Advances in Engineering Education

SUMMER 2020 VOLUME 8 ISSUE 2

Humanitarian Aid and Relief Distribution (HARD) Game

SUZAN ALASWAD

AND

SINAN SALMAN
Zayed University
Abu Dhabi, UAE

ABSTRACT

Coordinating humanitarian supply chains can be challenging in terms of getting timely aid to those who need it. While operations in commercial supply chains have been well studied, research studies that address coordination in humanitarian supply chains are still lacking. Unlike commercial supply chains, humanitarian supply chains focus on delivering what customers *need* rather than *want* within difficult environments rife with uncertainty. This paper introduces the "Humanitarian Aid and Relief Distribution (HARD) Game" as an experiential learning tool that explores the potential for increased operational efficiency while balancing decision tradeoffs impacting humanitarian supply chain performance, including beneficiary demand satisfaction, operational costs, and transportation resources utilization. The HARD game is intended for graduate and undergraduate students in courses dealing with topics on supply chain management. It allows students to analyze aspects that significantly impact humanitarian supply chain operations, such as: supply chain coordination and planning, supply chain risks, demand volatility, and competing objectives. Statistical analysis of students' survey responses provide evidence that the HARD game is an effective pedagogical tool that is engaging for students and complementary to the traditional lecture format in the field of supply chain management education.

Key words: Industrial Engineering, Simulation, Games

INTRODUCTION

The need for humanitarian aid and protection due to enduring conflicts, natural disasters, pandemics and displacement has reached record levels. The International Federation of Red Cross and Red Crescent Societies (IFRC) reports that over 6,000 disasters occurred between the years 2005 and 2014, with over 800,000 people reported killed (*World Disasters Report* 2015). This is a global problem, as the United Nations High Commissioner for Refugees (UNHCR) states that

"An unprecedented 65.6 million people around the world have been forced from home. Among them are nearly 22.5 million refugees, over half of whom are under the age of 18" (UNHCR 2017). In 2017, humanitarian agencies reached tens of millions of people in need, saving millions of lives, and donors provided record levels of funding to humanitarian response plans – nearly $13 billion (UNOCHA 2017).

Managing humanitarian operations in disaster relief has become a major concern for the global society. It is essential to manage relationships among all actors involved in humanitarian relief along the entire emergency supply chain to ensure efficient and effective delivery of aid to victims of the emergency. While there is a growing body of literature on humanitarian logistics (Holguín-Veras, Jaller, and Wachtendorf 2012; Cozzolino 2012; Manopiniwes and Irohara 2014; Gizaw and Gumus 2016; Jahre et al. 2016), only a few studies or applications deal with humanitarian supply chain management (SCM). Actually, humanitarian supply chain has been long viewed by many as an application of commercial supply chains. Only recently, the design of humanitarian supply chains has been recognized to be fundamentally different from commercial supply chains (Overstreet et al. 2011).

The sheer complexity of operating conditions separates humanitarian supply chains from their commercial counterparts. For one, relief organizations are always faced with unpredictability. Its sources include location, timing, and severity of the disaster as well as the affected population characteristics, post-disaster political volatility, and extent of infrastructure damage, to name a few. Even with accurate data, drastic variability in demand and supply over the length of the disaster relief effort complicates planning efforts. The absence of these basic information renders the task of setting up an efficient supply chain an extremely difficult one.

The unregulated nature of disaster relief and lack of oversight also limit coordination between relief organizations. Where market forces regulate commercial supply chains and incentivize better performance, humanitarian supply chains operate without such forces and so have little incentive to learn from previous performance issues. In addition, the number and diversity of actors involved in disaster response make coordination between them particularly complex. For example, the number of non-governmental organizations (NGOs) involved in the 2010 Haiti earthquake disaster was estimated between 3,000 and 10,000 organizations (Tatham and Pettit 2010). Typically, these organizations include local and international NGOs who need to overcome cultural and language barriers to coordination.

In commercial supply chains, market demand and financial cashflow propagating upstream from consumers who dictate much of the supply chain's priorities and goals. By contrast, in humanitarian supply chains, media's coverage of the humanitarian needs plays the crucial role in crisis visibility and ultimately response resources made available for it. The significant role of donors in humanitarian supply chains forces many relief organizations to regard them as their customers instead of aid recipients. In some cases, donors place restrictions on the types of activities that relief organizations may spend funds on, impacting coordination efforts with other relief actors. The lack of coordination and regulation in donation sourcing also affects the supply chain's performance. On one hand, relief organizations are sometimes inundated with unsolicited donations that create bottlenecks and divert resources from where they are needed the most. On the other hand, limited media coverage may result in demand for relief outstripping available resources. For detailed discussions of humanitarian supply chains and their differences from commercial ones, the reader is referred to (Yu et al. 2015; Balcik et al. 2010; L. N. Van Wassenhove 2006; Overstreet et al. 2011).

In summary, a humanitarian supply chain is more complex in terms of control and information flow, as it requires working with a large number of organizations in extremely difficult and unpredictable conditions. Thus, coordination and information sharing between these organizations are essential to enhance operations for the overall humanitarian response. Several studies emphasize on the importance of coordination and collaboration among all actors involved in a humanitarian emergency to improve the effectiveness of its supply chain in meeting its beneficiaries' demand (Altay 2008; Balcik et al. 2010; Akhtar, Marr, and Garnevska 2012; Pateman, Hughes, and Cahoon 2013; Yu et al. 2015).

Given the fundamental differences between commercial supply chains and humanitarian supply chains, typical supply chain coordination mechanisms may be impractical or infeasible for humanitarian operations (Balcik et al. 2010). However, this has not yet been reflected in operations and supply chain management education. Typically, practitioners who are educated on how to operate commercial supply chains self-adapt when faced with humanitarian supply chain challenges in the field (Duddy, Stantchev, and Weaver n.d.). Hence, there is still an urgent need to develop models that adapt to the unique relief environment to help understand the uncertainties involved and determine what can be done to improve the supply chain performance, particularly in terms of coordination. However, the literature lacks studies that analytically address coordination in humanitarian relief supply chains. We seek here to help fill this gap by presenting a simulation game designed as an experiential learning tool to analyze the effects of operations coordination and information sharing in humanitarian supply chains.

In recent years, simulation games have been widely used in the field of engineering education as they present engineering topics in inventive ways by allowing ‘‘what-if’’ analysis on different solutions, which may not be possible within the traditional lecture format. A review of existing applications of simulation games in engineering education can be found in (Deshpande and Huang 2011), in which they conclude that proper use of simulation games in engineering education would maximize students' transferability of academic knowledge to the industry.

This paper presents the HARD game as a cooperative online educational game that mimics humanitarian supply chains typically found in relief operations. The game is influenced by the structure and dynamics of previous supply chain simulation games. One of the earliest SCM games is the Beer Game, originally developed by Jay Forrester at the Massachusetts Institute of Technology (Forrester, J. W. 1957), which has been long used by educators to show students the effects of order variations on commercial supply chains (Sterman, J. D. 1984; Riemer 2008; Lau 2015; Sarkar and Kumar 2016). The Beer Game aims to show the importance and benefits of integration and information sharing in supply chains and the significant role of supply chain management. Since its initial introduction, the game has been adapted into multiple formats including a table game, different online games, and into other industries, e.g. the Wood Supply Game (D'Amours et al. 2017). Other examples of SCM games in the literature include: the Airplane Supply Chain simulation (Ellis et al. 2014), the Supply Chain Operations Reference simulation (Webb, Thomas, and Liao-Troth 2014), and the Sink or Swim Supply Chain activity (Harnowo, Calhoun, and Monteiro 2016).

The HARD game builds on previous games and extends on them in several aspects, taking into consideration the complexity of the humanitarian supply chain in terms of control and information sharing. The game's name hints to the inherent difficulty of achieving efficient supply chain operations in the challenging environments which humanitarian relief typically operate in. The presence of operating inefficiencies in humanitarian supply chains futilely divert funds from relief items to operational activities, severely impacting beneficiaries. Hence, managing supply chain operations, including replenishment, fulfillment, transportation, and inventory is critical to the relief goal of saving lives while using limited available resources efficiently. In disaster context, efficient transportation within the supply chain, i.e. on-time deliveries of commodities to locations of need, plays a critical role in meeting beneficiaries' needs and accounts for a significant percentage of supply chain costs. However, managing transportation can be challenging for relief organizations due to many reasons, such as damaged infrastructure, limited transportation resources, scarcity of vehicles, and the bulkiness of supplies to be transported. Therefore, in addition to replenishment decisions, the HARD game introduces fulfilment and shipping decisions, which allows players to manage the utilization of transportation resources. This increased player role adds to the traditional responsibility of balancing inventory and backorder risks, as commonly found in previous games. The game also includes order limitations on all stations to mimic operational capacities found in relief supply chains. Moreover, the game's supply chain network is designed to incorporate multi-sourcing at each station. Station multi-sourcing increases supply chain flexibility and allows players to make differentiated sourcing and fulfillment decisions between suppliers and customers, respectively. These design extensions enable the HARD game to present players with a more challenging and dynamic supply chain experiential learning opportunity. At the same time, it provides an environment that more closely resembles real humanitarian supply chains, highlighting in the process many of the critical success factors needed in a humanitarian supply chain (Pettit and Beresford 2009).

