INTEGRATING TRIPLE BOTTOM LINE SUSTAINABILITY CONCEPTS INTO A SUPPLIER SELECTION EXERCISE

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ABSTRACT

This paper discusses the integration of sustainability concepts into a quantitative supply chain management course in management science. Specifically, we discuss an exercise using the analytic hierarchy process (AHP) for making sustainability supplier selection decisions incorporating a triple bottom line approach (economic, environmental and social performance objectives). The multiple, conflicting objectives and the qualitative nature of the social performance objective require the use of multi-criteria decision-making. Our AHP exercise requires only Excel and could be expanded to include additional triple bottom line criteria.

JEL: M19, M21

KEYWORDS: Sustainability, Supply Chain Management, Management Science, Curriculum, Triple Bottom Line, Analytic Hierarchy Process

INTRODUCTION

Our Supply Chain & Operations Management department began integrating sustainability into our major in Fall 2006 with the introduction of a required course in Environmental Management, as discussed in an earlier article (Godfrey & Manikas, 2009). The first widespread definition of sustainable development was presented in *Our Common Future* (World Commission on Economic Development, 1987, p. 8) in which sustainable development was described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Later, other authors, e.g., Elkington (1994, 1998), expanded the definition of sustainability to include the triple bottom line of economic, environmental, and social performance. Tan, Ahmed and Sundaram (2010) presented a triple bottom line systems dynamic model for managing daily operations at a warehousing company.

They recommended modeling the relationships between the triple bottom line measures: economic issues (e.g., capital investment, warehouse rent, transportation cost, handling cost, packaging, information systems, hire cost, etc.); environmental issues (e.g., carbon minimization, recycling, solid waste, air pollution, water pollution, etc.); and social issues (e.g., health, safety, recruitment, retention, working hours, wages, job satisfaction, training, etc.).Probably the least understood and under-researched of the three bottom lines is social performance. Mass and Bouma (as cited in Castro & Chousa, 2006) classified social performance under two categories: internal measures (education, training, safety, health care, employee retention and job satisfaction) and external measures (sponsoring, volunteer work, investment in society, and stakeholder involvement). Norman and MacDonald (2004) argued that it is impossible to calculate a sound social performance bottom line in the same way that an income statement is created. Summing a company's performance on various social performance measures into a single bottom line is problematic due to: (a) the question of what units to use to express social performance, and (b) the manner in which social performance often is expressed—using percentages, which cannot be added or subtracted into a single meaningful measure. However, even though managers cannot calculate a bottom line for social performance, we propose that managers still could make value judgments and comparisons concerning which social justice objectives are more important. Multi-criteria decision-making (and AHP in particular) is ideally suited for making these value judgments and comparisons.

This paper discusses the continued integration of sustainability concepts in our supply chain management curriculum. We already have added several sustainability exercises in our Manufacturing Planning & Control, Supply Chain Management, Supply Chain Strategy and Advanced Quality Management courses. In the current paper, we outline the use of AHP for supplier selection decisions based on the triple bottom line.The remainder of this paper is divided as follows. First, we present literature discussing how universities have integrated sustainability in their curricula, how business schools have integrated sustainability in their curricula, and how supply chain management departments have integrated sustainability into their curricula. Second, we provide an overview of using AHP for supplier and other multi-criteria decisions in supply chain management. Third, we present the in-class exercise using AHP. Fourth, we conclude with a summary of the AHP exercise.

