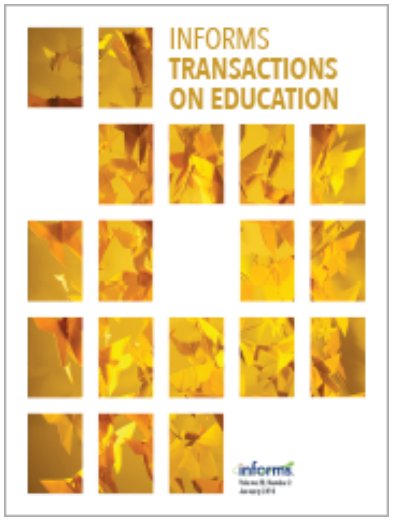

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Embedding a Sustainability Module Into Quantitative Business Courses

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Business schools face pressure to incorporate sustainability and ethics into curricula, not only by offering single-themed classes but also by including these topics in existing classes. We embed a stand-alone module, sustainability and supply chain management, into two quantitative courses, the graduate core operations class and an undergraduate concentration class in management science. We develop this module to provide students the background and tools to analyze energy usage and resultant greenhouse gas (GHG) emissions for a product or process. Students research a supply chain, use carbon auditing software, and make recommendations for improvement. To answer the research question of whether students perceive the module as useful and objective we perform an exploratory survey ($N = 76$). We find that students are engaged and consider delivery as unbiased. In short, this module adds value to the learning experience and can be integrated into classes without extensive instructor preparation. Readers may freely download all supporting materials for use in their own courses. More generally, our approach could prove useful in developing modules on other sustainability subtopics to place into quantitative courses, so as to support the relationship between analytical and qualitative approaches to decision making, especially when those decisions involve ethical or environmental issues.

Key words: teaching production/operations management; teaching supply chain management; teaching modeling; sustainability; GHG emissions
History: Received: October 2011, accepted: January 2012.

Introduction

While sustainability has always been an important topic, it is only since the end of the 20th century that it has received mainstream attention and, in turn, gained the attention of corporations and higher education. In particular, business schools are being asked by industry leaders and accreditors to incorporate ethics and sustainability into undergraduate and graduate curricula. Fisher and Bonn (2011) highlight the business community's desire to incorporate sustainability into its practices, but report that alumni of business programs do not feel they had learned the necessary skills to do so. In 2005, the United Nations declared 2005 to 2014 the Decade of Education for Sustainable Development (UNESCO 2005). While not providing direct standards for capturing "sustainability," the Association to Advance Collegiate Schools of Business (AACSB), the largest accreditation body for business schools, does encourage the inclusion of sustainability in curricula and even provides a Resource Center to facilitate the process (AACSB 2011). Beyond formal accreditation, many schools are trying to establish bona fides with such entities as the United Nations Principles for Responsible Management Education (PRME) initiative (UNPRM 2007) and the Aspen Institute's Beyond Grey Pinstripes program (Aspen Institute 2011a).

As emphasized by Carewa and Mitchell (2008), sustainability is an emotionally charged word that means different things to many people. Webster's dictionary defines sustainable as "able to keep in existence, maintain." Based on this, our definition of a sustainable firm shall be one that is able to produce and deliver its goods or services for the foreseeable future without causing degradation.

The College of Business at San Francisco State University (SFSU) has been at the forefront of including sustainability into the business curriculum at both undergraduate and graduate levels as the university's mission includes "social and cultural awareness" (SFSU 2011). Aspen Institute, in its annual evaluation of MBA programs, granted San Francisco State's MBA program a worldwide ranking of 16th (Aspen Institute 2011b). Both degree programs include a mandatory course dedicated to ethical and environmental issues. However, experts such as Holt (2003) and Shriberg (2002) suggest it is necessary to also present sustainability in traditional core and

discipline classes. In particular, we consider doing so within the graduate operations core class (BUS786) and the management science class (DS601), an undergraduate departmental elective. Both are taught as quantitative classes.

At first glance, use of quantitative modeling might seem an odd fit for a module on sustainability. In fact, quantitative modeling can assist in justifying sustainability initiatives; for instance, King and Lenox (2002) and Klassen (2000) demonstrate how operational improvements can both increase profitability and decrease environmental impact. Drake et al. (2011) emphasize the importance of reinforcing the responsible use of quantitative models in the ethical decision making process. Yet too often sustainability and ethics are considered only the domain and the responsibility of the "softer" disciplines.

In this paper, we describe a module to introduce students to a facet of sustainability in the context of supply chain management. We first consider current mainstream teaching approaches, and review extant literature and the challenges faced. We next present our approach, describing the development and delivery of the module in more depth. We introduce the survey that addresses the research questions as to whether students find the module to be useful and unbiased; additionally, it records prior exposure to sustainability within the curriculum. We then document survey results and lastly summarize our experiences and their pedagogical implications, and suggest steps for further action.