The remainder of this paper is organized in six sections, as follows. We detail the HARD game setup and describe its network and game parameter configurations in the Game Setup section. Next, we provide a guideline on deploying the HARD game in the classroom. Then, we discuss important focus areas in teaching humanitarian SCM, followed by a section on the assessment of learning outcomes for the HARD game. Afterward, we discuss some potential limitations of the game. Finally, the Conclusion section summarizes and concludes the paper.

GAME SETUP

The HARD game is designed as a team-based supply chain simulation game. In the game, players take on the roles of station managers in a small supply chain. It takes around 60 minutes to complete a 45-week simulation game. The game is played in synchronized turns with each representing a week in the supply chain's operation. Every week, players analyze their stations' stats and decide on orders to suppliers and shipments to customers, while managing multiple competing objectives. When deployed in classroom, the game helps players realize, through experiential learning, the complexities associated with managing humanitarian supply chains. It also enables players to explore and test strategies to improve supply chain performance.

We utilize the X-Supply Game (XSG) engine (Salman and Alaswad 2018) to facilitate the game mechanics and allow students to focus on analysis and decision making tasks rather than accounting of station stats and game operations. The XSG is an online engine developed with a goal to be flexible enough to enable various supply chain network topographies, operational configurations, and game scenarios. The engine enables a team of players to cooperatively manage a supply chain consisting of several interconnected stations. It is also possible to pit several teams (i.e. supply chains) against each other in a competitive race, enhancing the learning environment. The competitive element is optional but recommended as competition usually improves players' experience and challenge them to find more efficient ways to coordinate within themselves to beat other teams. Furthermore, competition is usually an essential element of any supply chain including humanitarian supply chains. The game can be deployed via multiple teams competing in the same class, across different classes, times, or locations. The game engine provides various performance information and analysis graphs which are useful in guiding debriefing discussions that follow the game. The XSG's flexible and interactive simulation design renders it a uniquely suitable platform for use in the HARD game over other supply chain simulation and general-purpose simulation platforms. The open source license used in the XSG also allows other educators to adapt it and even extend it to meet their unique classroom needs without licensing fees.

This section details the network setup as well as operational parameters used to configure the XSG game engine to achieve the HARD game design requirements while pointing out some of the differences between humanitarian supply chains and its commercial counterparts.

Supply Chain Network Setup

A humanitarian supply chain is a network created through the flow of supplies, finances, and related information among suppliers, donors, and other entities of humanitarian organizations for the purpose of meeting beneficiaries' needs (L. N. Van Wassenhove 2006). Humanitarian organizations can include government agencies, such as United States for International Development (USAID); multilateral agencies, such as UNHCR, United Nations Children's Fund (UNICEF), and World Food Program (WFP); NGOs, such as Medecins Sans Frontiers (MSF) and Save the Children. Public and private donors also play a key role in the humanitarian supply chain. While coordination among those different actors operating within the relief environment is essential to ensure efficient and effective delivery of aid items to beneficiaries, many sources of unpredictability may affect these coordination efforts, as previously mentioned.

In variance to previous supply chain game designs, a single humanitarian supply chain perceives items supplied in a shared, collaborative supply chain, where often a single identical commodity may be supplied by more than one donor (Duddy, Stantchev, and Weaver n.d.). The chain may involve multiple donors and multiple governmental and non-governmental organizations. The operational characteristics of relief supply chains differ depending on the disaster type and the type of relief actors involved. A typical flow of supplies in a humanitarian supply chain, as depicted by Balcik et al. 2010, is shown in Figure 1.

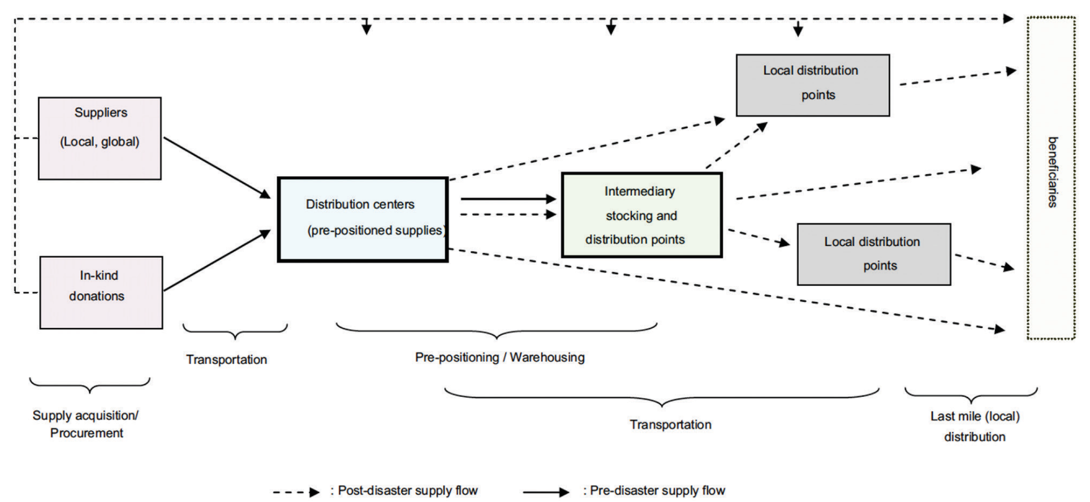

Figure 1. Humanitarian supply chain flow (adapted from Balcik et al. 2010).

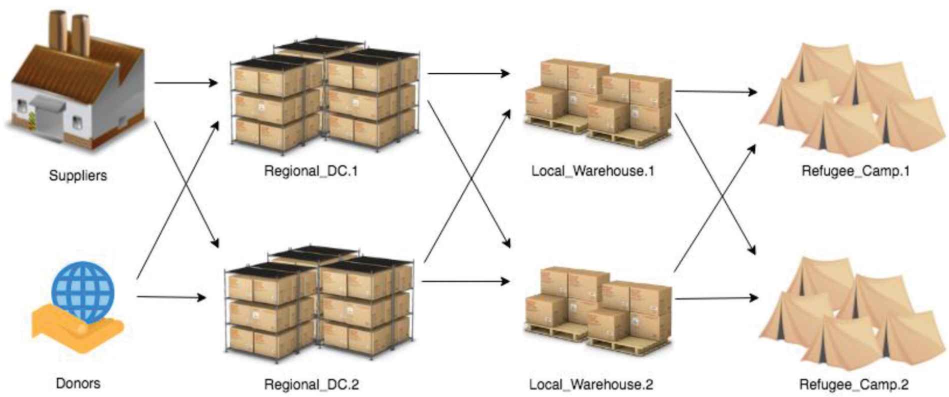

Figure 2. The HARD game supply chain network.

The HARD game (Figure 2) presents a variation of the above supply chain with some inspiration from the UNHCR supply chain design. The initial sources for relief items in the game are donors and suppliers. Relief items are then moved to regional distribution centers (RDCs), which are often operated by NGOs, before heading to local warehouses where commodities are distributed to beneficiaries at sites of need. The game incorporates the collaborative chain characteristics often found in relief supply chains via the use of dual sourcing for each station. That is, the modeled two RDCs receive supplies from the suppliers' station as well as the donors' station, and in turn each RDC can supply any of the two local warehouses' stations. Similarly, the local warehouses can receive supplies from both RDCs and supply both refugee camps simultaneously. The HARD game is designed to mimic real humanitarian supply chains, which provides the player with an opportunity to multi-source their supplies to mitigate inventory shortages. At the same time, it challenges the players to simultaneously manage multiple suppliers and customers in a supply chain that deviates from the typical single-sourced serial game network design.

The refugee camp stations are automated demand points whose only function is to provide predetermined weekly demand values for local warehouse stations. By design, both supplier stations receive identical weekly demand values from a given demand point. These demand values are concealed from players at local warehouse stations until the beginning of the weekly turn, at which point only the current week's demand value is revealed. As such, no demand forecasts are provided to the players. The remaining stations are all player-operated and only have visibility to their immediate customers' demand. Whereas RDCs and local warehouse stations attempt to meet their customers' demand via ordering supplies from their upstream stations, the suppliers and donors stations produce the needed supplies internally to meet downstream demand.

