The Green E-retail Game

An educational game approach towards sustainability in e-retail logistics

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Abstract (English)

This dissertation describes an operations game with focus on sustainable transportation to be played for approximately 3 hours in a classroom setting. Players manage the supply chain for one product of a grocery store along a multi-echelon system with several inventory positions and transportation modes. The shipping modes have different lead times, cost, and emission. The latter are regulated along an emission tax system, which is complemented with rewards in form of demand increases. Demand comes from two sources: traditional store sales and orders for delivery. Players have the objective of profit maximization, which is subject to balancing the trade-offs between responsive and cost-effective logistics, as well as lean inventories and high service levels. Next to the comprehension of these trade-offs, the educational goals of the game include for students to appreciate the logistical complexity of dual-channel retailers; becoming acquainted with strategies to cope with demand variability and volatility; and to experience challenges that companies face regarding environmental management in logistics. The complexity and diverse approaches that participants take can create interesting insights and stimulate discussion around the topic. We review the relevant literature in sustainability and transportation as well as trends in e-retail, describe the game and how to incorporate it into class, analyse different strategies that serve as benchmarks, and illustrate the development process of the game and related learnings.

Key words: logistic, inventory management, emission regulation, dual-channel retailer, e-retail, simulation game, experiential learning

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Abstract (Portuguese)

Esta dissertação descreve um jogo de operações com enfoque no transporte sustentável a ser jogado durante aproximadamente 3 horas numa sala de aula. Os jogadores gerem a cadeia de abastecimento de um produto de uma mercearia ao longo de um sistema multi-escalão com várias posições de inventário e modos de transporte. Os modos de transporte têm diferentes prazos de entrega, custos e emissões. Estes últimos são regulados ao longo de um sistema de impostos sobre emissões, que é complementado com recompensas sob a forma de aumento da procura. A procura provém de duas fontes: as vendas tradicionais das lojas e as encomendas para entrega. Os jogadores têm o objetivo de maximizar o lucro, o qual está sujeito a equilibrar os *trade-offs* entre logística responsiva e rentável, bem como inventários enxutos e altos níveis de serviço. Para além da compreensão desses *trade-offs*, os objetivos educacionais do jogo incluem a apreciação da complexidade logística dos retalhistas de dois canais; familiarizar-se com estratégias para lidar com a variabilidade e volatilidade da procura; e experimentar os desafios que as empresas enfrentam relativamente à gestão ambiental na logística. A complexidade e as diversas abordagens que os participantes adotam podem criar perspetivas interessantes e estimular a discussão em torno do tema. Revemos a literatura relevante sobre sustentabilidade e transporte, bem como sobre tendências em *e-retail*, descrevemos o jogo e como incorporá-lo na aula, analisamos diferentes estratégias que servem como referências, e ilustramos o processo de desenvolvimento do jogo e de aprendizagens relacionadas.

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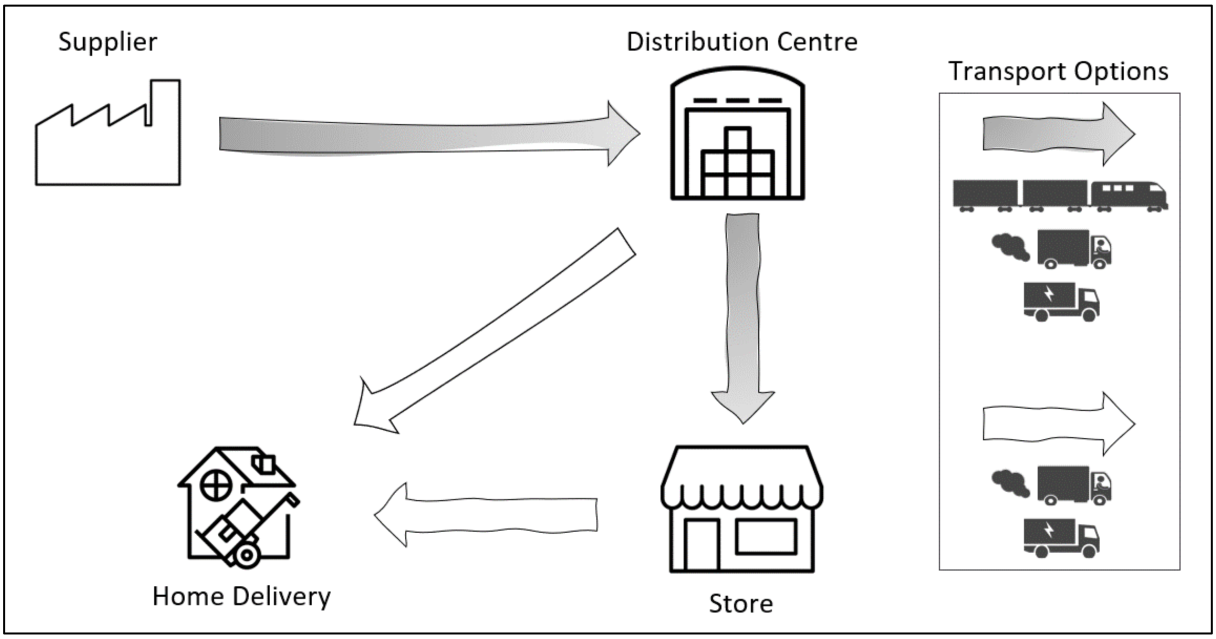
1. Introduction

The internet has revolutionized the way people buy and sell goods. The birth of e-commerce took place in 1992, when Charles Stack launched the very first online bookstore out of a small office in Cleveland, Ohio. Amazon followed only two years later, growing rapidly into a multi-billion-dollar organization. Their expansion has fundamentally re-shaped the way we shop today (The Birth of e-commerce, 2020). E-commerce has also found its ways into the retail market (from now on referred to as e-retail), allowing us to purchase groceries online and get items delivered to our doorstep. Having the consumer at the centre of the operation with next-day deliveries and relaxed return policies has added additional complexities of logistics operations, fulfilment decisions, and inventory management, forcing retailers to redesign their entire supply chains. While e-commerce allows customers to purchase products at the tip of their fingers, it also adds immense challenges for vendors. The environmental impact of e-commerce presents another important challenge that is at the top of mind of consumers and now retailers. This paper focuses on these trends, by using a gamified approach where transport-related emissions should be considered when introducing additional sales channels.

The Green E-retail Game puts players in charge of managing the logistics operations for a grocery store that sells products through both a physical store and via online orders. Units must first be moved from the supplier to a distribution centre, which subsequently is used to fulfil the stores and online orders. In addition to supplying online orders from the distribution centre, the store(s) may be used. Dispatching direct deliveries to customers is thus possible from either

Figure A: Locations and Transport Routes



the distribution centre or the store. Depending on the destination, participants are provided with several transportation modes: (1) traditional trucks, (2) more environmentally friendly (or green) trucks, or (3) railway transportation. (Figure A).

Along the logistic system, the modes have different costs, lead times, and emissions attached to shipping units. Emissions play an integral role, because the amount of CO2 emitted through moving goods results in either a penalty cost or a demand increase for each individual team. The latter mimics the fact that customers are more focused on environmental impact and prefer products that have a lower carbon footprint. The combination of this dynamic with the objective of optimizing ordering, distribution, and fulfilment decisions puts players into a challenging but enjoyable learning environment.

The remainder of this dissertation is structured as follows: Firstly, this thesis positions the research in the broader context of sustainability in transportation and within recent developments in the e-retail sector, including publications on enhancing fulfilment decisions. In addition, a review of the existing literature in classroom games for operations and supply chain is made. Secondly, the main body of the paper follows: a teaching note to introduce teaching staff to the game and guide them on how to create a high-quality and fun classroom experience while supporting the integration into their syllabus. This chapter should be seen as a stand-alone chapter, ready for educators to use without reviewing this thesis. Thirdly, the reasoning behind the key parameters and decisions for designing the game are outlined. Finally, we conclude the paper with limitations and a summary. Several appendices are also attached, including supplementary documents like a pre-read and extracts from the excel file in which the game is played.

2. Literature review

a) Sustainability in transportation

Tackling the current climate crisis has become one of the most apparent topics for policy makers, corporations, and society. The International Transport Forum (ITF, 2018)) states that the transportation industry should receive special attention because (1) it accounts for 23% of global energy-related CO2 emissions and, to make matters worse, (2) its greenhouse gas emissions are still increasing (in contrast to other sectors). In the EU for example, transport emission grew by 27% from 1990 to 2016, impeding the regions overall decrease in emissions (ITF, 2018).

Being the fastest growing consumer of oil, road freight trucks account for 80% of the worldwide net increase in diesel use since 2000 and are expected to surpass passenger cars as the major oil consumer. This trend is accelerated by policy makers that put more pressures on passenger transport compared to the road freight market (ITF, 2018). However, recently the freight industry has seen developments towards stricter handling of CO2 pollution. In 2019 and 2020, the EU and US set target levels for reducing emissions that stem from medium- to heavy duty vehicles towards 2025 and 2050, respectively (European Commission, 2019; MOU: Multi-State Medium- and Heavy-Duty Zero Emission Vehicle, 2020). Generally, the two most common legislations for curbing carbon emissions are cap-and-trade systems and carbon regulation taxes. The former one is implemented through tradeable emission credits, which are given to firms. They sum to a maximum amount, the "cap", and may be sold to each other (from heavy polluters to firms that produce below the cap). For instance, in 2017 Tesla received a substantial amount of their revenue by selling $700 million worth of emission credits in such a system (Huang and Zhu, 2020). In a system with carbon taxes, companies are charged a fee for every unit of CO2 emitted (Xu *et. al,* 2016).

