Beat the dice: sustainability uncertainty and implications on the total cost of ownership

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Abstract
Through this innovative dice based classroom simulation, students are exposed to supply chain sustainability, risk management, and total cost of ownership (TCO) while also understanding their linkages. Student teams compete by selecting sourcing options such as supplier location, transportation methods and sustainability reputation from a menu, then see how their decisions fare as the product life cycle is simulated with a dice. Successfully conducted by multiple instructors, in multiple countries and across all levels of management education (undergraduate, MSc, and executive MBA), survey results (n=381) confirm that the simulation accomplishes multiple learning objectives while providing a highly engaging experiential learning classroom environment.

Keywords: Sustainability, supply chain management, class exercise

Introduction

This paper describes a classroom simulation that enables supply chain students to learn about and experience the interrelation between total cost of ownership (TCO), sustainability, and risk management in a high energy 45 minute experiential learning activity. The first of three phases provides student teams with a 'menu' from which they select a supplier location, transportation method, supplier environmental and social reputation, and how they will manage the supplier relationship over the life of a clothing product line. Their chosen supply chain design provides their initial direct costs. In phase two, four corresponding indirect costs are then revealed while phase three involves students rolling a dice to simulate seven potential supply chain uncertainties that can occur over the life of the product. The additional costs that result in phases two and three are influenced (extent, probability, severity) by their original supply chain design selections from phase one. All teams' initial choices and corresponding ending TCO results are then contrasted and compared during the simulation debrief. Our primary objective/research question asks: is it possible to expose students to supply chain sustainability, risk management, and total cost of ownership (TCO) through an engaging experiential learning classroom simulation while also enabling them to experience and understand the linkages between these important supply chain concepts?

Literature Review

The field of operations and supply chain management has many classroom exercises for various topics such as inventory management (Robb et al., 2010), forecasting (Snider and

Eliasson, 2013), assembly line balancing (Fish, 2005), and of course Sterman's (1989) classic beer distribution supply chain simulation. Interestingly, although sustainability has been growing in prominence for management education, there appears to be a dearth of games and simulations developed for in class use to date. Simmers and Soderstrom's (2017) review of pedagogical tools, games, and simulations in the sustainability classroom reveals that passive approaches (articles, books, cases, and videos) represent over 85% of the current resources while providing only two online activity games and one finance based simulation among the 77 listed. Barth and Rieckmann (2012) argue that sustainability education not only requires innovation in teaching and learning, but that it also challenges the capabilities of academics to generate, bring about, and adopt the innovative practices necessary to teach sustainability. Measuring sustainability education has also proven challenging to date. Figueiró and Raufflet's (2015) literature review of sustainability in management education found that no article contributed assessment of learning outcomes. Simmers and Soderstrom (2017) suggest some direct and indirect methods but conclude that value added assessment is recommended "because the goal of sustainability education is not solely about knowledge acquisition but about knowledge usage to change the world" (p. 211). Considering that sustainability requires business students to think differently about business, historical approaches of management education such as lecture and cases may not be the most effective. Figueiró and Raufflet's (2015) review of sustainability management education stated that action learning is emerging as a very promising approach for teaching sustainability. Erkskine and Johnson (2012) state "because sustainability is, by its nature, a concept and topic that calls for action, the active learning approaches preferred by students may be more valuable in this emerging focus of business inquiry" (p.204).

Simulations provide both active and experiential learning for students. Kolb (1984) defines experiential learning as "the process whereby knowledge is created through the transformation of experience" (p. 38) while Itin (1999) defines it as "the change in an individual that results from reflection on a direct experience" (p. 92). McCarthy and McCarthy (2006) contend that although the case study teaching approach is very popular in business education, experiential learning techniques provide superior learning, with the authors advocating that experiential learning programs be mandatory in the major areas of a business curriculum. Given the importance of sustainability in management education, there appears to be an urgent need for a classroom simulation that can provide supply chain students with a sustainability based experiential learning opportunity. Investigation into classroom exercises focusing on supply chain sustainability and TCO found similar scarcity. On the sustainability side, classroom exercises often have a modelling focus (Belien, et al., 2013; Godfrey and Manikas, 2012; Frommer and Day, 2017), while there are even fewer TCO classroom exercises available. Bevilacqua et al. (2015) provide a 'cook and teach' three hour exercise where engineering students prepare a meal while also measuring the food supply chain environmental and social implications of that meal. Unfortunately the existing literature does not provide a classroom exercise that incorporates both supply chain sustainability and TCO, two emerging and highly critical concepts for today's supply chain managers.