Game Configuration

The game is configured with operational parameters that mimic humanitarian supply chain constraints to infuse a sense of realism for players. Although the XSG game engine allows each station to be configured with different values, similar operational parameters are used for all player-operated stations to simplify the game's introduction to students and lower their learning curve. Typically, students are introduced to the game just as they're about to play it for the first time in the classroom. Having similar stations setup reduces the number of decision inputs students need to take into consideration while playing the game, by an order of magnitude.

The game parameters include operational costs, operational delays, ordering and transportation capacities, as well as supply chain priming parameters for starting the game. Operational costs include inventory holding cost ($1 per item per week), backorder cost ($2 per item per week), transportation cost ($220 per truck), with each truck having a capacity of 200 items. Similar to prior supply chain games, the HARD game assumes that unfulfilled demand never disappears, rendering backorder cost a burden for the supply chain for as long as the demand remains unmet. For the purpose of simulating the supply chain, deterministic operational delays are included to model shipping and ordering time delays. A shipping delay of two weeks is used to model transportation time before items arrive at the customer station, and an ordering delay of one week is used to model order processing time at the ordering station. The inclusion of these delays mean that players will experience a delayed supply chain response to their decisions further complicating their responsibility. Ordering at each station is limited to a maximum of a thousand units per week, with no minimum set. This limit proved to be helpful in inhibiting network's inventory oversaturation in early weeks of the game as a result of panic-induced orders from some players. Finally, and to facilitate the start of the game, all stations are started with some inventory, two arriving shipments (one-week apart), and one outgoing order, all of which with the value of 100 items. Table 1 summarizes the game operational parameters setup.

Table 1. Station parameters for the HARD game.

Parameter	Description	Value
Inventory holding cost	Cost of holding an item for a week ($/item/week)	$1
Backorder cost	Cost of not fulfilling an item ordered for a week ($/item/week)	$2
Transport cost	Cost of shipping one truckload ($/truck)	$220 per truck
Transport size	Truck capacity (items/truck)	200 items per truck
Shipping delay	Shipment transit time between a supplier and a customer (weeks)	2 weeks
Ordering delay	Processing time before a supplier receives a customer order (weeks)	1 weeks
Queue initial value	Value used to initialize order/shipment queues for week 1 (items)	100 items
Beginning inventory	Inventory count at the start of simulation (items)	100 items
Order minimum	Weekly ordering minimum limit (items)	0
Order maximum	Weekly ordering maximum limit (items)	1000

The HARD game objectives are to meet beneficiaries' demand (fulfillment rate), optimize transport resource utilization (truck utilization), and minimize operational costs (inventory holding costs, backorder costs, and transportation costs). The three objectives are designed to simulate the Triple Bottom Line (TBL) performance measurement approach, where the holistic supply chain sustainability is considered: people, planet, and profit (or operations cost in aid operations). In this context, truck utilization is used as a proxy metric for the environmental footprint of the supply chain. Nevertheless, managing humanitarian supply chains to the TBL is particularly challenging, and many organization frequently overlook equity and sustainability despite their importance in humanitarian aid (Salvadó and Lauras 2017). Experience shows that the same behavior materializes in the HARD game as players struggle with the same challenge, which is an observation illustrated in more detail in the below subsection on Managing to Multiple Objectives.

DEPLOYING THE HARD GAME IN CLASSROOM

The HARD game can be played with as few as 6 players and can be scaled up in larger classes by creating more teams and/or assigning two players per station to collaboratively make decisions. Players connect to a central web server and take on the roles of virtual station managers in a HARD game instance. Every turn consists of a week in the simulation. At the start of each week, stations stats (inventory, backorders, suppliers' deliveries, and customers' orders) are updated with information reflecting players' decisions made across the supply chain in the previous week. Players analyze their stations' stats and make their decisions on orders to suppliers and shipments to customers. Players engage in decision making while managing multiple competing objectives; each station is measured on its fulfillment rate to its immediate customer, total operations cost, and transportation resource utilization.

To streamline the HARD game deployment into educators' classrooms, a template HARD game file is included in the XSG game engine distribution package at its GitHub website (Salman 2018a). The template game file allows the creation of HARD games on the fly in the XSG game engine, utilizing the configuration parameters described in this paper. A web server instance of the XSG, hosted by Zayed University (Salman 2018b), can be used directly in deploying the HARD game to classrooms, without the need to install the game software package on a local web server. The XSG user manual is helpful in getting started for the first time and is available on the same GitHub site.

Introducing the HARD Game to Students

As previously mentioned, the HARD game typically requires about 60 minutes to complete a 45 weeks simulation game, thus it is helpful to introduce the game objectives and mechanics to

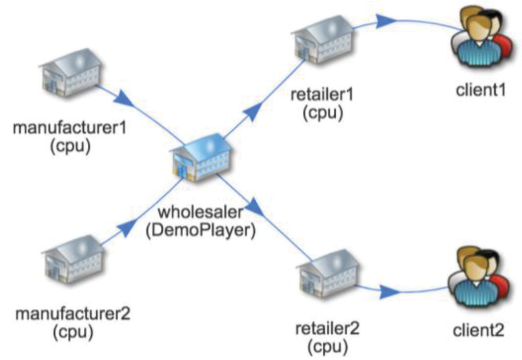

Figure 3. Single-player demo supply chain game.

students prior to the class planned for the simulation game. A brief presentation including the following information is appropriate for this purpose: an overview of humanitarian relief supply chains, the HARD game supply chain network setup, and the game's objectives and operational parameters. To help students learn the game interface before the group simulation, students can try, as a home exercise, a single-player instance by choosing the "Try Demo Game" option from the XSG main menu. The demo game (see Figure 3) allows the player to gain familiarity with the game's user interface (Figure 4) while managing their station at a slower pace. It is also a good practice to allow students to play the first 5 weeks of the group simulation activity as a dry run, before the game is reset by

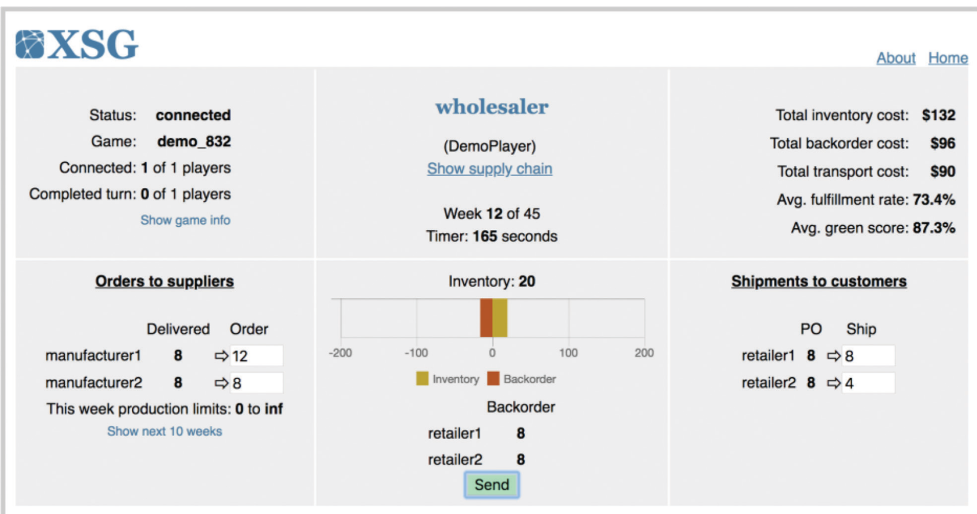

Figure 4. The XSG's player screen.

the instructor for the live run. These optional steps help reduce students' anxiety during the game and improve the overall enjoyment of the exercise.

Playing the HARD Game

Even with the steps described in the previous section, first-time players typically experience a stressful few turns (weeks) at the beginning of the game due to the pressure exerted on the player by their fellow players and game dynamics as orders, inventory levels, and backorders fluctuate. To help keep the game moving at a steady pace, it is recommended to keep the turn timer configuration set to 60 seconds per turn. As in real supply chains, time waits for no one, and players must complete their decision-making duties in the provided time. In early simulation weeks, the 60 seconds limit seems to be a rather restrictive constraint, however, as simulation progresses, players typically tend to complete their turns in much shorter time as they gain experience and confidence. Failing to make a decision within this time constraint means the player will forfeit their turn with zero orders and zero shipments submitted to the server as their decision data. Note that the turn timer restriction can be eliminated if class time is not a constraint and a prolonged game experience is desired. Additional game exposure and experimentation may lead to additional learning outcomes. This is possible through extending the game time or playing subsequent game sessions with added game elements such as the ones mentioned in the following section on Teaching Focus Areas. We recommend the latter approach to help students learn more advanced SCM topics through a scaffolded approach.

