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Lead-Time Manager: design, implementation and use cases of an operations management simulation game

Abstract

Recent research in Operations Management has shown that local manufacturing can be competitive against offshoring when lead-time's impact on supply and demand mismatch is correctly valued. However, these research outputs are counterintuitive, and it is challenging to change the deeply rooted and myopic focus on unit costs minimization of students and practitioners alike. This article presents the Lead-Time Manager, a simulation-game developed at the University of Lausanne to leverage the teaching and communication benefits of this booming type of active learning tools, and help transmit research insights. The paper describes the features of the simulation-game, its different use cases, target audiences, expected learning benefits and its integration in our Operations Management course. As the tool is freely available, we also provide a template to help any interested faculty member integrate it into their own courses.

Keywords: Serious Games, Simulation Games, Learning Sciences, Lead-Time

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be published in any other journal.

1) Introduction to the Lead-Time Manager

This chapter defines the context around the Lead-Time Manager. The first part provides a brief introduction of the simulation-game setting, the second part exposes its pedagogical purpose, and the third part describes its different use cases in terms of context and target audiences.

1.1) Description

In recent years, there is increasing awareness of how manufacturing can benefit local economy, but managers remain hesitant to take the leap to reshoring production. To bridge the gap between research outcomes that demonstrate the potential for local production competitivity, and people's perception, we created a software-based simulation-game called the Lead-Time Manager. The player – student, manager, policymaker, or anyone with an interest in the topic – is faced with a strategic choice between local production and offshoring, and will experience the consequences of this decision, put to the test of demand risk and supply-chain uncertainties. The aim is to transmit research insights that show how local manufacturing can be competitive, in a way that gives meaning and real-life relevance to the theoretical content we teach, so that participants feel empowered to apply it.

The player takes the role of the top operations manager of a skiwear shop in the mountains of Europe that sells two kinds of products. The Fashion ski jacket has a comfortable financial margin, but a volatile demand, and overstocked products cannot be stored. The Standard ski jacket has a considerably smaller financial margin, but also a more stable demand, and potential overstock can be stored, at a reasonable cost, to be sold the following year at full price: the residual value of the standard jacket is the acquisition cost less the holding cost. The rationale behind these storage rules is that Fashion jackets belong to a collection specific to the current sales period, will be out of fashion next season and will need to make room for the new collection, while Standard jackets are basic – plain black or white – items that do not follow fashion cycles.

The main goal is to maximize the company's profit. To reach this goal, the player controls sourcing and production decisions, for a predefined number of in-game years, and must choose between ordering the jackets from a low-cost offshore supplier or building local capacity to produce on-site and on-demand, at a cost premium. The player is given full information about the selling price and the costs of each product for each sourcing option – local or offshore – as well as limited statistical data about the demand for each product: its mean and median. Without knowing the demand for the current year, the player is prompted to make three decisions: the offshore order quantity for Fashion jackets, the offshore order quantity for Standard jackets, and the local capacity to build. Then, the demand for the current year is revealed, and the player is prompted to make two more decisions: the local production of Fashion jackets, and the local production of Standard jackets, the sum of which is limited by the local capacity previously chosen.

Ordering offshore decreases unit costs but exposes to discrepancies between supply and demand – mismatch – that arise from demand uncertainty. Producing locally increases unit costs but allows to delay production until after demand is known. The main fighting issue, assuming the player wants to maximize profit, is the tradeoff between minimizing unit costs and minimizing mismatch costs. The game's mechanics and its interface will be discussed in-depth in chapter 3.

1.2) Purpose

At the Undergraduate level, the pedagogical point is to familiarize students with demand volatility, production optimization under uncertain demand, and the value of minimizing mismatch costs via decision lead-time reduction. At the Master level, we want students to build a sustainable operations strategy by creating a portfolio of products with different volatility and leverage responsiveness.

A usual gap – and common student concern – in university learning process is a lack of application, hands-on experience, which in the sense of the Experiential Learning theory, makes it incomplete. University knowledge sometimes feels like lyophilized food, waiting for the water of professional experience. Simulation-games provide students with some experience, some edible food, instead of just loading them with powder. Through both levels, our course learning objectives, from the most basic to the most high-level, can be described as follows:

- Give students a solid theoretical background on demand randomness, Newsvendor model, Fill rate and the link between Lead-time and Mismatch costs, and make sure, as we tell them, that: “If we wake you up by surprise at 4AM, you are able to do the calculations as a reflex.”
- Add meaning to the course content: have students experience how the theoretical content of the course is a toolbox for real data analysis and decision making.
- Prepare students technically and mentally: make them capable and make them feel capable to apply university knowledge in an internship or employment.
- Have an impact on students overall organizational thinking, give them a transformational learning opportunity that goes beyond loading them with knowledge and onto inspiring them to use this important knowledge to change the world, one lead-time reduction at a time.

Switching from a classic ex-cathedra course format to a participative format articulated around the Lead-Time Manager has helped us achieving more of these objectives in the past years, as confirmed by the positive students' feedback presented in appendix.

As one of the main learning benefits we expect from the simulation-game is the development of practical job skills and knowledge that will be relevant for students during their internship and future jobs, we have also been attentive to feedback from operations management practitioners, and we want to share two comments that capture the purpose of the Lead-Time Manager.

Two guest speakers in our course, working as demand forecasters in fast-moving consumer goods companies – one focused on toiletries, the other on alimentation – were positive that our simulation-game captures the core dilemma of their job in balancing unit costs minimization with risks driven by lead-time increase. Interestingly, they both initially expressed concerns that the simulation-game was oversimplified and lacked elements of complexity that represent a large part of their work, such as communication issues and market monitoring. However, after attending the class session and seeing students play the simulation-game, they grew convinced that many of their daily hurdles fundamentally arise from supply-chain over-complexification that comes as a consequence of offshoring to pursue the myopic hunt for lowest unit costs, and that the data we present is accurate and helpful in exposing the problem in a meaningful way.

Another professional, with decades of experience in airport services, approached us at the occasion of an Executive Education course. She had been trying for years to change the mindset in her company from obsessive forecasting of demand – on which they spent a lot of money, but obtained disappointing results – to capacity management, and praised our simulation-game for its ability to help change the thinking frame in that direction.

1.3) Usage

We started using the Lead-Time Manager as a teaching tool. First, it was an experimental accessory, and as it improved through iterations, we developed accompanying content and activities, and made it more central to the teaching plan. The basic idea behind our courses is that students receive theoretical content as a toolbox to reduce lead-time and solve real-life mismatch issues. We use the Lead-Time Manager simulation-game as the link between theory and practice, and before the theory comes as a solution-inducing tool, we want the students to feel the true struggle of the problem and start a trial and error type of exploration.

At both Undergraduate and Masters levels, we start by making a basic version of the game available to students before teaching the material in class. In the spirit of the Experiential Learning theory (Kolb, 2014), we let students discover by themselves, giving them sufficient time to learn the ropes of the simulation-game; trial and error is at the heart of the learning experience with this kind of tool. In the following weeks, students learn the relevant theory, and are encouraged to play the simulation-game in teams to come up with more sophisticated solutions. Surprising events are added to the game, which, we agree with Wouters et al. (2013, p. 261), yields "a higher level of deep knowledge." At the end of the course chapter, students are asked to play a run in class, and to fill in a report explaining their strategy. By comparing recorded data of the player's run and the report, we evaluate consistency, strategy soundness and level of understanding of the material.

We also had the opportunity to use the Lead-Time Manager in Executive Education courses, in a one-day intensive format. The lack of time to get familiar with the simulation-game is a challenge in such settings, but this kind of public is usually already familiar with supply-chain stakes, and sending the game along with the basic video introduction shown in chapter 1.1 as a preparatory work for the session has proved effective to get the participants up to speed and generate passionate discussions. Participants are keen to compare the parameters of the simulation-game with the data from their company, which immediately engages them with the theory we bring, even for those who had never conceptualized the problem in terms of lead-time or mismatch costs.

As the work of Professor de Treville drew attention in discussions about developed countries competitiveness and reshoring, the spectrum of applications widened, and we were invited to address leaders in politics and industry. The Lead-Time Manager proved its formidable efficiency as an intervention tool, making research outcomes understandable to non-academics and provoking debates on aspects that are crucial, but usually too technical for such gatherings. Our scenario in public settings is to briefly present the context and mechanics of the game, and ask participants to make decisions. Early decisions are usually wrong, but the ice is broken, the room starts engaging and participants understand not only the gameplay but the operation of the model, bypassing the wall of technicalities.

We also used the game at an event organized for senior citizens, and developed a spin-off simulation for a laboratory trial. This versatility is allowed by the design and code of the Lead-Time Manager, that make it easy to customize. It is straightforward to change products' profiles, prices, costs and demand data, and to add events or alter their occurrence in the scenario. For example, in the spring of 2020, we added a custom event in which a pandemic blocked the cargo ships in the ports, resulting in the offshore order arriving too late to be sold during the season. The fit with current news helps players engage and see the relevance of the exercise.