Logistics providers are also increasingly expected to record and disclose their CO2 footprint to its partners and to the public (Wittenbrink, 2015). Therefore, it becomes apparent that managers of transportation companies need to be prepared to make environmental costs an integral part of their business. Especially, when looking at the growth predictions for transportation-intensive areas like e-commerce retail, which will be discussed next.

b) Covid-19 and the surge in online retail

In 2020, the COVID-19 pandemic created an unprecedented health crisis, which led to travel restrictions, social distancing, and lockdowns. In most parts of the world, non-essential businesses like apparel or furniture retailers had to close their physical stores for several months. Consequently, many consumers turned to online shopping. The retail e-commerce market, which already had strong growth numbers before the pandemic, is expected to almost double its global revenues from 2019 to 2024 to 6.4 trillion USD (eMarketer, 2020). McKinsey & Company (2020a) stated that in the first half of 2020 the number of online deliveries had increased in 8 weeks by what would have taken 10 years with pre-pandemic growth rates.

Pandemic-related measurements contributed towards expanding the e-commerce landscape: not only through new products, where a shift towards everyday necessities could be observed, but also through tapping into new customer segments, for example the less digitally focused elderly population (OECD, 2020). The Economist (2021a) reports an increase of the online spending of the 65-year-old plus consumers from the previous year by over 50% in the US in 2020, whereas Britain and France have seen roughly 35% and 20% increases, respectively. As a result, the e-commerce share of total retail sales is expected to increase from 14% in 2019 to 22% in 2024 (eMarketer, 2020). A major part of this trend is attributable to the increase in the share of food and beverage sales of overall e-retail market, which rose from 3% pre-COVID to a peak of 22% and is expected to settle between 6-8% (BCG, 2020a). Furthermore, BCG (2020a) emphasizes that growth level is beyond the threshold where e-commerce took off for other large product segments, such as car parts and electronics. While most of these metrics experienced their peak in spring 2020, for instance 30% of US consumers used online grocery services in March 2020, BCG (2020b) also expects the trends to be long-term and post-pandemic growth rates to be much higher than before. One reason is that providers face greater incentives to capitalize on digital sales channels, as well as learning costs, which decrease the extent to which companies return to how business was done pre COVID-19. Another rationale brought forward by OECD (2020) is that customers have adapted their purchasing habits sufficiently long and learnt to appreciate the wider range of choice, convenience, and immediacy of e-retail.

McKinsey & Company (2020b) suggests that businesses can launch an e-commerce site in less than 4 months. Firms in Europe leased 16% more property spaces for logistics' purposes in 2020, whereas in America and Asia, with 21% and 32% respectively, the rise was even higher. In Western countries one fourth of those new leases was connected to online shopping, in Asia one third (The Economist, 2021b). These developments put more pressure on delivery companies to expand, improve and automate their operations, which is reflected in companies such as Amazon hiring more employees and paying them better salaries (BCG, 2020a). But not only the logistics providers are under pressure, moving from brick-and-mortar to online sales also brings news challenges for the business operators. Examples include higher order complexity or reallocation tactics for SKU inventory levels (BCG, 2020b). Given changing consumer habits, showcased by the increase of grocery sales through e-retail, supermarkets which have focused heavily on traditional sales channels, are required to extend their skillset towards handling a more complex, dual-channel sales environment. The Green E-retail Game picks up this example and intends to simulate e-commerce as well as sustainability trends in an unconventional educational method.

c) Business simulation games and theory contribution

Combining more traditional teaching methods like lectures, readings, case studies, and other course frameworks, with experiential (or trial and error) training, may enhance the learning experience for students. Applications of simulation-based business games provide such an environment, where outcomes are observed quick enough to create a rapid feedback loop on decisions and strategies (Sauaia, 2006) and where players get the opportunity to link abstract concepts with real-world problems (Ben-Zvi and Carton, 2007). Beyond that, business games present a vehicle to easily reinforce the basic elements of motivation: autonomy, competence, and value (Yuhas, 2012). Participants will sense autonomy by directly earning the rewards or dealing with the repercussions that result from their decisions, whereas being capable to reach goals as well as improving one's skillset creates the feeling of competency. However, increasing engagement by conveying that the activities performed are meaningful, does not come as natural as the other two elements of autonomy and competency, and therefore presents a critical aspect of designing a game.

Consequently, it is not surprising, that 97.5% of all AACSB-accredited business schools have been incorporating simulation-based games to teach management disciplines into their curriculum since more than 20 years (Faria, 1998). Simulation games exist for a wide span of disciplines, like Talluri's customer valuations game for teaching pricing strategies and revenue management (2008), or Cesim's Marketing, Small Service Business, or Project Management simulations (Compare Business Simulations - Cesim., n.d.). Wood (2007) brings forward, that simulation games work particularly well in operations, due to their ability to better capture dynamic systems (in i.e., inventory management or production) than traditional, static case studies or problem sets.

The use of simulation games in teaching supply chain and operations include several examples of well-established games that enhance participants' learning experience. The most famous and oldest one is probably the Beer Distribution Game, which was developed in 1961 at MIT. In the past decades "there has been a strong trend to develop new games and retool older games to take advantage of the world-wide web" (Wood, 2007, p. 1). An example is the remake of the original Beer Distribution Game into a more complex version, in the form of an online mobile phone application (Le Scaon, 2020). While bringing basic dynamics of supply chains closer to the students in an interactive way, its focus is to showcase the "bullwhip" effect (Heineke and Meile, 1995).

Over time, many similar games have been developed, like Allon and Van Mieghem's Mexico China game (2010a), that presents a playground for understanding the complexity of dual sourcing in supply chains. This way, a highly complex mathematical problem (related to offshoring versus onshoring) is presented to students in a fun way. More specifically, participants need to trade-off between a manufacturer that is cheap but distant, and a nearby but expensive sourcing option. In Allon and Van Mieghem (2010b), the same authors develop an approach towards optimizing a specific dual-sourcing setting through a tailored base-surge strategy (TBS). They propose a simple strategy (which is used to debrief the Mexico-China gam): place a constant order from the distant source, while using an order up-to level at the fast source to maintain responsiveness and cover the variability of the demand. In the Beer Transportation Game, Dong and Boute (2020) translated this to a transportation setting. Their work presents an example for one of the publications closest to this paper's topic, combining logistics decisions with environmental considerations by demonstrating complications and possible strategies for decarbonizing transportation. In their setup, the cost effectiveness and low-emission characteristic of rail transport are leveraged through the constant order, while on-demand road shipments maintain a high service level. The aforementioned works are relevant to this thesis since they serve as a good benchmark to compare students' performance. Yet, this thesis goes several steps further by also including multiple echelons and different demand channels.

The Carbon Emission Game (Frommer and Day, 2017) has the objective to show students how carbon regulation can serve towards improved environmental performance in the energy market. Learners face a realistic, so-called "cap-and-trade" system for carbon emission credits, in which they seek to maximize their profits through strategic decisions combined with auction- and game-theoretic effects. This list of games is not exhaustive but provides a mixture of the most relevant ones for the introduction of the Green E-retail Game.

Table A provides a comparison of the above-mentioned games along some properties and highlights how this game is different and where the most additional value is created. Note, that some of the table properties and the corresponding characteristics of the Beer Distribution Game have been replicated from Katsaliaki et. al (2014). The authors compared their Blood Supply Game in a similar fashion, but with a partially different set of properties and games.

In terms of theory contribution, the proposed Green E-retail Game enables learners to develop a notion towards optimizing fulfilment decisions by reducing cost through postponing fulfilment decisions and considering inventory cost information when allocating units (Mahar and Wright, 2009). Participants can also experience how fulfilment decisions can be optimized by using current inventory levels paired with future demand forecast (Acimovic and Graves, 2015). Although the game does not necessarily incorporate the mathematical proofs of the two aforenoted papers, it presents an effective simplification to convey the concepts to students. Further, the focus of the Green E-retail Game spans not only inventory and demand management, but also requires players to manage a cost-efficient logistics system and decide from which location to fulfil certain demand. Hence, the complexity of the supply chain operations to be supervised is highest among the compared games. The consolidation of these fields, plus the inclusion of environmental regulation and consumer preference for greener operation, produce a more general but also more complete representation of the contemporary challenges faced by a company operating in a logistic-heavy environment.

Table A: Comparison Between Simulation Games

Game name / Properties	Green E-retail	Beer Transportation	Beer Distribution	Mexico China	Carbon Emission
Theory contribution	Fulfilment decisions	Synchromodality in logistics decarbonization	Bullwhip effect	(Dual) sourcing strategy	“Cap-and-trade” markets
Focus	Logistics, demand, and inventory management	Sustainable transportation management	Order fulfilment	Demand and inventory management	Environmental energy regulation
Game objective	Maximise profit	Reduce cost	Reduce cost	Maximise profit	Maximise profit
Player role	Distributor/retailer	Manufacturer/ distributor	Manufacturer, wholesaler, retailer	Manufacturer	Energy producer
Environmental cost management	Direct (monetized)	Direct (non-monetized)	Irrelevant	Irrelevant	Direct (monetized)
Player competition	Competing, with identical roles	Non-competing	Competing, with different roles	Competing, with identical roles	Competing, with identical roles
Playing mode	Computerized (spreadsheet)	Paper and dices; computerized (spreadsheet)	Paper; computerized (web app)	Computerized (web app)	Computerized
Supply chain complexity	High (decide on ordering & distributing quantities, transport modes, fulfilment locations)	Medium (decide on shipment quantity, transport mode)	Low (decide on order & shipment quantities)	Low (decide on production quantities)	Non-existent (no logistics/ supply chain decisions)

The following section is the teaching note, which should be regarded as a stand-alone chapter. We decided to present the guidance for educators first and provide more insights of the analysis only afterwards in the Methodology section. The motive behind this structure is to facilitate readers’ understanding by first introducing the broader context and then explaining the rationale behind certain decisions.