Depending on the quality of cooperation and communication between players, the game generally transitions between cycles of high backorder and high inventory levels. It is recommended that instructors keep their involvement to a minimum during the game so students can discover issues impacting their supply chain performance and find their own ways to address them. However, in some cases instructors may need to help a team initiate this process using carefully framed questions. Questions similar to the ones below can help get the team's critical thinking process started if it does not spark spontaneously:

- Why do you think your fulfilment/cost performance is deteriorating?
- How do your station's inventory/backorder levels compare to the supply chain as a whole?
- Are your ordering/shipping policies impacting performance?
- What is preventing you from achieving better performance?

If multiple teams are participating in a competition, the instructor can project a progress summary of the teams' performance using the "Monitor games" option in the XSG advanced menu, as shown in Figure 5. Experience shows that running multiple teams in a competitive environment significantly improves players' experience and challenges them to find better ways to coordinate within their teams by "borrowing" best practices from competing teams.

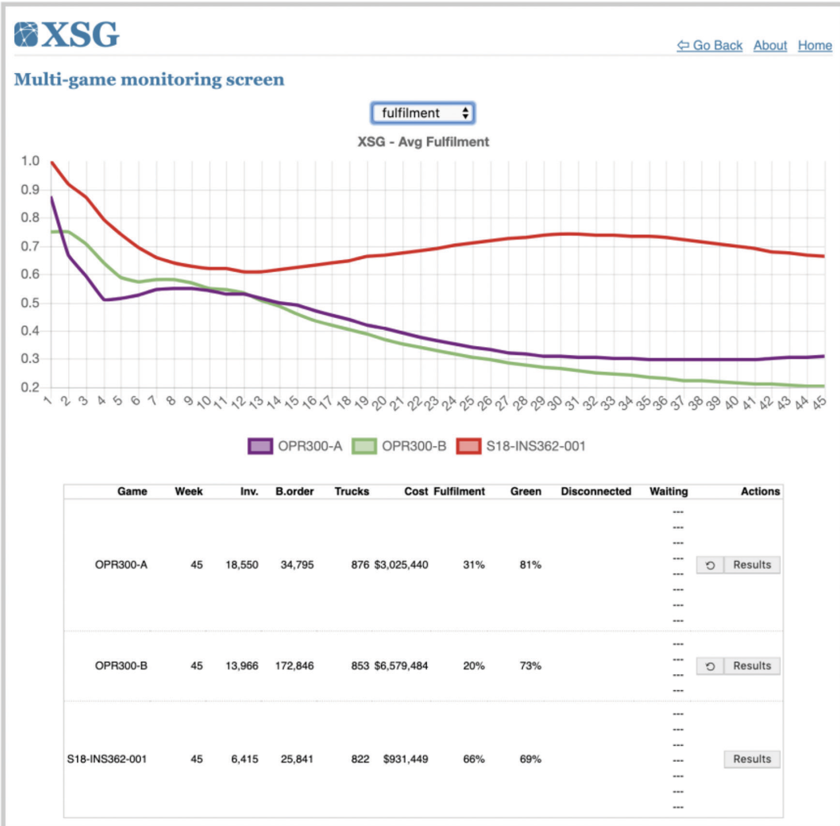

Figure 5. Multi-game monitoring screen in the XSG.

While playing the game, players will be presented with decisions on fulfilling their immediate customers' demands as well as replenishing their inventory via orders to immediate suppliers. If sufficient inventory is available to fulfill all customers' demands, the decision becomes a transportation utilization one; where players must decide whether to fulfill the entire demanded quantity or withhold part of the shipment to optimize truck utilizations. Obviously, over-shipping is not permitted in the HARD game. For example, a player may find that the week's customers' demand is 230 items. On one hand, the player may choose to ship the entire quantity utilizing two trucks with a capacity of 200 items per truck, costing a total of $440 for transportation. On the other hand, the player can ship a full truck load and withhold the remaining 30 items, hoping there will be underutilized space in the following week's truck(s). Consequently, if such space exists in the following week, the cost in the second scenario will then consist of the current week's truck cost ($220), a cost of holding the remaining inventory for an additional week ($30), a backorder cost of ($60) for not fulfilling customers' demands for one week. Note that there is no charge for transporting the remaining items as they utilize an already underutilized shipment. As a result, the second scenario promises savings of $130 over the first, although dependent on the risk of not having enough space in the following week's shipments; a risk that the player must consider as he or she makes the decision. Alternatively, if available inventory is insufficient to fulfill all customers' demands, the decision becomes a prioritization one; where players must decide how to split the available inventory between demanding customers, while considering transportation utilization and cost implications.

As for the replenishment decision, players must consider multiple factors in deciding orders to their immediate suppliers. These factors include estimated future demand, customers' backorders, suppliers' outstanding orders, current inventory level, planned shipments, and suppliers' prior fulfillment performance. In addition, players might also consider their stations' future order limits and plan for outages if existent.

In essence, through the weekly decision-making process, players balance between the risks of having backorders and possessing excess inventory using the available supply chain information. This information is conveniently presented to players on their play screen, as seen in Figure 4. The lower half of the screen is dedicated for data necessary for the player's decisions, which include customers' orders, suppliers' deliveries, and current inventory and backorder levels. The upper half is dedicated for game data, including game server status, game weekly progress, and Key supply chain Performance Indicators (KPI). The KPIs include inventory cost, backorder cost, transportation cost, fulfillment rate, and truck utilization. The results of this game scenario are presented in the following section.

An Example Game Scenario

The authors deployed the HARD game in multiple graduate and undergraduate courses, including Logistics and Supply Chain Management and Operations Management courses. In this section, we present results for the game scenario deployed in one of the graduate Operations Management courses as an example of the HARD game outcomes. It should be noted that the results are presented here as an illustration, and different class deployments yield different results, although certain trends tend to be present in most of all deployments. In addition, graduate students with industry experience typically perform better than undergraduate students. Naturally, their performance is boosted by their exposure to topics covered here in professional situations prior to playing the game in a class setting. The game supply chain network and player-station mapping are shown in Figure 6.

The predetermined refugee camp demand pattern can be set to allow different playing scenarios. For this game example, a simple pattern of one-time increment in beneficiary demand is utilized. This helps highlight the decisions made by the players in a controlled environment.

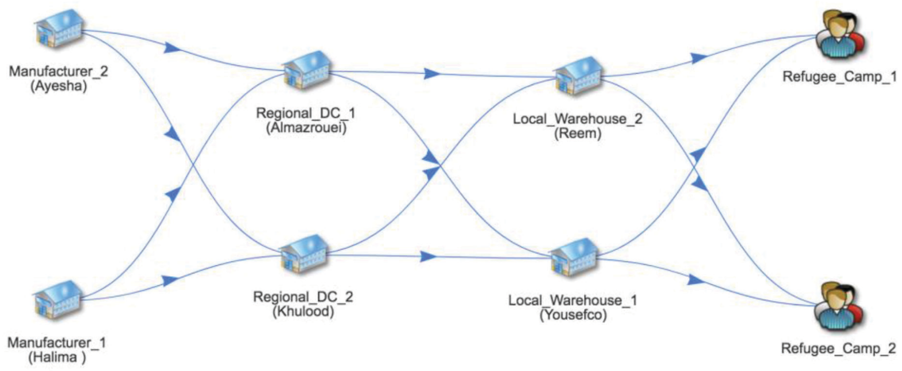

Figure 6. The HARD game supply chain network (with player names).

Specifically, both refugee camps demand patterns start at 100 items weekly, and suddenly increase to 150 items per week in weeks 6 and 8, for camp 1 and camp 2, respectively. Figure 7 shows total weekly orders for the whole supply chain and for a select set of individual stations. The figure's legend includes items with a strikethrough line to indicate hidden data-series in the current view.