It is also possible to customize the game to adapt it to a different industry or to a company that would share its data with us. As a communication tool, it adds more impact if the simulation-game is adapted to the topic of the conference or gathering. As a teaching device, it demonstrates to students that the methods they learned can be applied to a wide range of industries and problems.

2) Teaching with simulation-games: evidence from the literature

The dictionary definition (Flexner, 1970) of a game is "a competitive activity involving skill, chance, or endurance, played by two or more persons according to a set of rules, usually for their own amusement or for that of spectators." This strictly multiplayer definition can be extended to include games where a single person faces a virtual adversary, or simply the set of rules itself, such as Solitaire. Playing games involves problem solving in the sense of Simon (1996) as summarized by Hevner et al. (2004, p. 88): "Utilizing available means to reach desired ends while satisfying laws existing in the environment." Game-playing is a fundamental human activity in early stages of development that helps us acquire skills.

A lack of consensus exists in the literature – not to mention in practice – about the appropriate use of the terms "game," "simulation," and "serious games." Sauvé et al. (2007) argue this blur is a source of discrepancy in the evaluation of artifacts and their efficiency. They formalize a definition of games by identifying their attributes: player(s), a conflict or cooperation dynamic, rules, a goal, an artificial nature, and, if the game is to be educational, a pedagogical aspect. On the other hand, simulations are models of reality defined as systems. They must be dynamic, simplified as compared to reality – although it frequently startles practitioners – but accurate and valid, and if the simulation is to be educational, include learning objectives. Games include a winning process and follow their own artificial rules. Simulations do not imply a competitive aim, not even necessarily user interaction – think of a solar system simulation – and their rules mimic those of a real, natural phenomenon.

Two visions exist regarding what qualifies a game as serious. Abt (1970, p. 9) argues that serious games "have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement." Zyda (2005, p. 26) states that "pedagogy must, however, be subordinate to story – the entertainment component comes first." Despite disagreement about the prevalence of amusement or pedagogy, the authors agree serious games have an educational purpose, which goes beyond winning the game and transforms it into a medium for learning. Possible purposes include, but are not limited to: persuading, raising awareness, communicating.

The work of Zyda (2005) is focused on video games. He is the author of America's Army, the first large-scale serious game used by the U.S. Army as a recruitment and training tool. This is reflected in his definition of serious games as "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (p. 26), excluding offline forms like board games and role plays, which, ironically, were the first examples of military serious games. However, Zyda is correct that democratization of computers since the 1990s ignited a boom in development and use of serious games. Fueled by the availability of programming tools and skills for researchers and teachers, and a mentality shift among digital natives about the meaning of playing, serious games and simulations developed in all fields, including supply-chain. An early and influential example is the Beer Distribution Game (Sterman, 1989) developed at MIT in the 1960s to illustrate the Bullwhip effect, which still inspires modern logistics collaborative games such as ColPMan (Mizuyama et al., 2016).

Ellington (1981, p. 15) defines simulation-games as “exercises which have the basic characteristics of both games (competitions and rules) and simulations (ongoing representation of real life).” His definition applies to many modern artifacts, including our Lead-Time Manager, which is based on a real-life supply-chain model, grounded in research, but includes an entertaining aspect and a goal, even though the conflict is internal, with no adversary other than the statistical model.

The learning objective of the Lead-Time Manager is to switch players’ thinking on the offshoring problem. Instead of using a default – and misguided – “Lowest per-unit landed cost” heuristic and creating buffer with inventory, we wish to provide learners the intuition and demonstration that they can approach the situation as a capacity allocation problem and create buffer with local capacity, which is a much more tractable problem and induces less detrimental biases. The challenges in teaching this content are the difficulty of reasoning with statistical demand risk, the non-linearity of the lead-time effects, and the counterintuitiveness of the local production solution. Simulation-games can be an effective way to overcome these hurdles.

The learning process in simulation-games can be approached through the Experiential Learning framework described by Kolb (2014), and its four phases: Experience, Process, Generalize and Apply. Ncube (2010, p. 568) notes that “games are especially relevant in the generalization and application phases by helping shift learner’s personal paradigms.” Simulation-games can touch all three types of memories – visual, auditory, kinesthetic – and can be asynchronous and therefore self-paced for the learner. The games also allow teachers to select events that can be rare in a natural setting, but give the learner the chance to gain experience and more importantly, expertise (Klein, 2001).

De-icing misconceptions is the first key to learning counterintuitive material. Van der Zee and Slomp (2009, p. 21) note that “[a long] time span is problematic for a clear understanding of cause and effect.” Simulation-games can clearly match an error with its consequence or a good decision with its reward, thanks to immediate feedback, replay and what-if scenarios. It is key when teaching complex phenomena like statistical risks and gives a sense of empowerment and competence to learners as they acquire skills.

Simulation-games foster intrinsic motivation of the player as their exploratory aspect is a strong source of engagement. According to Sauvé et al (2007, p. 250): “during the game, the learner plays first, understands after, and then generalizes.” The authors find that assessment to be even more pertinent in electronic games, as players usually deduce the rules as they go.

Finally, simulation-games have been found to be effective tools for learning about complex concepts or dynamic situations (Pasin & Giroux, 2011), and acquiring a global perspective toward systemic effects and unintended consequences (Machuca, 2000). This deep learning can be attributed to the opportunities players have to “learn from model responses to their decision-making” (Van der Zee & Slomp, 2009, p. 17), which is what the gaming layer offers over a classic simulation where the model is hardcoded. Jones (1998, p. 326) argues that a simulation-game “is essentially a case study, but with participants on the inside”, participants become part of the model themselves which puts them “in the hot seat for it is they job to take decisions.”

For these positive outcomes to occur, we identified four required features of simulation-games:

- Trial and error structure: making useful mistakes – that convey a lesson – should be part of the process and can be prompted by design. Progress in the game should come through a mistake elimination process, which is elegantly summarized by the expression from Annetta (2010, p. 108): “Pleasurable frustration.”
- Interaction and immediate feedback: the point of adding a game layer on a simulation model is to make it reactive and interactive. Causality between a player's actions and model's reactions should be made obvious through immediate feedback for the teaching point to be clear.
- Challenging but safe environment to experiment: the player should be encouraged to try many strategies, free from any real-life consequences – including the risk of losing face – or self-censorship. A simulation cannot fully reproduce real life’s stakes or stress, but should be challenging enough to be engaging.
- Gameplay and learning point synergy: Conceptual design of the game should be made so that style serves content, gameplay serves teaching point, and both are designed to merge coherently. Mitgutsch and Alvarado (2012) explain how simply putting the entertainment part and the learning part side by side does not make an effective serious game. Arisha and Tobail (2013) offer a good example by choosing to make their simulation-game real-time to mimic the dynamism and time pressure of the environment they simulate.

3) Lead-Time Manager development

This chapter goes in-depth into the mechanics of the Lead-Time Manager. The first part provides a description of the workflow and gameplay of the simulation-game, explains the interactions between the model and the player, and presents the interface. The second part explains how the algorithm of the model came to life from research outputs and how the structure of the game serves its pedagogical objectives. The third part recaps a set of best practices that our experience developing the Lead-Time Manager has brought to light.

3.1) Workflow and interface

The premise of the Lead-Time Manager is that the player is the top operations manager of a skiwear shop that sells Fashion and Standard jackets. Given price and costs information about each type of jackets, the player must make decisions about the sourcing – offshore orders or local production – of the jackets. The game runs for a predetermined number of simulated years, with each year divided in three periods. The first period takes place a few months before the selling season. At this point, the player does not know what the demand for the year will be, but has to place an order for both types of jackets to the offshore supplier – because of production and delivery lead-time – and to build local capacity for the year if desired – hire employees and buy machines for the upcoming season. All the player knows about demand is the mean and median for each type of product. The second period takes place during the selling season. The player discovers the demand for both products, receives the offshore order placed on the first period, and takes control of the amount of local capacity that was built. The goal is to use this local capacity to react to the discovered demand and try to match it with an appropriate supply. If local capacity is insufficient, potential sales are lost. If local capacity is too big, the player can produce Standard jackets to stock or let workers idle. If the offshore order is already greater than actual demand, there will be unsold jackets. The third period takes place after the selling season and is a time for the player to analyze the results of the year. Each year goes through the same three-period cycle.

To spice up the experience, real-life inspired events can be set to happen during the game. They include quality issues, offshore delivery problems, as well as such opportunities as short notice orders for custom jackets with very high profitability margin. These events truly capture the uncertainty of the supply-chain world, beyond demand risk modeling efforts. Events challenge player’s ability to react to unexpected hurdles, the robustness and resilience of the production structure that follows the player’s sourcing strategy. Alternative goals, beyond profit, can be pursued as the interface displays sustainability indicators like transport carbon footprint and number of scrapped jackets.