This innovation fills many of the current gaps in supply chain education by providing students with a sustainability based experiential learning opportunity which also integrates TCO and risk management concepts in a highly engaging dice based classroom simulation. Furthermore, our survey results also provide an assessment of learning outcomes within supply chain sustainability education across undergraduate and graduate level courses.

Exercise Description

This in-class 45 minute simulation requires no pre-class preparation for students and can be conducted at any point of the supply chain curriculum. Students compete in small teams and can be incentivised by awarding a prize to the team with the lowest resulting TCO at the end of the simulation. While we conducted the simulation in classes of up to 60 students, there is no limit to the number of teams that can participate. The simulation has three phases: 1) direct cost selection from a supplier 'menu', 2) resulting indirect costs, and 3) dice rolling to simulate risk events over the life of the product.

Phase 1: Direct Costs (Approximately 20 minutes)

An introduction slide (Figure 1) is first shown explaining the scenario and the phases.

Figure 1 - Exercise Introduction Slide

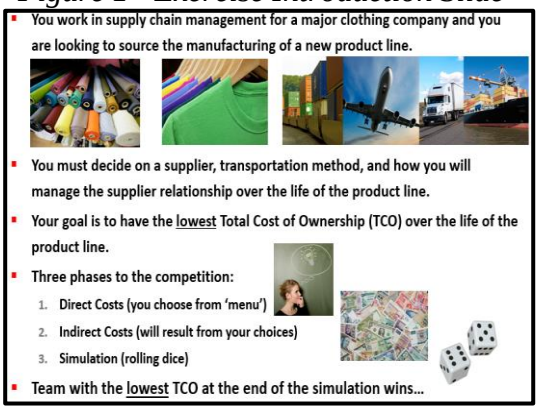


Figure 2 – Sample Supplier Menu Selections

Supplier Location: Local | Next Shore | Developing Country

Option	Selection			Cost
Transportation Method	Slow	Medium	Fast	30
Supplier Sustainability Reputation- Environmental	Low	Medium	High	9
Supplier Sustainability Reputation - Social	Low	Medium	High	15
Supplier Inspection Level	Low	Medium	High	10
Supplier Collaboration Level	Low	Medium	High	12
Total Direct Cost of Ownership:				76

Student teams are then provided a form with a 'menu' of supply chain design options and their associated direct costs from which to choose. Their primary choice is supplier location (local, next shore, or developing country) and transportation method. That combination provides their direct cost of materials and direct cost of transportation over the life of the product in a single value. Secondarily, the level of sustainability reputation (environmental and social) they desire, and how they will manage the relationship over the life of the product is selected. Just like a restaurant menu, some options are more expensive than others. Choosing 'low' for supplier inspection level would mean primarily trusting the supplier on their sustainability rather than funding more frequent independent inspections. While saving direct costs initially, such an approach could increase risks over the life of the product. A high level of supplier collaboration on product design and production processes would have higher direct costs to administer, but should lower potential risks over the life of the product. While time would tell in the real world how such decisions would play out, dice will be rolled in phase three to simulate seven supply chain risks. Figure 2 is an example of a team's supply chain design and associated costs as selected from the menu. The simulation values are non-currency specific to enable international usage, and menu costs are designed so that a supply chain designed entirely with medium levels of sustainability would result in a direct cost of 100. This baseline enables a quick categorization of a team's supply chain sustainability levels during the simulation (ex. low: 68-89, medium: 91-111, high: 112-132) while also enabling an efficient comparison of TCO results during the eventual debrief.

Phase 2: Lifetime Indirect Costs (Approximately 10 minutes)

The instructor reveals, one slide at a time, the four resulting indirect costs: inventory holding, purchase administration, quality validation, and customer service impact. For

each one, each team fills in their cost tracking worksheet for the type of indirect cost and their resulting value. All indirect costs are based on their menu choice of supplier location and transportation method. Once each indirect cost table is displayed, the instructor should ask the teams "what is the rationale for these table values?" challenging students to explain why some are high while others are low. For example, Figure 3's holding cost table reveals a relationship between the delivery lead time and the required levels of inventory in the supply chain, while frequent small purchases from a developing country would incur high levels of purchase administration costs.