LITERATURE REVIEW

Sustainability and University Curricula

Educating students on sustainability topics came to the forefront when UNESCO declared 2005-2014 the United Nations Decade of Education for Sustainable Development (Education for Sustainable Development). The Association of University Leaders for a Sustainable Future (About ULSF) promotes sustainability education as a critical focus of teaching, research and operations at universities worldwide (its members include more than 350 university presidents and chancellors from more than 40 countries who have signed the 1990 Talloires Declaration). Moore (2005) made seven recommendations for sustainability at the university level: (1) Infuse sustainability into all university decisions, e.g., update the sustainability development policy, use sustainability as the overall goal of the university, and use the campus as a living/learning laboratory; (2) Promote and practice collaboration, e.g., create incentives for collaboration, implement broader based admissions standards, and promote group work; (3) Promote and practice transdisciplinarity, e.g., increase program flexibility for undergraduate students, redesign programs, and promote reflection of worldviews; (4) Focus on personal and social sustainability, e.g., increase job security for lecturers, reduce workloads, and promote personal wellness; (5) Integrate planning, decision making and evaluation, e.g., by creating appropriate criteria for evaluation and rewarding of faculty; (6) Integrate research, service, and teaching, e.g., promote the scholarship of teaching and community service learning; (7) Create space for pedagogical transformation, e.g., create space and time for reflection, dialogue, and action. Regarding curriculum change at the university level, Kagawa (2007) cautioned that students strongly associate sustainability with environmental aspects; therefore, curriculum changes must demonstrate the connections between the other two aspects of sustainability—economic and social performance. Integration of sustainability in non-business curricula appears to be strong particularly in the engineering disciplines (El-Zein, Airey, Bowden & Clarkeburn, 2008; Lourdel, Gondran, Laforest, & Brodhag, 2005; Mulder, 2004). This is not surprising given engineering's influence in product design, process design and project management.

Sustainability and Business School Curricula

As sustainability topics have become more prevalent in universities as a whole, those topics have filtered into business school curricula. For example, the Aspen Institute Center for Business Education (Beyond Grey Pinstripes, 2007-2008), in a recent study of 112 full-time MBA programs accredited by AACSB, found that 35 of those MBA programs offer a special concentration or major that allows students to focus on social or environmental issues; however, the proportion of schools requiring content in core courses regarding social and environmental issues remains low. Murray (2006) complained that sustainability topics often are taught as optional units rather than being integrated into mainstream business courses. In another study, Biello (2005) listed sixty courses in sustainability offered in accredited graduate programs and in two non-accredited business schools (Bainbridge Graduate Institute and Presidio School of Management) that offer MBAs in sustainable business. Much of the literature concerning sustainability in business schools appears to focus on what skills students should develop and how to integrate sustainability into the curriculum. These topics are discussed below.

Some authors emphasize the development of students' skills when integrating sustainability into the business curriculum. For example, Kearins and Springett (2003) advocated that instructors develop the following skills in students: reflexivity, critique and social action/engagement. Reflexivity would require students to reflect on the personal and societal values that impact on personal and management decisions. Critique requires students to consider issues of power and ideology that shape a given reality, e.g., the way in which a company is organized, to challenge those issues, and to investigate organizational forms that are more democratic. Social action/engagement motivates students to think about ways in which they could act in a more sustainable manner and how they could facilitate making their broader environment more sustainable. Bradbury (2003) discussed experiential exercises in sustainability geared toward management, organization behavior and strategy courses. The intent of these experiential exercises is to prod students into questioning what sustains their own lives, the lives of others close to them, and the organizations in which they work. The experiential exercises could be designed around case studies of companies that have implemented sustainability concepts, personal vision quests (walking around campus and pondering issues important to themselves), exercises that require students to reflect on their personal use of natural resources, and participating in projects to make an environmental improvement.

Regarding research on integrating sustainability into undergraduate business curricula, Bridges and Wilhelm (2008) proposed a framework for integrating sustainability into a marketing curriculum. They discussed a 4Ps (product, price, place/distribution and promotion) approach to curricula in sustainable marketing with which sustainability issues could be included in courses as the 4Ps are presented. Then, they described an MBA elective that they developed and their use of current readings and cases that focus on sustainability. Their future plans include adding an experiential learning activity to the course, creating a database of marketing internships with sustainable firms, requiring students to develop a marketing plan for making the university more sustainable, and starting a speaker series on sustainable marketing strategies.

More recently, Rudell (2011) described her experience with creating a green marketing course for undergraduates at Iona College. She found that her students' environmental consciousness was increased and that those students recognized the importance of their individual actions on the environment. Bates, Silverblatt and Kleban (2009) discussed their experience with creating a new green management course at Florida International University (FIU). Their new course emphasized experiential learning and required students to conduct a sustainability audit at local firms. In addition, Bates, Silverblatt and Kleban (2010) reported on the updating of the business environment management track at FIU. Administration at FIU originally had recommended deleting the track due to low enrollment. The authors analyzed other programs having the words sustainability or environment in their title and/or containing several courses in sustainability. Based on their study, they updated their curriculum to prepare students for green collar jobs in eco-tourism, green management and green trade.