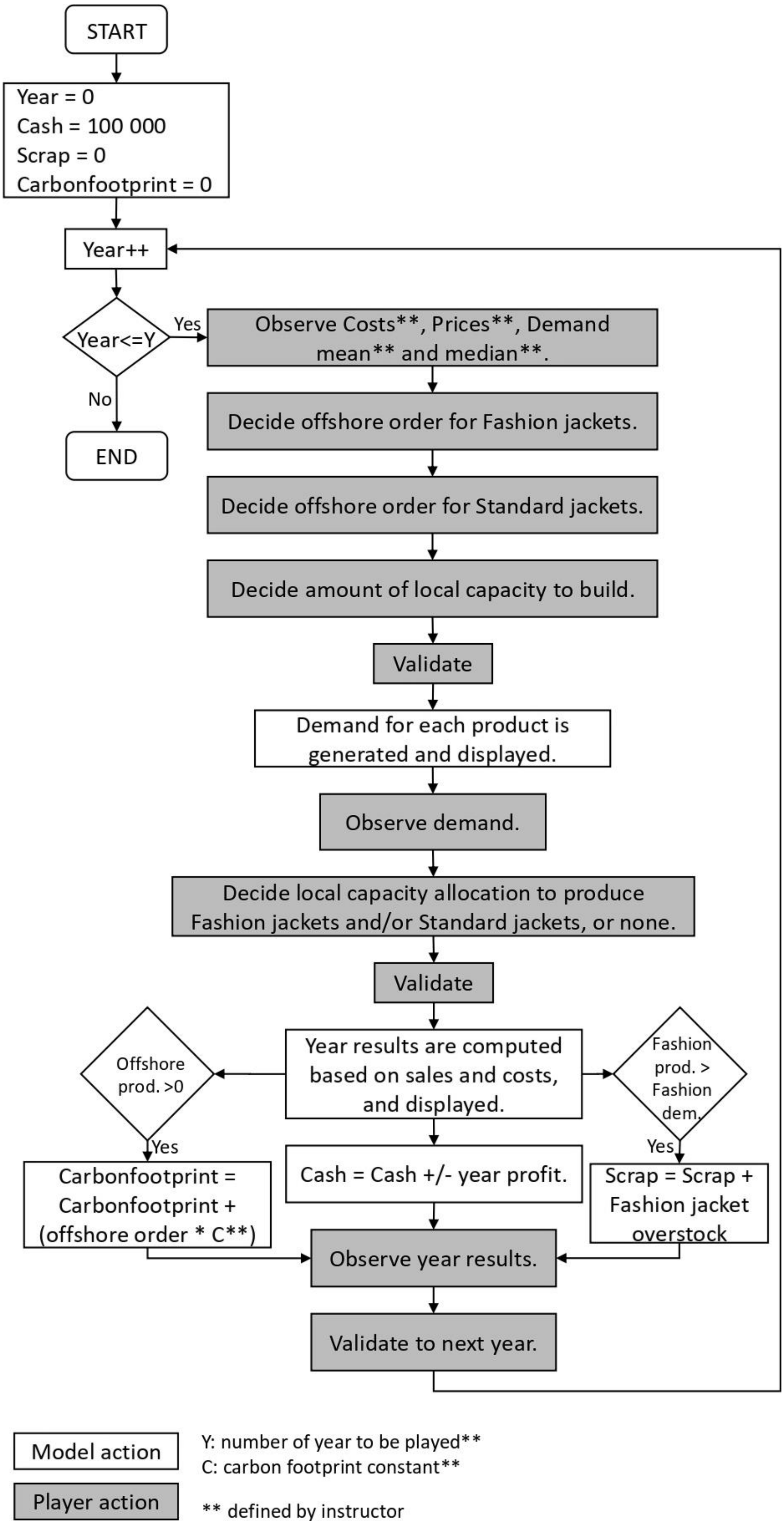

Figure 1: Lead-Time Manager game flow. The model generates demand values, and computes financial results in response to the player's sourcing and production decisions.

Figure 1 shows the general game flow of the Lead-Time Manager. Each new game year goes through the three periods described above, with the model generating stochastic demand for each product and keeping track of the financial and ecological results according to the player's production decisions.

Buchanan et al. (2011) note that different types of game interfaces fit different learning objectives, and that 3D worlds do not offer added value for knowledge acquisition. Instead, casual games' basic controls speed up the interface learning curve and focus on content. The Lead-Time Manager interface does not represent any particular environment or display any skeuomorphic elements. Instead, it focuses on presenting only the figures necessary for player decision-making along the lines of a classic management game.

The interface is built around five main blocks, four of them display information while the central block is used to gather player's input for each period.

Figure 2 shows the schematic representation and figure 3 shows the actual implementation of the interface of the Lead-Time Manager simulation-game.

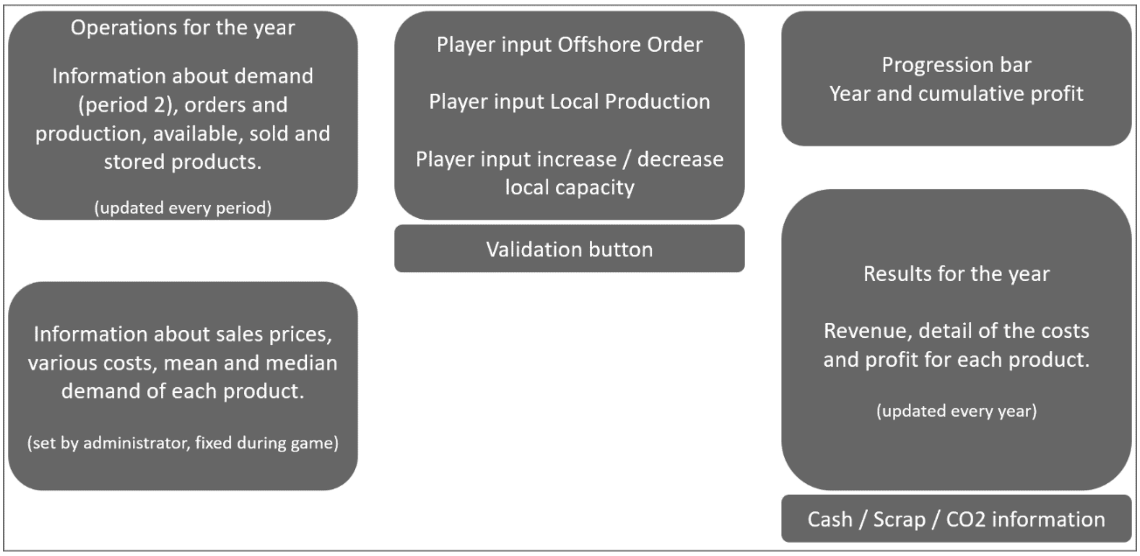

Figure 2: Schematic representation of the Lead-Time Manager interface. Information about products and current situation appear on left blocks, decision inputs are in the center of the screen, and results appear on the right blocks.

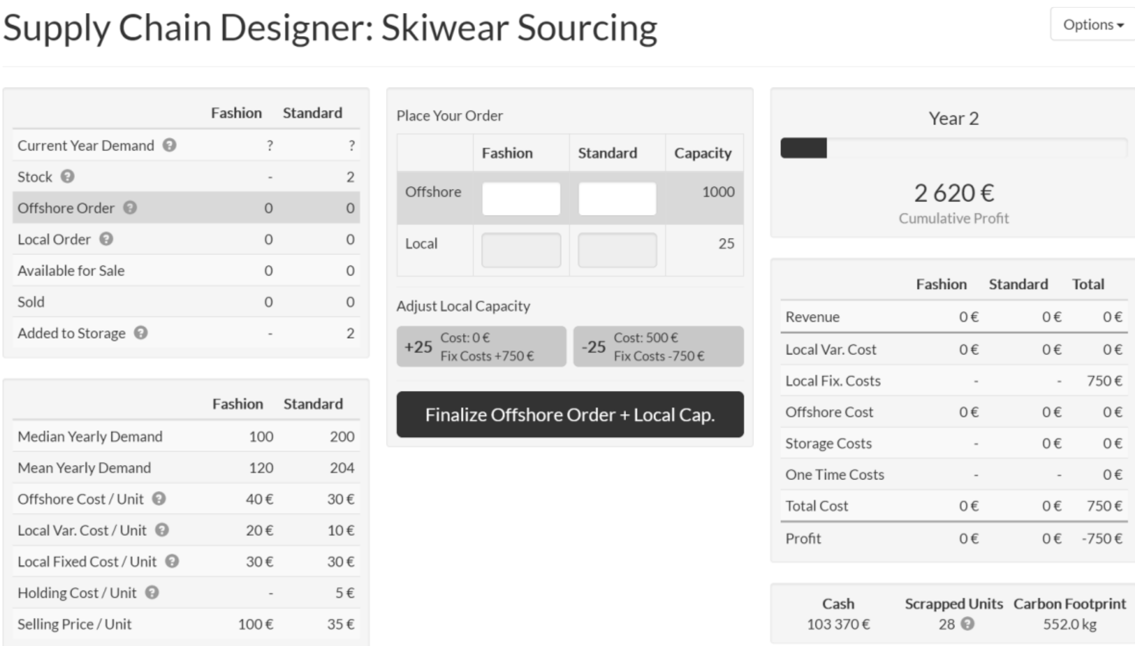

Figure 3: Lead-Time Manager interface. Top left block shows current operational situation, bottom left block shows financial information about the products, central block asks for player's input, and blocks on the right give financial and environmental results.