Figure 3 – Indirect Inventory Holding and Purchase Administration Costs

		Lifetime Inventory Holding Costs		
		Slow	Medium	Fast
Supplier Location	Local	8	6	4
	Next Shore	10	8	6
	Developing Country	12	10	8

		Lifetime Purchase Administration Costs		
		Slow	Medium	Fast
Supplier Location	Local	4	6	8
	Next Shore	6	8	10
	Developing Country	8	10	12

For each indirect cost, the instructor can ask students if their accounting department would receive and invoice for such costs. Students typically answer that even though these costs are real and potentially significant, they would not appear as supply chain costs in an accounting system. This can help slowly chip away at their reverence for accounting information, encouraging them to adopt TCO concepts and sustainability concerns into their supply chain decision making.

Phase 3: Roll the Dice for Lifetime Supply Chain Risks (Approximately 10 minutes)
Prior to revealing the seven supply chain risks that will be simulated by dice rolling, ask the class to speculate what risks they think the dice will be rolled for. While some suggest risks that will be simulated, others suggest things like natural disasters, trade wars, and conflict / social unrest which are not currently incorporated due to their extremely low probability. Such suggestions expose to fellow students that even more supply chain risks could occur than the seven upcoming in the simulation. Mirroring risk management, each risk has two components that are simulated by rolling the dice, probability and severity. Their menu choices from phase 1 influence their impacts on foreign currency fluctuation, inflation, environmental incident, social incident, inspection incident, quality recall incident, and market demand for sustainable products. For example, if a team chose a local supplier, they would not be exposed to a foreign currency risk. Rather than the instructor rolling, having various students roll the dice each time creates an even more interactive classroom environment and absolves the instructor for any responsibility for the dice roll results. Figure 4 provides an example of how the probability and severity work for the environmental incident risk. The first roll determines if the risk occurred for each team based on their selection of supplier location and supplier environmental reputation. Low sustainability selections increase the chances of the risk occurring and if it does, also the severity of the risk. Over seven risks and related rolls, lucky or unlucky 'streaks' tend to even out. Groups nervously await the roll results, then cheer or groan when the roll value reveals if the risk occurred for them, and if so, what their severity was. In this example, an occurrence roll result of 3 would only result in the risk occurring for teams that chose developing country and low environmental reputation. The rest of the teams would have avoided this risk by their menu selections and then enjoy watching the affected groups squirm as the severity impact roll occurs.

Figure 4 – Probability and Severity for Environmental Incident Risk

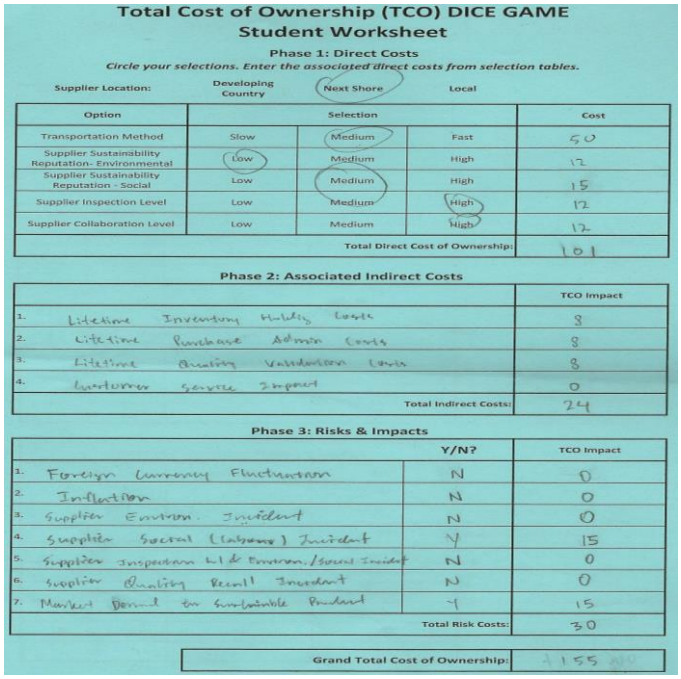
		Supplier Environmental Reputation & Environmental Incident - Occurrence?		
		Low	Medium	High
Supplier Location	Local	if roll = 1	N/A	N/A
	Next Shore	if roll = 1/2	if roll = 1	N/A
	Developing Country	if roll = 1/2/3/4	if roll = 1/2	if roll =1

		Supplier Environmental Incident - Severity TCO Impact					
		1	2	3	4	5	6
Supplier Location	Local	5	5	10	10	15	15
	Next Shore	10	10	15	15	20	20
	Developing Country	15	15	20	20	25	25

The seventh risk simulates the market demand for sustainable products impacting all teams. If the market demand roll is high, teams that chose high sustainability supply chains would profit and thus are provided with a negative TCO value for this risk while low teams incur additional costs. If however demand for sustainable products is low, the opposite results will occur.