3. Teaching note

a) Introduction and background

The urgency to reduce greenhouse gas emissions to mitigate further increases of the global temperature has been recognized by most governments and businesses. The transportation sector has seen a significant increase in emissions in recent years, as demonstrated by a 27% increase in the EU from 1990 to 2016. Despite technological advancements in fuel efficiency, freight trucks remain the fastest growing source of oil consumption (ITF, 2018). Thus, policy makers like the European Commission (2019) agreed on target levels for reducing medium- and heavy truck emissions towards 2025. Reaching these targets becomes a greater challenge when considering recent trends in e-commerce, which is heavily reliant on truck transportation. Heavily accelerated by COVID-19 restrictions, the retail e-commerce market is expected to double its global revenues in the coming 5 years and reach 6.4 trillion USD by 2024 (eMarketer, 2020). Furthermore, consumers adapted their purchasing habits and got used to the convenience, wider choice, and immediacy of online shopping, even including the typically less digital elderly population (OECD, 2020). Hence, these developments are expected to be long-term and require logistics providers to expand and enhance their operations.

Moving from brick-and-mortar to a dual-channel system (in which both online and offline customers are served) brings new challenges for retailers, including reallocation tactics for inventory levels or higher order complexity (BCG, 2020b). In a dual-channel setup with two fulfilment centres, it has been demonstrated that overall fulfilment cost can be optimized when considering future demand forecasts (Acimovic and Graves, 2015) as well as including current inventory levels and the respective holding costs (Mahar and Wright, 2009). Concerning the need to decarbonize logistics, Dong and Boute (2020) present a relevant theoretical contribution to optimizing the problem of the Green E-retail Game. They apply the tailored base-surge (TBS) strategy for dual sourcing (Allon and Van Mieghem, 2010b) into a transportation setting where the cost effectiveness and low-emission characteristic of rail transport are leveraged through placing a constant order, while on-demand road shipments are used to maintain a high service level.

This game has been developed with the purpose of giving participants a feel for such logistical complexities, paired with environmental pressures from regulators and consumers. When selling their products via both physical and online channels, grocery stores present an intuitive example for a business to which this applies. The Green E-retail Game does not resemble a true company or field case, but rather falls into Roberts (2012) classification of a general experience case. The target audience for the game are preferably graduate students, with some background knowledge in supply chain operations, specifically inventory management and lead time dynamics.

The Green E-retail Game aims to provide a high-quality and fun learning experience. The overall estimated in-class time required for preparing, executing, and debriefing the game sums to approximately 2 to 2.5 hours. After playing, the students should be able to:

1. Appreciate the complexity of dual-channel (physical and online) retail logistics through different distribution options;
2. Within a multi-echelon supply chain system, become acquainted with strategies of coping with demand variability that stems from randomness and forecast error, as well as demand volatility caused by customer reactions to environmental performance;
3. Develop understanding for the trade-offs between flexibility and cost effectiveness within different transportation modes, as well as the trade-offs between holding cost and high service levels within inventory management;
4. Experience the logistics challenges and opportunities that companies face with regard to environmental regulation (carbon tax) and consumer preferences;

Through simplification and gamification, this work aims to meet the previously mentioned objectives in an entertaining and challenging way. Instructors benefit from the alternative way of evaluating students based on their analyses and derived decision-making, as well as teaching logistics/inventory management practices while emphasizing the need for sustainability in operations. The following sections give a brief description of the game and all relevant dynamics, provide guidance on how to implement the game in class, and finally conclude with possible extensions and a summary.

b) Description of the game

In the Green E-retail Game, the participants will take on the role of a supermarket that starts offering an online channel (in addition to traditional offline sales). Players need to manage the logistics of one product for a duration of 20 days (representing four working weeks) with the objective of maximising profit. The corresponding supply chain consists of four locations: the supplier, the distribution centre (DC), the store, and the customer location (see also Figure 1). There are two sources of daily demand: Store and online demand. The former has no backlog, while subject to late delivery fees, the latter allows backlogging up to four days Online demand can be fulfilled from either the store or the DC. Although players are provided a daily demand forecast, they do not receive upfront information about the exact split between the two channels. For each route, different transportation modes are available. There are three modes: truck, green truck, and rail. Green trucks are only available if an investment has been made before and rail can only be used on R1 and R2. If available, each transportation mode has different cost, lead time, and emission parameters (see Figure 2). The DC and the store can hold inventory, contingent on a holding cost per unit, which is higher in the store.

Figure 1: Supply Chain Overview

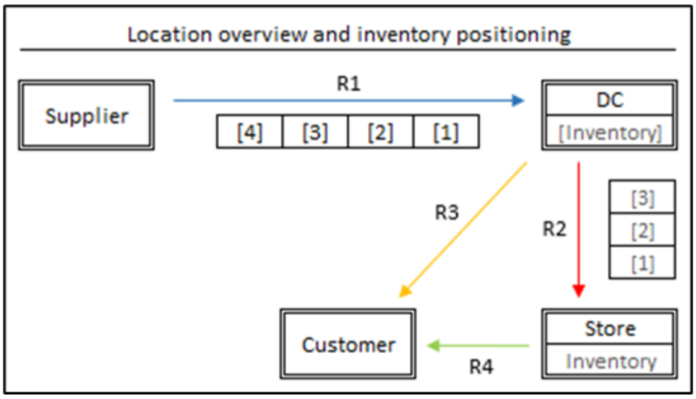


Figure 2: Shipment Parameters

Per	Route	Transport mode	Cost (€)	Time (days)	Emission (kg CO2)
Unit shipped	R1	Truck	0.30	2	0.150
		Green	0.12	3	0.012
		Rail	0.06	4	0.036
	R2	Truck	0.20	1	0.100
		Green	0.08	2	0.008
		Rail	0.04	3	0.024
Order (inde-pendent of units)	R3	Truck	5.00	1	20.0
		Green	3.00	1.3	5.0
		Rail	-	-	-
	R4	Truck	4.00	0.7	16.0
		Green	2.40	1.0	4.00
		Rail	-	-	-

The carbon regulation system that participants face combines aspects of the two most common forms of legislation to curb carbon emissions: cap-and-trade systems and carbon regulation taxes (Xu *et. al,* 2016). The system measures emission per unit sold and has a threshold ratio beyond which companies (players) are charged a penalty cost, which scales like a carbon tax. To include changing consumer preferences, staying below the threshold is rewarded with demand increases. Further, although setting a threshold is distinct from the "cap" in a cap-and-trade system, the emission regulation in this game behaves similarly in the sense that it represents a relative maximum to how much can be emitted without incurring additional emission-related cost.

Players must take the following main decisions: (1) whether to invest in the green truck mode for a given week; (2) the number of units to purchase from the supplier and distribute from the DC to the store each day; and (3) how to fulfil daily online orders. Fulfilment of an order can be postponed up to four times, subject to late delivery penalties. Consolidating the above-mentioned information, the objective function of the problem can be formulated as follows:

$$Profit = Sales\ Revenue - Product\ Purchases - Transportation\ Cost - Inventory\ Cost - Late\ Delivery\ Penalty - Emission\ Penalty - Investment\ Cost$$

One limitation of the game is that players know about the time horizon of the game. We created some properties that retaliate undesirable end of game effects. For information on these and a more detailed description of the game, please consult the appendix.

c) Instructor guide

i. Preparation

The game is played in teams of one to four members. Excluding at home preparations (approx. 1 hour), it takes around 30 minutes to introduce participants to the game and to convey the meaningfulness of the problem. Priming students to appreciate the importance of the task can be done by linking logistics to strategy and competitive advantage, as suggested by Heskett (1977), and by presenting some of the afore-mentioned developments in sustainability in transportation or e-retail. Another option to drive engagement and motivation is to help learners identify with the decision-maker, whose role they will assume (Roberts, 2012). This can be done within the pre-read and tutorial file, which serve as at home preparation materials (see appendix). Due to the complexity of the game and decisions to be made, we strongly encourage that students play the tutorial and write down questions beforehand. To ensure students are fully prepared, we recommend integrating a short quiz into the class preparation time (examples provided in the appendix).

ii. Execution

To drive engagement and competition, we recommend comparing key metrics like each team's account balance and emission ratio in between periods. The accumulated account balance serves as the direct comparison for performance in between teams. Beyond that, the weekly review provides a range of graphs that facilitate performance evaluation (see appendix for extract). Some of the key insights that can be derived are: (a) which parts of the operations result in the most expenses; (b) where peaks in inventory or logistics cost stem from; (c) how much demand occurs through which channel and the respective fill rates; (d) the split between using different transportation modes.

Instructors should plan between 60 and 90 minutes for playing the game. The time that players need to go through the decisions will decrease week by week. Following this suggestion, the first week should be completed in roughly 30 minutes, including 10 minutes for taking the initial setup decisions and reviewing the week by evaluating metrics. This leaves on average 4 minutes to complete each individual day. The second week should take 20 minutes, leaving 5 minutes for the review and 3 minutes for decisions in each day. Completion of the last two weeks usually is quicker, lasting approximately 10-15 minutes each.

iii. Debrief

To assure that the earlier mentioned learning objectives are met, we recommend dedicating another 30 minutes for the debriefing phase. To initiate this part, the instructor shows the final account balances and honours the winning teams. To create an interactive learning environment, encourage participants to share their strategies regarding investment, how they derived daily ordering and distributing amounts split over the different transportation modes, and potential policies applied for order fulfilment. Here it makes sense to outline the extremes, by focusing on the best/worst performing teams. Teams should not only be evaluated based on their final profit, but also on their ability to analyse and reflect on their performance. A relative increase in performance from one week to another could be an indicator for this. Generally, having a consistent approach and a holistic perspective are features of good performance.

The instructor should draw students' attention to strategies for managing emission. Legislation and consumer preferences are increasingly pressuring companies to reduce the carbon footprint of their operations. Similarly, simply ignoring the emission regulation system results most of the time results in a bad overall performance. However, when placing the highest weight on emission for all decision-making, inventory planning becomes more difficult and lost sales as well as late deliveries are more likely to arise. Hence, learners develop an intuition for the fact that companies need to find a balance between pollution impact and constraints of their internal supply chain structure.