Figure 4 shows the interface during the first period of each year. Demand is not yet known, and the player is prompted for the offshore order decision for each product and can increase or decrease the local capacity that will be available later in the year. In the case shown here, the player decides to order 50 Fashion jacket and 100 Standard jackets offshore and increases the local capacity to 75 units for a fixed cost of 2250€.

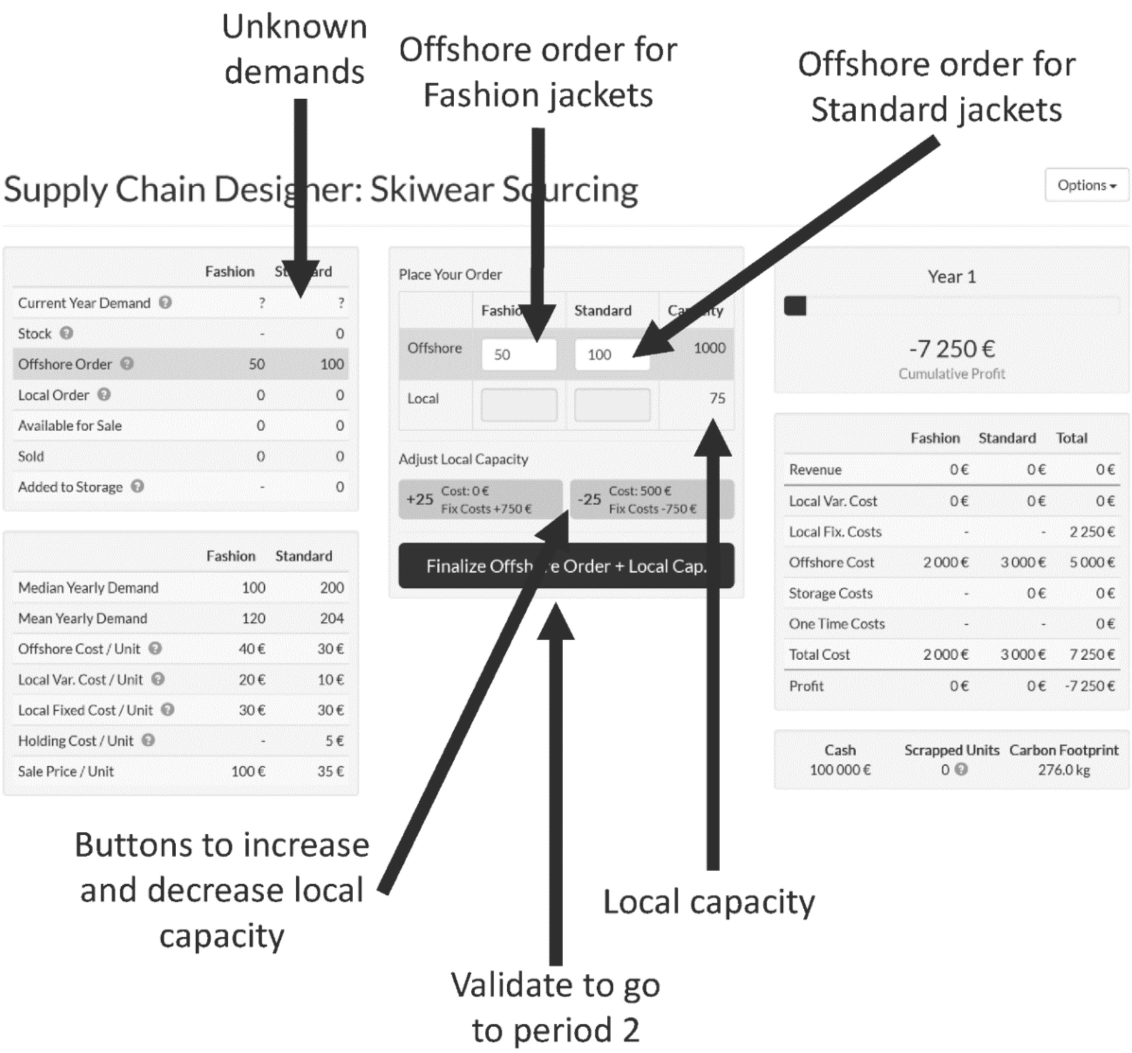

Figure 4: Annotated interface of the Lead-Time Manager during period 1. The player is placing an offshore order for each type of jacket and deciding the quantity of local capacity to build.

Figure 5 shows the interface on the second period of each year. Demand is now known, and the player is prompted to allocate local capacity to each jacket's production. In the case shown here, the player chose in period 1 to increase the local capacity to 75, and to make an offshore order for 50 Fashion jackets and 100 Standard jackets. Discovering that the demand this year is respectively for 110 and 230 units, the player chooses to allocate 60 units of local capacity to the production of Fashion jackets – which added to the 50 from offshore is enough to cover the demand – and is left with only 15 units to allocate to Standard jackets production and therefore unable to satisfy all demand.

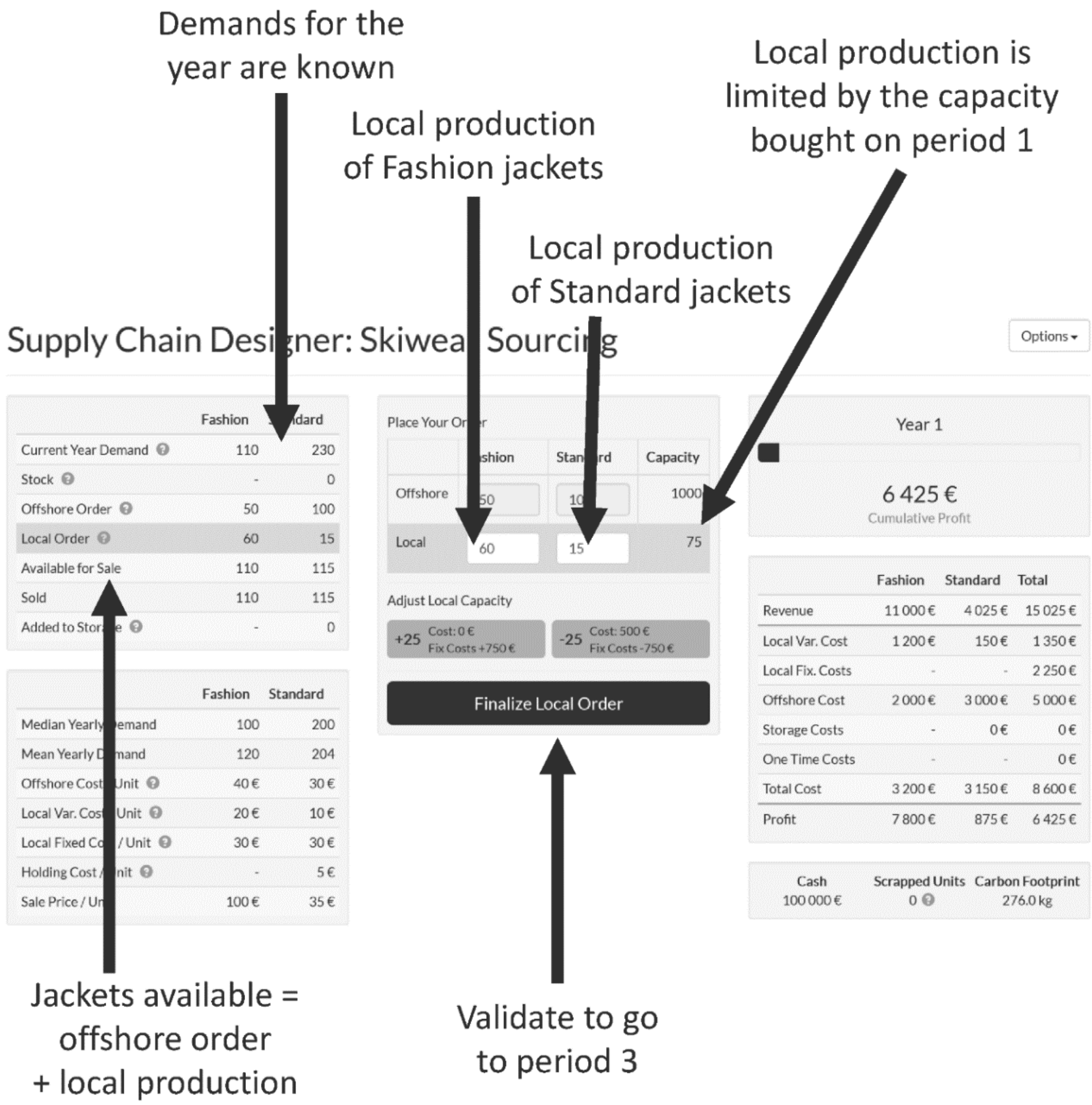

Figure 5: Annotated interface of the Lead-Time Manager during period 2. The player discovers demand and in order to satisfy it, can use local capacity to complete the offshore delivery.