Exercise Debriefing: (approximately 5 minutes)
Contrasting and comparing team's original direct costs with their resulting total TCO is critical for students to recognize the linkages between sustainability, risk management, and TCO. If no team chooses the extremes (68, 132), it is recommended to have how those would have fared included in the debrief comparison. The instructor should group the teams into low sustainability supply chains (direct costs 68-89), medium (91-111), and high (112-132), then highlight the resulting TCO values for each grouping. Low teams typically have higher increases and a wide range of possible TCO values, relative to medium and high teams because their supply chain design has higher indirect costs and is exposed to more supply chain risks. The comparison can be done by displaying each team's completed tracking sheet (Figure 5) on a document camera or simply posted on the classroom wall. Alternatively, the data can quickly be entered into a spreadsheet and displayed on screen.

Figure 5 – Sample Completed Cost Tracking Worksheet



Total Cost of Ownership (TCO) DICE GAME
Student Worksheet

Phase 1: Direct Costs
Circle your selections. Enter the associated direct costs from selection tables.

Supplier Location: Developing Country / (Next Shore) / Local

Option	Selection			Cost
Transportation Method	Slow	(Medium)	Fast	50
Supplier Sustainability Reputation- Environmental	(Low)	Medium	High	12
Supplier Sustainability Reputation - Social	Low	(Medium)	High	15
Supplier Inspection Level	Low	Medium	(High)	12
Supplier Collaboration Level	Low	Medium	(High)	12
			Total Direct Cost of Ownership:	101

Phase 2: Associated Indirect Costs

		TCO Impact
1.	Lifetime Inventory Holding Costs	8
2.	Lifetime Purchase Admin Costs	8
3.	Lifetime Quality Validation Costs	8
4.	Customer Service Impact	0
	Total Indirect Costs:	24

Phase 3: Risks & Impacts

		Y/N?	TCO Impact
1.	Foreign Currency Fluctuation	N	0
2.	Inflation	N	0
3.	Supplier Environ. Incident	N	0
4.	Supplier Social (Labour) Incident	Y	15
5.	Supplier Inspection Lvl & Environ./Social Incident	N	0
6.	Supplier Quality Recall Incident	N	0
7.	Market Demand for Sustainable Product	Y	15
		Total Risk Costs:	30

Grand Total Cost of Ownership: 155

Analysis of the results from 79 student teams over 8 simulations reveals the design is pedagogically robust (Table 1). Low sustainability teams result in the highest TCO percentage increases and standard deviation of possible results. Conversely, high teams experience much less uncertainty surrounding their TCO results. Note that while the design of the simulation makes it possible for an extremely low sustainability team to win, it would require a highly unlikely streak of good luck to occur, a fact recognized by students during the debrief discussion. Despite the randomness that can occur, the simulation effectively illustrates that higher levels of sustainability in supply chain design provides higher predictability of TCO results while also providing supply chain risk mitigation.

