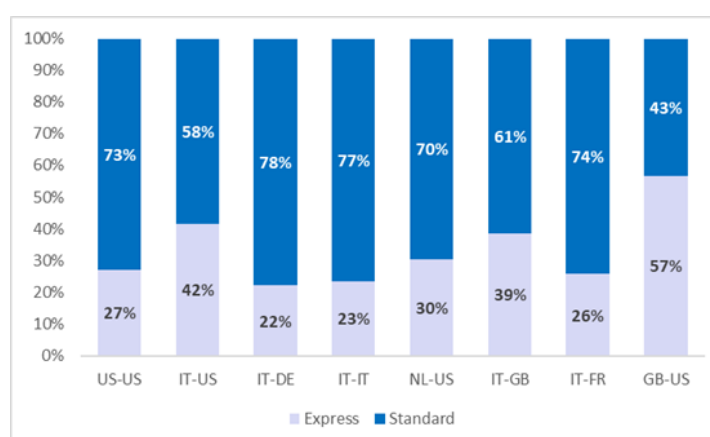


Figure 3.8: Comparison between standard and express of routes with both services

Apart from the shipping type service, provided by the carriers, the route type is also another important characteristic. There are three routes types: international, intra-EU and domestic. Currently, international routes account for 74% of the deliveries. Regarding the mode of transport, for each shipping service and route type, standard shipping for intra-EU and domestic routes is generally done by

road freight, whereas international routes are done by air freight. Express shipping for domestic, intra-EU, and international routes are done by air freight, but intra-EU routes within the same country are done by road freight. No other mode of transport is currently provided by the carriers.

3.1.3 Shipping Cost Structure

The shipping cost structure is an important delivery dimension, as it is the factor that weights more in strategic decisions. Therefore, understanding Farfetch's shipping cost structure allows making better decisions that do not compromise the cost when it comes to sustainability.

The shipping cost is composed of three different components: shipping (rate card), fuel, and extra costs, which make up the full shipping cost. The first component is the cost of moving items from the origin to their destination. The carriers charge by route, volumetric weight category, and shipping type of service (express or standard). The volumetric weight is a common measure adopted by carriers, which estimates the weight of the package measured by its volume and divided by a constant defined by the carrier. Between the actual weight and the volumetric weight, carriers charge the greater value of the two. The categories of the volumetric weight are usually charged 0.5 by 0.5 kg/cm³, meaning if an order has 0.7 kg/cm³, it will be charged as 1 kg/cm³.

The rate card is the cost provided beforehand by the carrier to Farfetch, representing on average 90% of the total cost. The other components represent, on average, 8% and 2%, respectively, and are later charged along with the provided rate card.

The shipping income, paid by the customer to secure the delivery of their orders, only covers 50% of the total shipping cost. Therefore, for this project, finding a viable solution that increases Farfetch sustainability without compromising the shipping cost is necessary, as there is only a small margin to increase the shipping costs for sustainability purposes.

3.2 Distribution Environmental Footprint Analysis

Following the exploration of Farfetch's operations and its distribution services, this section starts with a general characterization of the company's distribution footprint. Then, it deep dives into each of the dimensions of the company's delivery chain.

The most recent analysis of Farfetch corporate carbon emissions was performed by Quantis, a sustainability consulting company. This analysis characterized the company's footprint per emissions scope, mentioned in Chapter 2, is based on the methodology created by the GHG protocol. The GHG protocol is a guidance document assisting companies to calculate the emissions. Within scope 3 emissions, the GHG protocol proposes the structuring of 15 categories to provide companies a framework to measure, manage, and reduce emissions, across the companies' value chain (Barrow et al., 2013). From the results of the analysis, depict in Figure 3.9, the category with the greatest emissions was attributed to category 9, which corresponds to downstream transportation and distribution. This scope 3 emissions category considers the transportation and distribution of products sold by air, road, rail, and sea, including the transportation to and from warehouses and distribution centers. Within this category, emissions from customers traveling to and from retail stores may also be considered (Barrow et al., 2013).

This logistics category represents 55% of the total emissions, followed by purchased goods and services, which accounts for 39% of emissions. The latter category includes upstream emissions from the production of products purchased (Barrow et al., 2013). The ones responsible for this category of emissions are the 1P partners, NGG, Browns, and Stadium Goods. The assessment provided by Quantis proves the impact of logistics on Farfetch's overall footprint.

In Farfetch, the distribution of goods can be structured into three main dimensions: first leg, line-haul, and last leg. The first leg is characterized by the collection of the orders from the suppliers. Line-haul corresponds to the transportation of the orders between two distant locations by any means of transportation, representing the greater distance traveled. The last leg takes place usually in a city environment, and it is related to the final delivery of the products to the customer.

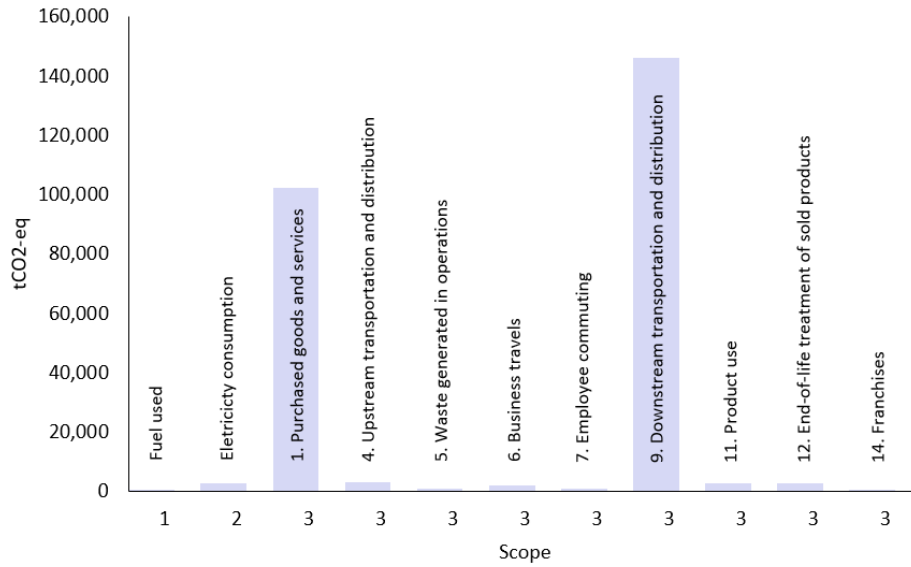


Figure 3.9: Farfetch's carbon footprint per emissions scope and respective category, adapted from Simonin et al. (2021)

3.2.1 Line-Haul Footprint

Given that the distribution of goods is one of the major contributors to Farfetch footprint, the deconstruction of the results is critical to fully comprehend the main sources of the emissions.

The analysis of Farfetch's distribution footprint only accounts for the emissions between the stock point origin and customer destination, for the forward and the return flow for long-distance routes, not accounting for stock movement between warehouses, stock transportation to Farfetch fulfillment warehouses, and first and last leg emissions. The analysis was performed using the distance-based methodology for scope 3 GHG emissions calculations and the scope is 2021. The explanation of the different methods is in Appendix A. Equation 3.1 shows how it was calculated.

$$TE = \sum CE \times TW \quad (3.1)$$

where TE are the total CO2 emissions in tonnes, CE is the CO2 emission factor for air freight per kg transported per route, which is a value used to equate the amount of emissions released with air freight, and TW is the total weight transported in tonnes per route.

The CO₂ emission factor per route was provided by Farfetch's sustainability team. Considering the assumptions from Section 3.1.2 of the mode of transport, when the shipping was done by road freight a reduction factor of 0.0665 was applied. This reduction factor was also provided by the sustainability team. For returns, double the emissions were considered, as there is a two-way journey.

Figure 3.10 presents the results of the analysis structured in shipping type service and route type. Farfetch footprint, in 2021, was 180,000 tonnes of CO₂, which corresponds to 2,700,000 trees needed to be planted to offset the total emissions. The main conclusions are that express shipping service, on international routes, is the greatest contributor to Farfetch's logistics footprint, accounting for almost 95% of the total logistics emissions, because it is mainly done by airplane. However, these orders account for 79% of all shipped volume. The main environmental issues with international express delivery are the distance traveled, the mode of transportation, and the speed of delivery, which forcefully makes carriers not being able to consolidate orders and ship with a low-capacity utilization, increasing the number of trips done.

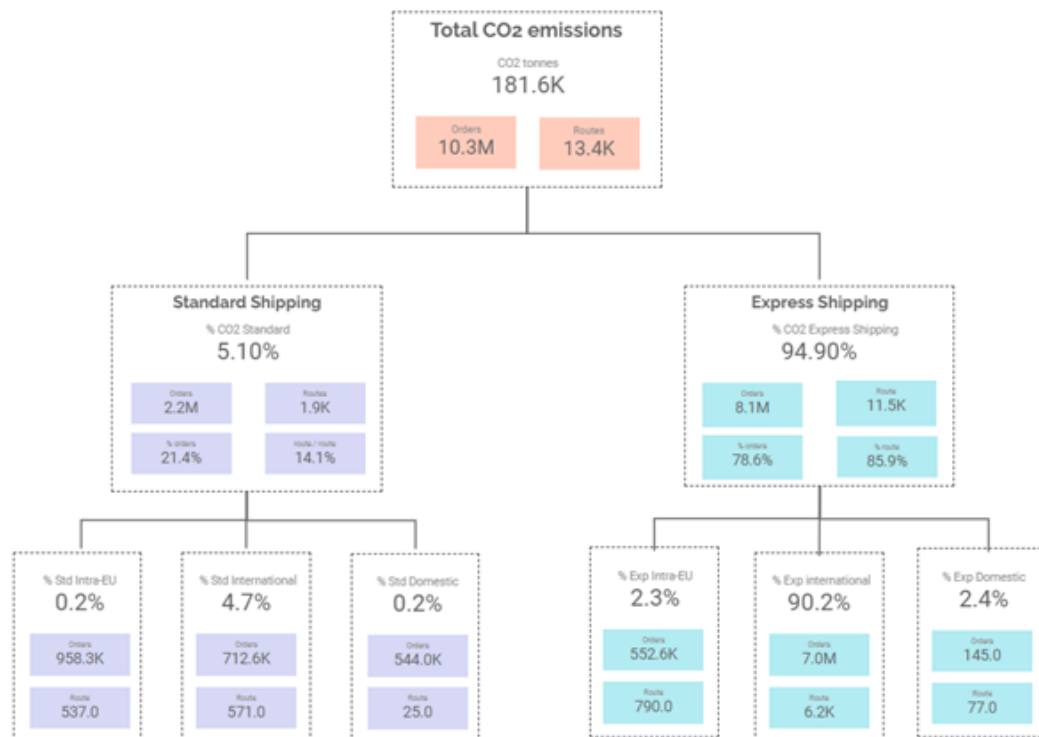


Figure 3.10: Total CO₂ emissions per delivery service type and respective route type

Table 3.2 presents the top five routes with the greatest carbon emission's contribution by type of route, which corresponds to a third of the total emissions. The most carbon-intensive flow is from Italy to the United States, followed by the domestic route within the United States.

Another important characteristic of the delivery system of Farfetch, that has a great impact on the footprint, is order consolidation. Farfetch does not consolidate portal orders, sending multiple packages to the final customer, if the purchased items come from multiple boutiques. This movement has a significant impact, not only on sustainability, as it does not allow a bulk shipment of the order to the customer in fewer journeys, but also on shipping costs.

Table 3.2: Top five routes with the greatest carbon contribution

Route	Type of Route	Shipments	CO2 (tonnes)	% Total CO2
Italy-United States	international	696,888.0	14,260.0	7.9%
United States-United States	domestic	437,258.0	7,407.0	4.0%
United Kingdom-United States	international	6,510.0	6,509.0	3.6%
Italy-China	international	331,627.0	6,435.0	3.5%
Italy-Australia	international	132,106.0	6,250.0	3.5%

3.2.2 First Leg Pick-ups

Farfetch's first leg is responsible for the movement of products from 1700 boutiques, to the carrier's fulfillment centers. Therefore, the first leg plays a significant role in Farfetch's delivery footprint. In this process, there is no differentiation between express or standard delivery, meaning that when the boutique has an order ready to be picked up, carriers pick up the parcel at the same speed.

Currently, Farfetch does not have visibility on the environmental impact of the first mile, not being able to quantify the contribution of the boutiques' parcel pick-ups to releasing emissions. Additionally, it lacks control over how the packages are being picked, not being able to be more environmentally efficient.

3.2.3 Last Leg Delivery

Last leg also plays a fundamental role in Farfetch's environmental impact, as it implicates the travel of multiple parcel delivery vans to fragmented customers, where consolidating orders is a challenge. It also adds the possibility of missed deliveries, where the impact increases. However, in regard to Farfetch's last leg delivery, the footprint characterization also lacks monitoring and visibility.

In the UK, governments are funding companies to address the challenges of transitioning commercial vehicles to electric in the last mile, with the prospect of being carbon-neutral by 2035 (HM Government, 2022).

3.3 Sustainability Commitment & Reporting

Although Farfetch's carbon footprint is excessive, the company has been improving its sustainability commitment, mainly driven by the sustainability team. In fact, in 2020, the company publicly posted its first ESG report, committing to addressing sustainability issues and working through the improvement of the corporation's footprint. Therefore, Farfetch has been working on a strategy to become the global platform for good in luxury, known as the Positively Farfetch strategy. This strategy comprises five action pillars: positively cleaner, focusing on decreasing the released emissions; positively conscious, where it started to classify products as sustainable or not; positively circular, where the company started to buy and sell pre-owned products; positively inclusive; and governance and engagement.

This project is inserted in the positively cleaner pillar, where the goal is to emit zero carbon emissions by 2030, reducing and offsetting the total emissions. In an analysis, provided by the sustainability team, detailed in Figure 3.11, the carbon offsetting cost is set to steeply rise, reaching \$66 per tonne in 2029. As Farfetch, currently, has a footprint of almost 180k tonnes, this could incur in a very high cost for the company. This is an important breakthrough, as it motivates the company to start looking into

ways to reduce the carbon footprint, since it has a cost associated. Additionally, Farfetch has committed to science-based targets (SBTs), which is the globally recognized authority for setting credible carbon reduction targets, in accordance with the Paris Agreement goals of limiting global warming by 1.5°C (Science Based Targets, 2022).

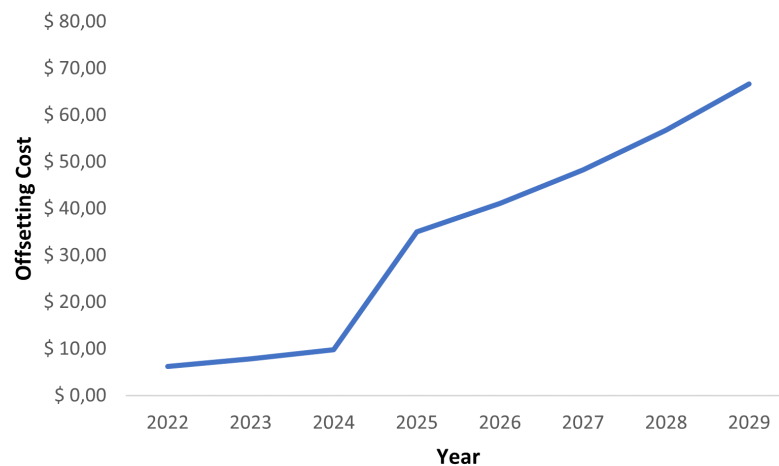


Figure 3.11: Offsetting cost projections until 2029 per tonne of CO₂

The sustainability team is also involved in other projects to push forward the company's environmental commitment, working alongside the multiple agents influencing Farfetch's environmental footprint, such as the boutique partners and carriers. Regarding the boutiques, the sustainability team has been encouraging the partners and supporting the brands to increase their supply of conscious products. This classification is done by the sustainability team, and for a product to be classified as conscious, the item needs to fulfill several criteria. The main parameters are the material composition, the material production processes, the product certification, and if it is pre-owned. As for the carriers, Farfetch has been pushing them to commit to SBTs. The future aim is to strengthen relationships with the carriers committed to sustainability.

However, at a logistics level, Farfetch environmental performance is challenging to assess and monitor. As Farfetch has complex operations involving different agents, having full visibility of the operation's sustainability of the different flows is quite difficult, making it very hard for the sustainability team to monitor the logistics footprint. Therefore, defining relevant KPIs to capture the company's supply chain environmental impact is imperative.