Figure 6 shows the interface during the third period of each year. No input is required at this step, the player is given time to analyze the results of the year, including product sourcing, financial summary, and environmental data, and to think twice about the adjustments to the strategy that can be made next year. Clicking on the green button starts the period 1 of the next year. In the case shown here, the player managed to make a profit of 6425€, mainly driven by the fulfillment of all demand for Fashion jackets. No units have been scrapped because no Fashion jacket was produced in excess. The carbon footprint is not negligible due to 2/3 of the production having been made offshore.

Figure 6: Annotated interface of the Lead-Time Manager during period 3. The player can observe the results for the year, then start a new year.

Here is a link to a video that offers a better overview of the interface: https://mega.nz/file/HaoiBRJK#FNtoZo1AXWVSoFExJtVxtmLtv_pNGP_YYsNaTJCfSUw

3.2) Content

The setting of the Lead-Time Manager was inspired by many practitioner's testimony and academic case studies, including Sport Obermeyer (Hammond & Raman, 1994), while the simulation model itself – which is shown in the game flow (figure 1) to intervene at two key points in the game for generation of the demand and computation of the results – is based on the outcome of research led by Professor Suzanne de Treville.

In 2014, de Treville, Schuerhoff et al. (2014) developed a model, using real-options theory, that gives a monetary value to lead-time reduction. In a subsequent study, de Treville, Bicer et al. (2014) applied the model at three companies in vastly different industries – a carmaker, a food and beverages company, and a pharmaceutical firm – and showed that the value of lead-time was consistently underestimated in companies, mainly because managers overlooked demand volatility, or oversimplified it by looking at sales data instead of investigating actual demand. These results imply that the potential reduction in landed costs per unit obtained when offshoring industrial activities might be offset by mismatch costs more than anticipated by managers, and that local production – in high-cost countries – of goods with a significant volatility, can be competitive. In 2017, de Treville, Cattani and Saarinen (2017) published a technical note about their Quantitative-Finance-based model, that is the base used in the Lead-Time Manager, and can be explained as follows.

Demand for each product is assumed to follow a lognormal distribution, which captures the peaks inherent in volatile demand and avoids negative demand. Players are given mean and median demand for each of the two products. Because of the assumption that demand follows a lognormal distribution, the mean is greater than the median. The player is expected to use the ratio of the mean to the median to estimate demand volatility for the two products. For example, with a median of 100 and a mean of 120 for the Fashion jacket, we can estimate that $\frac{120}{100} = 1.2 = e^{(\frac{volatility^2}{2})}$.

Therefore volatility = $\sqrt{2\ln(1.2)} = 0.6$.

With that information and the use of the Newsvendor model to estimate the optimal order quantity given the price, cost and residual value of each product, the player can compute the expected Fill rate, sales, leftover inventory and profit for each product, and can thus make an informed decision about how to balance offshore and local production.

To comply with this mathematical structure of the problem, the role of the model at this point is to generate a demand value according to a lognormal distribution with the parameters set by the administrator. The scenario of the game asks for a rather important volatility for the Fashion jacket, and a more modest volatility for the Standard jacket. This core feature makes the repetition of play possible for the Lead-Time Manager. Even with the same parameters, every run of the simulation generates different values, testing the robustness of the player's strategy. However, it also means that two runs are hardly comparable, as a player might be lucky over the 10 or 15 years of a run and have only high demand values that flatter even a wobbly strategy, while another player might get mostly low values that undermine a sound one. To keep it a fair competition, each run result is compared with its own possible optimal result given the demand values – which can be done using the data trace from the backend. Alternatively, it is possible to replace the stochastic demand generator with preset demand data for a special event or a class in which student will benchmark their strategies.

The second task of the model is to compute results at the end of each year, which is a set of basic calculations that can be described as follows for each product:

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Available products  = offshore order + local production.
Sales               = MIN(demand ; Available products).
Leftovers           = MAX(0 ; Available products – demand).
Offshore costs      = order cost * offshore order.
Local costs         = fixed costs + (variable cost * local production).
Storage costs       = storage cost * Leftovers.     [if storable]
Earnings            = Sales * price.
Total cost          = Offshore costs + Local costs + Storage costs.
Profit              = Earnings – Total cost.
Money               = Money + Profit.
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The challenges posed by the material we teach can be summarized in three points:

- Statistical reasoning: risk, rare events are difficult to grasp for the human brain.
- Counterintuitiveness: students must overcome gut feelings and preconceptions.
- Non-linearity: timing and interactions of decisions create divergent consequences.

To tackle these obstacles, we needed the simulation-game to offer quick feedback, clear link between decisions and consequences, and a gameplay that would let the player easily try, fail, and retry, even without an in-depth understanding of all aspects of the simulation from the beginning. This idea oriented us towards a cyclical structure for the model: offshore decision, then discovery of demand and local decision, then results and back to offshore decision for a new period. This three-step cycle is coherent with the trial and error learning process that we wish to achieve, in which the player could take a decision, get an immediate feedback on its efficiency and consequences, and tweak the decision on the next round. It is simple enough to be explained in a minute, and at the same time allows for the introduction of more complications – such as the events, extra products – when desired.

Still with the objective of giving the player a maximum freedom, we opted against imposing a strict and binding decision between offshore and local supply, and kept the barriers and commitment to going offshore or back at the lowest possible level. Arguably these barriers are lower than they would be in real life, as the player only incurs a modest cost for firing local workers, and can pass even very small orders offshore, down to one unit, without penalty. But these settings allow players to try all kind of mixed-sourcing strategies that have a pedagogical interest. Being able to try and see the flaws of the solutions that first come to their mind, players end up shifting from a research of unit costs minimization to a more global approach that values supply and demand matching. This is exactly the change of heuristics that we are trying to provoke, as it opens participants to more sophisticated thinking about lead-time value.

During the development, we tested several versions of the interface showing more or less details about the costs. In the end, and guided by students' feedback, we settled for a level of details that is enough for advanced players to redo on their side the calculations that the model is doing behind the scenes, but not a full accounting breakdown of costs that would make it intractable without a sophisticated spreadsheet.

Finally, although we developed several versions of the scenario – with electronic connectors, vaccines, etc. – we chose to use the ski jackets as the main version of the simulation. Most people are aware that the textile industry has massively offshored its production, and many are concerned by the environmental, social and political issues that follows. It is an industry that is significant at the global industrial level, and at the same time feels familiar to everyone, at least as consumers. The fashion aspect exemplifies high volatility, low residual value and criticality of the lead-time, and it coexists with basic items that are mostly immune to trends, so that our characteristics of the Fashion and Standard products are easily understood by players. Ski jackets add an element of seasonality and uncertainty as the sales are dependent on weather conditions, and they are also a nod to the Swiss origin of the simulation-game.

3.3) Best practices from our experience

Looking back on six years of development and use of the Lead-Time Manager, here are a few lessons learned and best practices advices for such endeavors.

First, it is paramount to get the software technical aspects right. Nothing ruins a class session like a bad bug or a piece of software that cannot run on some computers. Another tool that we use in the course, with a powerful teaching message, has stopped evolving and can only be run on old computers of the university lab. Although this software is powerful, the fact that it can no longer run on a student's devices dramatically reduces their engagement with it. Avoiding these pitfalls with our tool translated into two objectives: compatibility and robustness. HTML 5 web-apps have limits in terms of performance and features compared to native programs, but reliability, multi-platform compatibility and ease of use with any modern web browser have been such an asset in so many cases that it was the right option. The developer and the teaching team must have this discussion at an early stage of the project.

The second point, to paraphrase Osterwalder et al. (2014), is not to fall in love with your first idea. Opt for an iterative development and accept necessary changes even when they do not fit your original idea. Development of the Lead-Time Manager began in 2015 as a project to help understand and demonstrate course theory. Professor de Treville had an enthusiastic vision for developing it further, and did not hesitate to change many aspects – interface, scenario, gameplay – through an iterative process fueled by students' feedback. In 2016, we obtained funding from University of Lausanne to hire a professional developer to improve the interface and create a backend allowing us to record participants runs, and we benefited from a partnership with Forio, a well-known and reliable platform, so anyone can access our simulation-game for free on any device with a modern web browser. Six years later, we are still in this continuous improvement mindset and we still regularly tweak the program. For instance, in 2020 we added a pandemic-related event, which helped students contextualize the value of lead-time in a disruption example that was very much rooted in current events and sprang passionate discussions in our remote classes.

Third, in accordance with Van der Zee and Slomp (2009, p. 25), make sure to not only record the performances and results, but also a “decision trace” of the players choices, so that they can replay their run and identify turning points. Pasin and Giroux (2011) add that simulations must be transparent enough – as opposed to copyrighted black boxes – that students can understand the mechanics of the model step by step.