Table 1: TCO Simulation Results Analysis by Direct Cost Category

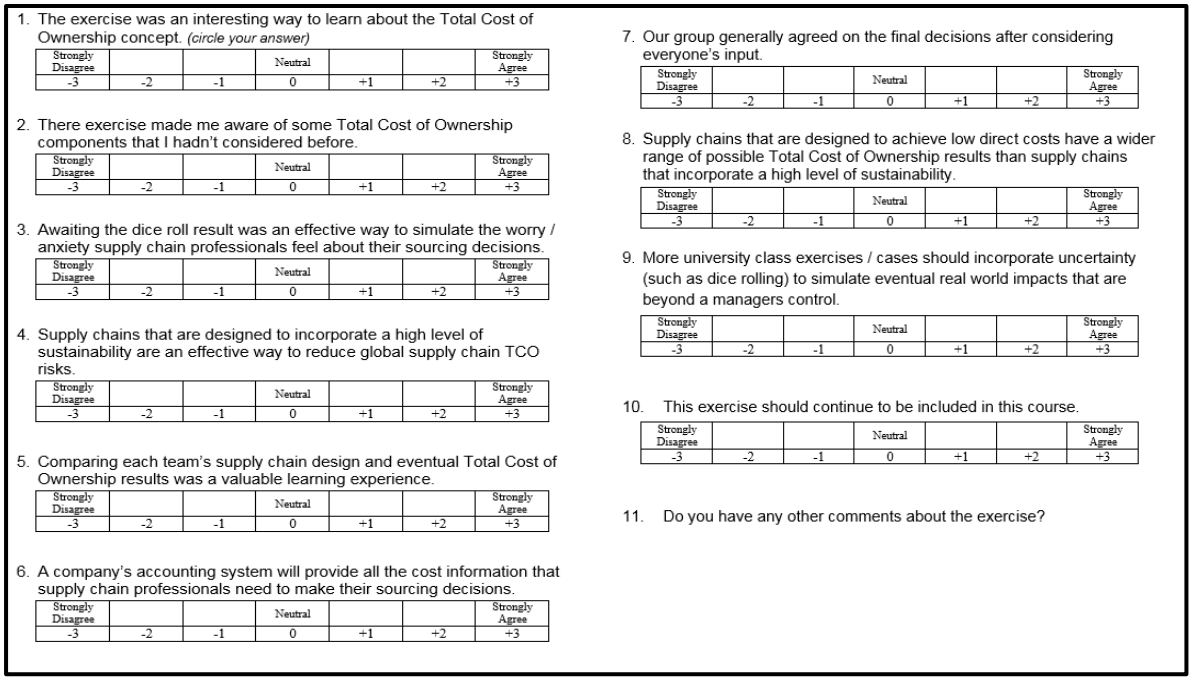
Direct Cost Category	Direct Costs Range	Count	Average Direct Cost	Average Indirect Costs	Average Risk Costs	Average TCO	Average % Change	Standard Deviation
Low	68-90	14	83.0	36.9	43.2	163.1	100.7%	58.4%
Medium	91-111	53	101.3	23.2	6.6	131.1	30.1%	26.8%
High	112-132	12	118.3	7.6	-15.8	110.0	-6.7%	6.5%

Methodology

The effectiveness of the simulation was measured via an optional anonymous eleven question student survey that was conducted immediately after the exercise (Figure 6). The survey was comprised of ten Likert scale questions (-3 strongly disagree, +3 strongly agree) and one for written comments. Some questions seek feedback on the simulation approach while others were designed to provide an assessment of learning. The simulation and survey was first piloted in a UK MSc Logistics course. Survey results (n=30) revealed support for the simulation and learnings across all questions, but recommended more clarity in how the simulation is administered. In response, additional slides were created to better facilitate students through the simulation, one slide for each indirect cost and risk. This improved process was subsequently conducted in both an undergraduate business required course (n=309) and an executive MBA course (n=41) in Canada with the exact same survey instrument used.

Statistical significance testing (Mann-Whitney U test) was conducted comparing the undergraduate survey results to the MSc pilot and the EMBA results. Relative to the pilot, significant positive differences were found in over half of the undergraduate metrics indicating the efforts to improve the clarity of the administration of the simulation were effective. Comparing the undergraduate responses to the executive MBAs found no significant differences for any of the survey questions at the $p<.05$ level. This finding allows the responses from these two groups to be combined analysis purposes. Furthermore, it also reveals that executive MBAs accrue the same experience as undergraduates from the simulation despite their significant work and life experience differences. Table 2 provides mean the scores for the MSc pilot study, undergraduate, and executive MBA responses while Table 3 provides combined undergraduate and executive MBA response details.

Figure 6: Survey Instrument



1. The exercise was an interesting way to learn about the Total Cost of Ownership concept. *(circle your answer)*

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

2. There exercise made me aware of some Total Cost of Ownership components that I hadn't considered before.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

3. Awaiting the dice roll result was an effective way to simulate the worry / anxiety supply chain professionals feel about their sourcing decisions.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

4. Supply chains that are designed to incorporate a high level of sustainability are an effective way to reduce global supply chain TCO risks.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

5. Comparing each team's supply chain design and eventual Total Cost of Ownership results was a valuable learning experience.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

6. A company's accounting system will provide all the cost information that supply chain professionals need to make their sourcing decisions.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

7. Our group generally agreed on the final decisions after considering everyone's input.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