Bridging over to connecting the game to relevant research, it should be clarified that there is no single optimal solution for such a complex problem. However, referring to papers related to optimizing fulfilment decisions (Acimovic and Graves, 2015; Mahar and Wright, 2009), there are benchmarks for assessing approaches that learners take. When focusing only on transportation cost, online demand would never be pushed through the store. Even for the cheapest way of shipping units from DC to store, it is still more economical to fulfil the average online order directly from the DC (assuming default parameters). However, most teams fulfil at least some part of online orders from the store location. This is induced by recognising that losing store sales is worse than losing online sales, due to the lower sales margin (no additional transportation cost) plus the limited backlog option for online demand. Given the average 60/40 split of demand between store and DC, a better strategy is to allocate more than 60% of the demand forecast to the store and less than 40% to the DC. In case the buffer in the store grows to large and burdens the bottom-line with high inventory cost, it can be easily reduced by fulfilling online orders. Such an approach is connected to Mahar and Wright (2009), who validated that opposed to only using transportation cost when deciding from which location to fulfil, inclusion of current inventory levels as well as opportunities for delaying order fulfilment can further reduce overall cost. Players that additionally consider future demand predictions assimilate the notion of a heuristic developed by Acimovic and Graves (2015). Based on a true company case, the authors developed a heuristic that accomplishes to capture roughly one third of the potential cost savings over a myopic decision rule.

Extending on the above-mentioned strategy for demand allocation, we developed three intuitive approaches that serve as benchmarks for discussion in the debrief. (1) transporting units exclusively via the traditional truck option along the entire supply chain; (2) using rail for purchasing and distributing, while delivering orders to the customer via truck; (3) similar two the previous but using the green truck for door deliveries as well as a complement to the rail shipments. All three approaches consider the respective lead times to ensure lean inventories and prioritize store sales (for example in the truck only approach: each day, purchase 70% of the forecast for store demand happening four days later plus 30% of the forecast for online demand three days later). Table B summarizes the outcomes under the default parameter set. Only using the flexible but polluting truck option yields the best service levels and would be profitable without the emission tax. Although using slow rail for shipments from supplier and DC decreases the fill rates, it is more profitable due to the cost- and emission savings of rail transport. Nonetheless, the use of trucks for delivering presents further cost saving potential. This is done in the third approach with the highest after-tax profit, where rail and green trucks are combined for purchasing/distributing and deliveries to the customer happen only with green trucks. The decreased service level for online demand as well as an additional 1000 € investment for the green trucks are offset by the cost savings from eliminating the use of expensive trucks and the consequent emission taxes.

Table B: Benchmark Comparison

Metric	**(1)** Only truck	**(2)** Rail then truck	**(3)** Rail with green
Profit without emission tax (€)	2,004	1,991	1,642
Total emission tax (€)	3,600	1,500	0
Demand fill rates store/online (%)	100 / 98.1	91.9 / 79.8	100 / 89.3

Another strategy that we observed in the game trials relates to the tailored base-surge strategy (Allon and van Mieghem, 2010a). Specifically, this it was applied by placing a constant purchasing order via rail and using the (green) truck option to adjust for demand variability and volatility. Dong and Boute (2020) show that a similar approach in a transportation setting is successful in reducing both cost and emission. Despite standing the test in two other games, here the complexity of the problem does not allow a simple application of this strategy.

d) Summary and extensions

Most consumers value an additional online sales channel, which not only leads to high rewards but also adds operational complexity. Additionally, including environmental constraints, the Green E-retail game presents a tangible application for this matter. Players compete to make the most money by managing logistics and inventory expenditures, as well as meeting consumers' demand and sustainability expectations during the game. A variety of metrics that evolve in response to their decisions serve as basis to engage students with traditional operations management topics and to facilitate development of skills associated with monitoring a system, detecting problems, and enhancing performance. We applied some theoretical frameworks to provide a benchmark of performance. Yet, we acknowledge that a more extensive analysis is required to attain the optimal base stock level within the tailored base-surge strategy.

Within the set of existing parameters, the game can be extended easily towards (a) increasing demand variability and/or volatility towards further complicated inventory planning and thus increasingly rewarding consistency in pursuing strategies; (b) boosting the relative importance of environmental performance versus cost-efficient inventory/logistics management and vice versa; (c) emphasizing success of different purchasing, distribution, and fulfilment strategies. Further noteworthy extensions, that however require more sophisticated adaptions, include further prioritization of sales through a certain channel by differentiating selling prices. Moreover, adding the option to extend the forecasting horizon by taking an investment can be a measure to highlight the relevance of precise demand projections in inventory management. To avoid undesirable end of game effects, instructors should consider making the time horizon of the game ambiguous. Further elaborating on sustainable practices in operations, applying the package consolidation fulfilment method (Zhang *et.* al, 2017) can be integrated by raising the number of products managed and allowing order consolidation. Finally, connecting shipments on different routes through backhauling options introduces another action to reduce emissions through maximising fleet utilization. For instance, vehicles can deliver products to the customer on the one way and pick up more units from the supplier on the way back.

4. Methodology and further comments

In this section we describe the development process of the game and how learnings from test trials have shaped the dynamics as well as the suggested parameter set. Further, we provide additional comments for a successful in-class integration of the game.

So far, the game has been played by a handful of people, including PhD candidates in the field, undergraduate business students, and other young professionals. The main take-away from these trials was the rather broad performance spectrum we observed, as measured by the ending account balance. Depending on the level of understanding and strategies pursued, some players finished with balances up to negative 3,000 €, while others obtained positive balances that come close to those that we achieved when combining the rail and green truck option earlier. In the direct comparison between two players and their strategies, we noticed an interesting remark: Player A centred his decisions around optimizing the environmental performance, while Player B prioritized attaining the highest possible service level. While A managed to achieve higher demand increases, B performed better through a higher fill rate. In the end, B satisfied more of the less demand she had, resulting in a higher number of absolute sales as compared to A. Observations like these affirm the suitability of the game design to stimulate discussion in the debrief.

Another important learning concerns the duration of playing the game. Together with time for preparation and debrief, the initial setup with 28 days was simply too lengthy to incorporate it into a class setting. We abstained from reducing the number of weeks from four to three or two, because it would compromise on the learning that players obtain from iterated evaluations of their environmental performance that in turn influence potential increases in future demand. Instead, reducing the number of days per week from seven to five poses a solution that serve to this purpose without impeding other learning objectives.

In the teaching note we touch upon prompting participants' engagement by creating the story of the game around a persona that they can identify with. Roberts (2012) describes this as a mean to enable a powerful energy that drives preparation, discussion, and learning. To achieve this, we recommend adjusting the pre-read (appendix) towards stimulating identification of the audience with the decision maker. For example, when playing the game within a class of students that are about to enter the job market, incorporate a recent graduate that is new in the company and receives his first meaningful assignment into the story.

As mentioned before, in the beginning of the game players are given a certain number of units that, without incurring any transportation cost, they must place along the pipeline under considerations of upcoming demand. According to the default parameter set, students can allocate 400 units in this process, which is enough to satisfy at least the entire demand up until day 3. We select this amount to avoid lost sales which with regard to the lead times cannot be avoided, but at the same time aim to create pressure for using one of the faster transportation modes to not run short. Given that students grasp the logic behind the pipeline, an intuitive way of setting up the pipeline with the provided 400 units, is to prioritize store sales by allocating a bit more than 60% of the demand forecasts (for example 70%) to the store demand of each day, and a bit less than 40% (30%) in the DC for the online sales. Overshooting the store demand while undershooting the online demand is motivated by the fact that losing online sales is less bad in terms of profit than store sales. The latter has a higher margin given that they do not incur further transportation or emission cost. Further, online demand allows some backlogging and can also be fulfilled from the store. Learners that grasp these more complex dynamics demonstrate a deeper comprehension of the trade-offs in cost-effective supply chain management.

Considering the complexity of the described process, plus further observations, we create a list of aspects that are crucial for participants to understand before starting the game. The accompanying tutorial file and some example questions provided in the appendix can be used to facilitate clarification of the following elements:

I. The beginning of the game where players must fill the pipeline and place their first orders to set up the flow of units is critical. It is important to understand how units move through the supply chain, as well as comprehending that the pipeline filling in the beginning is distinct from the other, re-occurring purchasing decisions made. It should be clear that fields in pipeline are the sum of all units in transit, independent of the transportation mode they are shipped with, but rather grouped by the number of days until they arrive. Only the rail shipments will take the units through all fields of the pipeline, while other modes place them closer to the destination at the point of purchase.

II. Purchasing units must be done with care: ordering a significantly too large amount can pose a problem throughout the entire game. Further, players should understand the inherent delay of the lead times. When they sense they will lose sales in the short term, getting units from one day to another is not possible. Point I and II describe elements that relate to the bullwhip effect (Heineke and Meile, 1995). Purchasing too many or too few units in response to variability in demand can generate larger variances of stock further down the supply chain.

III. The demand forecast is dynamic, meaning that it changes with the current emission ratio. Demand increases are only set after the end of one week and will determine potential demand increases for the entire following week. In other words, forecasts for days in the same week are stable, whereas forecasts for days of the next week might change based on evolving expected demand increases as outcome of the decisions taken by the players.

When choosing the transportation modes available for moving units, we initially considered road, rail, waterway, and air transport. Given the setup of a grocery store and the rather short supply and delivery routes, shipping units via water or air were excluded. With predominantly short urban routes, the electrification of delivery trucks exerts unique advantages, like proximity to charging stations and elimination of "range anxiety" (Zhao *et. al*, 2016). Thus, we decide to include the "green truck" as an option, that is significantly cheaper than trucks, albeit having slower lead times, especially for longer routes. Zhao *et. al* (2016) find that using electric trucks does not automatically reduce energy consumption and the level of greenhouse gas emission, but that the share of cleaner power sources in the electricity mix play an important role. Thus, the emission attached to using the green truck are not zero, although being significantly lower than both rail and traditional trucks. In general, we try to design the greener road freight option in a way that makes it the preferred solution, without making the decision a no-brainer. This conveys the importance of electrifying commercial delivery truck to students, while accentuating the difficulties it comes with in the real world.