As for logistics sustainability metrics, regarding the 3PL partners, Farfetch receives a yearly report on the carbon emissions of the major carriers, accounting for all the routes, weight transported, and total emissions. However, if Farfetch is committed to being carbon-neutral by 2030, tracking in a continuous way their environmental footprint is more pertinent.

Additionally, for fulfillment centers under the control of Farfetch, no sustainability metrics are monitored. Monitoring the waste generated is important, such as the stock that is not sold; percentage of recyclability; total water and energy consumption, and percentage of renewable energy (Swallow, 2022).

For the packaging flows, since Farfetch is responsible for buying the boxes and then sending them to the boutique partners, the total emissions of the flows, as well as the waste generated by the boxes is

not tracked. As for the CROPS facility, previously mentioned in Section 3.1.1, the flow between boutiques and the latter is also not monitored in terms of emissions. Additionally, the waste, recyclability, and energy of CROPS facilities are also not controlled.

Although Farfetch has information on some components for sustainability reporting, the information is very fragmented, or it is not being actively monitored. To add to that, some information is also not being demanded from the partners to correctly measure metrics. Furthermore, the sustainability team cannot be the only team responsible for monitoring Farfetch's footprint, there must be a collective effort and engagement from all teams to actively address the company's environmental issues.

3.4 Benchmark Analysis on Green Practices

As environmental pressure for companies builds up, understanding how companies are responding and adapting to this external pressure is important. Some companies are already addressing the issue by implementing initiatives that could potentially decrease the environmental impact of their supply chains. The two focus areas for the benchmark analysis are green delivery and environmental impact tracking initiatives.

3.4.1 Green Delivery Initiatives

Zalando, an e-commerce platform, mainly offering fashion and lifestyle products to European consumers, has been transforming its delivery logistics to a greener approach, with multiple initiatives on eco last-mile deliveries, private Pick-Up and Drop-Off (PUDO) to avoid failed deliveries, and it has also introduced on its website the possibility of re-selling previously owned items (Zalando, 2022).

Amazon has also compromised on delivering 50% of shipments of last-mile with zero carbon, from the fulfillment center to the packaging and mode of transport used, using micro-hubs to fulfill last-mile orders by cargo bikes. For long-distance shipments, the company focused on electrifying its transportation networks, taking advantage of hydrogen power vehicles, and investing in testing new solutions for air freight, trying to develop more sustainable fuel (Amazon, 2022). Green parcel delivery companies have also been on the rise. One example is Ecomize, a logistics start-up based in Berlin (ecomize, 2022). This company has been working on decarbonizing parcel logistics. The company has been potentializing the possibility of having flexibility in parcel deliveries, not delivering the order as quickly as possible, allowing for greater consolidation.

3.4.2 Supply Chain Transparency Initiatives

Kering group is responsible for managing brands such as Gucci and Balenciaga and has been considered one of the most sustainable companies in fashion. In 2022, the company was ranked 12th by the Corporate Knights for the 100 most sustainable companies (Knights, 2022). Over the years, the group has been investing heavily in sustainability, committing to reduce 50% of all emissions by 2030. It has also committed to being 100% transparent by 2025, allowing traceability, especially on the origin of raw materials. For this matter, the group developed a methodology to monetize the environmental impact of its supply chain, publicizing the method and the results. These initiatives further motivate the company's engagement in sustainability (Kering, 2022).

Chapter 4

Proposed Solution

This chapter unravels the most promising initiatives to accomplish the scope of the project. After analyzing the multiple areas of opportunity, the strategies with the greatest potential to start designing the green supply chain of the future were selected, first focusing on the company's delivery service, and then on the sustainability reporting metrics to monitor Farfetch's supply chain environmental performance. The green delivery system is structured in three dimensions, and each was developed in a separate model. The final aim was to display, in an intelligible business format, the benefits of such strategies.

The chapter will start with an overview of the simulation models of the three defined dimensions, followed by a deep dive into each initiative. The models will be structured according to the modeling methods outlined in García et al. (2013). The steps of the methodology are: model conceptualization, model translation, followed by the data collection of the output metrics.

Lastly, the chapter ends with an overview of the sustainability KPIs strategy.

4.1 Green Delivery System

Before achieving the design solution, the framework in Figure 4.1 was developed for structuring all the opportunities found within the company to understand their potential.

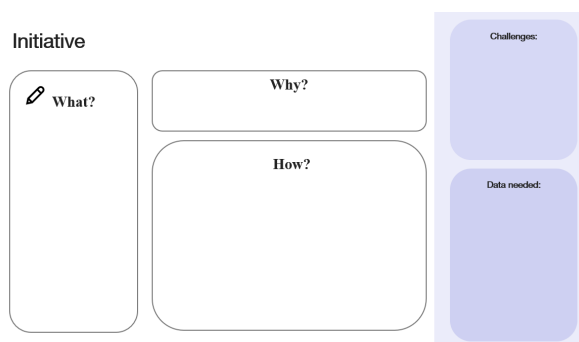


Figure 4.1: Framework for assessing each opportunity

After identifying all the potential solutions to decrease Farfetch's footprint, the starting point to design the green delivery system that will sustain the green supply chain of the future is characterized

in Figure 4.2. It is divided into the three main dimensions of Farfetch's delivery chain: first leg, line-haul, and last leg.

The first leg corresponds to the boutique orders being picked up by the carrier via milk runs in electric vans (EV). Then, the respective orders are delivered to the closest depot. The purpose of this design is to cut down carbon release by using EVs while increasing the LCU of the vans to decrease the number of pick-ups, the number of trips, and, consequently, testing the limits of an EV.

The line-haul considers the transportation of the boutique orders after pick up from the origin depot to the customer's region depot, in bulk shipments. In this way, the LCU increases and the number of trips decreases. Another component considered is alternative transportation methods, such as ships and trains, which compared to airplanes are less emissions-intensive.

The last leg is characterized by the delivery of the order to the final customer from the customer's region depot to local hubs in an eco-delivery mode of transportation, such as cargo bikes or EVs. Additionally, there is the possibility of customers choosing to pick up their orders in a local hub by foot or public transport.

Within the scope of the project, the designed low carbon delivery was divided into three models, which are described in the next sections. Not every aspect of the green delivery system was possible to analyze. Nevertheless, the first model tests having EVs doing milk runs. The second model is only related to the alternative methods of transportation, since the supply chain network design team will build the bulk shipments model. Finally, the third model includes the eco-delivery system. All the models were validated, as the calculated errors were less than 5%. The details of the validation are in Appendix B.

The simulation models designed are an extension of the work conducted by the supply chain network design team, which had already developed, in the digital twin, Farfetch supply chain on the overall line-haul leg.

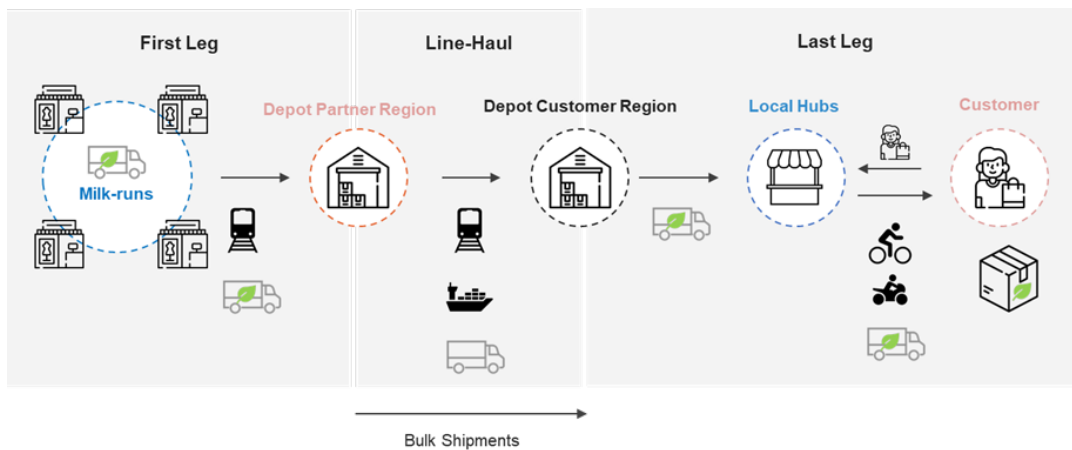


Figure 4.2: Green delivery system to lay the foundation to create the green supply chain of the future

4.2 First Leg Green Optimization

Milk runs are characterized as a delivery method to transport multiple items to a single destination. For the first leg green optimization, the milk runs concept was applied to picking up several goods

in a row, from boutiques to delivering them to a nearby Farfetch hub for packaging. The items are transported by an EV, belonging to Farfetch. After the packaging of the orders is complete, the EV takes the orders to the 3PL carrier's depot. The scope of the model is Italy, as it is responsible for 38% of Farfetch supplied volume.

The model is an agent-based simulation, centered on the entities' operations, which can measure the environmental, cost, and service impact of performing milk runs in an EV, limiting the number of carrier's vans, consolidating orders, and implementing new hubs in the network, and others. Additionally, it has the flexibility of analyzing different setups and scenarios by allowing the modification of the model parameters and location.

A general overview of the simulation model is given in Figure 4.3, where the model receives inputs from the user and the data collected, and it outputs the performance indicators, which can be compared with different scenario results.

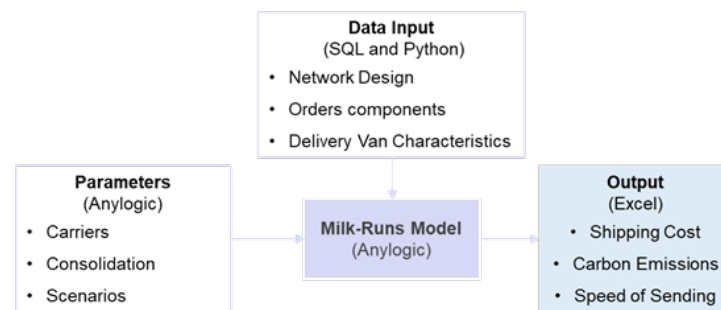


Figure 4.3: First leg green optimization model general overview

4.2.1 Model Conceptualization

The flowchart in Figure 4.4 was designed to understand better the problem, the agents, and processes of the first leg model.

The process starts with the order being placed by the customer, followed by its processing. In the boutique, the products from an order are placed in three transportation boxes: a large, a medium, and a small. The orders are consolidated until the larger box is filled, according to the arrival sequence. However, when the order has been waiting too long, and it does not fill a larger box, it is placed in the medium or the small box along with the products from other orders. When the box is closed, it is ready to be picked up. The carrier only picks up orders from multiple boutiques at a single time when its LCU will be at 80%. When this threshold is surpassed, the carrier leaves the FxFF warehouse (hub) in Italy. If it does not reach 80% capacity, the carrier waits for more orders to be ready for pick-up. In this case, the mentioned carrier is owned by Farfetch and is not a 3PL.

One of the aims of the process is to test the possibility of having an EV do the pick-ups, considering the distance and charging limitations of the vehicles. Therefore, the multiple boutiques that the carriers must go to in a milk run, need to be ordered according to distance, so that the carrier takes the shortest path.

Once all the orders from the different boutiques in the milk run are picked up, the carrier goes back to the hub that it has departed from. In the warehouse, the orders are packed individually with Farfetch's packaging and put in larger transportation boxes, according to their customer destination

country. When there are enough orders to fill the van capacity at 80%, the Farfetch carrier takes the transportation boxes with the orders to the 3PL carrier's depot.

Direct transport from the boutique to the depot was not considered, because the orders need to be boxed with Farfetch's packaging. This is being done at the hub in order to lower the overall amount of volumetric weight being carried by controlling better the air in the packaged shipments. The hub is a crucial place for parking and charging EVs as well.

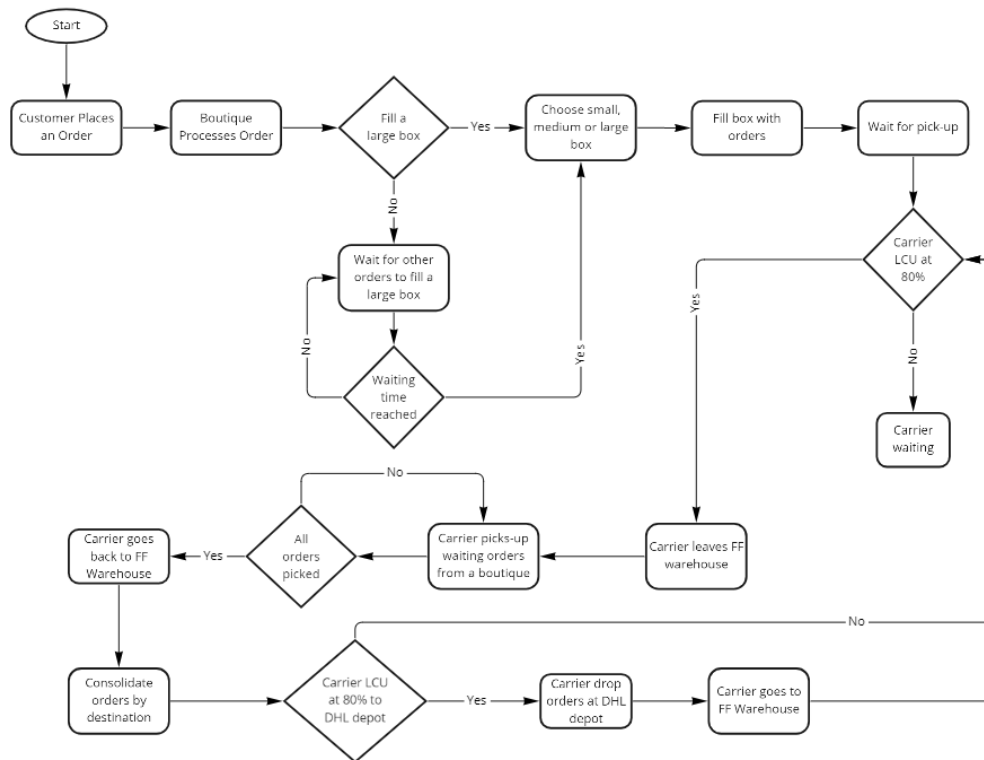


Figure 4.4: First leg model flowchart for model conceptualization

As Farfetch does not have visibility on the first leg, an as-is model was also designed, following the logic of the flowchart described in Figure 4.5. For the as-is model, the 3PL carrier assumed is DHL, as it handles 68% of all shipments to Italy. When a boutique has an order, the DHL carrier picks it up according to the boutique's pick up frequency. The DHL carrier does not perform milk runs for collecting the boutique orders of Farfetch, and the orders are not consolidated.

Then, the orders are taken to a DHL hub in a nearby location, and afterwards to the main DHL depot in Malpensa, Milan (Gill, 2021). Finally, the DHL carrier goes back to the hub. This transfer from the hub to the depot was verified in Farfetch's database with information from the carrier's log location. The hub is a local auxiliary facility that assists DHL with order collection and deliveries, whereas the depot is a central warehouse located outside the city where orders are sorted and shipped to the end customer. This is the fundamental distinction between hubs and depots.

4.2.2 Model Translation

The model was created using Anylogic 8.7.10 for simulation based on the preceding flowcharts, Python 3.9.7 for data processing and preparation, and SQL for data collection.

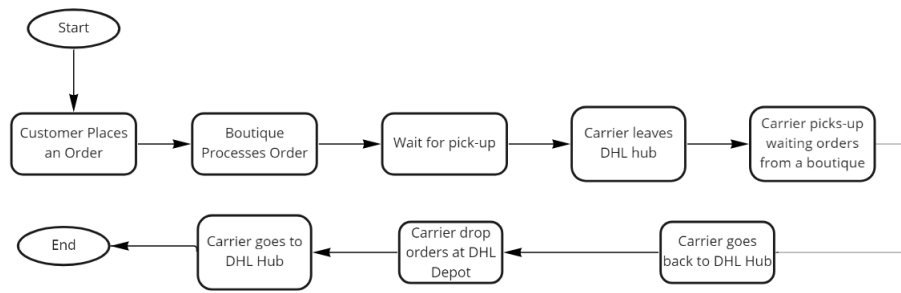


Figure 4.5: First leg as-is model flowchart for model conceptualization

This section is divided into three subsections. The description of the data that was collected and prepared for the model is the first subsection. The next section explains how the model was developed to accurately reflect the issue addressed, and then what settings the user can adjust to evaluate various configurations.