Sustainability and Supply Chain Management Curricula

Integration of sustainability topics in supply chain management courses appears to be just beginning, but promising. For example, Bandyopadhyay (2004) conducted a study of thirty supply chain management courses offered by AACSB accredited universities and identified fourteen key areas in those courses. Reverse logistics/green issues was one of the key areas listed. Roome (2005) reported on a Sustainability and Supply-Chain Management residency (module) offered by OneMBA, a consortium of five MBA programs located in Hong Kong, Brazil, Mexico, Europe and the U.S. This module used three different types of pedagogy: (1) Lectures, (2) Experiential learning (cases, exercises, projects, and role playing), and (3) Visits to companies. We believe that our Supply Chain & Operations Management program is unique with its emphasis on sustainability throughout the curriculum. We share Doksai's (2010) belief regarding business schools being able to attract more students if they offer environmental courses.

Our Supply Chain & Operations Management program covers the breadth of topics in supply chain management, including sustainability. Our Supply Chain & Operations Management program also has included experiential exercises in sustainability, but unlike the studies reported by Rudell (2011) and Bates, Silverblatt, and Kleban (2009, 2010), neither are we preparing our students primarily for green collar jobs, nor are we in the process of focusing exclusively on green in our major. Most of our graduates work for companies on our advisory board. Although most of those companies engage in green activities, advisory board members want us to prepare our students primarily in the fundamentals of supply chain management and then to provide our students with environmental awareness. Over the last five years, we have not placed any of our Supply Chain & Operations Management students in positions focused solely on green, sustainability or environmental management. Therefore, the intent of our program is to provide students with a solid knowledge of supply chain management concepts augmented with sustainability decision-making tools that they could use, for example, when sourcing products, designing production and warehousing facilities, and selecting projects.

<u>Using AHP for Supplier Selection and Other Multi-Criteria Decisions</u>

The analytic hierarchy process (AHP) was developed by Saaty (1999). AHP was designed to solve multi-criteria problems and requires a decision maker to provide judgments about the relative importance of each criterion and to specify a preference for each decision alternative using each criterion. The result is a priority ranking of the alternatives based on the preferences of the decision maker (Anderson, Sweeney, Williams, & Martin, 2008). AHP has been used in a wide variety of supply chain management problems in the areas of information system project selection (Lee & Kim, 2000), business process improvement project selection (Kendrick & Saaty, 2007), selecting a nonprofit for donation (Ramirez & Saraoglu, 2011), and R&D project selection (Meade & Presley, 2002). Kendrick and Saaty (2007) discussed the use of AHP to select a project portfolio based on the alignment of those projects with the four perspectives of the balanced scorecard (financial, customer, operational, and human resources).

<u>In-Class Exercise Using AHP for Supplier Selection</u>

The possibilities for triple bottom line selection problems in supply chain management are numerous; for example, selecting a new supplier, locating a new plant or warehouse, selecting a smoking cessation program, selecting a wastewater treatment option, etc. Each of the aforementioned projects will affect economic performance, environmental performance within or outside of the facility, and social performance (effects on employees or the community). The exercise described below analyzes the selection of a new supplier to replace a current hazardous material used in the manufacture of a company's product. An explanation of the supplier selection criteria follows:

1. Net Present Value (NPV) includes cost increases and/or decreases in purchase cost, transportation costs, handling costs, landfill costs, etc. Positive values of NPV indicate improved performance.

2. % increase / decrease in hazardous waste: Positive values indicate an increase in the % sent to the landfill, and negative values indicate a reduction in the % send to the landfill. Therefore, negative values indicate improved performance.

3. % reduction in lost workdays: We will assume that none of the alternatives considered will increase lost workdays. Therefore, higher positive values indicate improved performance.

4. The ability to increase the diversity of the supply base: We may use a surrogate measure for this, e.g., the number of female and minority employees at the supplier. Alternatively, we may use a qualitative scale of 1 – 100 to rate the diversity of the supplier. Here, we assume that we use the qualitative scale; therefore, higher positive values indicate improved performance on diversity.

As shown in Table 1, the criteria focus on economic, environmental, and social performance objectives.