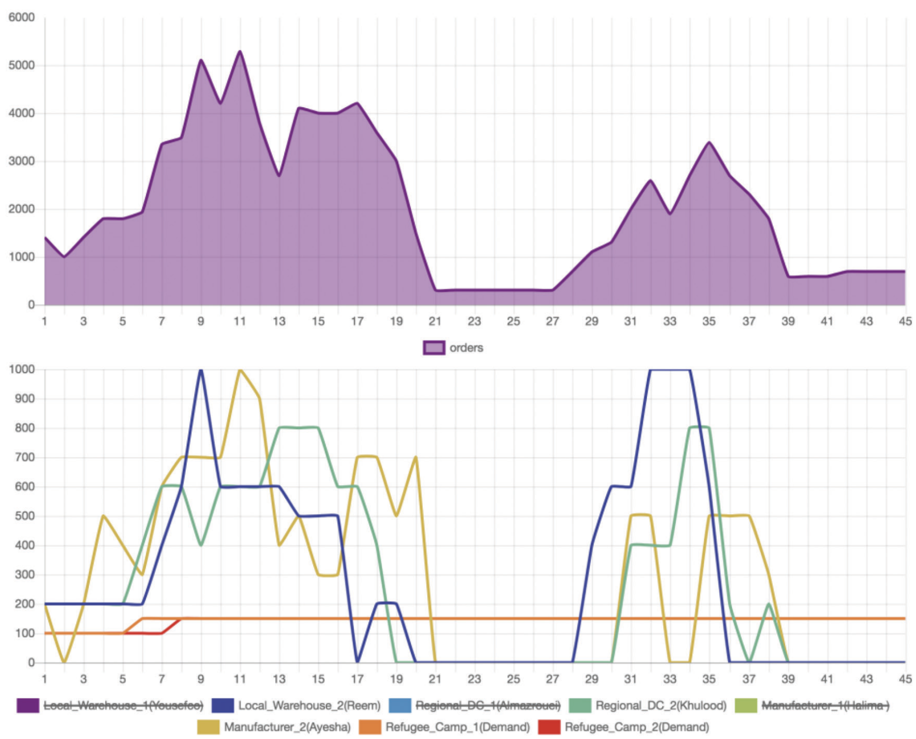

Figure 7. Total weekly orders for the supply chain (top) and for a select set of stations (bottom).

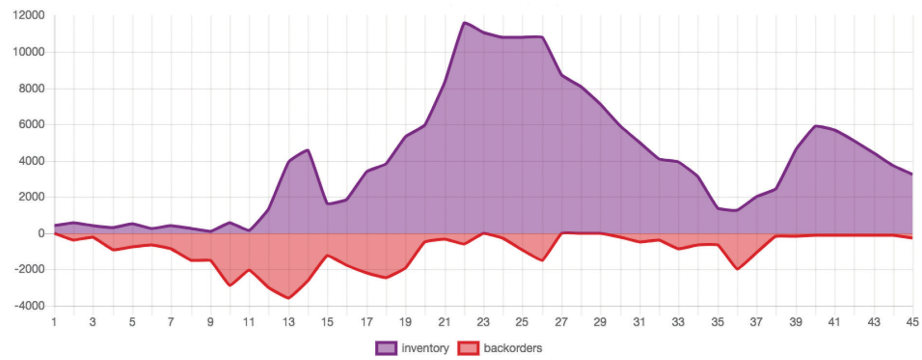

Figure 8. Supply chain weekly status: overall inventory and backorders.

The ability to hide a set of data series is one of the XSG's interactive graph features and is used here to improve graph readability. The figure shows that the supply chain goes through cycles of large-quantity orders (weeks 5–20 and 29–38) followed by little or no orders (weeks 21–28 and 39–45) to consume the accumulated excess inventory. It's noticeable that the first cycle of high-quantity orders starts when the first refugee camp increases its orders (week 6) and intensifies when the second refugee camp follows suit (week 8). One can also see the learning effect in managing the supply chain as the players improve their performance in the second order cycle. Clearly, best performance is achieved when orders are steady and little, or no bullwhip effect is exhibited in the supply chain.

Figure 8 shows the supply chain overall inventory and backorder status. After game completion, the instructor might want to draw players' attention to the fact that backorders existed in the supply chain for the majority of the game, and surprisingly even when the supply chain was awash with inventory (weeks 20–30). Students should be encouraged to analyze this phenomenon and deduce the root cause of inefficient and siloed management approaches typically used by players, which is compounded by delays included in game design. Figure 9 shows the net weekly available inventory view for the supply chain as a whole and for a select set of stations. Net available inventory is defined as the number of items in inventory minus the number of items on backorder. Figures 8 and 9 show once more the self-restraint some players showed in the late part of the game (weeks 37-45) to not fall again into the impulse of repeatedly ordering more when backorders start to show up in their weekly station status view. This reveals the learning impact from the previous cycle.

Finally, Table 2 compares stations' performances, and lists KPI values for each station/player participating in the game, as well as the aggregated game scores for each KPI.

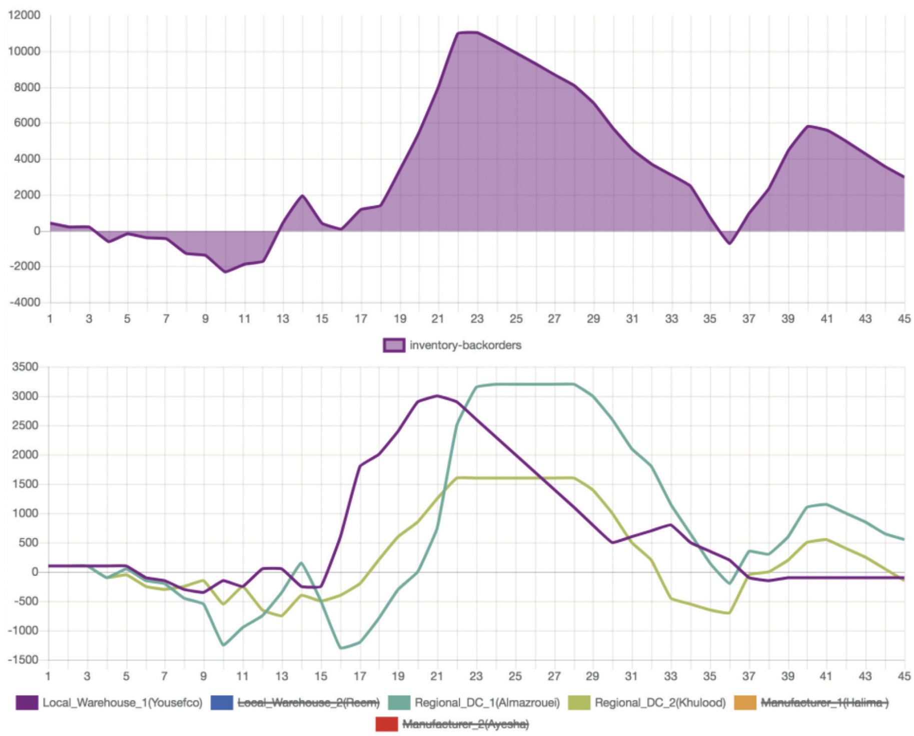

Figure 9. Net weekly available inventory for the supply chain (top) and for a select set of stations (bottom).

Table 2. The HARD game scenario results.

Station (Player)	Inventory	Backorder	Transport	Total	Fulfillment	Transport Utilization
Local_Warehouse_1 (Yousefco)	$35,250	$12,500	$19,800	$67,550	72%	74%
Local_Warehouse_2 (Reem)	$38,050	$12,700	$20,240	$70,990	74%	72%
Regional_DC_1 (Almazrouei)	$45,850	$28,000	$17,820	$91,670	75%	84%
Regional_DC_2 (Khulood)	$19,450	$14,700	$18,260	$52,410	79%	79%
Manufacturer_1 (Halima)	$29,350	$8,600	$17,160	$55,110	86%	86%
Manufacturer_2 (Ayesha)	$17,000	$7,300	$18,040	$42,340	87%	83%
Total ($) / Average (%)	**$184,950**	**$83,800**	**$111,320**	**$380,070**	**79%**	**80%**

Game Debriefing

After the completion of the game, students should be allowed a few minutes to decompress and share impressions. At this point, it is highly beneficial for students to engage in a class-wide discussion, reflect on their performance, and analyze the forces and consequences that were involved in the game. The debriefing session can be as short as 10 minutes and can extend to a much longer session using quantitative analysis of the results. Debriefing is vital in simulation games as it helps participants process the game experience and turn it into learning (Kolb 2014; Crookall 2010). Moreover, debriefing sessions are used to confirm knowledge, correct any misunderstandings/mistakes, and emphasize on previous learning (Asakawa and Gilbert 2003). Without debriefing sessions, the effect of an educational game may be limited as some learners will see the activity as a stand-alone event and not properly connect it to other aspects of class (Nicholson 2013). Other studies emphasizing the importance of debriefing include Peters and Vissers 2004; Ben-Zvi and Carton 2008; Kriz 2010; and van der Meij, Leemkuil, and Li 2013.

The instructor can serve an important role in guiding students into the analysis through carefully poised questions. The investigation areas and questions will vary based on the team's performance and game results. However, regardless of the specifics, most teams' results are likely to follow a similar pattern. The following exploratory questions can be used as examples for the debriefing session while utilizing the resulting graphs to guide the discussion:

- How did you feel while playing the game? Did you feel in control?
- How was your team's performance? What are the main performance issues? What are the sources of these performance issues? Use graphs to explore interactively.
- If this performance occurred in a real-world supply chain, what would be the impact?
- Who is to blame? A typical response here is: everyone blames everyone else, but not oneself!
- Which KPI did you focus on? Why? Use radar chart (e.g., Figure 13) to discuss relative performance and individuals' partial focus on KPIs.
- How can you improve supply chain performance? what would you do differently if you could play again? In most cases supply chain performance can be improved by many folds.