Data Input

A preliminary process of data understanding, gathering, and preparation, preceded the model creation.

Farfetch stores most data in Big Query, a data platform that supports SQL. However, some parts of the database are in SQL server. The first process was to gather relevant data from Farfetch database in the year 2021, so it would be possible to determine the most recent yearly impact. The main data collected were related to network design, the components of the order, and the van's characteristics.

For network structuring, data about the boutique partners' coordinates was collected from SQL server. However, for Farfetch and the 3PL warehouses, the coordinates were retrieved from the addresses, resorting to the Geocoder algorithm from the Mapbox package using Python. Therefore, obtaining the addressed as accurate as possible was crucial.

Regarding the boutiques, understanding how they were grouped geographically was also necessary to restrict carriers doing the pick-ups in a specific area, and therefore, avoid long-distance milk runs. By adopting a clustering tool in Python, using the K-means algorithm from the supply chain network design team, the multiple boutiques were clustered in six different groups, as shown in Figure 4.6.

For the order specifications, data about the order destination, volumetric weight, shipping cost, number of products, and respective family category of the products in an order was retrieved. The order generation in the model was given by a beta distribution, which is a continuous probability distribution (Kim, 2020). The parameters of the distribution were previously calculated by resorting to Python, considering the daily orders generated per boutique. The van was classified as a light commercial vehicle with a loading capacity of 1.5 tonnes and an average LCU of 30% (NTM, 2022).

In the as-is model, one important factor to take into consideration is the boutique's pick-up frequency of the DHL carriers. As boutiques have different pick-up frequencies, the number of daily pick-ups per boutique was also given by a beta distribution and the parameters were calculated with the same method as the order generation.

After the data was collected, there was an exhaustive process of data cleaning, to improve the data quality and remove inconsistencies. This process was assisted by Python, which helped to more

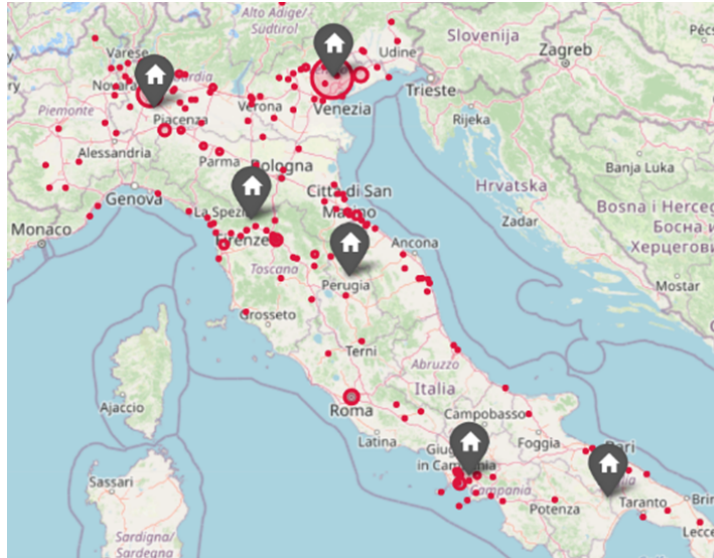


Figure 4.6: Boutiques clustering groups using K-means algorithm

efficiently process the heavy data retrieved. Some cleaning methods were the removal of boutiques without latitude and longitude, the average was used to replace the null values of the volumetric weight, and the transformation of the real volumetric weight values to volumetric weight categories. As rate cards of shipping cost could not be obtained, historical data had to be used to calculate the shipping costs. Since in the database, there are no rate cards for every destination and weight category, an average was computed for each destination per 0.5 kg/cm^3 .

The prepared data was then stored in an Excel file and connected to Anylogic.

Translation

Several procedures were taken to translate the flowchart in Figure 4.4 into the model.

The first step was to create the model agents: boutiques, warehouse, orders, depot, and carriers. After that, the milk run logic was programmed. Additionally, the autonomy of EVs was also taken into consideration, as they can only travel a maximum number of kilometers before needing to go back to the hub to charge. The EV was assumed to only travel a maximum of 150 km, according to Mercedes Benz (2022). Therefore, the charging operation was also included in the warehouse. Then, the processes of pick-up and drop-off the orders in the boutiques, warehouse, and depot were added. After, the consolidation of orders into boxes was programmed in the boutiques and warehouse agents. Later, the order generation was modeled, according to the given beta distribution parameters from the data preparation, where seasonality is also taken into account. When generating an order, the customer country, the number of products and the product family category are set by a random probability defined by the tool. This probability is then matched with the cumulative frequency (probability) of the data input, which corresponds to a value.

For the to-be model, the order volumetric weight is determined by the products' volumetric weight, as it is more accurate to fill the transportation box according to the product's volumetric weight, instead of the boutique order. However, Farfetch only keeps track of the order volumetric weight, and not the items, which have less volumetric weight than the order because of the box. Since boutiques can claim

that the suggested Farfetch packages are being used without actually use the correct box, there is a very high likelihood that an order's products may arrive in a larger package. So, a reduction factor of the item's volume was set as a parameter. For the as-is model, as there is no transportation box involved and the carrier picks-up the order with Farfetch's packaging, the order volumetric weight is not set by the products, but by a probability.

Figure 4.7 is a demo of the model running.

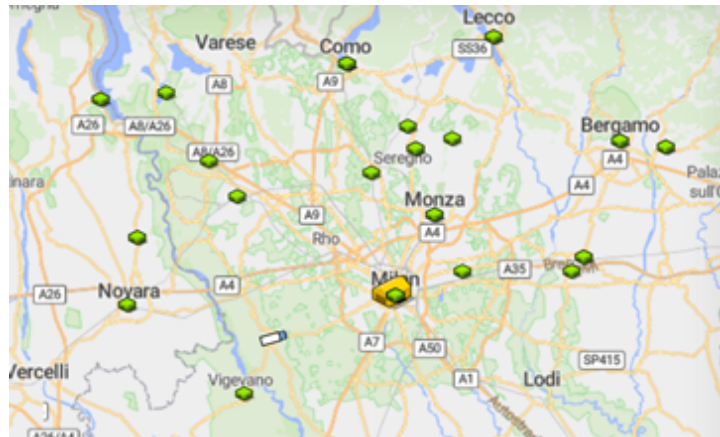


Figure 4.7: First leg green optimization model simulation running

Simulation Parameters

The model was developed so that the user would be able to modify the parameters to test different network scenarios. Also, by modifying the data input, different parameters and scenarios can be tested. The parameters are divided into three categories and are displayed in Table 4.1.

Table 4.1: Simulation parameters for the first leg model

Category	Parameter	Details
Carriers	Vehicle capacity	Maximum volumetric weight transported
	Vehicle loading factor	LCU against the vehicle capacity
	Number of vehicles	Number of carrier's vans to perform the milk runs
	EV	Number of EVs to perform the milk runs
	Maximum EV Kms	Self-explanatory
Consolidation	Consolidation factor	Percentage of minimum volume filled in a box
	volumetric weight reduction	For the products of an order
	Max waiting time	For the orders to be put in a transportation box
Scenarios	CO2 emission factor	CO2 emissions by transportation and fuel
	Agents locations	Self-explanatory
	As-Is or To-be	Self-explanatory

4.2.3 Output Metrics

After the model validation, various scenarios can be tested by modifying the simulation parameters and data input. The results obtained from the different simulations are retrieved by the Anylogic tool and exported to an external Excel file, to be further analyzed.

One of the sheets of the output file contains information on the total number of orders, total volumetric weight transported, shipping cost, and SoS per boutique, country destination, and month. The second sheet contains data on the km traveled, fuel consumed, and CO2 emissions per trip.

The output metrics are structured in three categories: sustainability, cost, and service. The KPIs collected are described in Table 4.2 and can be compared to the as-is model results, to fully understand the benefits of the scenarios.

Table 4.2: Output metrics of the first leg model for comparing results

Category	KPI name	Description
Sustainability	CO2 emissions release	Released emissions per tonne-km
Cost	Shipping Cost	All the costs associated with the delivery of an order
Service	SoS	Time spent between the boutique receiving the order until the carrier picks up the order

The CO2 emissions were calculated according to the fuel-based method, already explained in Appendix A. This method is more accurate as it takes into consideration the impact on fuel spending of consolidating the orders. Equations 4.1, 4.1a, 4.1b and 4.1c calculates the fuel consumption, from data provided by (NTM, 2022). Whereas equations 4.2, 4.2a, and 4.2b is the combination of the fuel consumption and the emission factor, according to Protocol (2022), calculating the total emissions released.

$$\text{Fuel Consumed (FC)} \frac{L}{Km} = FC_{empty} + (FC_{full} - FC_{empty}) \times LCU_{weight} \quad (4.1)$$

$$LCU_{weight} = \frac{\text{cargo physical weight}}{\text{max weight capacity}} \quad (4.1a)$$

$$FC_{empty} = \frac{FC \text{ factor } \frac{kg}{km}}{\text{fuel density } \frac{kg}{L}} = FC \text{ factor } \frac{L}{Km} = \frac{0.08345 \frac{kg}{km}}{0.830 \frac{kg}{L}} = 0.1006 \frac{L}{Km} \quad (4.1b)$$

$$FC_{full} = FC_{empty} \times \frac{0.134}{0.110} = 0.122 \frac{L}{Km} \quad (4.1c)$$

$$\text{Total CO2 (kg)} = \sum \text{Total FC} \times \text{CO2 emission factor for fuel (kg CO2 e / L)} \quad (4.2)$$

$$\text{Total FC (L)} = FC \frac{L}{Km} \times \text{Km traveled (Km)} \quad (4.2a)$$

$$\text{Emissions factor for fuel } \frac{kg \text{ CO2}}{L} = 2.676 \text{ kg CO2/L} \quad (4.2b)$$

For the as-is CO2 calculations, the assumption was that the van would pick up not only Farfetch orders, but also orders from different companies. Therefore, as the as-is output only monitors the kilometers traveled to pick up Farfetch orders, an increase factor of the total distance traveled of the DHL carrier was applied. This distance factor was computed with the average distance traveled by the carriers with a 30% LCU, by resourcing to the model and comparing to the average distance traveled in the as-is model. Then, the total CO2 calculated was allocated according to Farfetch orders volumetric weight and the total volumetric weight transported by the carrier's van. An average of 30% of LCU was assumed from the research by NTM (2022).

The shipping cost was calculated by obtaining the end-to-end cost. The cost for the as-is model only considers the shipping cost component in Table 4.3, while the to-be model considers the inbound, outbound, and shipping cost component in Table 4.3. But, since a Farfetch EV will be handling the milk runs, the cost of the first leg was subtracted from the end-to-end shipping component, and the EV investment cost per order was instead added. The cost of the first leg was considered to be 4% of the end-to-end shipping cost, based on Intelligence (2022). Additionally, the carbon offsetting cost of the order's emissions was also considered.

Table 4.3: Cost components of the cost output metric for the first leg model

Cost Component	Description	Formula
Shipping	The end-to-end shipping cost was computed per 0.5 kg/cm ³ which varies with the customer country	$\frac{Weight}{0.5} \times Rate\ Card$
Inbound Processing	The cost of processing the orders arriving at the warehouse	<i>Inbound Cost</i>
Outbound Processing	The cost of packaging the orders and consolidate them according to the customer destination.	<i>Outbound Cost</i>
EV	The investment, employees', and maintenance cost of having an EV doing the milk run. The investment details is later presented in Chapter 5.	$\frac{Total\ Investment\ Cost}{Orders\ Transported\ by\ EV}$
Carbon Offsetting	Compensate emissions release by paying an entity that will invest in projects to absorb the emissions.	$offsetting\ cost \times emissions$

4.3 Rail Freight

Regarding the long-haul dimension, two alternative modes of transportation for long-distance were evaluated: rail freight and sea freight. As the rail freight analysis has the most significant impact, the sea freight analysis is presented in Appendix C.

Rail freight has great potential as it is the most fuel- and cost-efficient mode of transportation in comparison with road and air freight, decreasing emissions release and cost. According to Heath (2020), in the US there is a potential of decreasing costs by 10 to 40% by changing from road to train in long-haul transport, which in most cases is even faster than a truck.

Based on the assessment of the top five routes with the greatest carbon contribution, presented in Section 3.2.1, the route connecting United States (US) suppliers and US customers is the domestic route that releases the most emissions. Therefore, the rail freight analysis scope is focused on this route in 2021, to analyze the yearly impact.

The model is an agent-based simulation, which can measure the environmental, cost, and service impact of rail freight in the US.

Figure 4.8 provides a general overview of the simulation model that explains how the model functions, receiving inputs from the user and the data collected, and outputs the performance indicators.

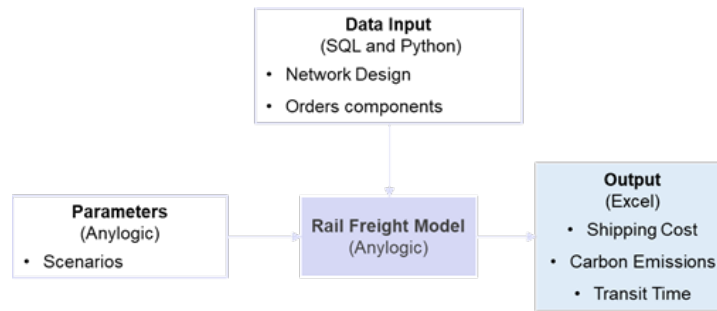


Figure 4.8: Rail freight model general overview

4.3.1 Model Conceptualization

Figure 4.9 presents a flowchart for the rail freight model. The process starts by the customer's city placing the orders. Then, the orders are processed by the respective boutique city. The customers and boutiques are by city as trains are limited by train stations per city. The order is then grouped with other orders in the train station, with the same customer city destination, and once a day the train transports them. The process ends with the orders arriving at the customer's city.

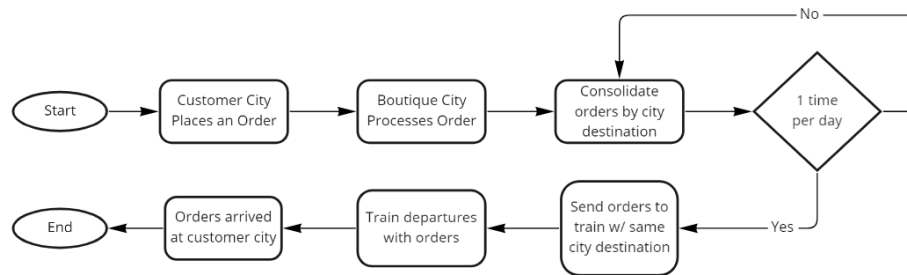


Figure 4.9: Rail freight flowchart for model conceptualization

4.3.2 Model Translation

Based on the previous flowchart, the rail freight model was built in Anylogic 8.7.10. For this model, Python 3.9.7 was also used to connect to Big Query and to prepare the data to be inserted into the model. SQL was additionally used to collect the data.

The first stage, in translating the model, was to collect and prepare the data to input into Anylogic. The second stage was to create the agent-based model in Anylogic. Then, the model was validated with the as-is data collected.

Data Input

The data was collected resourcing to Python, which connects to Farfetch Big Query database.

Firstly, the boutiques' data was retrieved, grouping the US boutiques by cities and states. The same approach was done when collecting the US customer data. The total number of orders between a boutique city and customer city per state was also collected. Many inconsistencies were found in the customer location, as the clients can freely write their address, creating a lot of variation in a city's

name. Therefore, the name of the cities had to be corrected, and the ones that could not be corrected were removed. Of the stores' data, not many inconsistencies were found.

Regarding the orders, information on the volumetric weight probability per boutique city and shipping type service was collected. The beta distribution parameters for the order generation were also computed through Python.

After the data collection and cleaning were completed, the data went through further processing to be ready to be inputted in Anylogic. The latitude and longitude of the customers and stores were retrieved by resourcing to the same method presented in the first leg model in Section 4.2.2. For this matter, the coordinates were retrieved considering the city and the state, as there are cities in different states with the same name. After getting the coordinates of the customers and boutiques, the remaining data on the characteristics of the order, such as volumetric weight, city destination, and shipping type service were organized and ordered in an Excel file by the cumulative frequency.

Finally, regarding the as-is data, the transit time, and shipping cost were outputted, as well as computed the CO2 emissions, to later be compared with the rail model. For the missing values on transit time, an average on express and standard delivery was used.