Background

Shortcomings of Current Approaches

The inspiration for this project is the shortage of existing teaching tools for sustainability within mainstream textbooks for quantitative modeling and analysis. A perusal of popular current operations management (Heizer and Render 2008, Stevenson 2009) and supply chain management (Bozarth and Handfield 2007, Chopra and Meindl 2009) textbooks shows a modest emphasis on sustainability. The standard approach appears to be defining terms, introducing vocabulary, and then providing a few vignettes on companies that have improved some aspect of their environmental or social performance. No analytical methodologies are presented. Thus, while students are made aware of sustainability content, they are not given the tools to perform even a rudimentary quantitative analysis. We reviewed recent editions of two popular quantitative methods textbooks (Taylor 2006, Ragsdale 2010) and found no mention of sustainability.

The need for competent sustainability analyses can be seen when considering stories and marketing campaigns that have received media coverage. One of the problems that plagues many sustainability efforts is a lack of clear definitions, standards, and metrics (Bustillo 2009). For example, the size of a company's carbon footprint varies dramatically depending on how far back its supply chain is traced, as with Dell Computer's disingenuous claim to having become a carbon-neutral company; its analysis does not include the more significant processing and transportation emissions of upstream suppliers (Ball 2008).

Another problem concerns the use of overly simplistic measurements. "Food miles," the distance food travels from the farm to the retailer, fails to take into account different transport modes and efficiencies of scale. For example, Lebel and Lorek (2008) determine that while grass-fed lamb shipped by water may travel half the globe to reach British consumers, GHG emissions are lower compared to that from sheep raised in UK feedlots. Likewise, many studies (Browne et al. 2005, van Hauwermeiren et al. 2007, Cholette and Venkat 2009) show that the journey from the retailer to the consumer can contribute the most to a product's overall supply chain emissions. Nicholson et al. (2011) show that focusing solely on reducing the distance travelled for raw milk negatively impacts the overall efficiency of the supply chain, as raw milk is both a finished good and an intermediate product within the dairy network. Yet the concept of "food miles" has received sufficient popular acceptance that UK supermarket chain Tesco now labels much of their grocery offerings with this metric.

It is understandable that an introductory text would not address such nuances. Yet the basis of this paper and the motivation for the underlying curricular developments described herein is that sustainability teachings need to be addressed within the core curriculum from a quantitative angle. It is imperative that more people understand and are trained to apply analytical methods to solving these problems.

Literature Review

Given the lack of emphasis in mainstream textbooks, we peruse the literature on how others approach teaching sustainability at the university level. Brunton (2006) gives extensive background on the need for sustainability in higher education. Brunton outlines the implications and challenges for business schools. Christensen et al. (2007) provide a survey of the *Financial Times* 50 top-rated business schools, analyzing their approaches to teaching ethics, corporate social responsibility, and sustainability. They find that over half these schools require at least one course which covers one or more of these topics. Fisher and Bonn (2011) survey published sustainability offerings at Australian universities and find that the availability is limited.

Several contributions in the literature focus on how to *categorize* pedagogical efforts in sustainability. Lourdel et al. (2005) present a cognitive mapping for the different aspects of this complex subject. They propose a multidisciplinary approach, replete with a method of evaluation for measuring student retention. Stubbs and Cocklin (2008) consider how sustainability is presented in MBA programs, either in an eco-centric manner, which is often in conflict with another approach, the neoclassical economic viewpoint. They not only consider a hybrid of the two but also emphasize that students should learn to understand and reconcile differing perspectives.

A few researchers envision frameworks for the overall program. Rusinko (2010) defines a matrix considering first whether the material delivery is discipline-specific or cross disciplinary and then whether material is embedded into the existing curriculum or if new classes, such as an environmental capstone seminar, are created. From their experiences with Lund University, Lidgren et al. (2006) create a systemic view of an institution's progress, detail the barriers to creating and implementing sustainability curricula, and propose appropriate interventions. Jabbour (2010) specifically addresses business schools in a curricular redesign and proposes a structure that encompasses more than the curriculum, also considering the creation, diffusion, and adoption of environmental knowledge. Ceulemans and De Prins (2010) provide a teacher's manual to train instructors on incorporating sustainable development into existing courses throughout the curriculum, known as horizontal integration.

Many of these works either directly or indirectly consider whether it is better to deliver materials in dedicated classes or to embed them in core classes. Lourdel et al. (2005) argue that a single supplemental sustainability class for engineers is insufficient. Survey results from Holt (2003) suggest discipline-specific modules improve student awareness more than generic modules. Such a question may be moot, as it seems likely that both approaches are needed. Shriberg (2002) maintains that not only are sustainability electives important to offer, but also that sustainability education must additionally be incorporated into core courses. Vanderburg (1999) investigates the extent to which sustainability is integrated into engineering education in North America. Pearce and Ahn (2010) provide an overview of recent efforts to incorporate sustainability into engineering curricula, as well as strategies for doing so. Bridges and Wilhelm (2008) provide an extensive discussion of how sustainability is addressed in marketing programs.