Table 1: Estimated Supplier Performance on the Criteria

Criterion	Supplier 1	Supplier 2	Supplier 3
1) NPV	-$100,000	$25,000	$-10,000
2) % increase / decrease in hazardous waste	-5%	-6%	-3%
3) % reduction in lost workdays	4%	2%	2.5%
4) Diversity of supply base	80	60	65

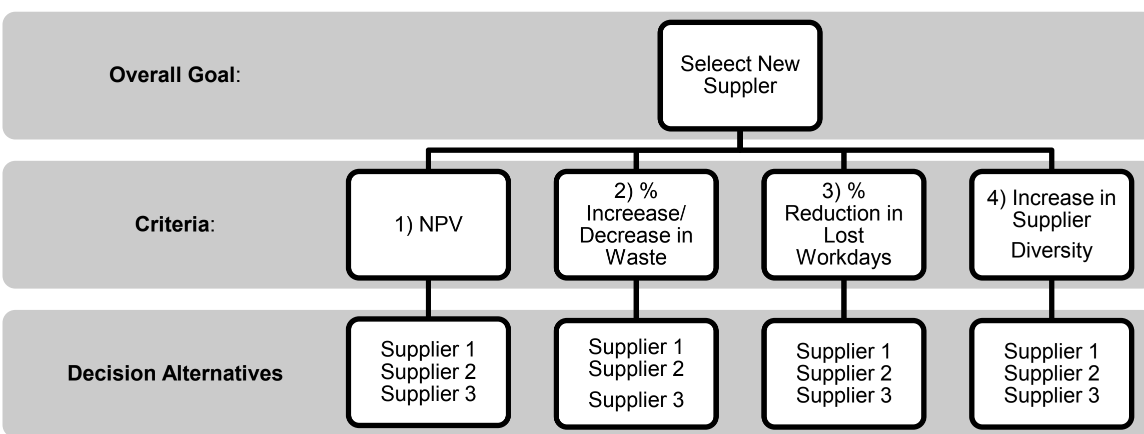
This table shows estimated supplier performance for all three suppliers on the four criteria considered.

Supplier 2 performs best on net present value (NPV), followed by Supplier 3 and then Supplier 1. Supplier 2 performs best on decrease in hazardous waste, followed by Supplier 1 and then Supplier 3. Supplier 1 performs best on percent reduction in lost workdays, followed by Supplier 3 and then Supplier

2. Supplier 1 is rated the best for its diversity, followed by Supplier 3, and then Supplier 2. Clearly, no supplier performs best on all four criteria, hence the need for a multi-criteria approach. Next, we follow the steps in AHP as described in Anderson et al. (2008):

Step 1: Develop a graphical representation of the problem in terms of the overall goal, the criteria, and the decision alternatives. This graph illustrates the hierarchy of the problem: the overall goal, the criteria and the decision alternatives. The graphical representation of the problem is shown in Figure 1.

Figure 1: Graphical Representation of the Supplier Selection Problem



There are four criteria and three decision alternatives. Note: An alternative approach when developing this figure could be to add an additional level of categories of selection criteria, e.g., economic, environmental and social performance above the individual criteria (similar to the approach taken by Kendrick & Saaty, 2007). However, this approach adds to the complexity by requiring more pairwise comparisons and additional calculations.

Step 2: Establish priorities for the criteria. Here, the supply manager must specify how important each criterion is relative to each other criterion. We use a scale from "1" to "9" as shown in Table 2. Using this scale, we perform pairwise comparisons of the criteria.

Table 2: Comparison Scale for the Importance of the Criteria

Verbal Judgment	Numerical Rating
Extremely more important	9
Very strongly more important	7
Strongly more important	5
Moderately more important	3
Equally important	1

This table shows the numerical ratings to be used when making comparisons. Note: Intermediate values are possible, e.g., strongly to very strongly more important would receive a numerical rating of 6.

We need to perform six comparisons for the four criteria as shown in Table 3. We list which of the two criteria is more important, a verbal description of how much more important that criterion is, and a numerical rating of that importance.

Table 3: Pairwise Comparisons of Criteria

Pairwise Comparison	More Important Criterion	How Much More Important	Numerical Rating
Criterion 1 – Criterion 2	Criterion 1	Extremely	9
Criterion 1 – Criterion 3	Criterion 1	Strongly	5
Criterion 1 – Criterion 4	Criterion 1	Moderately	3
Criterion 2 – Criterion 3	Criterion 3	Equally to moderately	2
Criterion 2 – Criterion 4	Criterion 4	Moderately to strongly	4
Criterion 3 – Criterion 4	Criterion 4	Moderately	3

This table lists each pair of criteria, which criterion is more important and the numerical rating of that importance.