As the data collected was very heavy, only 80% of the total data was considered, to improve the model performance.

Translation

For the model, three main agents were created: boutique city, customer city, and train.

The boutique city agent generates the orders and sets the parameters of the orders with the same logic as the first leg model.

One important characteristic of the Anylogic software is the possibility of using railroad map. If a rail route is not found and, consequently, does not exist between cities, the order is not created, and the non-existing route is stored in the output file. Therefore, only orders between cities with rail routes were accounted for, meaning orders without available railways were disregarded in the simulation. However, there was a 97% coverage of the 2021 orders by rail.

Figure 4.10 is a demo of the model running, where the train routes are being created for delivering the order.



Figure 4.10: Rail freight model simulation running

Simulation Parameters

The user has the flexibility to change the location of the boutiques, customers, and trains.

4.3.3 Output Metrics

The resulting data from the simulations is outputted to an external Excel file. For every simulation, the model outputs the total number of orders, the total volumetric weight, the total CO2 emissions, the shipping service, and the transit time between each boutique city and the customer city. The comparison metrics used were the same as the first leg model.

Regarding the calculation of the CO2 released metric, the distance-based approach for GHG emissions was employed, because there is insufficient data on rail freight to calculate the emissions by the fuel-based method.

The shipping cost was computed according to a rate of \$1.09 per km tonne, obtained from an external search (Heath, 2020). This rate was only applied to 37% of the end-to-end shipping cost, representing the line-haul cost, while the first and last mile cost were considered to be the same.

The transit time was measured from the time the order was created until it was delivered to the customer. As the model does not consider the first mile order pick-ups and last mile delivery time, an estimated two-day buffer was added to the transit time.

4.4 Last Leg Green Optimization

The final model designed, regarding last mile deliveries, tested the possibility of adopting an eco-delivery system. As EVs had already been analyzed in the first model, the last leg green optimization model focuses on cargo bikes potential. Therefore, the aim of the last leg simulation was to retrieve the environmental, cost, and service impact of using cargo bikes. The chosen location to test this approach was Manhattan, New York City (NYC).

NYC is one of the best locations to test the model, as it is a very dense and congested central urban city, with a lot of traffic and parking difficulties, making cargo bikes an effective way to deliver orders to customers (Peters, 2019). Additionally, in the US, New York state (NY) is the second state with the larger volume of orders and Manhattan accounts for 30% of the NY orders. Therefore, the scope of the model was Manhattan, and the orders analyzed were placed in 2021.

A general overview of the simulation model, given in Figure 4.11, shows that the model is able to receive input from the user and the data collected, and it outputs the performance indicators, which can be compared with the as-is model results.

4.4.1 Model Conceptualization

Figure 4.12 presents a flowchart regarding the model processes. Firstly, Farfetch orders arrive at a carrier depot, where they are immediately transferred to a hub closer to NYC. This immediate transport was confirmed since the carriers, on average, deliver 1.16 orders per transfer. Then, the orders are delivered to the customers by cargo bikes, when the LCU is at the chosen percentage by the user.

As Farfetch does not have visibility on the last leg, an as-is model was also modeled. The difference lies in the orders being transported by van from the hub to the customer, instead of a cargo bike.

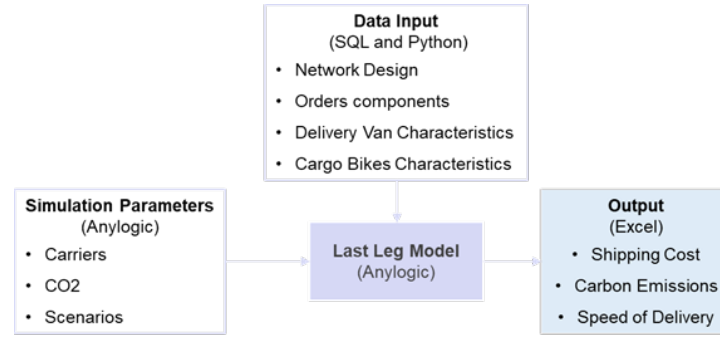


Figure 4.11: Last leg green optimization model general overview

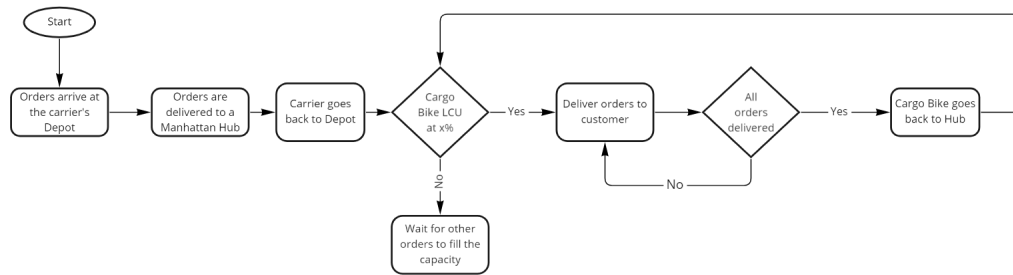


Figure 4.12: Last leg flowchart for model conceptualization

4.4.2 Model Translation

Based on the previous flowchart, the last leg model was built in Anylogic 8.7.10. The data processing and collection were supported by Python 3.9.7 and SQL.

The first stage, in translating the model, was to collect and prepare the data for input. The second stage was to create the agent-based model. Then, the model was validated, comparing the results from the as-is built model with the as-is data collected.

Data Input

The data was gathered on the features of the delivery trucks and bikes in 2021, as well as the customers, depots, hubs, and order components.

Respecting the customers, the full address of the NY customers was retrieved, where the data had to be cleaned to obtain the correct addresses. After that, the coordinates were retrieved using the same approach explained in Section 4.2.2. The addresses were then filtered to just Manhattan zip codes, as the scope is Manhattan.

For the hubs and the depot location, the carrier was assumed to be FedEx, as it is responsible for 64% of the total deliveries. One important aspect was to establish the depot location. Based on the FedEx location logs on Farfetch database, the depot location was assumed to be in Newark, New Jersey. Another important information collected, to be later used in the model, was the number of daily orders per van delivered from FedEx depot to the customer.

Regarding the hub's data, in the FedEx location logs, the carrier drops-off the items from the depot to local hubs in NYC. The exact location was not possible to retrieve. Therefore, the two local hubs

were assumed to be from FedEx in Manhattan, and the coordinates were gotten from Google Maps. To allocate the nearest hub to the customer, so that the cargo bikes do the shortest path, the team's clustering tool was used. This tool allowed for getting information on which hub the customer would receive their orders from. Concerning the orders, information about the total number of orders per origin country with NY destination and per volumetric weight category was collected. Additionally, the shipping cost was retrieved with the same approach as in the first leg model by obtaining a rate card per 0.5 kg per cm³ per origin.

Translation

The agent-based model was created with six agents: customers, depot, hubs, van carriers, cargo bike carriers, and orders.

Then, the delivery logic of the van and the cargo bikes was modeled. The cargo bikes were also programmed to use bike routes in the Anylogic software. Then, the orders' generation was computed given a beta distribution per each customer, considering seasonality.

Figure 4.13 illustrates the simulation of the model.



Figure 4.13: Last leg green optimization simulation running

Simulation Parameters

The simulation parameters can be divided into three categories: carriers, CO₂, and scenarios.

The carriers are related to the cargo bike and van characteristics, being possible to modify the mode of transportation capacity, the LCU, and the number of vehicles. Regarding the CO₂, it is possible to change the emissions factor. For the scenarios, the model enables setting the as-is or the cargo bike scenarios.

4.4.3 Output Metrics

After the validation, the model was simulated, and the resulting data was outputted to an external Excel file. One of the sheets of the output file contains information on the total number of orders, total volumetric weight, shipping cost, and speed of delivery per customer and month. The second sheet contains data on the km traveled, fuel consumed, and CO₂ emissions per trip.

The three metrics collected are the CO₂ emissions, the shipping cost, and the speed of delivery. The CO₂ emissions were calculated with the same method as the first leg model.

The shipping cost was calculated only considering the last mile cost. First, the total end-to-end shipping cost was computed with the same approach as the shipping cost calculation in Table 4.3. Then, from the total shipping cost, the last mile cost was calculated assuming that it corresponds to 53%, based on Dolan (2022). After obtaining the last mile cost, the cost was split into two, corresponding to the cost of shipping from the depot to the hub and from the hub to the customer. When the delivery is done by cargo bikes, a reduction factor of 80% between the hub and the customer was considered, according to Sheth et al. (2019). For the van's delivery, no reduction factor was taken into account.

The speed of delivery measured the time elapsed between the order arriving at the depot until arriving at the customer.

4.5 Sustainability KPIs Reporting

In Chapter 3, the lack of reporting in terms of sustainability at a logistics level and its importance was characterized. Therefore, one of the initiatives to build a green supply chain is the definition of sustainability KPIs to be monitored, to find opportunities, and to better keep track of green logistics initiatives already implemented within the company.

The scope of this initiative was to make available, on a company level, a sustainability dashboard with the most relevant KPIs. Looker is the tool adopted transversely in the company by multiple teams. This tool is a business intelligence software and big data analytics platform used and maintained by the global Farfetch teams. Therefore, the dashboard is available on Looker, so that it can be consulted by different teams.

The approach to building this dashboard was to organize a workshop with teams across logistics and sustainability, with an end-to-end knowledge of Farfetch's supply chain. The workshop was performed with the assistance of Miro.

The results of the workshop are displayed in Figure 4.14. In the workshop, the attendees had to write the KPIs related to each agent influencing Farfetch footprint and set them according to three environmental categories: waste and recycling, emissions, and energy. In the end of the workshop, the participants voted for the most relevant KPIs, in their opinion.

After the workshop, the results were structured in a matrix and organized according to the amount of data available to measure the KPIs and by the number of votes. The most voted and with more data available were considered the most relevant KPIs. The remaining were saved to be analyzed at a later stage.

The most relevant metrics were then filtered, considering only the ones regarding orders, returns flow, and boutique partners. KPIs regarding warehouse, packaging, and CROPS were also saved for later review alongside the remaining KPIs, as getting the information would be more challenging.

The sustainability KPIs chosen to be part of the dashboard were divided into three environmental categories: emissions, and waste & recycling. The energy category was saved to be reviewed later, as there is not much information available. The dashboard is presented in Appendix D.

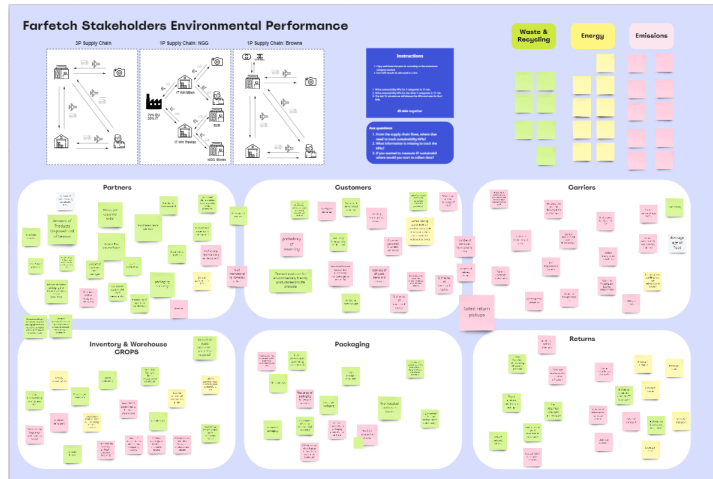


Figure 4.14: Workshop sustainability KPIs dashboard results

For the emission's category, the KPIs were divided into three areas: deliveries, returns, and partners. The waste & recycling category were only divided into one subcategory - products. Table 4.4 presents the KPIs for each category.

Table 4.4: Sustainability KPIs obtained from the workshop

Category	Subcategory	KPIs	Relevancy
Emissions	Deliveries	• Service type shipping ratio • Routes available for each service type	Reveal the impact of standard shipping versus express shipping, as express is the most available service
	Returns	• Customer country return • % Wrong items returns per boutique	Returns are responsible for double the trips, and therefore, double the emissions
	Partners	• Packaging accuracy	The bigger the box is chosen, the greater the emissions released
Waste & Recycling	Products	• Quantity of conscious products by boutique and by customer country • Second-hand items sold	Monitor customer sustainability preferences to push forward more green initiatives

One important metric, not possible to display on the dashboard, is the total CO2 emissions of the long-distance routes. However, this metrics was calculated outside Looker through Python. But, to make the data available on Looker, it is necessary to go through an exhaustive process along with the business intelligence team to be approved. For the CO2 emissions calculation, the method employed in Chapter 3 was adopted.

Another initiative implemented was the creation of a sustainability task force. This focused team will be responsible to meet every month to discuss ongoing sustainability projects at a logistics level. This initiative will bring more awareness to the sustainability theme and engage Farfetch employees on the company sustainability journey.

Chapter 5

Results

After the models were completed, multiple simulations were performed. The retrieved results supported the decision on the most promising strategies to follow.

This chapter starts by explaining the scenarios analyzed and the respective results for the three models simulated. The results' metrics for the models are presented in three levels: sustainability, cost, and service. Lastly, the chapter ends with a discussion of the obtained results, where it compares the strategies by effort and impact.

5.1 First Leg Model

After the base model validation, the scenarios were set, according to the imposed restrictions. Farfetch has two warehouses in Italy, one in Treviso for fulfillment and another in Milan, used by NGG. So, only these two areas were considered for the scenario setting. Additionally, Farfetch can only acquire one EV. The EV investment analysis is displayed in Table 5.1, considering a depreciation time of six years. The simulations were carried out for a complete calendar year, simulating the orders being placed in 2021.

Table 5.1: Total EV yearly investment for Farfetch

Component	Investment	Source
Cost	€ 53,900.00	(Mercedes Benz, 2022)
Government Subsidy	€ 5,000.00	(WattEV2Buy, 2022)
Electricity Price	0.23 €/Kwh	(Reuters, 2022)
Battery Autonomy	50.00 Kwh	(Global Petrol Prices, 2021)
Km Range	150.00 Km	(Mercedes Benz, 2022)
Total Km in a year	146,103.00 Km	(Mercedes Benz, 2022)
Charging	€ 10,001.10	-
Employee Cost	€ 24,000.00	-
Total Cost (€)	€ 42,151.10	-
Total Cost (\$)	\$ 45,101.68	-

Due to these restrictions for the scenarios, Milan was only considered, as it is the region with the greatest volume density, supplying 30% of the total orders coming from Italy. However, an additional data cleaning was necessary, as EVs cannot travel great distances, limiting the number of boutiques. Therefore, the total number of orders tested was 500,000.

The first trial scenario was with one EV carrying out the milk runs with 10% volumetric weight reduction of the products of the orders. However, the SoS was 29 days, and for this reason, the scenario was discarded. The second trial scenario was with two vans. In this case, the results were more promising. However, as one of the restrictions was having just one Farfetch EV performing the milk runs, after collecting the results, 50% of the orders were considered to be collected by Farfetch's EV and the other 50% by DHL carriers. Another simulated scenario considered a 35% reduction of the items' volumetric weight of the order with the same base conditions.

The packaging team usually considers that the shipped items are packed in boxes with 50% of air. However, to be more conservative, a 10% and a 35% factor for volumetric weight reduction was preferred for both simulated scenarios.

The results were compared with the as-is simulated scenario and are presented in Figure 5.1. Scenario 1 considers 10% volumetric weight reduction, and scenario 2 35%. Table 5.2 presents the reduction of emissions translated in trees and kg per order.