Fourth, we found it useful to make clear in the faculty syllabus that our course requires active involvement. Some students, especially at the Undergraduate level, cling to a traditional course structure, and although it would certainly be an enriching experience for them, it is better that nobody feels misled or trapped and only those interested in such a format register for the course.

Finally, it is fundamental to integrate gracefully and meaningfully the “serious” and gamified parts. Planting a décor and unrelated gameplay around a teaching point does not make an efficient teaching tool. Asking a Biology question at the end of a Mario Kart race does not make a serious game, even if you get a bonus mushroom for a right answer.

4) Integration to Operations courses

At the University of Lausanne, we use the Lead-Time Manager simulation-game in two different courses. The first part of this chapter describes its integration in an Undergraduate introductory course of Operations Management. The second part focuses on its use in a Master's course in Supply-Chain Analytics. The last part provides a synopsis of our curriculum and teaching methodology in the Undergraduate course, which is intended as an example framework for faculty members wishing to integrate the Lead-Time Manager into their own courses.

4.1) Use in an Undergraduate class

The Undergraduate course covers a wide array of Operations topics like process analysis, bottlenecks, lot sizes, optimal order quantities and queuing theory. However, the most important topic of the semester is matching supply with demand. We start with demand volatility, geometric Brownian motion and the idea that demand information gets noisier as decision lead-time – the length of time between the moment at which the production decision is made and when demand is observed – increases. We instruct the students in use of the Newsvendor model, the concepts of Service level and Fill rate. This allows us to cover the calculation of mismatch costs under uncertainty, taking into consideration the risks of overstock and understock. Although some of the material is technically challenging (e.g., the assumption arising from a forecast-evolution process that follows a geometric Brownian motion that demand follows a lognormal distribution), the course material brings students to a high level of expertise in balancing mismatch losses. Optimal strategies for balancing over and under stocks are often counterintuitive: a high-cost producer may well turn out to be competitive when we consider the real options that are created when we reduce the decision lead-time. We use the Lead-Time Manager to help students get familiar with demand volatility as they experience various demand values for the two different products, and to make them face the dilemma of choosing between lower cost offshore production with unknown demand, and higher cost, local on-demand production.

The Lead-Time Manager is introduced early in the course plan, during the third or even second lecture if time permits, in a simplified form, without events. Only a brief introduction of the scenario is done in class, and students are instructed to practice at home to get familiar with the gameplay. The pedagogical goal at this point is not to guide students toward a “solution” but to let them explore freely with a trial and error approach.

As the lectures continue, students gradually get technical keys – Newsvendor model, Fill rate calculation, Mismatch cost calculation – to better inform their strategies, but at this point it remains up to them to apply these tools to the simulation-game as we do not explicitly mention the link between theory and this particular application.

Finally, after four to five weeks of lecture and with the “matching supply with demand” part of the course coming to an end, we organize a session dedicated to the Lead-Time Manager as a wrap-up. Students are instructed to play a new version of the simulation-game, complete with events, in groups – playing alone is also an option but teamwork fosters more variety in the strategies put at test. We mention in the lectures that the fluctuation of demand numbers is only the quantifiable risk part of the equation, and that unforeseen events can happen and bring off-charts uncertainty, but we do not warn that such events will appear in the simulation-game. Students are therefore surprised at the beginning of this last session, and those who arrive with a rigid strategy will have to rethink it, as they usually do when they face the reality and complexity of a real-life situation in a company. The session goes back and forth between game rounds and debrief times, when students and the teacher discuss different strategies, their strengths and weaknesses, and how theoretical tools from the lectures allow to calibrate them. It is usually a major "eureka moment" for students who did not fully see the link between theory and applications, while students who already had a solid grasp of this link are fascinated by options and alternative goals they had not considered. The takeaway conclusion states that no solution is perfect in an uncertainty context, but that heuristics derived from the course content that help lead-time valuation and reduction can be used to increase profit expectancy, Fill rate, and decrease carbon footprint.

4.2) Use in a Master's class

At the Master's level, we build upon the technical knowledge and analyze case studies to challenge students to imagine supply-chain strategies that would give a competitive advantage to a company in a given industry. We analyze and classify the different types of products a company makes in terms of profitability and demand volatility. We encourage students to come up with "what-if" scenarios, reimagining the industrial organization. An example would be replacing a monolithic production line with versatile cells to allow more production variety. The goal is to leverage a lead-time cut, an increase in reactivity, to gain in competitiveness, create a servitizing or customizing activity around the product to add more value for customers, and make a local manufacturer, in a high-cost country, not only competitive but innovative and a leader in its industry. For these advanced users, the Lead-Time Manager can be understood in its full complexity and the challenge is to optimize the sourcing strategy by correctly balancing the portfolio of products that have different volatilities. Local capacity can be built to respond to the volatile demand of the high-margin product, which fully covers its costs. When demand for this product is low, the available capacity is not wasted thanks to a more standard product that can be made to stock if necessary, and that becomes profitable if you consider only its variable costs. High Fill rate and greener operation are bonuses. Regarding events, Master's students are expected, after an initial shock reaction, to incorporate them into their strategies and see the potential to use a reactive production to transform surprise orders issues into opportunities.

Traditional teaching might be enough to convey knowledge, but it fails to prepare students to apply this knowledge to real-life situations. The case-study based approach of the Master's course was a first step towards bridging the gap between theory and practice, and integrating the Lead-Time Manager pushed the envelope further in terms of students involvement. Using the simulation-game as a hands-on activity and encouraging students at this level to "hack" it with innovative strategies, created a context where students turn into experts, owners of the course content able to analyze and adapt to a range of ill-formatted situations, and not only to the tradition "clean problems" found in textbook exercises. Students also tend to get competitive and do not hesitate to defend the soundness of their strategy in a way that prepares them to react to pushbacks in a company. Overall, the Lead-Time Manager biggest benefit at the Master's level is a switch in attitude of students, with a greater appropriation of the course content and feeling of competency to reuse it beyond the strict context of the course.

4.3) Availability and guide for instructors

The Lead-Time Manager is online and freely available, the main version can be found at https://forio.com/app/lausanne/ltmle

Access is simple as "Student ID" and "Email" fields are optional, with only a name – any pseudonym works – required to start playing, and we encourage any interested instructor to integrate this tool into their course, as we believe it can fit many different teaching plans. In particular, the course level – Undergraduate, Master, Executive Education – and time available – from 1-day intensive course to a semester – will allow for more or less self-exploration or instead more guidance about the objectives and the strategic options. Therefore, the following suggested teaching plan is only a framework that we encourage instructors to adapt to their needs.

Step 1: Introduction

Timing and organization:

- At the beginning of the course, or the beginning of the chapter about supply and demand mismatch and lead-time, before the theoretical material is taught.
- We take 10 minutes to give initial instructions outlined below, while showing the interface, and then give 15 minutes to students to start playing and asking questions.
- At this point we do not answer questions about strategy, we focus on questions about the basic understanding on the game mechanics, wording, and interface, as well as organizational questions.
- In an online class setting – although it can also be applicable in a face-to-face setting – we encourage students to ask their questions on the course online forum board, and to try to answer each other's questions. The teaching team intervenes when a wrong advice is given or when no answer is posted after 24h.

Learning objective:

- We purposedly put participants in a situation where they do not have the keys to solve the problem, not even to fully formalize the problem presented by the simulation-game, and can only rely on their intuition and default heuristics. This is a priming step so that the course content will come as an answer to an authentic problem, and its usefulness and real-life application will be obvious.
- No technical knowledge is required at this point, only a general sense that supply-chains can be spread globally and that over the past decades, many retailers have come to buy goods from offshore suppliers, often delivered via cargo boats.

Typical mistakes:

- Students may not understand that each particular year's demand is different from the median and mean demand.
- Students may not understand the chronology of the game: offshore order, discovery of the demand, local production.
- Students may not understand that local cost per unit is the sum of variable costs and fixed costs, misleading them into thinking that local production is cheaper than offshore production.

Material:

- Link to a version of the game without events: https://forio.com/app/lausanne/cas4

Student instructions:

- "Here is a simulation-game that we will play with thorough the next weeks. In the game, you take the role of the top operations manager of a skiwear shop in the mountains of Europe that sells two kinds of ski jackets. You face demand uncertainty before the season and have the choice between ordering the ski jackets to a low-cost supplier before knowing demand, or producing locally, on-demand, at a higher cost. Discover the simulation-game by yourself, play as much as you want, explore different strategies, and we will come back to it in the coming weeks."

- Guiding questions: What is the fundamental problem that you face in the game? Can you list the decisions that you have to make, and the options that you have for each decision?

Step 2: Self-exploration of the simulation game in parallel with theoretical lectures

Timing and organization:

- In the three to four weeks following the introduction. Playing time is at each student's discretion. We ask them to play until they feel familiar with the simulation-game and satisfied enough with their strategy. One hour may be enough, but we have had students spending dozens of hours on the game, developing a full analysis and even coding a dedicated statistical program.
- We make sure to continually monitor questions, and raise the most relevant ones during classes, to clear out any remaining misunderstanding or to comment on strategic options. Online format has no impact at this step except favorizing the course online forum board as a medium for questions.