Explaining the choice of transportation modes, we already touched upon justifications for the default set of parameters. In general, this choice intends to approximate reality. The focus, however, lies with demonstrating the afore-mentioned trade-offs within supply chain operations and sustainable transportation. We carefully finetuned certain aspects to resemble the real world while illustrating such trade-offs at the same time. For example, fulfilling all online demand through the store should not be the optimal solution, considering limited storage space and the longer time units spent in transit. In an older version, this strategy was very successful, which we eliminated by increasing the related cost and reducing the time needed to fulfil online orders from the DC. With respect to the calculation of transportation cost and emission for purchasing and distributing, we decide to make them linear to the number of units shipped instead of having a fixed amount. Having in mind that a supplier usually provides high numbers of a range of products, the cost can be considered variable per unit. Further, this encourages lean inventory management over ordering in bulk and therefore caters to the other learning effects. We do not follow the same logic for fulfilling orders, because home deliveries do not offer much saving potentials due to the individual routes and smaller vehicles that are used.

We also have considered scaling up demand into the thousands to convey a higher impact of managing the operations. We refrain from doing so to avoid making decisions more computational and thereby distracting from the actual learning objectives. A similar explanation holds for why participants only need to manage one product. We do not perceive additional value for the learning objectives in managing two or three products, but rather see it is as unnecessary complexity. Players might perceive the outcome in terms of profit or loss as rather marginal, considering the overall numbers which similar businesses usually exert. To amplify the impact of those outcomes, it is advantageous to highlight the fact that they were managing only one product, instead of the tens of thousands that grocery stores usually hold.

Figure C: Emission Regulation System

Cumulative level of kg CO2 emitted per unit sold		
Lower (excl.)	Upper (incl.)	Consequence
0	0.25	Demand increase: 5-30%
0.25	0.55	Penalty cost: 150 €
0.55	0.6	Penalty cost: 300 €
0.6	0.65	Penalty cost: 450 €
0.65	0.7	Penalty cost: 600 €
0.7	0.75	Penalty cost: 750 €
0.75	0.8	Penalty cost: 900 €
0.8	0.85	Penalty cost: 1050 €
0.85	0.9	Penalty cost: 1200 €
0.9	0.95	Penalty cost: 1350 €
...	...	...

To provide a more complete experience, both institutional regulation and consumer preferences are included in the system that measures emission. Depending on the industry and products sold, usually these two different stakeholder groups react simultaneously to environmental performance of a given firm. In other words, when a company emits beyond a certain limit, the amount of tax payments due increase while also a decreased consumer demand applies. For the sake of simplification, we decide to avert such overlapping outcomes, but select a certain emission per sale ratio (0.25 in default parameters) that presents the threshold between the penalty and the reward aspect of the system (see Figure C). Initially, the ratio was not accumulative between weeks, but would give players the chance for a reset regarding emission beginning of each week. However, this resulted in a very volatile demand increases that complicated lean supply chain management drastically. Moreover, due to the nature of the game, the first and last week always incur less emission because of the "free" starting inventory as well as less purchasing and distributing activities in the last week. This is a limitation of the game that we will touch upon later. Consequently, we opt for using an accumulated emission ratio, which is closer to reality in the sense that customers do not forget a company's sustainability strategy from one week to the other. An interesting dynamic worth mentioning here is, that given a good environmental performance, the demand increase is not entirely proportional to the increase of emission necessary to fulfil it. This is the case because the emission values of the online orders are unit independent, and hence present some sort of economies of scale. While debriefing the game, some players may report that they tried to exploit certain characteristics of the system, by for example postponing order fulfilment on day 5 of a given week to day 1 of the following, and thereby maintaining a larger demand increase for the upcoming week. This presents another property approximates reality, where companies might find space to circumvent regulation to their benefit.

The demand forecast plays a central role for successfully managing the operations. However, since the focus of the game does not evolve around forecasts, we choose to keep the forecast horizon relatively short. One argument in favour of this decisions is that forecasts are more accurate in the short term. Furthermore, to not make the game a perfect planning exercise, the predictions are subject to some error (MAPE of 4% in default parameters). The reason why the forecast error is relatively small is twofold: (1) due to the rather short duration of the game (20 forecasting instances in total), larger deviations could result in a significant bias of over-/underestimation of the actual demand; (2) given that there is no precise indication for the split between the demand channels, the forecast error is not the only uncertainty that players face with respect to demand. This game property highlights that one cannot plan everything from beginning to the end. There will always be ambiguities, which translates to the real world. To facilitate awareness of the forecast errors, we provide a metric for the daily forecast error. Within the debriefing stage, the instructor might ask the students to what extent this indicator influenced their decision making.

A comparable indicator that we provide to reduce the number of overall decisions to be made, is the “Impact on account balance” for fulfilling orders (see last column in Figure D). Note that the calculation reflects sales revenue, transportation cost, potential late delivery fees and savings on inventory cost. However, it does not take potential emission cost into consideration, that could result from the respective order being the tipping point for moving to another penalty level. The intention is to reduce the cognitive burden of learners, by not having to calculate which late order fulfilments are still profitable. A pitfall here is that fulfilling orders from the store seems always more profitable, given the higher savings through avoiding the more expensive inventory cost in the store. Yet, this only reflects the current state of the system, meaning not sending too many units to the store in the first place is the more economic option.

Figure D: Projected Profit Indicator for Fulfilment Decisions

Fulfilment decisions							
Order	Fulfill?	Fulfill from	Transport mode	New store inventory	New DC inventory	Delivery status	Impact on account bal.
3A	Yes	Store	Truck	41	53	On time	53.00 €
3B	Yes	Store	Green truck	14	53	On time	78.60 €
2A	Yes	DC	Green truck	14	29	Delayed	-8.00 €

5. Conclusions

a) Contributions

The concluding section is structured along the contributions of the Green E-retail Game to research, as well as limitations that specify needs for further developments and future work. One contribution of the game to theory is the facilitation of knowledge acquisition for students and professionals of the operational complexities that dual-channel retail sales bring to logistics, i.e. managing several inventory positions and demand sources for one SKU and deciding from where to fulfil online demand towards reducing overall cost. Further, it presents an interactive and engaging way of developing an understanding for how maintaining lean inventories and high service levels simultaneously interact, contingent on demand variability and volatility. The weekly performance reviews allow participants to flourish their analytical skills through monitoring a system and taking subsequent decisions to enhance performance. Learners also develop a sense for trade-offs in logistics when choosing between different transportation modes and their characteristics along cost, speed, and emission. Besides, going beyond the incorporation of emission taxes and cap-and-trade systems, the Green E-retail Game embodies the dependency of consumer demand on companies' environmental performance. To our knowledge, the game is unique as it is the only business game that combines the aforementioned learnings into one single simulation. Such a consolidation creates a good representation of the real world and provides players with ideas and skills on how to approach similar situations they might encounter. Finally, the structure and parameters of the game allow instructors/players to customize the game towards different business settings, experiment with different strategies, and test related theoretical frameworks.

b) Limitations

Nonetheless, there are several limitations to the game that we want to address. During the trials, it became apparent that the complexity and interconnectivity of decisions can strain participants and be demotivating. Instructors need to dedicate time and effort to ensure players understand the rules of the game beforehand. Therefore, developing a "light" version of the game, eliminating certain dynamics, or taking away further decision making from the players, could be an extension to make the integration into a class setting more practical.

The deeper assimilation of research in fulfilment optimization into the game presents another scope for future work. In the current version, some existing frameworks (Acimovic and Graves, 2015; Mahar and Wright, 2009) can be applied conceptually, but are not inherently incorporated with a numerical validation. The same holds for applying the tailored base-surge strategy for dual sourcing (Allon and Van Mieghem, 2010b), where a more in-depth analysis to find its optimal deployment is required. Moreover, the performance evaluation of different strategies analysed before was accomplished based on one sample path of the underlying distribution. To make the conclusions more robust, the different strategies should be probed against a variety of demand samples. The scope of this dissertation entails a preliminary analysis, whereas future research might use more advanced mathematical tools to derive the optimal policy in this setting.

Despite establishing several features to retaliate (see detailed description of the game in appendix), the undesirable effects that are caused by certainty about the end of the game pose a main limitation to this game. Players are compelled to manage the supply chain of a product in a rather unrealistic setting, because demand for the given product stops abruptly. The problem, which is not addressed in this paper, is how to solve the conflict between such undesirable outcomes and the equally distorting event where some teams perform better than others simply because the end of the game happens at a more favourable timing within their strategy. Another issue with the end of the game is that the online demand of the last few days cannot be postponed like on the other days. This can also disrupt certain strategies that should be rewarded, for example when postponing fulfilment of orders to reduce overall cost (Mahar and Wright, 2009). Similarly, the structure of the game leads to the end that the first and the last week are different in terms of purchasing activity. The differences that arise from an already filled pipeline in the beginning and a disruption of the purchasing cycle due to discontinued demand, present another factor that impede the consistent application of strategies. One possible solution to this would be to randomly end the game after a certain number of time periods took place, as well as to have a period without demand in the beginning of the game, that players use to fill the pipeline themselves, while already incurring transportation and holding cost.

Although we tried to make the set of default parameters as intuitive as possible, we are aware that not all of them can be justified with scientific research, nor that they hold true for a range of different business settings and regions around the world. Development of a more realistic and well-founded magnitude between parameters like transportation cost and emission, purchasing price and holding cost, or emission penalties and demand increases constitute another dimension for future work.

Even though the game has been probed, it has not yet been tested in a real classroom setting, nor been exposed to a wider range of possible audiences. In the trials that took place, competing teams were never composed of more than one individual. Examination of the effects that the division of work and discussion between team members have on the playing experience, might counteract the earlier mentioned limitation related to the game's complexity. We think out to run further probations with undergraduate and graduate students, as well as professionals pursuing an MBA, and acknowledge the necessity to enable more feedback loops to enhance the learning experience and extent to which the educational objectives are realized. The more iterations with different participants are completed, the more rigorous analyses can be done. So far, the game was only played on Excel spreadsheets, which naturally puts limitations on the authenticity of outcomes and thus, to what extent players can be evaluated based on them. Development of a centralized platform, like a web-browser application, that absorbs all inputs and automatically generates game statistics and leader boards is fundamental to leveraging the full potential of a fair competition and hence to drive student motivation.