Step 3: Complete the pairwise comparison matrix for the criteria. We take the values from Table 3 and start to fill in the initial values of the pairwise comparison ratings in the "Initial Values" panel of Table 4. For example, Criterion 1 was described as extremely more important than Criterion 2. Therefore, we list a "9" in the table at the intersection of the row corresponding to the favored criterion (Criterion 1) and the column corresponding to Criterion 2. We do not need to compare a criterion to itself (we automatically enter a value of "1" in the row and column corresponding to that criterion). Therefore, each cell of the diagonal in the table will receive a value of "1."

Next, we complete the pairwise comparison matrix for the criteria in the "Final Values" panel of Table 4. To show how these values are obtained, consider the numerical rating of "9" for the comparison of Criterion 1 – Criterion 2. We entered a "9" in the cell at the intersection of the row for Criterion 1 and the column for Criterion 2. At the intersection of the row for Criterion 2 and the column for Criterion 1, we enter the reciprocal of "9" = "1/9." We do this for each of the initial values listed in Table 4.

Step 4: Synthesization. We use the final values of the pairwise comparisons to calculate the priority of each criterion in terms of the overall goal of selecting the best supplier. We use the following three-step procedure:

1) Sum the values in each <u>column</u> of the "Final Values" panel of Table 4. These sums are shown in the "Column Sums" panel of Table 4. Note: We use Excel and carry all values to three decimals when summing the values.

2) Divide each rating value in the "Columns Sums" panel by its sum to derive the normalized pairwise comparison matrix (shown in the "Normalized Ratings" panel of Table 4).

3) Average the values in each row of the "Normalized Ratings" panel of Table 4 to derive Table 5 (Average of the Row Values of the Normalized Ratings).

Table 4: Pairwise Comparison Matrix of Criteria

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Initial Values:				
Criterion 1	1	9	5	3
Criterion 2		1		
Criterion 3		2	1	
Criterion 4		4	3	1
Final Values:				
Criterion 1	1	9	5	3
Criterion 2	1/9	1	1/2	1/4
Criterion 3	1/5	2	1	1/3
Criterion 4	1/3	4	3	1
Column Sums:				
Criterion 1	1.000	9.000	5.000	3.000
Criterion 2	0.111	1.000	0.500	0.250
Criterion 3	0.200	2.000	1.000	0.333
Criterion 4	0.333	4.000	3.000	1.000
Sum	1.644	16.000	9.500	4.583
Normalized Ratings:				
Criterion 1	0.608	0.563	0.526	0.655
Criterion 2	0.068	0.063	0.053	0.055
Criterion 3	0.122	0.125	0.105	0.073
Criterion 4	0.203	0.250	0.316	0.218

The first panel of this table shows the initial values of the pairwise comparison ratings based on the preferred criterion. The second panel shows the final values of the pairwise comparison ratings. The third panel shows the column sums. The fourth panel shows the normalized ratings. For example, looking at the column for Criterion 1, we see that 1.000/1.644 = 0.608, 0.111/1.644 = 0.068, etc.

Table 5: Average of the Row Values of the Normalized Ratings

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Avg. (Priority)
Criterion 1	0.608	0.563	0.526	0.655	0.588
Criterion 2	0.068	0.063	0.053	0.055	0.060
Criterion 3	0.122	0.125	0.105	0.073	0.106
Criterion 4	0.203	0.250	0.316	0.218	0.247

This table shows the averages across each row (priorities for each criterion).

As shown in Table 5, synthesization provides the priority of each criterion based on the average values (shown in the last column). Criterion 1 is most important, with a priority of 0.588. Criterion 4 is second, with a priority of 0.247. Criterion 3 is third, with a priority of 0.106. Criterion 2 is least important, with a priority of 0.060. Step 5: Check the consistency of the pairwise comparisons. Pairwise comparisons should be consistent. For example, if we look at the final pairwise comparisons in Table 4 (in the "Final Values" panel), we see that the Criterion 4 – Criterion 2 comparison had a rating of "4" (Criterion 4 was rated as moderately to strongly more important). The Criterion 1 – Criterion 4 comparison had a rating of "3" (Criterion 1 was rated as moderately more important). Therefore, the comparison of Criterion 1 to Criterion 2 should have a numerical rating of 4 X 3 = 12. However, this comparison shows a rating of "9" and is inconsistent. How to calculate the overall measure of inconsistency across all pairwise comparisons requires determining a consistency ratio. A consistency ratio of 0.10 or less is considered acceptable. If we calculate a consistency ratio greater than 0.10, we must review and revise the initial values of the pairwise comparisons in Table 4 (Anderson et al., 2008). Anderson et al. (2008) recommend approximating the consistency ratio with the following approach:

1) Multiply each value in the first column of the pairwise comparison matrix (Table 4 – "Final Values" panel) by the priority of the first item (Criterion 1), multiply each value in the second

column by the priority of the second item (Criterion 2), multiply each value in the third column by the priority of the third item (Criterion 3), multiply each value in the fourth column by the priority of the fourth item (Criterion 4), etc. These calculations are shown below. After we have repeated this process for all columns, we sum the values across the rows to determine a vector of values called the "weighted sum" (intermediate calculations using Excel are shown in Table 6).

$$0.588\begin{bmatrix}1\\1/9\\1/5\\1/3\end{bmatrix}+0.060\begin{bmatrix}9\\1\\2\\4\end{bmatrix}+0.106\begin{bmatrix}5\\1/2\\1\\3\end{bmatrix}+0.247\begin{bmatrix}3\\1/4\\1/3\\1\end{bmatrix}=\begin{bmatrix}2.399\\0.240\\0.426\\1.001\end{bmatrix}$$

Table 6: Weighted Sum Values

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Weighted Sum
Criterion 1	0.588	0.540	0.530	0.741	2.399
Criterion 2	0.065	0.060	0.053	0.062	0.240
Criterion 3	0.118	0.120	0.106	0.082	0.426
Criterion 4	0.196	0.240	0.318	0.247	1.001

*This table shows the intermediate values. For example, in the column under Criterion 1, 0.588 * 1 = 0.588; 0.588 * 1/9 = 0.065; 0.588 * 1/5 = 0.118; 0.588 * 1/3 = 0.196. The weighted sum value is the sum of the values in a given row.*

2) Divide the elements of the weighted sum vector above by the corresponding priority of each criterion.

   Criterion 1: 2.399 / 0.588 = 4.080
   Criterion 2: 0.240 / 0.060 = 4.000
   Criterion 3: 0.426 / 0.106 = 4.019
   Criterion 4: 1.001 / 0.247 = 4.053

3) Compute the average of the values above in 2). This average is denoted as λ_{max}.

$$\lambda_{max}=\frac{4.080+4.000+4.019+4.053}{4}=4.038$$

4) Compute the consistency index (CI) as follows (*n* = number of items being compared):

$$CI=\frac{\lambda_{max}-n}{n-1}=\frac{4.038-4}{4-1}=\frac{0.038}{3}=0.0127$$

5) Compute the consistency ratio, which is defined as CR = CI / RI, where RI is the consistency index of a randomly generated pairwise comparison matrix. The value of RI depends on the number of items being compared. Using the table provided on p. 678 of Anderson et al. (2008), RI = 0.90 for *n* = 4.

$$CR=\frac{CI}{RI}=\frac{0.0127}{0.90}=0.0141$$

   Given that the consistency ratio is less than or equal to 0.10, we consider this level of consistency acceptable.

Step 6: Perform the other pairwise comparisons to determine the priorities for each supplier alternative using each of the criteria. We use the scale shown in Table 7 to express pairwise comparison preferences for each supplier for each of the four criteria.

Table 7: Comparison Scale for the Preference of Each Decision Alternative

Verbal Judgment	Numerical Rating
Extremely preferred	9
	8
Very strongly preferred	7
	6
Strongly preferred	5
	4
Moderately preferred	3
	2
Equally preferred	1

This table shows the numerical ratings to be used when making comparisons. Note: Intermediate values are possible, e.g., strongly to very strongly preferred would receive a numerical rating of 6.

For brevity, we summarize the pairwise comparisons for each criterion in Table 8. For example, if we look at the original data in Table 1, we see that using Supplier 1 leads to a net present value of -$100,000 and using Supplier 2 leads to a net present value of $25,000. Clearly, Supplier 2 is preferred on this criterion (NPV). How much is Criterion 2 preferred? That answer depends on the subjective judgment of the supply manager. For example, the supply manager may assign a value of "9" for extremely preferred.