This discussion allows participants to reflect on their decisions and their impact on the supply chain dynamics and find ways to improve supply chain efficiency. It would be comforting for the students to learn that this exercise is designed to be intense, but enjoyable, and that most teams do not perform well in their first attempt.

HUMANITARIAN SCM – TEACHING FOCUS AREAS

This section extends previous discussion points into considerations that take on added significance in humanitarian supply chains. Some of these considerations require modification to the previously introduced HARD game setup to help investigate the impact. These modifications are highlighted when introduced.

Supply Chain Risks

Supply chain risks have more pronounced effects in humanitarian supply chains compared to their commercial counterparts. This is due to the rapidly changing environment they operate in and the potentially devastating human impact any disruption may entail. To infuse a factor of realism and introduce risk mitigation concepts into the game, players in the scenario presented in the HARD game were surprised in week 24 with the news of a breakdown in a ceasefire they were operating under. The event produced an interruption of supply affecting all shipments to refugee camps in weeks 25 and 26, with a real risk to the lives of relief workers if such shipments are carried out. The event is implemented in the game as a penalty of $500K per affected shipment in weeks 25 and 26. The players are also informed that the ceasefire is expected to resume in week 27.

Figure 10 shows the total number of weekly shipments (or trucks) used to transport demanded items within the supply chain. It is of interest to notice that although the surprise breakdown in ceasefire only impacted shipments to refugee camps, all players in this game instance chose not to ship any shipments during the two affected weeks in apprehension of the taxing penalty. However, due to the supply chain being saturated with inventory at this point in the simulation (see Figure 8), players were able to absorb this brief interruption of supply with a moderate impact to their ordering decisions, as can be seen above in Figure 7. Naturally, timing this event to coincide with prevalent backorders in the supply chain or extending its period would elicit a different reaction from players.

Managing Volatile and Increasing Beneficiary Demand

The HARD game can be set to be played with a variety of beneficiary demand profiles. However, the simplistic demand profile utilized in the HARD game, where a one-time increment in beneficiary

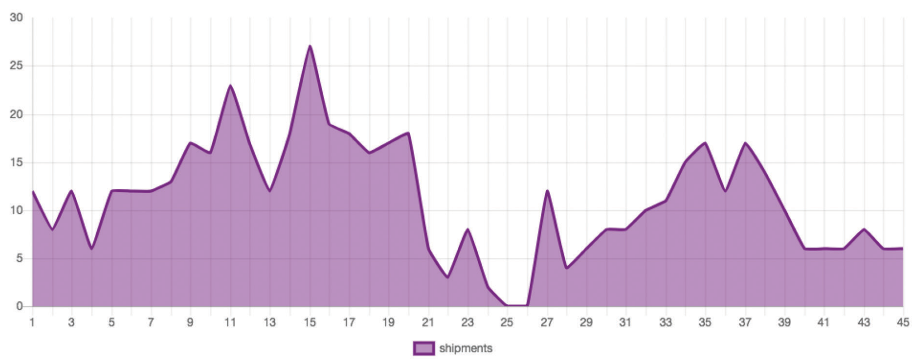

Figure 10. Weekly shipments (trucks) used within the supply chain.

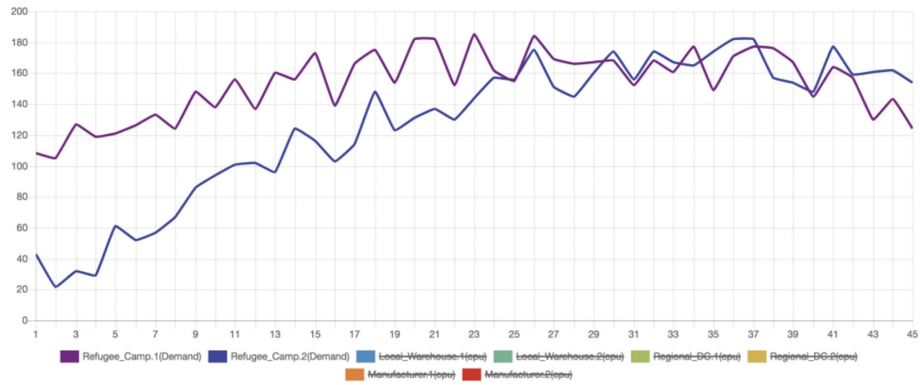

Figure 11. Example of volatile and increasing beneficiary demand, with refugee camp 2 demand rising more rapidly.

demand is exhibited, is used to highlight the decisions made by the participants in a controlled environment. This is designed to help pinpoint the source of performance issues and demonstrate that demand variability in this scenario is not the source of supply chain inefficiencies.

However, humanitarian supply chains frequently experience volatile and at times rapidly increasing beneficiary demand. The instructor can introduce a more realistic demand profile to allow students to experience a more challenging scenario and analyze its impact on supply chain performance. Figure 11 illustrates an example of two volatile beneficiary demand profiles, with refugee camp 2's demand rising more rapidly. Figure 12 shows the supply chain response when a fully automated game simulation is used to analyze the scenario. As expected, a pronounced bullwhip effect materializes in

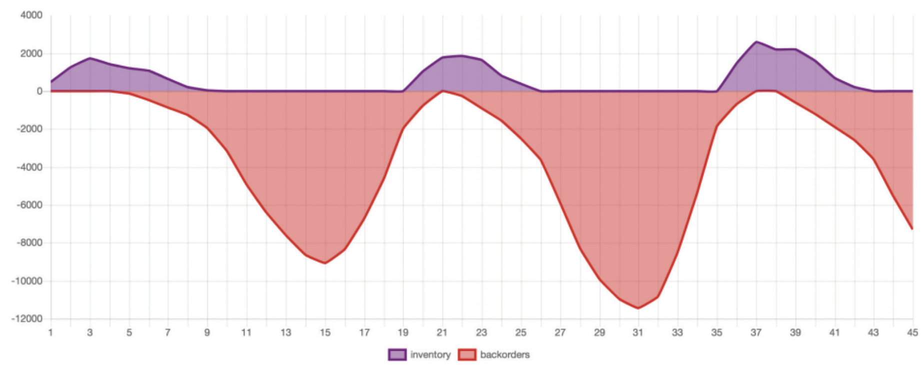

Figure 12. Supply chain orders and back orders resulting from volatile and increasing demand profiles.

this scenario. A modified game template file for this demand profile is included on the game server and engine distribution package.

Humanitarian Supply Chain Inventory Management Strategy: Push vs. Pull

In humanitarian supply chains, given the limited information and unpredictable demand in the early days of a disaster response, it is typical that emergency supplies are quickly "pushed" to the disaster location in the immediate response phase. However, once more accurate information on beneficiaries' requirements and locations of need are available, a more effective pull strategy is utilized during the subsequent response and reconstruction phases (Kovács and Spens 2007; Gatignon, Van Wassenhove, and Charles 2010).

In the early disaster response phase, flow of commodities is determined and controlled at a point close to the donor, hence, a push-model supply chain and logistics form. Under a push system, the local staff (interacting with beneficiaries) inform and update the global team (NGOs) of the need extent and the global team, who usually has the capability to manage the crisis situation in supply chain terms, facilitate flow of information along the humanitarian supply chain. In this model, the Bullwhip effect should not be as pronounced in humanitarian supply chains as in commercial supply chains. However, in some reported cases, this was not the case. For instance, during the Ebola crisis, deciding how much to order presented a special challenge for all organizations involved in the response due to poor data quality and delay in providing information (WFP 2017). Demand information was not shared with suppliers and manufacturers creating the bullwhip effect. For example, the demand for personal protective equipment components and the volumes requested were uncertain, and in some cases exaggerated, hindering the manufacturers' and suppliers' ability to supply effectively.

In the current HARD game design, we focus on the long-term response and reconstruction effort and adopt a pull strategy where demand materializes via orders placed by beneficiaries. While in reality, beneficiaries cannot really decide or influence the demand, a team of experts on the ground close to beneficiaries makes these decisions on their behalf. Future iterations of the HARD game can be modified to include a push strategy version of the game where forecasted beneficiaries' demand is communicated to the entire supply chain replacing orders placed between stations.