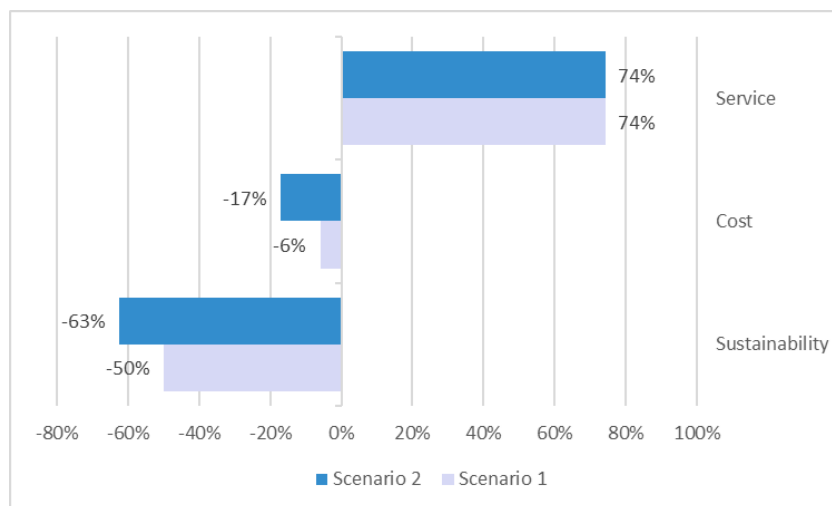


Figure 5.1: Percentage difference of the first leg model's results with the as-is model's outcome for sustainability, cost, and service

Table 5.2: Sustainability impact of the first leg model

	Scenario 1	Scenario 2
Trees to offset the carbon emissions	1,185.00	1,485.00
CO2 reduction per order in kg	0.21	0.22

Given the results, there is a verified decrease in emissions between 50% and 63% and in cost ranging from 6% to 17%. As for service level, there is an increase, but it does not compromise Farfetch's business model, as it is only 0.4 days. With this increase, boutiques cannot be penalized for a delayed in SoS.

5.2 Rail Freight

The rail freight model also simulated the orders being placed in 2021 and in total 245,000 orders were tested, only considering standard delivery, which represents 70% of the total volume of orders.

The decision to only account for standard delivery was made to guarantee the level of service the customer desires for express delivery, since this service transit time, on average, is one day and for standard service is three days. The results retrieved were differentiated into three scenarios: scenario 1 considered moving all the standard orders by rail freight, scenario 2 70%, and scenario 3 30% of the orders. The remaining orders were delivered in the same manner as the as-is model.

The results of each scenario are presented in Figure 5.2, compared with the as-is results. Table 5.3 presents the reduction of emissions translated in trees and kg of CO₂ per order.

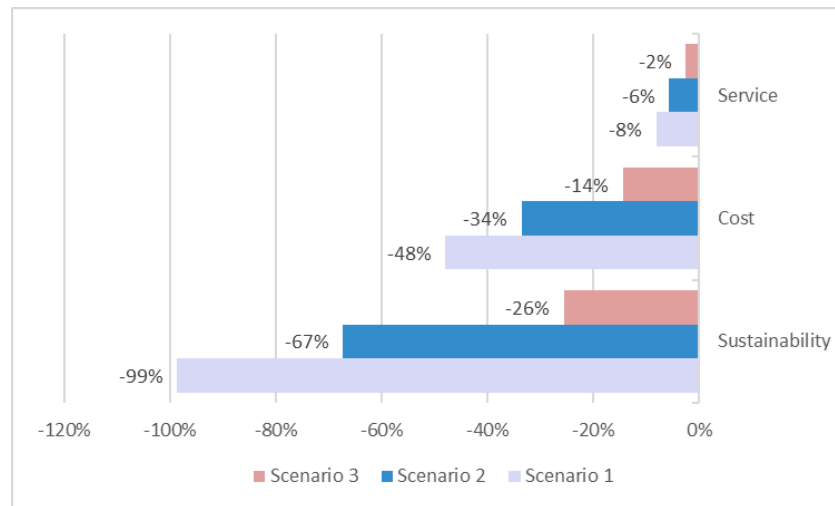


Figure 5.2: Percentage difference of the rail freight model's results with the as-is model's outcome for sustainability, cost, and service

Table 5.3: Sustainability impact of the rail freight model

	Scenario 1	Scenario 2	Scenario 3
Trees to offset the carbon emissions	48,000.0	32,776.0	12,435.0
CO₂ reduction per order in kg	13.0	9.0	4.0

Given the results, scenario 1 is the most promising one, as it decreases the emissions by 99%, while cutting down costs by 48%, without compromising the service time. However, all standard orders being delivered by train is very optimistic, as it will take a long time to make the transition to rail freight. Nonetheless, the results are highly encouraging. Looking into the other scenarios, a great environmental benefit is verified by delivering orders by rail. Even in scenario 3, the more conservative approach, a decrease in 26% in emissions is verified, without compromising the service level and decreasing cost in 14%.

5.3 Last Leg Model

The simulation of last leg green optimization model was also in 2021, between 01/01/2021 and 31/12/2021, focusing on Manhattan, New York City, where the total orders analyzed were 100,000.

In this model, one of the aims, besides verifying the impact of cargo bikes as a delivery method, was to test the optimal number of cargo bikes and respective LCU to secure a balance between sustainability, cost, and service. Therefore, by resourcing to the Anylogic optimization tool, the optimal parameters

were retrieved. This tool allows for finding the parameter value that provides the best performance. The aim was to maximize the speed of delivery, as the emissions and cost will not be affected by the number of cargo bikes. The optimal LCU set by the optimization experiment was 10%, to secure the speed of delivery.

However, as the greater number of bikes the greater speed, a complementary analysis in Anylogic was performed to get the differential benefit of each number of bikes. For this purpose, resourcing to parameter variation experiment, the different average speed delivery for each number of bikes was possible to analyze. This analysis was done over two months and not the full year, to improve the model performance.

One important factor is that, although cargo bikes are starting to be adopted by major delivery companies, the cargo bike fleet is still under development. In fact, in 2021, FedEx started a pilot across Canada with ten cargo bikes Curbside Cycle (2021). Therefore, the number of optimal bikes was limited to ten. The results of the experiment are displayed in the left graph of Figure 5.3, where it is possible to infer that having one, two, or three cargo bikes is not beneficial. The right graph of Figure 5.3 presents the results focusing on the number of bikes from four to ten, where it is verified that there is no added benefit of having more than six bikes.

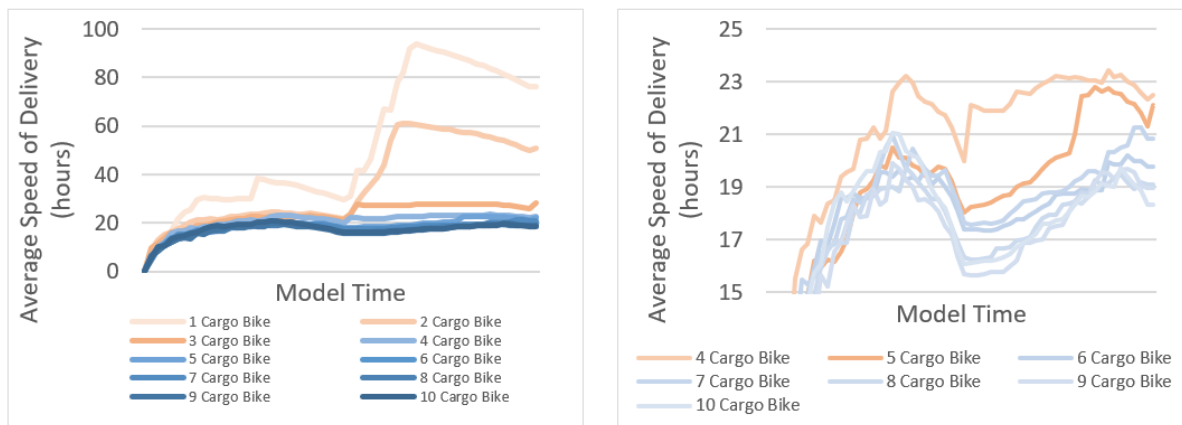


Figure 5.3: Last leg model parameter variation results for obtaining the optimal number of cargo bikes

Given that the experiment was only run for two months, having four and five bikes could be risky. Therefore, the scenario was simulated with six and ten bikes instead, with a loading factor capacity of 10%. The results, in comparison with the as-is results obtained, are presented in Figure 5.4. Table 5.3 shows the reduction of emissions translated in trees and kg per order.

Table 5.4: Sustainability impact of the last leg model

	Scenarios 1 & 2
Trees to offset the carbon emissions	2,175.0
CO2 reduction per order in kg	1.5

The results show the benefits of choosing cargo bikes as a mode of transport for last-mile deliveries, reducing emissions and cost while not compromising the speed of delivery, as the increase verified was 0.33 days. For this initiative, the possibility of Farfetch to own the cargo bikes was not considered, as the investment cost was very high, due to the labor. Therefore, the delivery cost benefit would be for

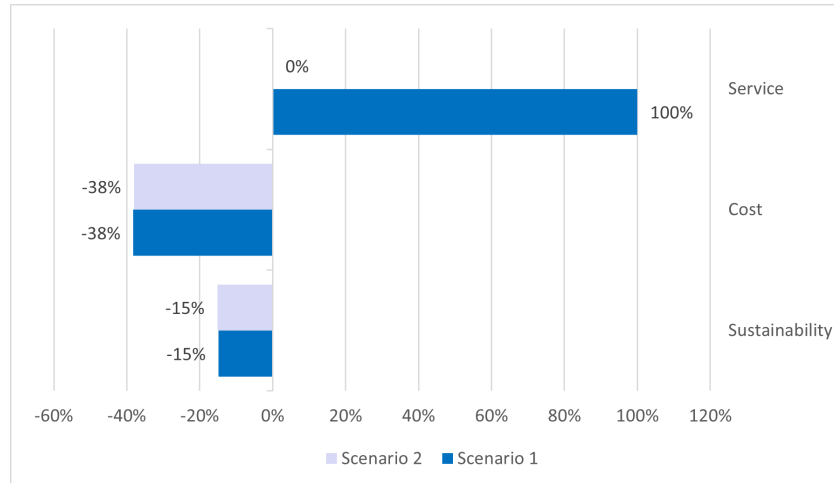


Figure 5.4: Percentage difference of the last leg model's results with the as-is model's outcome for sustainability, cost, and service

the carrier and not for the company, as in the first years the carrier needs to invest in this strategy. But, in the long run, there could be a potential delivery cost reduction, if the carrier adopts cargo bikes. Still, the company saves on offsetting costs and emissions.

5.4 Results Discussion

In this section, the benefits, the opportunities, and the obstacles of implementing the proposed strategies are explored, with the aim to understand the initiatives with the greatest potential.

A feature that was taken into consideration, in the project, was not to compromise Farfetch, analyzing initiatives that would sustain the company. An accomplishment of the overall models was not to compromise the service level.

After displaying the outcomes in terms of percentage difference between the simulated and the as-is scenarios, Figure 5.5 compares the three models results in absolute values instead, to understand the actual magnitude of the impact of the scenarios of each model.

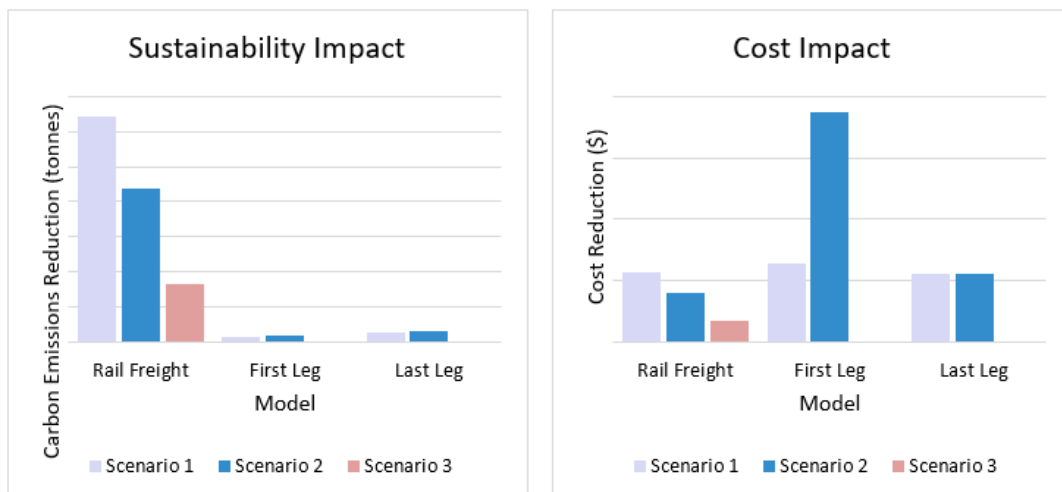


Figure 5.5: Sustainability and cost impact comparison of absolute values between models

Regarding the sustainability metric, the rail freight strategy proved to have the highest impact in all scenarios, followed by the last leg model. In terms of cost, while the first leg results, comparing to the as-is model, had the smallest percentage decrease, in absolute values this model provides the greatest benefit, followed by the last leg initiative. However, as the cargo bikes model cost benefit would be going to the carrier and not to the company, the rail freight can be considered as having a higher cost saving.

The findings support that there are crucial benefits sustaining opportunities for the company to seize. For instance, when it comes to the first leg initiative, although there is a need to invest in an EV, there is a great cost saving observed. To add to that, the scope of the model was just Milan and with one EV collecting 50% of the orders, a small difference in cost caused a great impact in the overall savings. This means, if this initiative is implemented, it will be simple to track the results because it will only be focused in one city. The results obtained, from having an EV for the first leg, serve as a proof of concept of the potential of Farfetch controlling its delivery process, in the company's quest on becoming more sustainable. For example, there is a chance to take advantage of the EV to scale this business model for last mile eco-deliveries and returns collection. Therefore, the first mile model will allow testing other designs, in cities with high volume density of supply or orders, with EVs in multiple dimensions of the supply chain, having a great potential.

When it comes to the rail freight model, the impact on sustainability is clear, if employed. These findings compel the company to deep dive into rail freight as a viable alternative for delivering orders not just in the US, but also in other regions, such as Asia and Europe. The investigation of new rail carriers or the adoption of the current carrier's rail services, is also motivated by the cost decrease, which will act as catalyst for transitioning to this strategy.

Farfetch may leverage the last mile results to put pressure on carriers to provide this type of delivery service. An alternative would be to find new carriers with this service or to join efforts through a collective investment, as it has benefits on emission savings, and it is motivated by the potential reduction of future delivering costs. Currently, the benefit is only on reducing offsetting costs and emissions.

Before implementing these initiatives, the impact and effort should be carefully analyzed. For instance, the EV first leg initiative, as it requires an investment, it needs to be carefully reviewed with the delivery and the fulfillment teams. Additionally, having EVs to potentially collect supply, deliver orders or collect returns, would involve changing Farfetch's current business model, which can be met with some resistance. The rail freight initiative has some setbacks as well, as it is an unknown territory for the company. If the current carriers do not offer rail options for the US routes, there will be a need to hire new carriers and employ new contracts, which will require additional work. Additionally, if there is no carrier performing the end-to-end transportation, the order must switch carriers between legs. This means that a distinct carrier would be required for the first leg and last leg to pick-up and drop-off orders in train stations, making tracking more difficult. Another important factor, when it comes to rail freight, is assuring the security of the items. The last mile, using cargo bikes, needs to be presented to Farfetch's current US carriers and adopted by them, meaning that the company does not have direct control over this initiative. As a result, if there is resistance from the carriers or lack of capacity to employ this initiative, it may indicate a high effort strategy with little impact. Furthermore, the safety of the products remaining in the cargo bike, when the carrier delivers the orders to the customer building, needs to be analyzed.

Figure 5.6 gives a framework using these dimensions to help determine whether the impact exceeds the effort of putting each method into practice. The impact is weighted according to opportunities and benefits, while the effort by the obstacles of implementing such strategies.

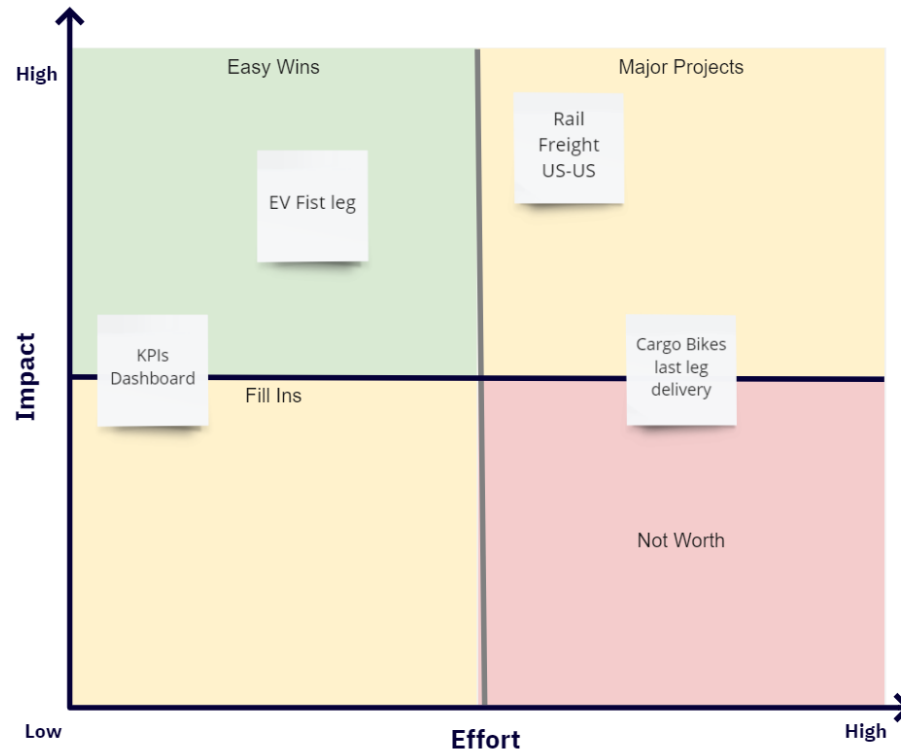


Figure 5.6: Effort-Impact Matrix of Initiatives

The KPIs dashboard initiative, which includes the sustainability task-force, was also added to the framework. This initiative was considered to have a medium impact, since it has the potential to raise sustainability awareness within logistics teams, enabling the discussion of sustainability to continue. As this initiative only requires the sustainability and business intelligence team's approval, the effort level was set as low.