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7. Appendix

a) Detailed description of the game

In the Green E-retail Game, the participants will take on the role of a supermarket that start offering an online channel (in addition to traditional offline sales). Players need to manage the logistics of one product for a duration of 20 days (representing four working weeks) with the objective of maximising profit. The corresponding supply chain consists of four locations: the supplier, the distribution centre (DC), the store, and the customer location, see also Figure A1.

There are two sources of daily demand: First, in-store sales that happen automatically, until stock in the store is depleted. In the proposed game parameters, the daily store demand follows a normal distribution with $\bar{x} = 60$ and SD = 10, but these can be modified up to the discretion of the instructor. Second, online demand can be fulfilled from either the store or the DC itself. Every day two online orders arrive, each drawn from a distribution with $\bar{x} = 20$ and SD = 5 and labelled with an expected delivery time. Late delivery is possible but will incur a penalty cost (50€ per day that units arrive late). Although players are provided a daily demand forecast, they do not receive upfront information about the exact split between the channels, but only are told the average demand split of 60/40 between store and online. The forecast exerts some error, which is normally distributed ($\bar{x} = 0$, SD = 7.5), resulting in a mean absolute percentage error (MAPE of 4%). Only the MAPE is disclosed to the participants.

Figure A1: Supply Chain Overview

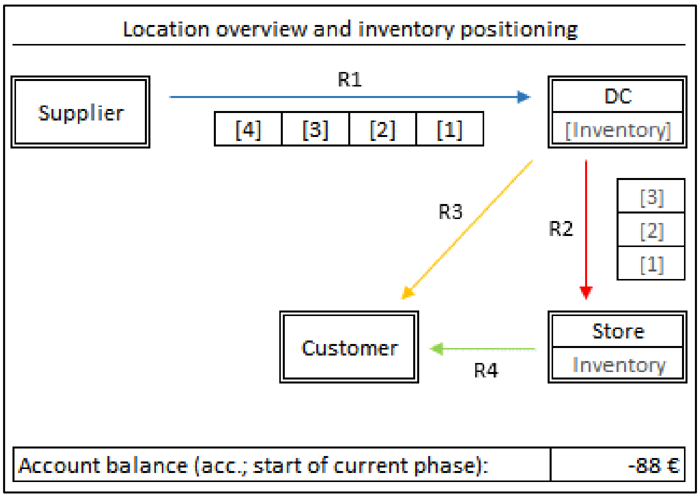


Figure A1 shows the different locations, routes, and location of the inventory in transit. Each day, units move on field to the right/bottom in the pipeline. On R3 and R4 there is no pipeline because units, that are shipped to the customer, leave the supply chain system. For each route, different transportation modes are available. There are three modes: truck, green truck, and rail. Green truck is only available if an investment has been made before and rail can only be used on R1 and R2. If available, each transportation mode has different cost, lead time, and emission parameters (see Figure A2). The lead time indicates where in the pipeline the units are placed. For instance, shipping X units from the supplier to the DC with a transportation mode that has the lead time 3, the X units would appear in the field marked with

[3]. To calculate the cost and emission of moving units on routes R1 and R2, the parameters are multiplied by the number of units. There is no minimum requirement or limit to transport, and units can be purchased/distributed every day. For routes R3 and R4, each set of parameters corresponds to one fulfilled order, meaning that the cost and emission parameters are independent of the number of units shipped. Orders cannot be consolidated, but there is no limit on how many orders to fulfil per day, except the number of outstanding orders.

The DC and the store belong to the supermarket and can store unlimited inventory, subject to holding cost that calculated per unit at the end of each day, where units in the pipeline are not considered. The holding cost per unit is 0.75€ and 1.25€ for the DC and store, respectively. Any stock that is left over at the end of the fourth week will be automatically converted back to cash at the salvage value (purchasing price plus average transportation cost). For the product at hand, expiration date and shelf-life can be neglected.

Figure A2: Shipment Parameters Per Route and Mode

Per	Route	Transport mode	Cost (€)	Time (days)	Emission (kg CO2)
Unit shipped	R1	Truck	0.30	2	0.150
		Green	0.12	3	0.012
		Rail	0.06	4	0.036
	R2	Truck	0.20	1	0.100
		Green	0.08	2	0.008
		Rail	0.04	3	0.024
Order (inde-pendent of units)	R3	Truck	5.00	1	20.0
		Green	3.00	1.3	5.0
		Rail	-	-	-
	R4	Truck	4.00	0.7	16.0
		Green	2.40	1.0	4.00
		Rail	-	-	-

The carbon regulation system that players are subject to, combines aspects of the two most common forms of legislation to curb carbon emissions: cap-and-trade systems and carbon regulation taxes (emitted (Xu *et. al,* 2016). In the game, first emissions are measured in CO2 per kg, and are then converted into the emission per unit sold ratio. This ratio is cumulative throughout the entire time horizon but will be compared after every week against a penalty/reward regulation system. The system has a threshold ratio beyond which companies (players) are charged a penalty cost, which is positively related to the ratio and will be added to the expenses of the corresponding week. Using such a threshold is distinct from the "cap" in a cap-and-trade system but behaves similarly in the sense, that it represents a relative maximum to how much can be emitted without incurring additional emission-related cost. The penalty cost behaves like a carbon tax, with the exception that it is not dependent on an absolute but a relative ratio. To include changing consumer preferences, the regulation system is complemented by rewards in form of demand increases. If players stay below the threshold in a given week, their demand in the following week will increase by a percentage contingent to the emission per unit sold ratio.

The decisions that the players must take can be categorized by phases and how frequently their occur: (1) Filling the Pipeline, where participants must place a fixed number of units along the inventory locations or in-transit positions. This serves as a starting point to setting up the flow of units and will happen only once, at the very beginning of the game. (2) Investment Phase, where participants must deice whether they want to invest and therefore enable the green truck transportation mode on all routes. This decision re-occurs at the beginning of each week. (3) Every day the Purchasing/Distribution and Fulfilment Phase happen, hence constituting the majority of decisions to be taken. First, in the Purchasing/Distribution Phase players decide how many units to purchase from the supplier and send to the DC, and how many to distribute from the DC to the store (Figure A4). Second, in the Fulfilment Phase they can opt to fulfil outstanding online orders (fulfilling orders can be postponed up to 4 times before they disappear), and if so, from which location. For all daily decisions it must be indicated via which mode the units shall be transported (Figure A5).

Figure A3: Filling the Pipeline (once) & Investment Phase (weekly)

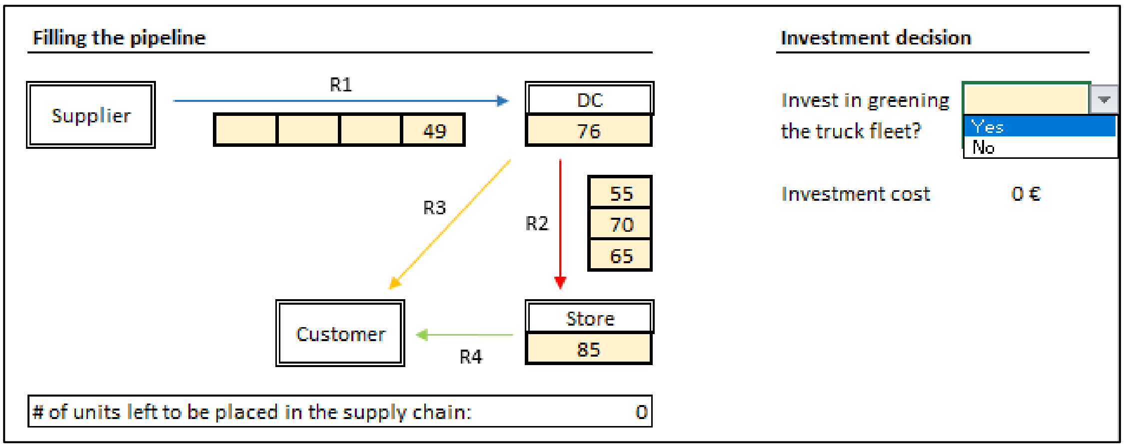


Figure A4: Purchasing and Distribution Phase

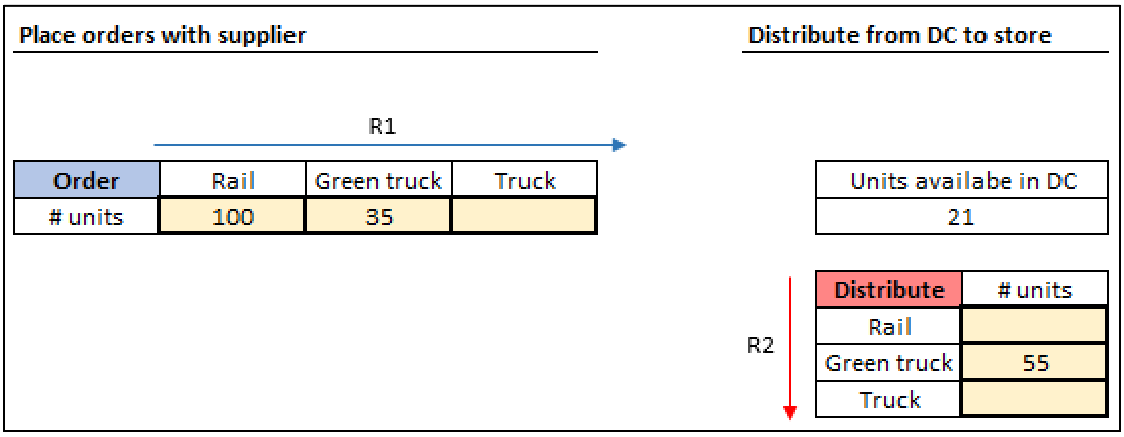


Figure A5: Fulfilment Phase

Fulfilment decisions

Order	Fulfill?	Fulfill from	Transport mode	New store inventory	New DC inventory	Delivery status	Impact on account bal.
2A	Yes	DC	Green truck	60	52	Delayed	42.00 €
2B	No			60	52		
1A	Yes	Store		43	52	NA	NA
			Truck	43	52		
			Green truck	43	52		
				43	52		
				43	52		
				43	52		
				43	52		
				43	52		

Consolidating the above-mentioned information, the objective function of the problem can be formulated as follows:

$$
\begin{aligned}
Profit = \; & Sales\ Revenue - Product\ Purchases - \; Transportation\ Cost \\
& - Inventory\ Cost - Late\ Delivery\ Penalty - \; Emission\ Penalty \\
& - Investment\ Cost
\end{aligned}
$$

Given that the participants are informed upfront about the number of weeks the game has, some properties are established to avoid undesirable effects. First, purchases and distributions to the DC or store that are still in transit at the last day of demand are automatically blocked. This reduces complexity for the players by not having to think about which shipping options prevent units from being sold. There is one exception for when it could be useful to ship units that arrive too late, which is to avoid holding cost for excess inventory. We will pick this up later as a possible extension of the game.