Managing to Multiple Objectives

Focusing players' attention to more than one objective is challenging. However, SCM often requires just that, and in humanitarian supply chains this requirement is even more pressing. On one hand, low fulfillment rate would mean increased exposure for beneficiaries who are in dire need. On the other hand, managing with cost inefficiencies means more financial resources are diverted from relief items to supply chain operations. Similarly, inefficient transportation resource utilization

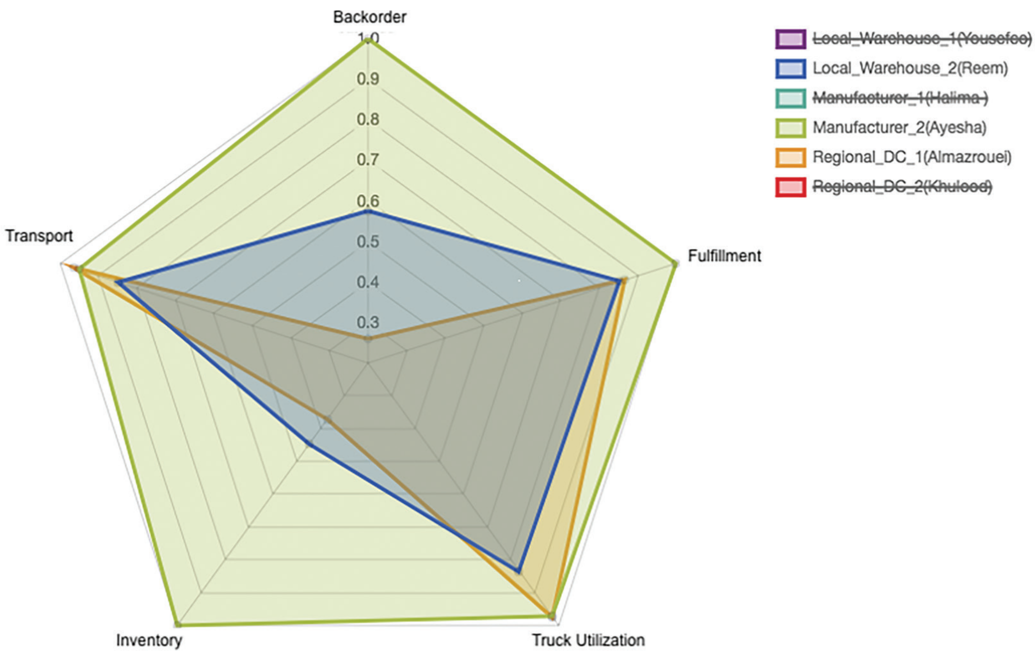

Figure 13. Players' performances radar chart.

could mean that some relief items may not reach their final destination in time due to transportation capacity, availability limitations, or transportation risks in a conflict or disaster areas.

Figure 13 compares stations' performances using KPIs for each station/player participating in the game. While Table 2 totals can be used to compare performance across competing teams, Figure 13 is more suitable for comparing players relative performance within a given game. The figure shows only a select set of players to highlight the best, median, and worst performers in the presented scenario. Scores are calculated by awarding a score of 1.0 to the top performer in each KPI and then scoring the remaining players proportionally according to their performance in that KPI. The figure suggests that players were focused on fulfillment and truck utilization (and consequently transportation cost) while inventory and backorder costs were harder to manage or took on a secondary priority. This focus (or lack of) on inventory and backorder costs provides grounds for differentiation between best and worst performers.

ASSESSMENT OF LEARNING OUTCOMES

Students surveys have been used in literature to assess the impact of a proposed class activity on students' learning of a given concept. Many studies utilize post-activity surveys (Sarkar and Kumar

Table 3. Students' feedback on the game (N = 50).

Scale: Strongly agree (5); Agree (4); Neutral (3); Disagree (2); Strongly disagree (1)		
Question	**Mean**	**SD**
a. The HARD game was a fun and engaging class room activity	4.40	0.926
b. The game improved my understanding of supply chain integration	4.28	0.970
c. I now have a greater appreciation of challenges faced in humanitarian supply chains	4.37	0.727
d. I proposed and tried different solutions to challenges encountered in the game	4.34	0.717
e. The game is a good complementary teaching tool to traditional lectures and reading assignments	4.40	0.782

2016; Ellis et al. 2014; Webb, Thomas, and Liao-Troth 2014; Angolia and Pagliari 2018; Ashenbaum 2010; Kanet and Stößlein 2008; Klotz 2011), whereas some utilize both pre- and post-activity surveys to measure the net impact of the activity on students learning, e.g. (Harnowo, Calhoun, and Monteiro 2016). In this study, we combine both approaches, as described below.

We use a post-activity questionnaire to survey students' game impressions using questions modeled after similar experiential learning literature (Sarkar and Kumar 2016; Webb, Thomas, and Liao-Troth 2014; Angolia and Pagliari 2018). The questionnaire includes five-point Likert scale survey questions as shown in Table 3. We also use ranking questions to evaluate students' understanding of key SCM concepts and challenges as they apply to humanitarian relief operations. Students are asked to rank the same items (see Table 4) before and after taking part in the activity. While the correct rankings of these concepts and challenges are debatable, students rank them from their perspective and the results allow the instructor to evaluate the game's impact on students' understanding of these topics. The results can also be used in the debriefing session (see Game Debriefing section) to discuss students' opinions on these topics. All of the above surveys are designed to be as brief as possible to be administered in 3-5 minutes of class time, saving the majority of class time for the activity itself. Nevertheless, the surveys cover essential aspects of the activity's learning outcomes and students' impressions.

As previously mentioned, the HARD game was deployed in multiple graduate and undergraduate courses: one section of a Logistics and Supply Chain Management course and five sections of an Operations Management course (including one graduate level class). To assess the educational value of the game, 76 students in three Operations Management classes participating in the game were asked to complete pre- and post-game surveys. The pre-game survey was distributed at the beginning of the class before playing the game, and the post-game survey was distributed at the end of the game. In total, 42 students completed the pre-game survey, and 50 students completed the post-game survey.

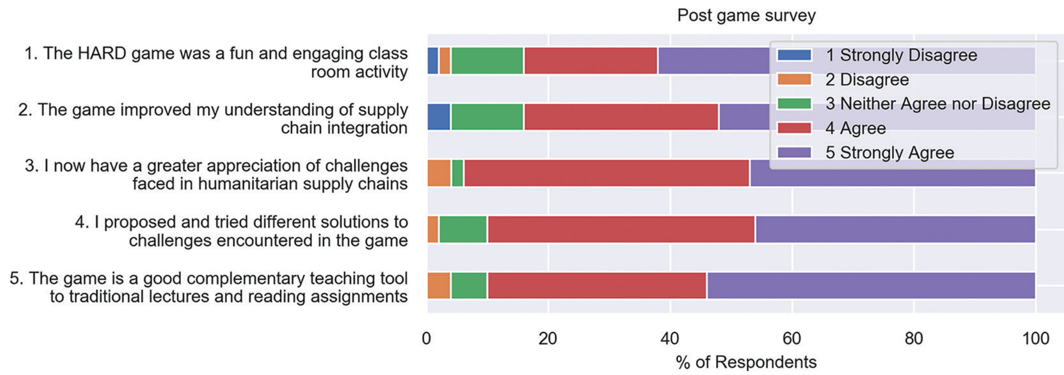

Figure 14. Students' feedback on the game.

Results of the post-activity Likert questions survey show that students perceived the game as a positive learning experience. Students found the game to be a fun learning activity (average score of 4.4 out 5) which kept them highly engaged. They also reported that the game improved their understanding of supply chain management in general (4.3 out of 5), and the challenges faced by managers in humanitarian supply chains in particular (4.4 out of 5). In addition, most students (4.3 out of 5) proposed and tried solutions to challenges faced in the game. Finally, students stated that the game was a good complementary teaching tool to traditional teaching instruments used in class (4.4 out 5). Actually, several students verbally indicated that the game helped them better understand the Bullwhip effect and how it materializes in the absence of information. Figure 14 shows the results of the survey based on the percentages of respondents for each question. The graph clearly demonstrates that the game experience was well received and appreciated by the students.

Table 4 summarizes the results of the two ranking questions included in the pre- and post-activity surveys. For simplicity, we refer to the first and second ranking question as R_1 and R_2, respectively. Survey results for R_1 show that the HARD game fosters better understanding of the unique relief environment and the uncertainties involved. In the pre-activity survey, students ranked the first three focus areas (information sharing, collaboration, and demand forecasting) higher than the remaining two (transportation planning and cost reduction). However, students were torn between the first three focus areas in terms of importance. This is evident by the fact that each area was selected by nearly a third of the students as the most important focus area. In contrast, post-activity results show that students were more confidently ranking information sharing as the first priority with 60% of responses and collaboration as the second priority with 48% of responses.

Survey results for R_1 are further analyzed using Friedman's statistical test (Friedman 1937; Sheskin 2003) revealing a significant rank difference between at least two of the analyzed focus areas. This holds true for both pre- and post-activity surveys, with both having *p*-values of 0.000, respectively.

Table 4. Summary of pre- and post-game survey results.