8. Supply chains that are designed to achieve low direct costs have a wider range of possible Total Cost of Ownership results than supply chains that incorporate a high level of sustainability.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

9. More university class exercises / cases should incorporate uncertainty (such as dice rolling) to simulate eventual real world impacts that are beyond a managers control.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

10. This exercise should continue to be included in this course.

Strongly Disagree			Neutral			Strongly Agree
-3	-2	-1	0	+1	+2	+3

11. Do you have any other comments about the exercise?

Table 2: Survey Mean Scores

Course Type	Survey Size	**Q1** *Interesting way to learn TCO Concept*	**Q2** *Made me aware of TCO components not considered before*	**Q3** *Awaiting dice roll simulated worry / anxiety*	**Q4** *Sustainable supply chains are effective way to reduce TCO risks*	**Q5** *Comparing each team's design and eventual results was valuable learning*	**Q6** *Accounting system provides all cost info needed*	**Q7** *Group agreed on decisions*	**Q8** *Low cost Supply chains have wider range of results than sustainable ones*	**Q9** *More university classes should simulate real world impacts with dice*	**Q10** *Exercise should continue to be included in course*
MSc (Pilot)	30	2.33	1.80	1.37	1.63	2.00	0.43	2.03	1.63	1.97	2.23
Undergrad	309	2.46	2.09	2.20	1.90	2.26	-1.29	2.10	1.86	2.38	2.58
Exec. MBA	41	2.51	2.20	2.17	1.98	2.22	-1.27	2.07	1.90	2.17	2.37

	Q1 *Interesting way to learn TCO Concept*	**Q2** *Made me aware of TCO components not considered before*	**Q3** *Awaiting dice roll simulated worry / anxiety*	**Q4** *Sustainable supply chains are effective way to reduce TCO risks*	**Q5** *Comparing each team's design and eventual results was valuable learning*	**Q6** *Accounting system provides all cost info needed*	**Q7** *Group generally agreed on decisions*	**Q8** *Low cost Supply chains have wider range of results than sustainable ones*	**Q9** *More university classes should simulate real world impacts with dice*	**Q10** *Exercise should continue to be included in course*
-3	0	1	3	0	0	139	1	8	0	1
-2	0	1	4	4	1	62	3	8	0	2
-1	0	5	4	8	0	50	7	5	1	0
0	5	22	16	30	13	32	16	24	11	5
+1	29	56	32	56	48	20	46	44	35	22
+2	115	105	115	127	120	22	126	129	119	80
+3	201	160	176	124	168	25	151	132	184	240
Total	**350**	**350**	**350**	**349**	**350**	**350**	**350**	**350**	**350**	**350**
Mean	**2.46**	**2.10**	**2.20**	**1.91**	**2.26**	**-1.29**	**2.10**	**1.87**	**2.35**	**2.56**
-'ve	0.0%	2.0%	3.1%	3.4%	0.3%	71.7%	3.1%	6.0%	0.3%	0.9%
0	1.4%	6.3%	4.6%	8.6%	3.7%	9.1%	4.6%	6.9%	3.1%	1.4%
+'ve	98.6%	91.7%	92.3%	88.0%	96.0%	19.1%	92.3%	87.1%	96.6%	97.7%

Table 3: Combined Undergraduate and EMBA Survey Response Details

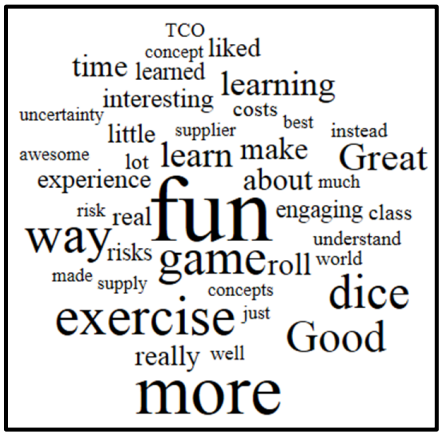
Evidence of Impact

An assessment of the simulation's impact was conducted by analysing written comments received and also by separately analysing the combined undergraduate and executive MBA Likert scale responses on the simulation approach and the learning outcomes.

Written Comments:

Written comments were received on 172 of the 380 surveys (45%). To analyze the entire 1984 comment words, a word cloud was generated. Word clouds display text in graphical form where font size represents frequency, and can be used to enable instructors to assess student learning and feedback (Miley and Read, 2012). Settings of a minimum of three characters and five occurrences resulted in 42 most common words (Figure 7). 'TCO' had 10 occurrences while 'fun' had 48.