The strategies in the high-impact and low-effort positions of the matrix are viewed as quick wins for the business, and their execution should be given priority. Therefore, the KPIs dashboard should be introduced first, which is already being implemented, followed by the EVs initiative. The plan for rail freight delivery should be implemented next because it has great benefits for the company. The cargo bikes strategy should be investigated to understand whether there is an opportunity, since Farfetch will not be able to fully control the outcome. Therefore, this initiative was placed in last to be implemented.

Chapter 6

Conclusions and future work perspectives

Farfetch's mission to become the luxury fashion platform for good requires a balanced strategy between sustainability, cost, and service, with a special focus on the firm's supply chain. As Farfetch keeps growing its sales, accompanied by an increase in carbon emissions and offsetting costs, there is a priority to decrease the carbon footprint and to give more visibility to the several dimensions affecting the company's environmental performance.

In this context, the main goals of the project were to start designing the green supply chain re-sourcing to the digital twin simulator and to develop a 3-year roadmap to lay the foundation to create the green supply chain of the future, with the aim to reduce Farfetch footprint. Therefore, the first stage was to have a holistic overview of the company's carbon footprint, focusing on downstream transportation and distribution of goods to identify strategies that would minimize the carbon emissions. The assessment of other companies' environmental initiatives was also critical. Another important dimension was to characterize sustainability metrics for the company's supply chain. The sustainability KPIs workshop with different identities allowed to define important metrics to give visibility to the company's environmental performance.

From these assessments, a green delivery system to start developing the green supply chain of the future was design, structured in three dimensions: first leg, line-haul, and last leg. In each, different strategies were modeled and simulated with the digital twin tool.

In the first leg, two scenarios were presented. The first scenario involved an EV collecting 50% of boutique orders from Milan's boutiques with a 10% volumetric weight reduction of the products, while the second scenario considered a 35% reduction. This strategy needs an investment from Farfetch to acquire an EV. In the second dimension, alternative methods of transportation were analyzed, focusing on having rail delivery from US boutiques to US customers. The first scenario is characterized by having 100% of all standard orders delivered by rail, while the second scenario considered only 70% of the orders, and the last scenario just 30% of all standard orders. To do so, it is necessary to resource to the company's current carriers rail services or find new rail carriers capable of providing such service, in the US.

Finally, in the last mile, the possibility of having cargo bikes delivering to the final customer from local hubs was simulated, in NYC. Two scenarios were analyzed, the first with six cargo bikes and the second with ten cargo bikes. For this strategy, it would be interesting to join efforts with the current US carriers through a collaboration or do a joint investment of cargo bikes.

All scenarios were modeled resourcing to Anylogic software, and the results were provided in an external Excel file. This file was later processed to be presented in an intelligible business format. The main metrics were presented in terms of sustainability, cost, and service.

In all proposed initiatives of the green delivery for the future supply chain, a reduction in carbon was observed, ranging from 15% to 99%, along with cost savings between 6% to 48%, without compromising the service level. After comparing all scenarios, resourcing to an effort-impact matrix, the conclusion was to implement first the KPIs dashboard initiative, followed by the EV first mile initiative, then the rail freight, and finally the cargo-bikes last mile strategy.

However, there are still next steps to be taken, to develop further these initiatives. To improve the first mile model, the average volume per family product category needs to be measured using a sample to prove the added benefit of the model with an EV. In addition, testing the EV full potential for deliveries and returns would be interesting, not only in Italy, but also other regions with high volume. For the rail freight between US and US, a full research on potential rail carriers is still necessary to do and to understand the first and last mile implications of rail freight deliveries, as well as the safety implications. In the last mile, using the cargo bikes to do pick-ups from boutiques in NYC would be interesting, and to test the possibility of having click and collect from micro fulfillment hubs or boutiques. Another potential use case with the models is to test the emissions savings from standard delivery and green delivery, that would be a slower delivery service, enabling greater consolidation and fewer trips done. For the KPIs dashboard, there is still the need to get information on the remaining KPIs selected from the workshop, such as from the warehouses and CROPS. It is important to point out that these models are only being applied to specific locations, and analyzing different potential areas to implement the same models would be beneficial. These models serve as a proof of concept of their potential and are a starting point for advocating for initiatives that prioritize sustainability.

One of the main challenges of this project was the demanding learning curve, as in a short period it was necessary to fully comprehend Farfetch's business model, understand the database, create three programming models, and build a dashboard in a new tool. Additionally, during this time, it was not possible to fully deep dive into other potential initiatives. However, after analyzing the full specter of Farfetch supply chain operations, the identified environmental opportunities, for future projects, were added to the 3-year plan to design the green supply chain of the future, presented in Figure 6.1. This road map shows the current initiatives and the next steps of Farfetch's logistics sustainability journey.

Each year is structured into design and analysis of the solutions, and the implementation of the strategies deployed. The first year, which is the current year, is characterized by traceability and transparency, where the main milestones are to create the sustainability task-force and the KPIs dashboard, which is already being implemented. This initiative will push forward sustainability opportunities within the company, such as increasing the number of standard routes by displaying the dashboard to the delivery team. In the design, it is presented the initiatives being tested. The shop local filter is an initiative, being developed by the supply chain design team, to allow customers to select only products from boutiques on domestic routes.

The second year is defined by the implementation of the green network optimization initiatives, currently analyzed. One addition is the disclosure of the delivery impact of the customer purchase with the number of trees needed to offset the total carbon from the shipment, as presented in Figure 6.2. On the design part, as the focus of this project was on the forward flow, it is important to analyze the



Figure 6.1: 3-year roadmap of sustainability initiatives to create the green supply chain of the future

environmental impact of the reverse supply chain and CROPS. The carbon tax initiative would work as a penalization for customers purchasing unsustainably, such as continuously selecting express delivery, as shown in Figure 6.2.

Express delivery £20 + Carbon tax of £5 To be delivered Feb 4 400 trees to offset your delivery emissions	Standard delivery £10 + Carbon tax of £2 To be delivered Feb 10 200 trees to offset your delivery emissions	Green delivery £5 + Carbon tax of £0 To be delivered Feb 20 50 trees to offset your delivery emissions
--	--	---

Figure 6.2: Carbon tax mock-up at checkout for 3-year roadmap

Finally, in the third year, most of the initiatives to create a green delivery system are employed. For this reason, this year is characterized by the availability of a green delivery service to the customer. Another initiative suggested is adding as a feature the customer's environmental impact, in the customer account in the platform. For example, this impact could be measured by the amount of environmentally friendly products purchased, the carbon taxes paid, and the carbon footprint of the shipping service. This feature would incorporate a customer reward system to encourage eco-friendly behavior. In the design dimension, the next step would be to investigate the potential of a circular supply chain, for example, how to re-use unsold stock, mostly focused on 3P partners. Additionally, enabling blockchain technology would potentialize the full transparency and traceability of Farfetch's supply chain, being possible to track more accurately emissions, material composition, and origin of clothing production.

The project's findings made it possible to understand how Farfetch can keep growing by implementing new transformational business models to its supply chain, without increasing the company's footprint. For instance, the proposed initiatives enable Farfetch to be the go-to provider of luxury eco fulfillment, creating a new revenue stream, where other luxury retailers resource to their green services, empowering them to be better.

Bibliography

- Agi, M. A. and Jha, A. K. (2022). Blockchain technology in the supply chain: An integrated theoretical perspective of organizational adoption. *International Journal of Production Economics*, 247:108458.
- Altıparmak, F., Gen, M., Lin, L., and Paksoy, T. (2006). A genetic algorithm approach for multi-objective optimization of supply chain networks. *Computers & Industrial Engineering*, 51:196–215.
- Amatulli, C., Angelis, M. D., Pino, G., and Guido, G. (2020). An investigation of unsustainable luxury: How guilt drives negative word-of-mouth. *International Journal of Research in Marketing*, 37:821–836.
- Amazon (2022). Amazon sustainability. <https://sustainability.aboutamazon.com/>. Accessed: 2022-05-21.
- Ammara, R., Fradette, L., and Paris, J. (2016). Equipment performance analysis of a canadian kraft mill. part i: Development of new key performance indicators (kpi). *Chemical Engineering Research and Design*, 115.
- anyLogistix (2022). Supply chain digital twins definition, the problems they solve, and how to develop them executive insight. Technical report, The AnyLogic Company.
- Balchandani, A., Jense, J. E., Hedrich, S., Rolkens, F., and Amed, I. (2022). State of fashion 2022: An uneven recovery and new frontiers. *McKinsey & Company*.
- Barrow, M., Buckley, C. T. B., Kjaerbøll, G., Cochran, A. E. K. D., Bodlak, A.-L. I., Cepeda, A. S. A., Vergoulas, A. L. G., Paczkowski, A. N., Schreiber, B. S. W., Teixeira, B. F. F. R., Pax, S., Associates, B., Rittenhouse, D., Brown, D. C., Grünauer, B., Reich-Weiser, E. A. C., Hall, E. D., Jiménez-González, F. C., Owen, G. T., Adams, H. M. D., Andrews, K. F. J., Atkinson, L. R. M., Avelleneda, L. L. S. S. J., Stensen, M., Line, M., Goldstein, D. B. D., Alcantara, J. A. P., Shufro, P. C. N., Lau, P. L. W., Kloow, E., Kato, T. Y., Yoshida, T. J. G. A. Y., Co, T. G., Douglas, L. A., Clouse, M., Sottong, J., and Miller, J. (2013). Technical guidance for calculating scope 3 emissions. Technical report, GHG Protocol.
- Berg, A., Magnus, K.-H., Kapperlmark, S., Granskog, A., Polgampola, P., Lehmann, M., Syrett, H., and Arici, G. (2020). Fashion on climate: How the fashion industry can urgently act to reduce its greenhouse gas emissions. *Mckinsey & Company*, pages 1–57.
- Bertram, R. and Chi, T. (2018). A study of companies’ business responses to fashion e-commerce’s environmental impact. *International Journal of Fashion Design, Technology and Education*, 11:254–264.
- Boehm, M., Arnz, M., and Winter, J. (2021). The potential of high-speed rail freight in europe: how is a modal shift from road to rail possible for low-density high value cargo? european transport research review. *European Transport Research Review*.
- Bruzzone, A. G., Massei, M., and Frosolini, M. (2022). Redesign of supply chain in fashion industry based on strategic engineering. *Procedia Computer Science*, 200:1913–1918.

- Brydges, T. (2021). Closing the loop on take, make, waste: Investigating circular economy practices in the swedish fashion industry. *Journal of Cleaner Production*, 293:126245.
- Chorfi, Z., Berrado, A., and Benabbou, L. (2015). Selection of key performance indicators for supply chain monitoring using mcda. In *2015 10th International Conference on Intelligent Systems: Theories and Applications (SITA)*, pages 1–6.
- Choufan, L. (2020). Op-ed | how luxury became fast fashion | bof. *Business of Fashion*.
- Coppola, D. (2022). E-commerce worldwide - statistics & facts.
- Coppola, M. and Blohmke, J. (2019). Impact of climate change on business | deloitte insights. <https://www2.deloitte.com/us/en/insights/topics/strategy/impact-and-opportunities-of-climate-change-on-business.html>. Accessed: 2022-03-19.
- Craft.Co (2022). Farfetch company profile - office locations, competitors, revenue, financials, employees, key people, subsidiaries | craft.co. <https://craft.co/farfetch>. Accessed: 2022-03-22.
- Curbside Cycle (2021). Fedex launches first official cargo bike fleet across canada. <https://curbsidecycle.com/blogs/blog/fedex-launches-first-north-american-fleet-of-cargo-bikes-for-last-mile-logistics>. Accessed: 2022-06-05.
- Dolan, S. (2022). Last mile delivery logistics explained: Problems & solutions. <https://www.insiderintelligence.com/insights/last-mile-delivery-shipping-explained/>. Accessed: 2022-06-05.
- ecomize (2022). Optimizing resources in parcel logistics. <https://ecomize.io/>. Accessed: 2022-05-28.
- Eitelwein (2021). Why sustainability has become a corporate imperative. https://www.ey.com/en_gl/strategy/why-sustainability-has-become-a-corporate-imperative. Accessed: 2022-04-24.
- Faccioli, G. and Sheehan, E. (2021). Global powers of luxury goods 2021: Breakthrough luxury. <https://www2.deloitte.com/global/en/pages/consumer-business/articles/gx-cb-global-powers-of-luxury-goods.html>. Accessed: 2022-03-27.
- Farfetch (2020). 2020 esg report think, act and choose positively. Technical report, Farfetch.
- Farfetch (2022). What is farfetch? - about farfetch. <https://aboutfarfetch.com/about/farfetch/>. Accessed: 2022-03-20.
- Fashion Charter (2018). Fashion industry charter for climate change | the climate impact of fashion. <https://www.fashioncharter.org/chapters/the-climate-impact-of-fashion>. Accessed: 2022-03-21.
- Freightos (2022). Ocean freight: Ocean & sea freight rates. <https://www.freightos.com/freight-resources/ocean-freight-explained/>. Accessed: 2022-06-23.
- Fu, A. J. and Fu, A. J. (2018). Would you be willing to wait?: Consumer preference for green last mile home delivery.
- Fuels, H. (2022). Carbon offsets vs carbon credit. <https://www.harmonyfuels.com/how-it-works/carbon-offsets-vs-carbon-credit>. Accessed: 2022-06-01.

- Gabardi, C. S. (2022). What happens to unsold clothes may surprise you! *Eluxe Magazine*.
- García, E. D., García, H. R., and Cárdenas, B. (2013). *Simulación y análisis de sistemas con ProModel*. México: Pearson educación.
- Gill, D. (2021). Dhl express opens new international hub at malpensa airport. <https://www.airfreight-logistics.com/dhl-express-opens-new-international-hub-at-malpensa-airport/>. Accessed: 2022-06-04.
- Global Petrol Prices (2021). Italy electricity prices. https://www.globalpetrolprices.com/Italy/electricity_prices/. Accessed: 2022-06-23.
- Granskog, A., Lee, L., Magnus, K.-H., and Sawers, C. (2020). Survey: Consumer sentiment on sustainability in fashion | mckinsey. *McKinsey & Company*.
- Grosman, L. (2018). What the amazon effect means for retailers. <https://www.forbes.com/sites/forbescommunicationscouncil/2018/02/22/what-the-amazon-effect-means-for-retailers/?sh=345662432ded>. Accessed: 2022-04-04.
- Gunasekaran, A., Subramanian, N., and Rahman, S. (2015). Green supply chain collaboration and incentives: Current trends and future directions. *Transportation Research Part E: Logistics and Transportation Review*, 74:1–10.
- Heath, H. (2020). How much does it cost to ship freight by rail? https://rampfest-hudson.com/how-much-does-it-cost-to-ship-freight-by-rail/#How_much_does_it_cost_to_ship_freight_by_rail. Accessed: 2022-06-05.
- HM Government (2022). Transitioning to zero emission cars and vans: 2035 delivery plan. Technical report, HM Government.
- Hooper, A. and Murray, D. (2019). E-commerce impacts on the trucking industry. Technical report, American Transportation Research Institute.
- Hristov, I. and Chirico, A. (2019). The role of sustainability key performance indicators (kpis) in implementing sustainable strategies. *Sustainability (Switzerland)*, 11.
- Intelligence, M. (2022). Last mile delivery market | 2022 - 27. <https://www.mordorintelligence.com/industry-reports/last-mile-delivery-market-in-the-united-states>. Accessed: 2022-06-09.
- Jones, D., Snider, C., Nassehi, A., Yon, J., and Hicks, B. (2020). Characterising the digital twin: A systematic literature review. *CIRP Journal of Manufacturing Science and Technology*, 29:36–52.
- Kamble, S. S., Gunasekaran, A., Parekh, H., Mani, V., Belhadi, A., and Sharma, R. (2022). Digital twin for sustainable manufacturing supply chains: Current trends, future perspectives, and an implementation framework. *Technological Forecasting and Social Change*, 176:121448.
- Karaosman, H., Perry, P., Brun, A., and Morales-Alonso, G. (2020). Behind the runway: Extending sustainability in luxury fashion supply chains. *Journal of Business Research*, 117:652–663.
- Kelly, E. and Marchese, K. (2015). Supply chains and value webs. *Deloitte University Press*, pages 1–16.
- Kent, S. (2021). The sustainability gap. *Business of Fashion*.