	Rank									
	Pre-Game Responses					Post-Game Responses				
Questions	**1st**	**2nd**	**3rd**	**4th**	**5th**	**1st**	**2nd**	**3rd**	**4th**	**5th**
R1: Rank the following focus area in humanitarian relief supply chains in order of importance (where 1 is most important and 5 is least important):										
a. Information sharing between supply chain partners	**33%**	24%	17%	12%	10%	**60%**	16%	10%	8%	4%
b. Collaboration between supply chain partners in order fulfillment	**33%**	33%	19%	14%	0%	24%	**48%**	16%	12%	0%
c. Demand forecasting	**36%**	14%	17%	26%	7%	28%	22%	22%	18%	10%
d. Transportation planning	12%	10%	19%	26%	33%	16%	12%	14%	14%	44%
e. Cost reduction	7%	19%	24%	24%	26%	24%	8%	26%	32%	10%
R2: Rank the following challenges in humanitarian relief supply chains in order of their impact (where 1 is most impactful and 5 is least impactful):										
a. Supply chain risks (disruptive environment)	21%	33%	33%	7%	2%	30%	18%	14%	16%	14%
b. Unpredictable and unstable demand (volatility)	14%	19%	24%	29%	14%	18%	16%	36%	14%	10%
c. Aid items availability (scarcity)	21%	21%	21%	19%	14%	24%	24%	24%	12%	10%
d. Competing objectives (saving lives, efficient aid distribution, equity in distribution, and environmental footprint)	33%	17%	12%	14%	24%	26%	18%	14%	20%	16%
e. Time delays (e.g., processing and transportation)	1%	0%	2%	6%	1%	2%	2%	4%	6%	0%

Table 5. Students' ranking of humanitarian relief supply chains focus areas.

Focus areas	Pre-activity mean rank*	Post-activity mean rank*
Information sharing between supply chain partners	2.38	1.86
Collaboration between supply chain partners in order fulfillment	2.17	2.38
Demand forecasting	2.69	3.04
Cost reduction	3.83	3.64
Transportation planning	3.93	4.08

* 1 is most important and 5 is least important

Table 5 shows the mean rank for each focus area in pre- and post-activity surveys. To analyze the differentiation between focus areas individually, we use the Bonferroni-Dunn post-hoc test (Dunn 1961) on the top two focus areas (per post-activity ranking): information sharing and collaboration. Each focus area is pair-tested against all the other focus areas. The Bonferroni-Dunn post-hoc test results are shown in Tables 6 and 7. For this analysis we use a significance threshold of 0.01; a pair of focus areas are said to have statistically significant differentiation in their rankings if the $\acute{p}$ (adjusted p) value is less than 0.01.

Table 6. Bonferroni-Dunn post-hoc test results: information sharing* vs all.

Comparisons	Pre-activity survey results		Post-activity survey results	
Information sharing vs Transportation planning	4.49	0.000	7.02	0.000
Information sharing vs Cost reduction	4.21	0.000	5.63	0.000
Information sharing vs Demand forecasting	0.90	1.000	3.73	0.001
Information sharing vs Collaboration	0.62	1.000	1.64	0.400

* Some focus areas were shortened for space consideration. Please see Table 4 for the full description.

Table 7. Bonferroni-Dunn post-hoc test results: collaboration* vs all.

Comparisons	Pre-activity survey results		Post-activity survey results	
Collaboration vs Transportation planning	5.11	0.000	5.38	0.000
Collaboration vs Cost reduction	4.83	0.000	3.98	0.000
Collaboration vs Demand forecasting	1.52	0.516	2.09	0.148
Collaboration vs Information sharing	0.62	1.000	1.64	0.400

* Some focus areas were shortened for space consideration. Please see Table 4 for the full description.

The results for R_1 (seen in Tables 5 through 7) show that both information sharing and collaboration are ranked significantly higher than cost reduction and transportation planning in both pre- and post-activity surveys ($\acute{p}$ = 0.000 for the eight comparisons). More importantly, while demand forecasting is ranked similarly to information sharing and collaboration in pre-activity surveys ($\acute{p}$ = 1.000), it's ranked significantly lower than information sharing in post-activity surveys ($\acute{p}$ = 0.001). The results, however, fall short of establishing statistical significance in rank difference between information sharing and collaboration ($\acute{p}$ = 0.400), or between collaboration and demand forecasting ($\acute{p}$ = 0.148), although $\acute{p}$ value decreases considerably in both cases (post- vs. pre-activity). In all, the results demonstrate a significant trend where students more confidently rank information sharing and collaboration over all other focus areas in post-activity surveys.

Contrary to R_1, results of R_2 analysis are less conclusive and differences between ranks in pre- and post-surveys are not statistically significant. We address this finding in the Conclusion section. Table 4 includes R_2 results for completeness sake.

LIMITATIONS

While we highlight here the advantages of using the HARD game in SCM education, we also acknowledge that there are some aspects related to the game design and assessment that may impact its deployment or outcomes in certain settings. First, the game design is based on a single-product supply chain, which disregards SCM concepts dealing with multi-product or product assemblies. Similarly, ordering and shipping delays in the game are assumed to be deterministic which precludes realistic variability in such delays. Second, the relatively lengthy execution time of the game may curb its use in experimenting with different supply chain setups as each experiment requires a full simulation run to produce results. However, this may be mitigated using varying setups for different teams playing parallelly in class. Finally, while the survey questions are modeled after similar experiential learning literature in the SCM education field, the framing of some of the survey questions may be perceived as leading which could influence assessment outcomes.

CONCLUSION

This paper introduces the Humanitarian Aid and Relief Distribution (HARD) Game as a tool that allows students to explore humanitarian supply chain management concepts through an experiential classroom-based learning activity. The game challenges students to find ways to increase operational efficiency while balancing decision tradeoffs impacting the supply chain's operations.

Particularly, it aims to help students understand the unique relief environment and the uncertainties involved while allowing them the opportunity to determine the best coordination strategies to improve the humanitarian supply chain performance. Special attention is given to considerations that take on added significance in humanitarian supply chains such as: supply chain risks, demand volatility, inventory management strategies, and competing objectives.

The presented example game scenario highlights the game's potential in humanitarian SCM education. On one hand, the scenario results show the coordination pitfalls players typically fall in, which manifests through the cyclical bullwhip phenomenon, the struggle to effectively manage multiple KPIs, and the coexistence of high backorders and high inventories in the supply chain, simultaneously. On the other hand, the results also show the players' ability to learn from prior mistakes and collectively adjust their coordination behavior to minimize the severity of these phenomena as simulation progresses. Overall, the game has been well received by students. Results of pre- and post-surveys provide strong evidence of the game effectiveness in class. Students indicated that the game was a fun learning experience that improved their understanding of humanitarian supply chain management. Probably, the most telling evidence of the game effectiveness is the observation of how students felt undecided while ranking focus areas in humanitarian relief supply chains before the game, and how they were able to confidently rank them after the game based on their in-game experience.

The surveys also reveal a weakness in students' differentiation between challenges in humanitarian supply chains after completing only one HARD game session. The pre- and post-survey results do not reveal statistically significant distinction in students' ranking of the surveyed challenges. We believe that the full appreciation of challenges found in humanitarian supply chains can only come after establishing a good understanding of the dynamics involved in its operations. Therefore, it may be best to separate advanced teaching topics (discussed in the Teaching Focus Areas section) into subsequent HARD game sessions, where students are introduced to these challenges after foundational concepts have been absorbed. Exploration of this idea is left as a future work direction.

The HARD game can be extended in the future to include a push strategy version of the game, replace deterministic delays (i.e. ordering and shipping delays) with stochastic delays to allow an added level of realism into the game, or introduce supply chains with multi-product distribution or product assemblies.

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AUTHORS

Suzan Alaswad is an assistant professor of Operations Management at Zayed University in Abu Dhabi. Dr. Alaswad received her PhD and MS degrees in industrial engineering from University of Arkansas. She also holds a BSc in Mechanical Engineering from Jordan University of Science and Technology. Prior to joining Zayed University, Dr. Alaswad worked as an adjunct Professor at the Industrial and System Engineering Department at Lehigh University. Her teaching interests include Operations Research, Operations Management, Statistics, and Stochastic Processes. Her research interests include decision making under uncertainty, health care system engineering, and operations management.

Sinan Salman is an assistant professor of Information Systems and Technology Management at Zayed University. Dr. Salman received his PhD and MS in Industrial Engineering from University of Arkansas and Oklahoma State University, respectively, and BSc in Mechanical Engineering from Jordan University of Science and Technology. Prior to joining Zayed University, he worked in the US in the field of Supply Chain Management for 13 years. His professional career included logistics consulting, supply chain and transportation management, and optimization software development. His areas of interest include operations research and its applications in supply chain, logistics, and healthcare systems.