Step 7: Synthesize each of the pairwise comparison matrixes for each criterion from the previous step.
We follow the three-step procedure specified previously for synthesization, i.e., we would take the values for Criterion 1 (Table 8) and perform the synthesization calculations demonstrated previously. These calculations would provide the average row values (priorities) for each supplier on Criterion 1. After that, we need to check the consistency of the pairwise comparisons for Criterion 1. Assuming that the consistency ratio was less than or equal to 0.10, we repeat the three-step procedure and check the consistency ratios for the remaining three criteria. Here, we assume that we checked the consistency ratio for each criterion, and each consistency ratio was acceptable (CR ≤ 1.0). The averages of the row values (priorities) from the synthesization three-step procedure, similar to the last column of Table 5, are shown in Table 9.

Table 8: Criteria Pairwise Comparison Matrix

	Supplier 1	Supplier 2	Supplier 3
Criteria 1:			
Supplier 1	1	1/9	1/5
Supplier 2	9	1	2
Supplier 3	5	1/2	1
Criteria 2:			
Supplier 1	1	1/2	3
Supplier 2	2	1	4
Supplier 3	1/3	1/4	1
Criteria 3:			
Supplier 1	1	5	3
Supplier 2	1/5	1	1/2
Supplier 3	1/3	2	1
Criteria 4:			
Supplier 1	1	4	3
Supplier 2	1/4	1	1/2
Supplier 3	1/3	2	1

This table shows the preference ratings for each pairwise comparison on all four criteria.

In Table 9, we see that Supplier 2 is the preferred alternative based on Criterion 1 (0.615), Supplier 2 is the preferred alternative based on Criterion 2 (0.557), Supplier 1 is the preferred alternative based on Criterion 3 (0.648), and Supplier 1 is the preferred alternative based on Criterion 4 (0.623). No supplier is the clear favorite; therefore, one more step is needed as described below.

Step 8: Develop an overall priority ranking for the three alternatives. In this step, we weight each supplier's priority (Table 9) by the corresponding criterion priority (last column of Table 5) as follows:

Overall Priority of Supplier 1:
0.588(0.066) + 0.060(0.320) + 0.106(0.648) + 0.247(0.623) = 0.281

Overall Priority of Supplier 2:

0.588(0.615) + 0.060(0.557) + 0.106(0.122) + 0.247(0.137) = 0.442

Overall Priority of Supplier 3:
0.588(0.319) + 0.060(0.123) + 0.106(0.230) + 0.247(0.239) = 0.278

Based on the overall priorities above, Supplier 2 is preferred, followed by Supplier 1, and then Supplier 3.

Table 9: Average of the Row Values (Priorities) for Each Supplier for Each Criterion

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Supplier 1	0.066	0.320	**0.648**	**0.623**
Supplier 2	**0.615**	**0.557**	0.122	0.137
Supplier 3	0.319	0.123	0.230	0.239

This table is a result of synthesizing the ratings for each criterion contained in Table 8 and combining those values into a single table.

SUMMARY

The goal of this paper was to demonstrate an in-class exercise using (AHP) for analyzing supplier alternatives based on triple bottom line criteria. We presented triple bottom line criteria along with performance metrics for each criterion. To use AHP, the decision maker (supply manager) had to compare criteria to each other to determine which were more important. Then, the decision maker had to compare the performance of different decision alternatives (suppliers) on each criterion. The outcome of the AHP process was an overall ranking of the three supplier alternatives. The benefits of this exercise follow: (a) students learn about triple bottom line metrics, (b) students learn how to rate the importance of those metrics when making a decision and (c) students learn how to apply a multi-criteria decision-making technique. To teach AHP to our students in this course, we plan to provide them with a copy of the exercise contained in this paper along with the Excel spreadsheet used to perform the calculations. One possible limitation is the difficulty of adapting this exercise to problems with different parameters (e.g., a different number of criteria and/or a different number of suppliers). Our future research will assess this difficulty by requiring students to solve a problem with different parameters. In addition, we plan to require students to apply this AHP approach to a real-world scenario in which they have to work with a supply manager to make such a decision.

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