Figure 7: Student Comment Word Cloud



Selected comments provide more insights into the impact the exercise had on students:

- *A great exercise to bring awareness of the many considerations to take into account of a global supply chain.*
- *Best way to emphasize the considerations of indirect costs and risks that we completely overlooked when looking at our sourcing decisions.*
- *It was fun - made it clear sustainability (environmental & social) decisions are important*
- *I learned a lot about external factors to really consider before making final decisions. I now understand that even if it is the cheapest decision, it doesn't mean that it's the best.*
- *Good learning opportunity to understand all risks with uncertainty and importance of a high level of sustainability. Engaging and great!*
- *Fun way to learn about TCO and the risks involved with taking cheaper costs up front.*
- *I thought it was very valuable. It gave a world experience that we could relate the concept to.*
- *Randomness of dice roll is important because it proves it is not a perfect case scenario as most class material in business school teaches us / makes us think.*
- *Using dice to incorporate risk into the exercise makes it much more exciting.*
- *Letting others roll the dice was a fantastic idea!*
- *This was a great game - really got my heart racing! Next time I'd suggest more risks to include!*

Simulation Approach (Table 3, Questions 1, 3, 7, 9, 10):
The survey results indicate that using dice to simulate supply chain uncertainty was strongly supported across all groups of students. In addition to a very high mean value of +2.46, 98.4% of students rated the simulation positively (+1/+2/+3) as an interesting way to learn about TCO. Although they only had to wait briefly in the classroom for the roll of the dice, students experienced worry and anxiety surrounding that uncertainty (mean of +2.20, 92.3% positive ratings). Although it made them uncomfortable, they apparently valued the learning experience it provided as they strongly encouraged the expansion of simulating uncertainty with dice in other university classes (mean of +2.35, 96.6% positive ratings), and the continued use of the simulation in the course (mean of +2.56, 97.7% positive ratings).

Assessment of Learning Outcomes (Questions 2, 4, 5, 6, 8):
The simulation created high levels of awareness of TCO components not previously considered by the students (Question 2). Interestingly, the simulation generated slightly more new awareness for the executive MBAs. Although these executives possess more work and life experience, these results appear to indicate they have a similar level of incoming knowledge on sustainability and TCO concepts as undergraduates do. Perhaps this is attributable to the topics emerging more recently as key management education concepts. Questions 4 and 8 provide multiple assessments of the primary intended learning objective of the simulation; the interellationship between supply chain sustainability, TCO, and risk management. Question 4's results indicate that students experientially learned that sustainable supply chain decisions provide TCO risk mitigation (mean of +1.91, 88.0% positive), enabling increased business stability in a turbulent world. Question 8's results confirm these learnings as the students recognized that low direct cost supply chains will experience higher levels of TCO uncertainty (mean of +1.87, 87.1% positive). Question 6's results (mean of -1.29, 71.7% negative) indicate the simulation educates students on the limitations of relying on traditional accounting information for supply chain decision making. Considerations such as indirect costs and impacts on risk probability and severity need to be analysed in addition to accounting provided cost information. Question 5 (mean of +2.26, 96.0% positive) also shows strong support for the pedagogical approach of the simulation debrief as it enables expanded experiential learning reflection beyond their own team's performance.

Conclusion

This innovative simulation and paper fills existing research gaps by not only providing a much needed supply chain sustainability and TCO classroom experiential activity, it also is one of the first to provide assessment of learning outcomes for a sustainability simulation (Figueiró and Raufflet, 2015). Survey results confirm that this simulation successfully accomplishes multiple learning objectives while also providing a highly engaging experiential learning classroom environment. The simulation has been successfully conducted by multiple instructors, in multiple countries and across all levels of management education (undergraduate, MSc, and executive MBA). Through this simulation, students are exposed to supply chain sustainability, risk management, and total cost of ownership (TCO) while also experiencing and reflectively understanding the linkages between these important supply chain concepts. Finally, it illustrates an example of the learning effectiveness enabled by using dice to simulate uncertainty for business students (similar to Heineke et al., 2010) while also providing a call from these students for the dice approach to be expanded in their education.

Note: All files for the simulation are available upon request and are also easily modifiable for adding or adjusting costs and risks. A video of the full simulation being conducted in a 60 student undergraduate class is also available.

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