Learning objective:

- This self-discovery phase lets students explore the simulation-game, get familiar with the interface and the gameplay so they can focus on strategy. Learning by trial and error confronts players with their preconceptions, and being able to do it at home at their own rhythm gives them opportunity to try even the wildest strategies without any consequences on grades or any risk of losing face.
- In parallel, students learn the relevant technical content that will allow them to exploit the data in the simulation game: Demand Randomness to analyze the demand distribution of each product, Newsvendor model to compute optimal order quantities, Fill rate calculations to estimate expected sales and leftovers, and Supply/Demand Mismatch cost to estimate the premium they should be willing to pay to cut the lead-time by producing locally some or all of the ski jackets.
- Required concepts (to acquire progressively over three to four weeks): Statistical knowledge of demand randomness, being able to compute an estimate of the volatility based on the demand parameters of the game. Knowledge of the Newsvendor model, being able to compute a profit-maximizing offshore order based on the price, cost and salvage value parameters of the game. Knowledge of Fill rate calculations, being able to compute expected sales and expected leftover inventory based on the game's parameters.

Typical mistakes:

- Students may not see how the data given in the simulation-game can be used to apply the computations learned in class.

- Students may feel like their decisions have no impact if they do not grasp the combined effects of strategy and demand randomness.

Material:

- Here are the slide decks for the lectures on Demand Randomness (L1), Newsvendor model (L2), Fill rate calculations (L3), and Mismatch between Supply and Demand (L4) by Prof. Suzanne de Treville. Each lesson can be taught in a one-hour class session. However, for the past six years, we chose a flipped-classroom approach and made the material available for students to study at home, in the form of these slide decks, as well as videos and lecture notes. Students are then quizzed on the calculations at the beginning of each session, and the class time is dedicated to discussion the applications of these calculations to examples and cases.

  L1: https://mega.nz/file/La5QjLKa#GggRnUjRg58YmV_ZAIdD1jfRUUfpuYOGUqmqgaGi3T0

  L2: https://mega.nz/file/iWg01L5D#zHL7ykD-NoI31lOJLqv57Y0yAann4co4UtDpmFFPk4U

  L3: https://mega.nz/file/iHwmkJRZ#-xNmCkhXFGSyvumfDqsKFnsiguXHoZCIUaUgJWpLIXE

  L4: https://mega.nz/file/Tao2TJTb#GK_4YRYsYoZWYb7Ybv_fFXQBT3Q1PE6l9oUwd9cHQVQ

Student instructions:

- “Think about how these theoretical tools could be applied to the Lead-Time Manager simulation-game. How could you plug the data available in the game into these models to make sense of the problem and get useful information outputs to guide your decisions?”

- “Do not hesitate to try different courses of action with the simulation-game, even very audacious ones, before settling on your favorite strategy, do not fall in love too quickly with the first option you try.”
- Guiding questions: How can you measure your performance in the game? Can you find strategies that consistently lead to similar outcomes? Did you try extremely bold strategies to explore what their effects could be?

Step 3: Main session

Timing and organization:

- After the theoretical lectures and the self-exploration phase. A two-hour session is ideal, organized as explained in the student instructions point.
- This session is the most sensitive to the course format as it involves teamwork. In a face-to-face format, we like to match students in random teams to favorize the chance they will be confronted to different strategies, as opposed to playing with their friends, whose strategies they have probably already heard of. In an online class format, the priority is to make sure that no technical issue hinders students’ communication, and to this end we let them free to choose their team as well as alternative ways of communication beside the official course videoconference software. We stand by to match students who do not have a group and to support those who have technical issues.

Learning objective:

- Primary objective is for all participants to share the ideas and strategies they have come up with and test their robustness against a more complex version of the simulation-game that includes events.
- Secondary objective (optional, depending on the curriculum objectives) is to evaluate participants. We recommend an evaluation that emphasizes the coherence between the strategic goal of each participant and the implementation of this strategy in the simulation game. For example, a participant wanting to guarantee a 100% Fill rate should build a large local capacity, but a participant wanting to maximize profit per unit can justify offshore sourcing. If the profit is evaluated, the evaluator must keep in mind that demand is stochastic, therefore participants must be benchmarked against their own potential maximum profit depending on the demand values they got, and not on an absolute scale.
- Required concepts: Being able to compute the expected mismatch cost in case of a fully offshore sourcing strategy, and to deduce the cost premium that would be rational to pay to eliminate demand uncertainty. Understanding why the sourcing strategy that maximizes profit can be different from the sourcing strategy that maximizes Fill rate or the one that minimizes wasted unsold units.

Typical mistakes:

- Students may not understand that once local capacity is acquired, it makes financial sense to use it to produce standard jackets, even to stock, instead of leaving it idle.

- Students may set conflicting goals for themselves or take practical decisions that do not fit their general strategy, for example striving for zero waste but still ordering a significant quantity of Fashion jackets offshore.

Material:

- Link to a version of the game with events: https://forio.com/app/lausanne/cas5

(compared to the main version link given at the beginning of this chapter, this version is shorter, which can be useful depending on the session length).

- For reference, slides 1 to 4 from the slide deck used in the main session with undergraduate students in the spring semester 2021: https://mega.nz/file/ua4mzLzC#jnxeYQhL2wMA3Tf6yqcqA9w8Z2NM1WtIVXzntdXriEE

Student instructions:

First 30 minutes: "Play in teams to this new version of the simulation-game, some things might be slightly different from the version you know."

Second 30 minutes: "What happened and how does it impact the strategy that you prepared?" The goal is to debrief the events, explain the difference between risk and uncertainty, explain how reactivity through short lead-time and local production can turn disruptions into opportunities.

Third 30 minutes: "Play individually and submit your results along with a summary of your strategy." We used the https://www.forclass.com platform to collect the results and strategy summaries, with six questions:

- Briefly explain (100 words maximum) your procurement strategy, and the goal you wish to achieve with it. Do not hesitate to give a numerical objective to illustrate your words.

- How many Fashion jackets will you order from the Offshore supplier?

- How many Standard jackets will you order from the Offshore supplier?

- What local capacity will you acquire?

- Upload a screenshot of your results.

- Retrospectively, are there any points of your strategy that you would change? If so, explain briefly (100 words maximum) which ones and why?

Fourth 30 minutes: wrap-up, see next step.

- Guiding questions: Explain your goal. How do you translate your strategy into practical decisions in the game? What are the key performance indicators that will tell if your goal is achieved or not?

Step 4: Wrap-up

Timing and organization:

- At the end of the main session. 30 minutes minimum. If available, more time can allow for the intervention of a guest speaker.

Learning objective:

- Make sure the link between the theoretical concepts (Demand randomness, Newsvendor model, Fill rate, Mismatch cost calculation) and the simulation-game is clear for all students.
- Detail how we can build a strategy, starting from the simulation-game data and the definition of objectives, and using the theoretical content of the course to reach decisions about each type of jacket order and the amount of local capacity we need (example slides 6 to 9).

- Emphasize on the fact that the calculations learned in class are the tools to turn high-level objectives into actionable decisions.
- Present and/or let students present different strategies with alternative and possibly competing goals: fully local sourcing to maximize Fill rate and minimize transport CO2 emissions, dual-sourcing to maximize profit.
- If the class is advanced enough, make a link with production implementation (Seru cells instead of production lines, customization options), volatility portfolio and cost allocation – premium product pays for fixed costs and standard product can be profitable just by covering variable costs (de Treville, Cattani & Saarinen, 2017).
- Required concepts: Demand randomness, Newsvendor model, Fill Rate calculations, Mismatch cost calculations, understanding of the impact of each decision input on the different output results.

Typical mistakes:

- Students may be tempted to continue playing their own round of the game rather than listening to the debrief, especially in an online setting.

Material:

- For reference, slides 5 to 9 from the slide deck used in the main session with undergraduate students in the spring semester 2021: https://mega.nz/file/ua4mzLzC#jnxeYQhL2wMA3Tf6yqcqA9w8Z2NM1WtIVXzntdXriEE

5) Conclusion

Serious games, or pedagogical simulation-games, mix a real-life-based model with the mechanics of games. The recipe for creating an effective simulation-game is not simple and cannot easily be standardized because it is essential that gameplay and educative aspects have an authentic synergy and coherence, and that the technical aspects be on point. When this sweet spot is found, a simulation-game can be a powerful teaching and communication tool.

In this paper, I presented the Lead-Time Manager, a simulation-game that aims to transmit research insights about the value of lead-time and the competitiveness of local manufacturing. Given the counterintuitive, non-linear, and mathematically sophisticated nature of the content, we draw on pedagogical assets of simulation-games such as trial and error process, immediate feedback and challenging gameplay to provoke a shift in players' heuristics and approach of the problem.