- Kering (2022). Sustainability: crafting tomorrow's luxury. <https://www.kering.com/en/sustainability/>. Accessed: 2022-05-21.
- Kim, A. (2020). Beta distribution — intuition, examples, and derivation | by aerin kim | towards data science. <https://towardsdatascience.com/beta-distribution-intuition-examples-and-derivation-cf00f4db57af>. Accessed: 2022-06-04.
- Knights, C. (2022). The 100 most sustainable corporations of 2022. <https://www.corporateknights.com/rankings/global-100-rankings/2022-global-100-rankings/100-most-sustainable-corporations-of-2022/>. Accessed: 2022-05-21.
- Lagoudis, I. N. and Shakri, A. R. (2015). A framework for measuring carbon emissions for inbound transportation and distribution networks. *Research in Transportation Business & Management*, 17:53–64.
- Laura, H., Martikainen, Jönköping, J., and Julia, M. (2019). Measuring sustainability in supply chain with key performance indicators.
- Logistics City (2021). E-commerce mobilities: The impact on cities. *Logistics City*, pages 1–37.
- Lone, S., Harboul, N., and Weltevreden, J. (2021). European e-commerce report. Technical report, Amsterdam University of Applied Sciences & Ecommerce Europe.
- Loon, P. V., Deketele, L., Dewaele, J., McKinnon, A., and Rutherford, C. (2015). A comparative analysis of carbon emissions from misc retailing of fast moving consumer goods. *Journal of Cleaner Production*, 106:478–486.
- Magnin, C. and Hedrich, S. (2019). Refashioning clothing's environmental impact. <https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability-blog/refashioning-clothings-environmental-impact>. Accessed: 2022-03-27.
- Martí, J. M. C., Tancrez, J.-S., and Seifert, R. W. (2015). Carbon footprint and responsiveness trade-offs in supply chain network design. *International Journal of Production Economics*.
- Mastercard (2021). How the covid-19 pandemic has impacted consumer attitudes about the environment. Technical report, Mastercard.
- Melkonyan, A., Gruchmann, T., Lohmar, F., Kamath, V., and Spinler, S. (2020). Sustainability assessment of last-mile logistics and distribution strategies: The case of local food networks. *International Journal of Production Economics*, 228:107746.
- Mercedes Benz (2022). esprinter furgão | veículos comerciais ligeiros mercedes-benz. <https://www.mercedes-benz.pt/vans/pt/sprinter/e-sprinter-panel-van>. Accessed: 2022-06-09.
- Mommens, K., Rai, H. B., van Lier, T., and Macharis, C. (2021). Delivery to homes or collection points? a sustainability analysis for urban, urbanised and rural areas in belgium. *Journal of Transport Geography*, 94.
- Moorhouse, D. (2020). Making fashion sustainable: Waste and collective responsibility. *One Earth*, 3:17–19.

- Muñoz-Villamizar, A., Velázquez-Martínez, J. C., Haro, P., Ferrer, A., and Mariño, R. (2021). The environmental impact of fast shipping ecommerce in inbound logistics operations: A case study in Mexico. *Journal of Cleaner Production*, 283:125400.
- NTM (2022). Vehicle type characteristics and default load factors. <https://www.transportmeasures.org/en/wiki/manuals/road/vehicle-types-and-characteristics/>. Accessed: 2022-04-25.
- ParcelBroker (2022). What is volumetric weight? <https://parcelbroker.co.uk/help/what-is-volumetric-weight-volume-calculator/>. Accessed: 2022-06-23.
- Peters, A. (2019). What will make cargo bike package delivery succeed in New York? <https://depts.washington.edu/scctlctr/news-events/in-the-news/what-will-make-cargo-bike-package-delivery-succeed-new-york>. Accessed: 2022-05-28.
- Pharand, A. (2021). Sustainable last mile delivery. <https://www.accenture.com/ie-en/insights/consulting/sustainable-last-mile-delivery>. Accessed: 2022-04-24.
- P.Pucker, K. (2022). The myth of sustainable fashion. <https://hbr.org/2022/01/the-myth-of-sustainable-fashion?registration=success>. Accessed: 2022-05-02.
- Protocol, G. (2022). Calculation tools. https://ghgprotocol.org/calculation-tools#cross_sector_tools_id. Accessed: 2022-06-04.
- Raghunathan, V. (2019). Digital twins vs simulation: Three key differences. <https://www.entrepreneur.com/article/333645>. Accessed: 2022-04-07.
- Rai, H. B. (2019). Environmental sustainability of the last mile in omnichannel retail.
- Rai, H. B., Verlinde, S., Merckx, J., and Macharis, C. (2017). Crowd logistics: an opportunity for more sustainable urban freight transport? *European Transport Research Review*, 9:39.
- Reuters (2022). Italy approves new car incentives of 650 mln euros per year. <https://www.reuters.com/business/autos-transportation/italy-approves-new-car-incentives-650-mln-euros-per-year-2022-04-07/>. Accessed: 2022-06-23.
- Ritchie, H. (2020). Cars, planes, trains: where do CO₂ emissions from transport come from? *Our World in Data*, 9.
- Saeed, M. A. and Kersten, W. (2019). Drivers of sustainable supply chain management: Identification and classification. *Sustainability (Switzerland)*, 11.
- Science Based Targets (2022). How it works. <https://sciencebasedtargets.org/how-it-works>. Accessed: 2022-05-02.
- sendcloud (2021). E-commerce delivery compass. https://www.sendcloud.co.uk/wp-content/uploads/2020/09/Sendcloud_ConsumerResearch_UK.pdf. Accessed: 2022-04-04.
- Sheth, M., Butrina, P., Goodchild, A., and McCormack, E. (2019). Measuring delivery route cost trade-offs between electric-assist cargo bicycles and delivery trucks in dense urban areas. *European Transport Research Review*, 11:11.
- Simonnin, G., Frehland, S., and Toppi, M.-L. (2021). Farfetch corporate footprint 2020. Technical report, Quantis.

- Swallow, T. (2022). Five kpis that businesses use to measure sustainability. *Sustainability Magazine*.
- Swartz, S. and Bove, A.-T. (2016). Starting at the source: Sustainability in supply chains. *Mckinsey & Company*, pages 1–8.
- Tao, F., Zhang, H., Liu, A., and Nee, A. Y. (2019). Digital twin in industry: State-of-the-art. *IEEE Transactions on Industrial Informatics*, 15:2405–2415.
- Terzi, S. and Cavalieri, S. (2004). Simulation in the supply chain context: a survey. *Computers in Industry*, 53:3–16.
- The Sustainable Fashion Forum (2022). 6 themes that will shape the future of sustainable fashion in 2022. <https://www.thesustainablefashionforum.com/blog/2022-sustainable-fashion-themes>. Accessed: 2022-03-28.
- Tordecilla, R. D., Juan, A. A., Montoya-Torres, J. R., Quintero-Araujo, C. L., and Panadero, J. (2021). Simulation-optimization methods for designing and assessing resilient supply chain networks under uncertainty scenarios: A review. *Simulation Modelling Practice and Theory*, 106:102166.
- UN (2021). Cop26 explained. *UN Climate Change Conference UK*.
- UNECE (2018). Un alliance aims to put fashion on path to sustainability. <https://unece.org/forestry/press/un-alliance-aims-put-fashion-path-sustainability>. Accessed: 2022-04-24.
- Verlinde, S. (2015). Promising but challenging urban freight transport solutions: freight flow consolidation and off-hour deliveries.
- Waltho, C., Elhedhli, S., and Gzara, F. (2019). Green supply chain network design: A review focused on policy adoption and emission quantification. *International Journal of Production Economics*, 208:305–318.
- Wang, B., Luo, W., Zhang, A., Tian, Z., and Li, Z. (2020). Blockchain-enabled circular supply chain management: A system architecture for fast fashion. *Computers in Industry*, 123:103324.
- WattEV2Buy (2022). European ev price list. <https://wattEV2buy.com/european-ev-market-price-list-electric-cars-eu/>. Accessed: 2022-06-23.
- Winston, A. (2016). Luxury brands can no longer ignore sustainability. <https://hbr.org/2016/02/luxury-brands-can-no-longer-ignore-sustainability>. Accessed: 2022-03-22.
- Wong, E. Y., Tai, A. H., and Zhou, E. (2018). Optimising truckload operations in third-party logistics: A carbon footprint perspective in volatile supply chain. *Transportation Research Part D: Transport and Environment*, 63:649–661.
- Wren, B. (2022). Sustainable supply chain management in the fast fashion industry: A comparative study of current efforts and best practices to address the climate crisis. *Cleaner Logistics and Supply Chain*, 4:100032.
- Yang, Y., Han, H., Lee, P. K. C., Dong, C., Shen, B., Li, Q., and Perry, P. (2017). An exploratory study of the mechanism of sustainable value creation in the luxury fashion industry. *Sustainability Magazine*.
- Zalando (2022). Zalando: do.more – our sustainability strategy. <https://corporate.zalando.com/en/our-impact/domore-our-sustainability-strategy>. Accessed: 2022-05-21.

Appendix A

GHG Protocol Emissions Calculation

The GHG protocol provides three different methods to calculate scope 3 emissions of category 9 of downstream transportation and distribution. The calculation methods are:

1. **Fuel-based method:** calculate emissions through the fuel consumption and the corresponding emission factor.
2. **Distance-based method:** calculate emissions through the weight, distance, and mode of transport and apply the respective emission factor for each shipment.
3. **Spend-based method:** calculate emissions through the amount of money spent on each mode of transport and apply secondary emission factor.

The fuel-based approach is the most accurate model, as it considers GHG emissions according to the total weight being transported. The diagram, represented in Figure A.1, gives insights into what method to use according to the information available.

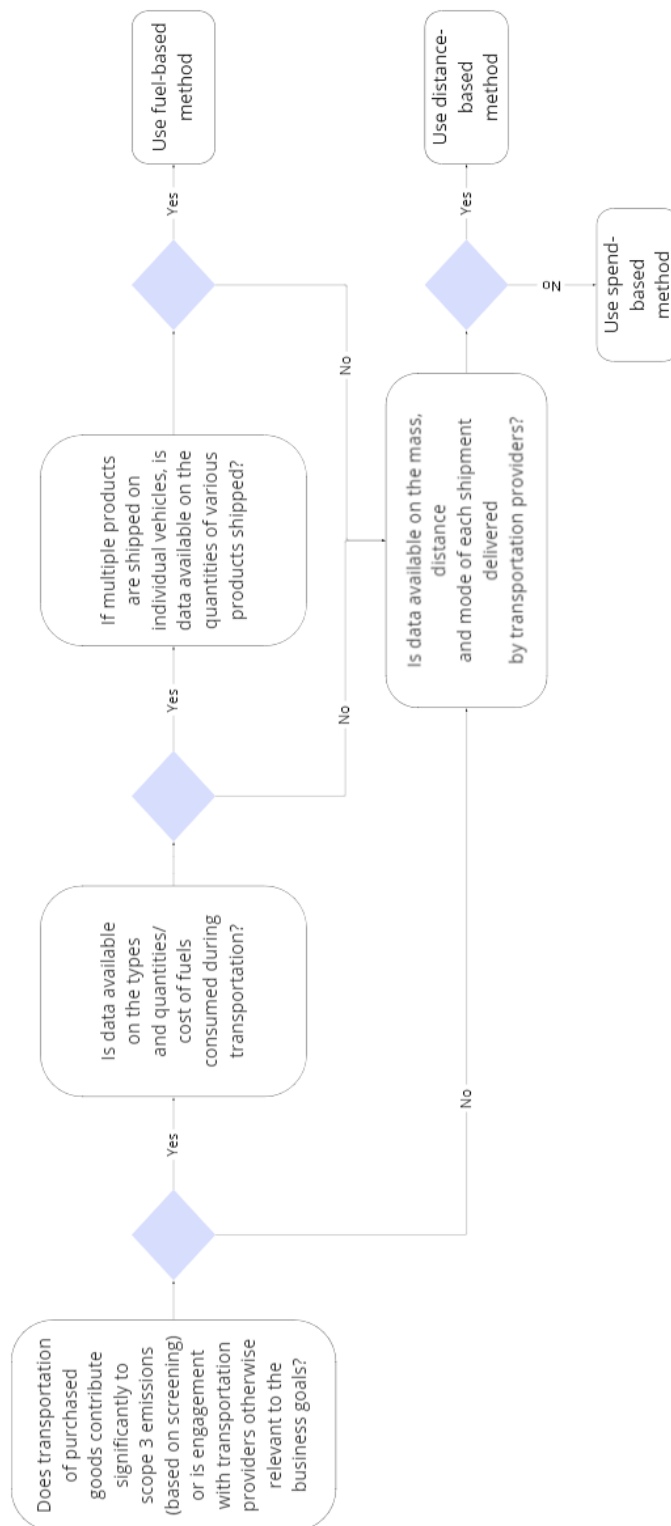


Figure A.1: Flowchart for selecting a calculation method for emissions from upstream transportation, adapted from GHG Protocol

Appendix B

Models Validation

The models were all validated by comparing the simulated results with the as-is results retrieved from Farfetch's database. The validation's goal was to verify the models' performance in accurately simulating the real world.

B.1 First Leg Model Validation

In order to validate the milk run model, the as-is model was simulated in the time frame from 01/01/2021 to 31/12/2021.

After the simulation, the results were compared to the as-is data retrieved from Farfetch data, in an external Excel. For this purpose, the total number of monthly orders of the boutiques, the total volumetric weight per boutique, the average shipping cost per order, and the SoS were validated. The results for the total orders and total volumetric weight comparison are found in Figure B.1.

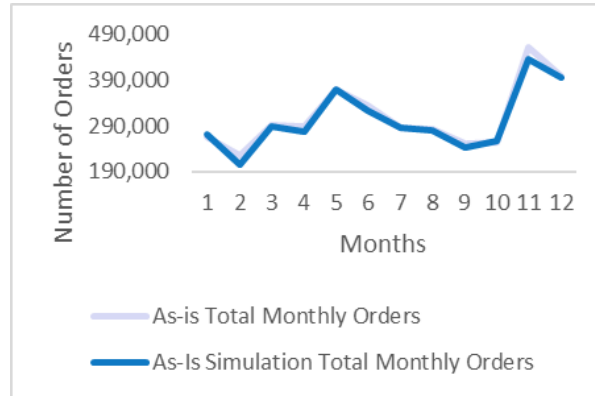


Figure B.1: First leg green optimization model total orders comparison for the model validation

The relative error for the number of orders was calculated according to Equation B.1. The same method was employed to calculate the volumetric weight, shipping cost, and SoS error. For the total orders and total volumetric weight, the error was 2%, for the average shipping cost was 1%, and for the SoS as it was less than a day in both cases, no error was considered.

The error for the number of orders and the total volume per boutique was 2%.

$$Error(\%) = \frac{|Total\ Number\ of\ Orders\ Simulated - Total\ Number\ of\ Orders|}{Total\ Number\ of\ Orders} \quad (B.1)$$

The total CO2 was not compared, as FF does not have visibility of this factor.

B.2 Rail Freight Model Validation

For the model to be validated, the total number of orders of the respective boutiques' cities and customers' cities, and the total volumetric weight transported in the time frame between 01/01/2021 and 31/12/2021 were compared with the as-is and the simulated data. The results for the total orders can be found in Figure B.2.