Furthermore, good environmental performance in the last week cannot be rewarded within the usual demand increase system. Instead, for the last week, an emission ratio below the threshold will be rewarded with cash, whose value is negatively correlated to the ratio. Finally, to mitigate the negative consequences of having ordered too many, any units left after the last demand are automatically transformed into a salvage value. The salvage value includes the purchasing price and the average of transportation cost required to move the units to their current location. However, it does not prevent incurring the inventory holding cost of the last day.

b) Pre-read (introductory note for participants)

Context and objective

Given evolving purchasing habits of customers, a local supermarket is pressured into opening an online grocery channel. Consequently, while satisfying in-store demand, the supermarket also starts serving customers through online orders, which are delivered to their homes. The supermarket is completely new to this field, but instead of hiring an experienced logistics partner, they want to build up their operations themselves.

At this point you are hired as the new logistics manager. To begin with, you will only be responsible for **one product**. At the end of the 4-week probation period, your performance will be evaluated at the generated profit (or loss). In the profit function, next to sales revenue, several cost factors are included: procurement, transportation and holding, service penalties, investments, and environmental rewards/charges.

Demand

There are two sources of demand: First, in-store sales that happen automatically, as long as enough stock is available in the store. Second, online demand which comes in the form of digital orders. However, the sales team provides only *one* forecast value for each day, the daily aggregate demand. They estimate a 60%/40% split between store and online demand, respectively. Forecasts for the following 5 days are available. The forecast is reasonably good but exerts error since the company has little experience with online sales. For the given period, the mean absolute percentage error is 4%.

Figure 1: Demand forecast

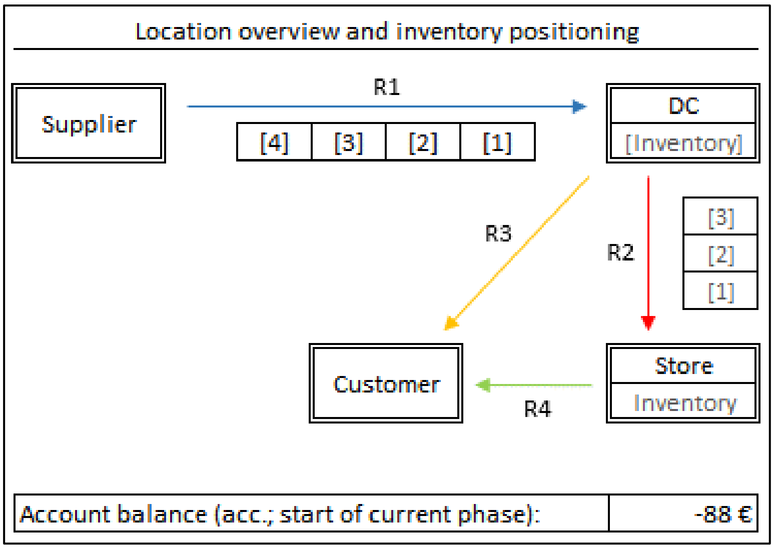
Aggregate demand forecast* (store & online)		
Week	Day	# units
1	3	95
1	4	89
1	5	96
2	6	114
2	7	139

Transportation parameters

The supply chain consists of four locations: the supplier, the distribution centre (DC), the store, and the customer location. In total there are four different routes, for which different transportation modes are available. There are three modes: truck, green truck, and rail. Green truck is only available if an investment has been made before. The figure on the right shows the different locations, routes, and where inventory is currently located (at a location or in transit). On R3 and R4 there is no pipeline because units, that are shipped to the customer, leave the supply chain system.

On every route, each transportation mode has different cost, lead time, and emission. The transportation costs are directly subtracted from profit. The lead times are important for to plan when the goods arrive. In case of a late delivery, a penalty cost can also reduce your profit. Emissions are first measured in kg of CO2 and then converted into emission per unit sold. This ratio is cumulative but will be compared *after every week* against a penalty/reward regulation system. Companies (players) are charged for emissions beyond a threshold, while staying below the threshold is rewarded by increased customer demand in the following week.

Figure 2: Map of the Supply Chain Nodes



For routes R1 and R2 there is no minimum requirement or limit to transport. Per day, for every transportation mode one shipment can be placed. The cost and emission parameters are per unit shipped.

For routes R3 and R4, each set of parameters corresponds to one fulfilled order, meaning that the cost and emission parameters are independent of the number of units shipped. Orders cannot be consolidated and there is no limit on how many orders to fulfil per day, except the number of outstanding orders.

Figure 3: Parameters for shipment options

	Route	Transport mode	Cost (€)	Time (in days)	Emission (in kg CO2)
Per unit shipped	R1	Truck	0.30	2	0.2
		Green truck	0.12	3	0.01
		Rail	0.06	4	0.04
	R2	Truck	0.20	1	0.10
		Green truck	0.08	2	0.008
		Rail	0.04	3	0.02
Per fulfilled order	R3	Truck	5.00	1.0	20
		Green truck	3.00	1.3	5.0
		Rail	-	-	-
	R4	Truck	4.00	0.7	16.0
		Green truck	2.40	1.0	4.00
		Rail	-	-	-

Inventory

As mentioned above, this optimization problem is about only one product. The supermarket acquires one unit for a purchasing price of 0,25€ and sells it at the retail price of 1,75€, which is the same for in-store and online demand. The supermarket faces inventory costs at its two locations. Holding costs are calculated per unit at the end of each day, where units in the pipeline are not considered. Any stock that is left over at the end of the fourth week will be automatically converted back to cash at the salvage value (purchasing price plus average transportation cost). The product at hand is a quite long-lasting food, so expiration date and shelf-life can be neglected in this case.

<u>Decisions</u>

In Bob's trial month (4 weeks of 5 days each), he needs to take certain decisions:

Filling the pipeline (once at beginning): The first decision each player must make, is where to distribute a fixed number of units in the supply chain. This will be the basis for setting up the operations and look like the format of F2.

Investment phase (weekly): Each week starts with the investment phase, in which an investment for greening the truck fleet can be made. If you choose to invest, next to the other modes, the "green truck" transportation will be available for all routes for the given week.

Order/distribution & fulfilment phase (daily): Each day consists of two phases. First, the order and distribution phase (F4 below), where it must be decided how many units to order from the supplier to the DC, and how many to distribute from the DC to the store.

Second, the fulfilment phase (F5), in which it must be decided whether to fulfil online orders, and if so, from which location. For all daily decisions it must be indicated via which mode the units are transported. Fulfiling orders can be postponed up to 4 times before they disappear.

Figure 4: Order/distribution phase

Place orders with supplier

Order	Rail	Green truck	Truck
# units	100		75

Distribute: DC to store

Units availabe in DC
25

Distribute	# units
Rail	
Green truck	
Truck	

Figure 5: Fulfilment phase decisions

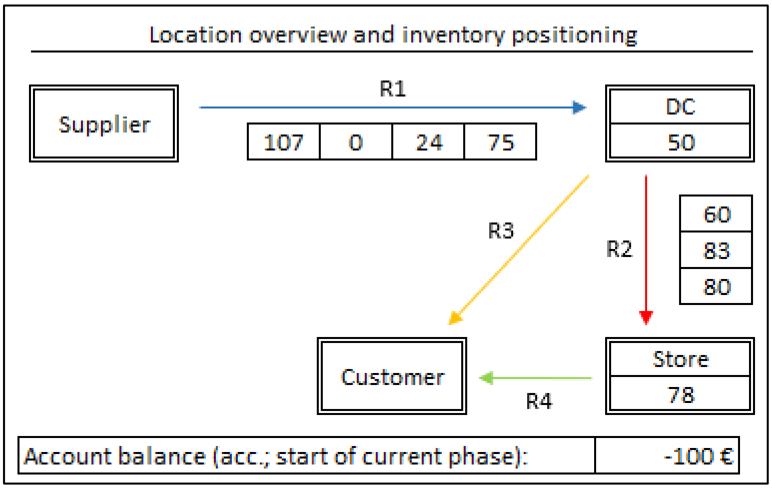
Fulfillment decisions

Order	Fulfill?	Fulfill from	Transport mode	New store inventory	New DC inventory	Delivery status	Impact on account bal.
1A				25	25		
1B				25	25		

Feeling a bit overwhelmed? Don't worry, before the actual game starts you can explore different inputs and the consequent outcomes for the first week in the tutorial file.

c) Screenshots game file

Units in Pipeline and Account Balance



Demand Forecast

Aggregate demand forecast* (store & online)		
Week	Day	# units
1	3	118
1	4	85
1	5	107
2	6	127
2	7	128