This simulation-game can be used in various settings, and the level of analysis around it can be adapted accordingly. In conferences with practitioners and policymakers it can be used as medium to introduce in an intuitive way a complex problem and start a discussion at an unusual level of technicality. In a university Operations Management course, it can be integrated in a pedagogical active learning plan to increase students' appropriation of the course theoretical content, and their ability to understand the applications of this content to real-life problems.

Development and use of Lead-Time Manager over the past six years increased the impact of our Operations management courses and research insights.

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Appendix: Feedback from an Undergraduate class

In this appendix, we will present the results of a course evaluation of the Lead-Time Manager as a teaching tool. For the Spring semester 2021, we adopted once again a flipped classroom approach for the Undergraduate course of Operations Management. An approach that has proven robust to the online-teaching situation imposed by governmental restrictions surrounding Covid-19. After a discovery period given to the students to get familiar with a basic version of the Lead-Time Manager, we dedicated a two-hour class session to its full version, including events. At the end of this session, we asked students to fill an anonymous survey assessing the impact of the Lead-Time Manager on their learning experience. 68 out of the 120 students following the course answered the survey, giving the following results.

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The simulation-game helped you understand technical aspects that were not clear in the previous classes sessions.	**0%**	**9%**	**13%**	**59%**	**19%**
Being able to try different strategies in the simulation-game convinced you of the relevance of the course content.	**0%**	**6%**	**13%**	**43%**	**38%**
The simulation-game helped change your opinion about the value of lead-time and balance it with the attractiveness of lower cost/unit.	**1%**	**12%**	**29%**	**38%**	**19%**
The simulation-game gave a real-life meaning to the theoretical content you learned in previous classes sessions.	**1%**	**1%**	**13%**	**46%**	**37%**
The simulation-game prepares you to use the course content in a company better than a traditional exercice session.	**0%**	**4%**	**6%**	**61%**	**28%**
The simulation-game increased the confidence you have in your ability to use the course content in a company.	**0%**	**19%**	**34%**	**33%**	**13%**

Figure 7: Results of the feedback survey about the simulation-game administered to Undergraduate students in our course of Operations Management. The first three questions received 68 answers, and the last three 67 answers.

Overall, the evaluation is extremely positive. Starting from the most basic level, 78% of students agree or strongly agree that the Lead-Time Manager helped them understand technical points that were not clear in previous classes. The next level objective is to switch students' thinking about the course content on the value of reducing lead-time. 81% of students agree or strongly agree that being able to try different strategies highlighted the relevance of the material that we teach, and 57% of them declare that the Lead-Time Manager helped them change their opinion on that topic. The top-level goal of our teaching program is to have an impact of real-life behavior of our students, and in particular to have them apply these research outcomes in companies. 83% of students agree or strongly agree that the Lead-Time Manager helped give a real-life meaning to this theoretical content. 89% of them feel better prepared to use it in a company by this simulation-game than they would have been by a traditional exercise session, and 46% of them agree or strongly agree that their confidence in their ability to do so has increased as a result, which is arguably the most challenging feat of a University course.

In addition to these questions, students were given open-text fields to answer two open-ended questions. The following quotes (translated when originally not in English) are representative of the answers we gathered.

<u>Question 1: In your own words, please describe the benefits of using this simulation-game in as part of your learning process.</u>

Many students praised the simulation-game for making a link between theory and practice thanks to a realistic scenario:

- "Much more concrete and provides a good tool to prepare for the future, which many courses lack."

- "Using this game allows us to put our skills to the test in a playful way. In our studies we have to learn a lot of theoretical concepts, and it does get boring after a while to always learn the same way. The game is like a breath of fresh air in a very dense semester, because it enables us to transform the theory into a real-life strategy for a realistic concept."

- "Practicing in a case that resembles real life goes a long way in understanding the impact of our strategic choices."

- "It allows a transposition of the real life of a company, and puts us in the shoes of managers with a responsibility to decide on the orders to be made annually while taking into account the different events that companies will face."

Students mention the sense of engagement that the experience produced:

- "The simulation game was nice as it engages us further with the material. I felt like it was my job to get the profit to the highest possible level and thus pushed me to invest more energy in the activity."

- “This game allowed me to think about the meaning of the formulas we see in theory and on mobius and Forclass [online exam platforms]. As a result, I was able to put myself in the state of mind of the real thing and thus invest myself completely in the game. I was also able to see the limits of the known models and above all the different possible strategies that can be applied in companies. What I appreciated is that there is no "right way". That is to say, as long as we can motivate our strategic approach, it can hold up. Because in the real world, there are going to be a lot of other factors that come into play that you can't add in a "general" game.”

Some students appreciate the “trial and error” format and the sense of free exploration that it gives:

- “I like the fact that we can redo the game as many times as we like, it helps us find our mistakes, discover new possibilities through new strategies.”

- “we can visualize better and it helps to be more comfortable because we can test several times.”

- “Confrontation with a more realistic scenario where thing don't fit in nice equations”

- “My comfort zone is in crisis management, and this game is exhilirating. There's a little punch every time I realized there was another variable I hadn't taken into account, but finding a way to account for it delivers a small "aha" moment every time.”

- “It's a way for me to realize that the same goal can be achieved in many different ways, unlike traditional exercises where there is only one correct answer.”

- “Those simulations allowed me to put an image on numbers that would have been blury without it. It allowed me to practice and try "funny" scenarios to see what would happen.”

Students also underline the importance of the discussion around the simulation-game, both with peers and professors:

- “It was good to see a more realistic application to what we have done in class. It was also a great way to discuss with team members about their point of view and planned strategies. It was a very dynamic way of learning”

- “I think the simulation games were great to illustrate the concepts in the course, they made it feel like we actually were in a company taking decisions and observing our profit. I also think one of the most important aspects of the simulation games is the discussion we have about it in class. I don't think a lot of people would have considered producing only locally as one of the best strategies just from playing the simulation. So I think the discussion we have afterwards is also extremely important.”

<u>Question 2: In your own words, please describe the negative aspects, issues encountered and points to improve regarding the use of this simulation-game as part of your learning process.</u>

For some students, the “trial and error” format and the exploratory and voluntary low-structure approach to the activity can prove unsettling, and they would prefer to be guided with more detailed instructions:

- “Did not have enough instructions. Wish I could have performed better!”

- “At the beginning of simulation -game, I was lost.. Maybe you should explain more about the goal and the rules of the simulation.”

- “Sometimes it wasn't clear what we were supposed to do, but I think that's part of learning because in life nothing is given easily.”

Some students are not comfortable with the fact that many good solutions are possible, and would prefer a unique correct solution to be designated:

- “we don't know the perfect number. In real life we won't have multiple answer and we'll need to know exactly what to do.”

- “We should spend more time explaining the ideal strategy for the simulation, maybe one more course dedicated to that.”

Some other students point at possible interface improvements:

- “I didn't directly understand all the parameters, so a more ergonomic interface would be better I think.”

- “I would have liked to see, instead of the boxes where we had to manually enter numbers, a bar with a slider to drag and a curve that evolves in real time. I think maybe that would help people who learn visually. Otherwise great! Thanks a lot to you, useful and interesting course!”

- “too much information on the interface, not enough detail seen.”

Some students mention that competitors, real or simulated, would make for a more motivating experience:

- “Perhaps having a competition would be even more realistic regarding the strategies”

- “I would like to have real competitors with market shares and developping more strategies.”

Only one student mentions a lack of engagement due to the absence of real-life consequences:

- “we can do pretty much whatever we want with our stock with no real consequences because it is a simulation so it doesn't mean anything for us”

Improvement of the simulation-game and its course integration based on students' feedback has been a characteristic of our development process. The question of “having enough instructions" is certainly difficult to solve as we purposedly put students in a state of exploration. Unlike a pure calculation problem, a straightforward resolution is not the goal, trial and error is critical to the teaching point. However, we must make sure students understand the problem enough to genuinely stumble on it, and not on a misconception. To that end, we recently developed a stripped-down version of the simulation-game, with only one product and without access to local production. This version with a considerably simplified interface and gameplay, can be used in the introduction session to familiarize students with the fundamental point of the problem: unknown demand at the time of order. Once this aspect is clear, we can add the layers of complexity that are the second product and the dual sourcing option. The stripped-down version is available at this address: https://forio.com/app/lausanne/starter4

Along the same lines, there is a balance to find between presenting "the right answer" during the wrap-up and insisting that several strategies based on different goals – profit maximization, Fill rate maximization, environmental impact – lead to different performance indicators, and therefore different "right answers". Optimization is contextual, not absolute, and its context is based on a choice that players must make. Inviting guest practitioners can be effective to convince students about this reality. Supply-chain professionals have plenty of experiences to share about decisions under uncertainty, ill-structured problems, lack, absence, or poor quality of data, occasionally wild hypothesis, and long delays before a choice's outcomes can be assessed to be positive or not, if ever. Going forward, we plan on inviting practitioners during the wrap-up session to increase the meaning of the simulation-game and possibly improve the confidence students have in their ability to reuse their insights in a company context.