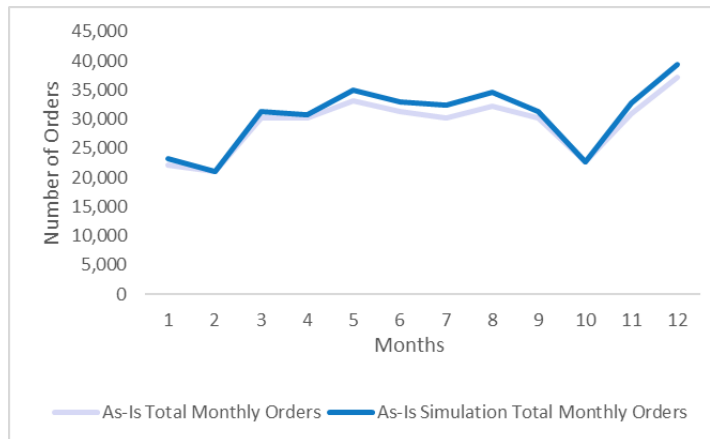


Figure B.2: Rail freight model total orders comparison for the model validation

B.3 Last Leg Model Validation

For the model to be validated, the total number of orders of the NYC customers was compared. The total volumetric weight was not compared, as it was not possible to retrieve information on the as-is order's volumetric weight. The error calculated was 1% and the results can be found in Figure B.3.

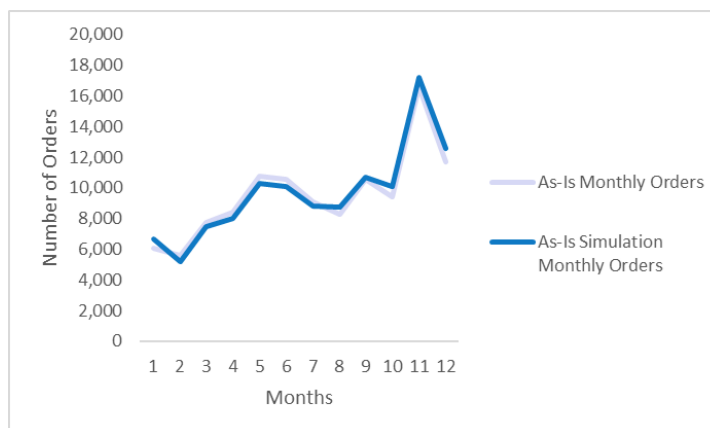


Figure B.3: Last leg green optimization model total orders comparison for the model validation

Appendix C

Ship Stock Movement

Regarding the sea freight opportunity, as it is a slow mode of transportation, transporting directly from the stock point's country to the customer country is not viable, as it would take much longer, and the service level would steeply decrease. Therefore, the only viable option is to take advantage of the 3P partners' stock in the warehouse that is being sent to the customer countries, and place it closer to the customers, beforehand.

Currently, the greatest volume of 3P stock comes from warehouses in Italy and the Netherlands (NL). As NGG has more complex operations, only Browns stock from the NL was considered. The regions with the greatest volume being supplied are the United States and the Asia Pacific (APAC) region, comprising Australia, China, Hong Kong, Macau, and Singapore. The United States destination was not a viable option, due to high duty costs that rendered transportation costs incompatible with the company model.

Therefore, the sea freight analysis was focused on creating routes between NL and APAC of Browns stock by ship, as presented in Figure C.1.



Figure C.1: Ocean freight overview

The sea freight analysis was done with Excel combined with SQL for retrieving the important data from the Farfetch servers. The analysis output contrasted the as-is state to the to-be situation in terms of environmental impact, cost, and service.

The data gathering focused on getting information from the year 2021 on the orders shipped from the NL warehouse to the APAC region, as well as collecting the weight transported, the total number of orders, and the shipping cost. The data was also filtered to only account for Browns stock. These orders are sent by air freight B2C.

The data collection also went through a cleansing process. In this process, the weight retrieved as null was replaced with the average weight transported per order. After the data was prepared, the CO2 emissions were calculated for the as-is situation, considering the CO2 factor of each route per kg transported.

For the to-be analysis, the Honk Kong (HK) warehouse that Farfetch will have at the end of the year was considered. Therefore, from the NL warehouse, the stock would be shipped by sea freight to the Farfetch warehouse in HK, by B2B. From the HK warehouse, the orders would be then shipped to the customers, by B2C air freight, when placed.

In order to compute the emissions of the to-be mode, the same method for the as-is model was applied, breaking the calculations into two legs: the B2B and the B2C. For the stock shipped by the sea, a reduction factor was applied.

To be able to calculate the total shipping cost by sea freight, an outbound cost and inbound cost for the stock movement to the HK warehouse was considered. For the actual stock movement, the only value retrieved was shipping cost by B2B airfreight, already analyzed in another business case. However, for the sea freight, the cost would be four times smaller was considered that (Freightos, 2022).

Regarding the transit time, according to the delivery team the transit time was 30 days, which is not a viable option for the company's business model.

Nevertheless, for the to-be analysis, the three scenarios in terms of emissions and cost savings were compared.

1. 100% of the stock moved by sea freight by B2B
2. 70% of the stock moved by sea freight by B2B and 30% by air freight B2B
3. 30% of the stock moved by sea freight by B2B and 70% by air freight B2B

The results of the analysis are presented in Figure C.2.

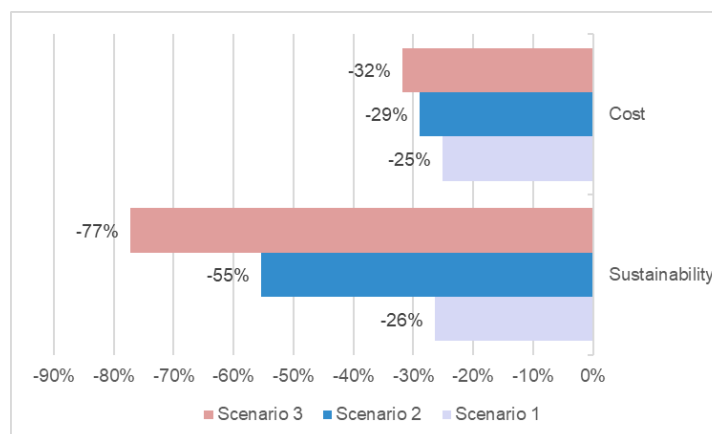


Figure C.2: Ocean freight analysis results in terms of sustainability and cost comparison

From the results, it is possible to understand the benefit of having stock being moved by ship. However, since the service is a critical factor since clothing has a short time-to-market, this approach is unviable for the business.

Appendix D

Sustainability KPIs Dashboard

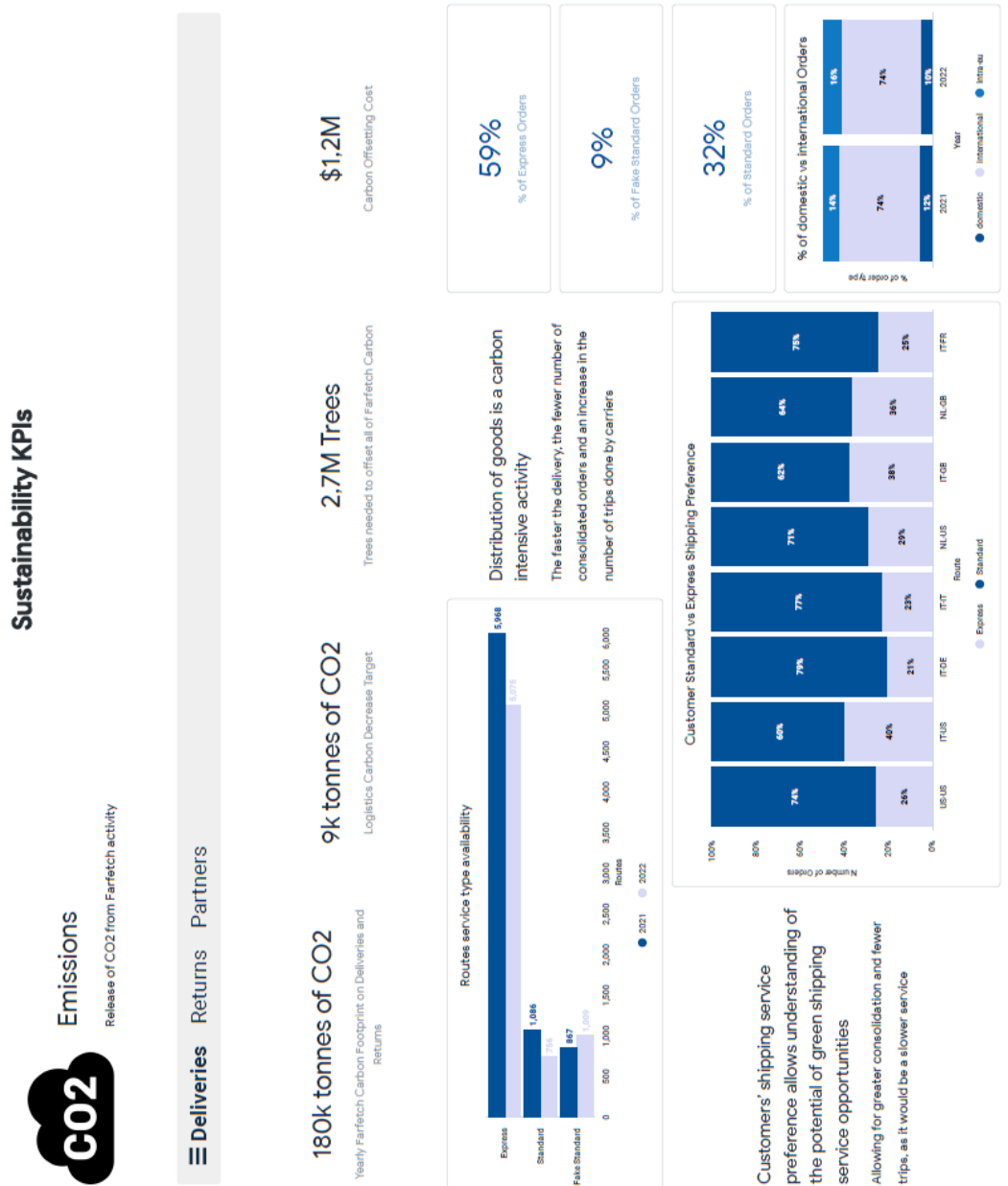


Figure D.1: Emission Deliveries section

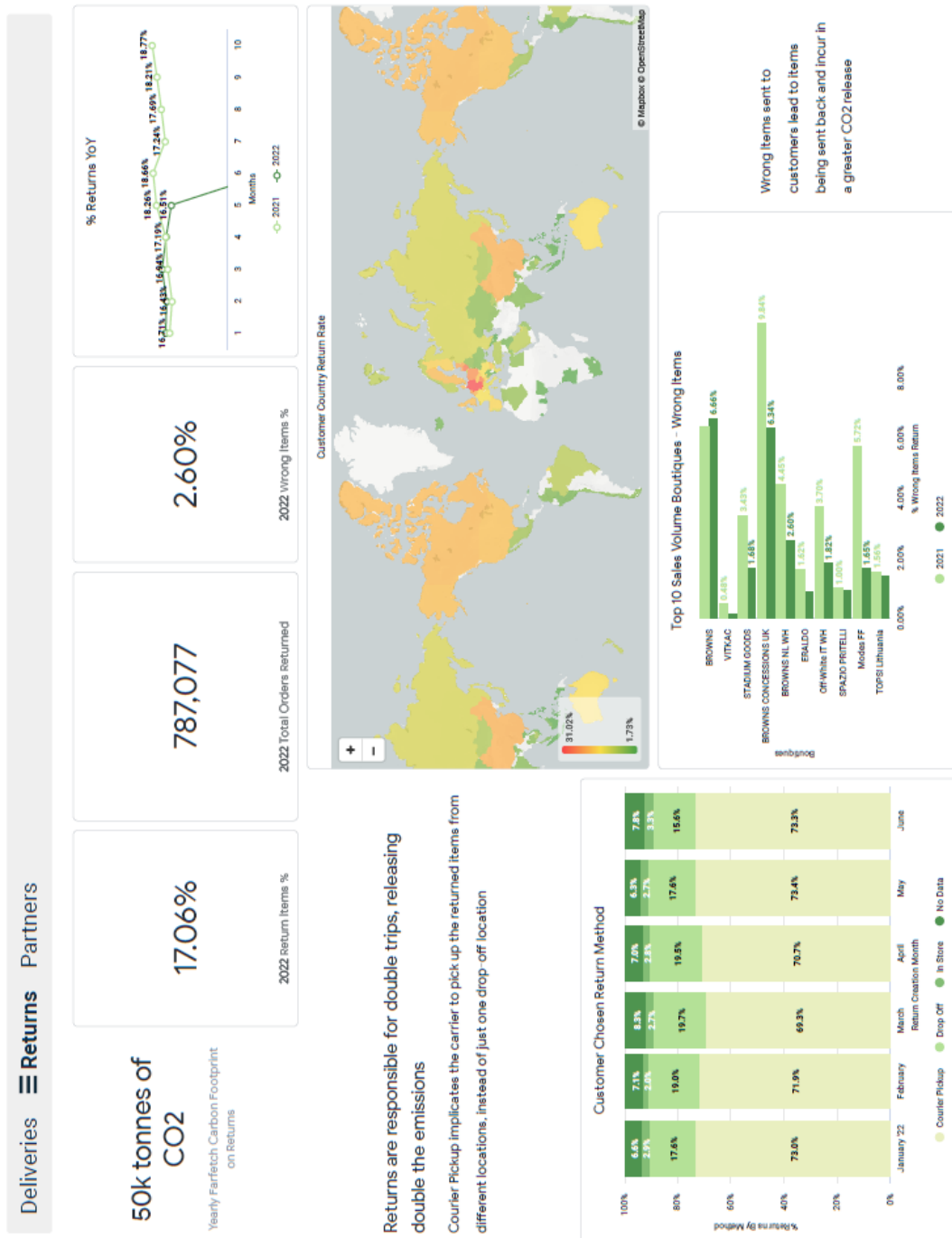


Figure D.2: Emission Returns section

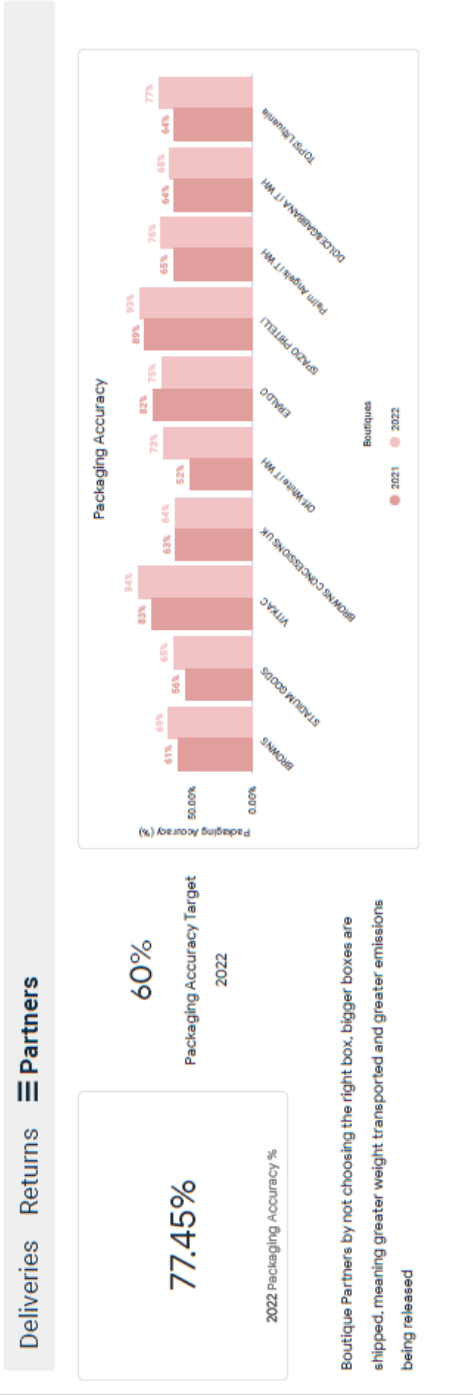




Figure D.4: Waste & Recycling Products section