*Includes expected demand increases

Daily Store Demand

	# units
Demand	76
Inventory	85
Rest	9
Lost sales	0

Outstanding Orders

Order	# units	Delivery	Days
3A	19	Express	2
3B	27	Express	2
2A	24	Premium	0

Daily revenue and expense calculations

Daily Overview

Revenue		# units	Day	Acc. (week)
	Total sales	**107**	**187 €**	**543 €**
	Store	70	123 €	345 €
	Online	37	65 €	198 €

Expenses		Day	Acc. (week)
	Total expenses	**50 €**	**165 €**
	Total emissions (CO2 kg)	**9**	**31**

			# units	Day	Acc. (week)
Product Purchases			**0**	**0 €**	**0 €**
Inventory			**55**	**44 €**	**128 €**
	DC	Starting	71		
		Distributior	0		
		Deliveries	22		
		Ending	49	37 €	101 €
	Store	Starting	91		
		Sales	70		
		Deliveries	15		
		Ending	6	8 €	28 €

		Amount	Day	Acc. (week)	CO2 in kg Day	CO2 in kg Acc. (week)
Logistics		**2**	**5 €**	**22 €**	9	31
	Supply/Internal Logistics	0	0 €	6 €	0	4
	R1: From supplier by	0	0 €	0 €	0	0
	Truck	0	0 €	0 €	0	0
	Green truck	0	0 €	0 €	0	0
	Rail	0	0 €	0 €	0	0
	R2: From DC to store by	0	0 €	6 €	0	4
	Truck	0	0 €	0 €	0	0
	Green truck	0	0 €	0 €	0	0
	Rail	0	0 €	6 €	0	4
	Customer logistics	2	5 €	16 €	9	27
	From DC to customer	1	3 €	9 €	5	15
	Truck	0	0 €	0 €	0	0
	Green truck	1	3 €	9 €	5	15
	From store to custome	1	2 €	7 €	4	12
	Truck	0	0 €	0 €	0	0
	Green truck	1	2 €	7 €	4	12

		Amount	Day	Acc. (week)
Late deliveries		**0**	**0 €**	**15 €**
	By order			
	18A	0	0 €	
	18B	0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
		0	0 €	
Capex investment		**0**	**0 €**	**250 €**

Weekly environmental performance overview

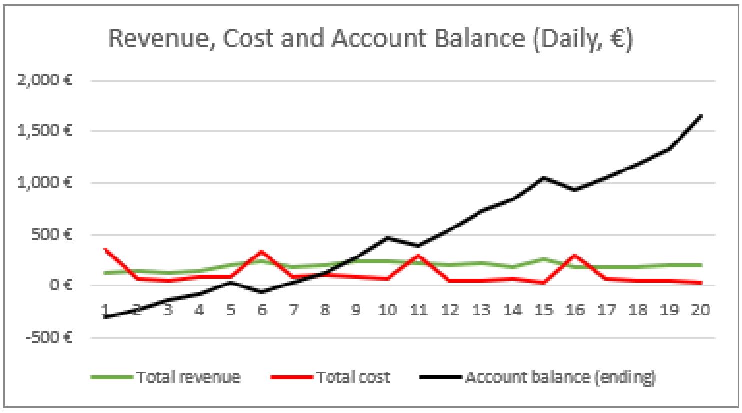
Day	6	7	8	9	10
CO2 emission (accumulated, kg)	72	84	101	117	137
Sales (accumulated, units)	557	663	775	912	1053
Emission per unit sold	0.13	0.13	0.13	0.13	**0.13**
Exp. demand increase next week	15%	15%	15%	15%	**15%**
Exp. penalty cost	0 €	0 €	0 €	0 €	**0 €**

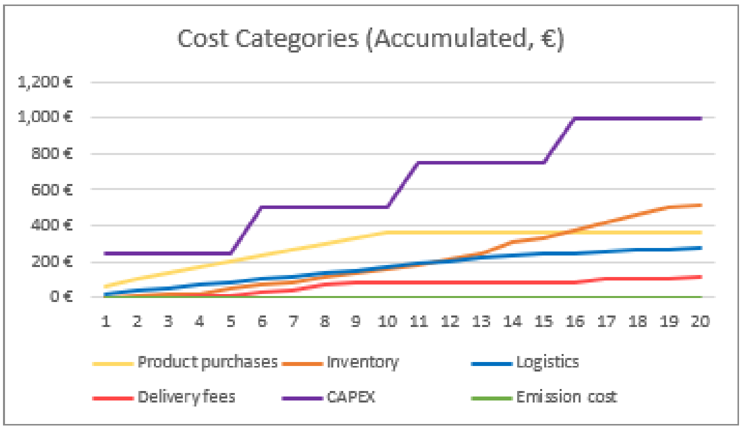
Unfortunately, this you've exceeded emission of per unit sold target set by the government.
Customers like that! Your demand next week will increase by:

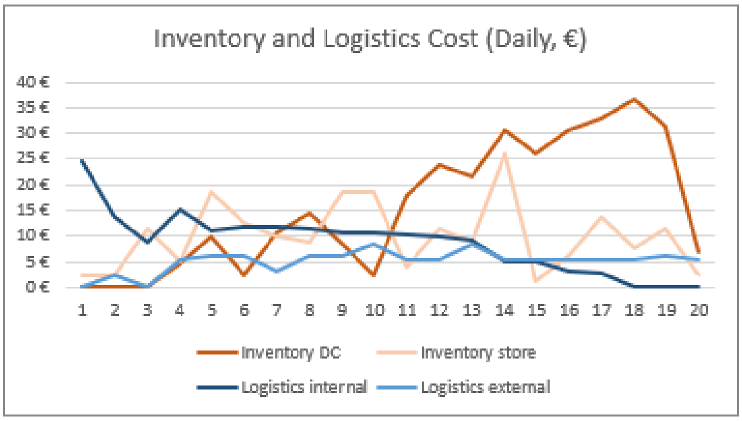
15%

End of week review (1)

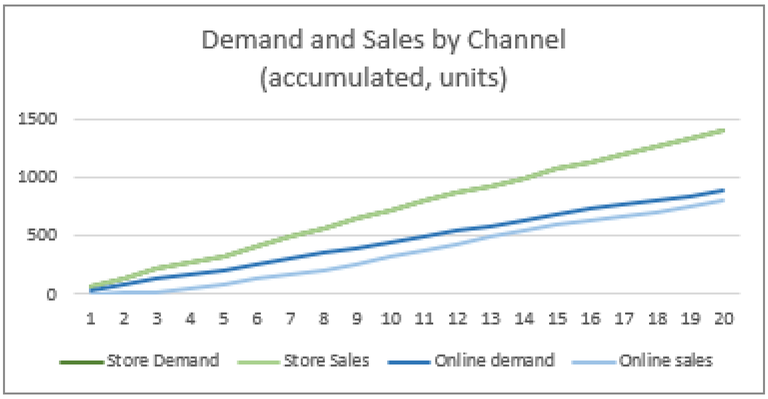
Overall Financials

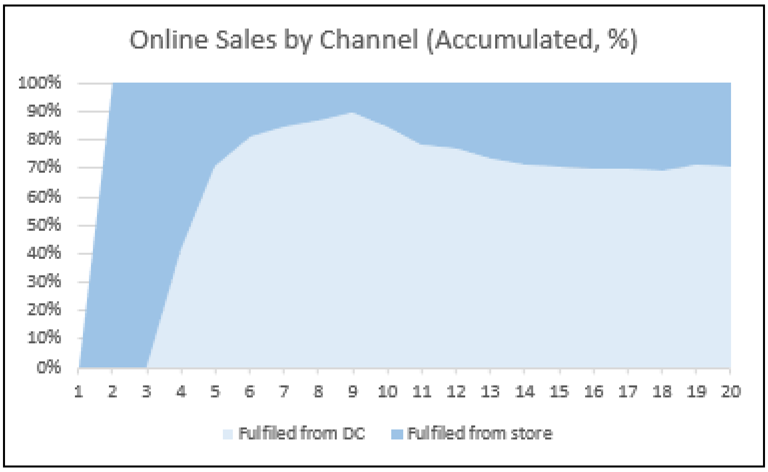


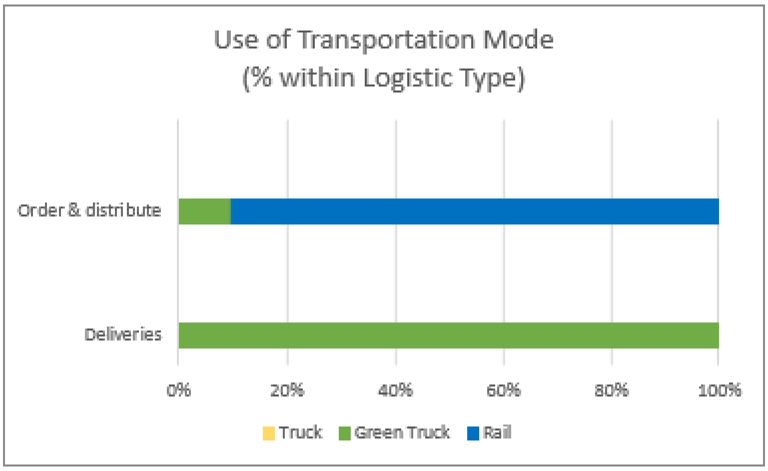




End of week review (2)







d) Preparation example questions

To ensure comprehension of the game, we suggest asking questions to stimulate discussion and engagement during the class preparation time. To make it more entertaining, this can be done in the form of a quiz.

Example questions:

"How many investment decisions will occur throughout the entire game?"

"What transportation options do you have for sending units to the customer versus to the store?"

"When is fulfilling online orders not profitable anymore?"

"What is worse: Lost store sales or online sales? Why?"

"What incremental impact has fulfilling an online order of 20 units by truck from the DC versus from the store on the environmental performance metric? Which one is the preferred one?"

"You want 50 units to be ready for sale/distribution in the distribution centre and 100 units in the store on day 4 of week 1. What purchasing and distribution options do you have to achieve this?"

"Under which conditions is sending units through the store to fulfil online demand more lucrative than through the DC?"