While many of these efforts are germane to a longer-term redesign of the university experience, we needed an immediate, pragmatic approach. We particularly study papers considering sustainability from a more limited, directed standpoint, especially as applied to analytic classes. Even proponents of cross-disciplinary, revolutionary programs such as Rusinko (2010) recognize that sustainability is often first addressed at a university through evolutionary means, namely through integration of a new module into an existing discipline-specific class. Rusinko (2005) incorporates sustainability into discussion of quality management, a topic that is covered in both traditional management and operations classes. In the exercise, students analyze a company's sustainability practices and apply quality management theory to improve the practices. In the process, students gain insight into the complexity of sustainability and become critical consumers of business information on sustainability. Boks and Diehl (2006) infuse sustainability into a graduate-level industrial design class; citing potential resistance from instructors and students, they provide practical advice. Walker et al. (2009) experiment with an online operations management class focused on purchasing.

Whether engaged in restructuring a program or in more modest improvements, many of these researchers address an important aspect of including new material: assessing its efficacy. Holt (2003) performs a multi-year longitudinal study of Middlesex University students from social science and business programs, not only measuring knowledge gained but also how subjects' attitudes toward environmental and social issues changed over the course of their studies. Cordano et al. (2003) measure the change in environmental sensitivity in undergraduate business students after a dedicated course, and find statistically significant increases. Hayles and de la Harpe (2007) analyze the complexity of student understanding of sustainability and show that students whose initial understanding was less sophisticated were more likely to gain from instruction in sustainability. Ryu and Brody (2006) assess post-class behavior and claim that after graduate students perform an environmental analysis, they tend to have a smaller ecological footprint. Jabbour (2010) moves beyond assessing student knowledge and includes the school itself, such as the generation of relevant research.

Challenges for Our Classes

Although others, such as Lidgren et al. (2006) and Lozano (2006), have thoroughly documented general challenges to embedding sustainability into the curriculum, we present some that are particularly relevant to our university and have influenced the module's design and delivery. First, both graduate and undergraduate students at the College of Business come from a variety of backgrounds. The University's emphasis on cultural and ethical awareness

encourages other departments and colleges to offer courses that focus on social and environmental issues. Therefore, our students may or may not have already been introduced to these topics. We felt our approach must not only accommodate this diversity of previous experiences, but also consider a priori attitudes.

While some students may have taken electives in sustainability, those students are more likely to be predisposed to learning about social and environmental issues. Benton (1994) finds that business students do not necessarily have less environmental knowledge than nonbusiness students. However, he shows "they do appear to care less, they do indicate less willingness to act in a proenvironmental manner." In contrast, College of Business students are not able to opt out of most upper division classes within either the business core curriculum or their area of specialization. An instructor teaching sustainability in this type of class is more likely to encounter skepticism about the topic because students have not self-selected into it. For example, Ridener (1999) shows that business students are less influenced by an environmental education program than are other majors. Holt (2003) works with a similarly diverse pool of students and finds that business students are less sustainability-focused than students in the social sciences. This can require a very different approach to the topic than in an elective where there may be greater uniformity of opinion. While some instructors might perceive this as a liability, we chose to see this as an advantage: Students and instructors alike must be able to present work and defend their conclusions to a broad audience, not just one predisposed to be favorable.

Our view is similar to that expressed in Walker et al. (2009), who posit that sustainability causes are better advanced by not merely, as they state, "preaching to the choir." Kearins and Springett (2003) take an analogous approach; they teach students to think reflexively and critically about sustainability and about business sustainability practices. Their methodology is framed in terms of management critical theory. Drake et al. (2011) lead the students through an ethical decision-making methodology after they have performed an optimization of a logistical network; students re-evaluate the recommendations that arise from considering only the mathematical solution. Stubbs and Cocklin (2008) attempt to shift students' mindsets to view sustainability from different perspectives by introducing students to multiple frameworks and methodologies. While we are certainly trying to enhance students' cognitive learning, likewise a goal of Shephard (2008), we also aim to attain affective changes: by teaching students to think critically and analyze problems objectively, we may change students' values by causing them to critically re-think "truths" they may have once believed. Shephard (2008) states such acts of reflection and analysis may then lead to shifts in attitude and behavior.

Students' wide ranging quantitative abilities can pose a challenge. Operations management classes are contained within both the graduate and undergraduate core curricula, and students in both degree programs range in their mathematics and modeling skills. Such differences occur as well within a concentration class; students who have completed more concentration classes are likely to have more developed modeling skills than students from other departments or for whom this is their first concentration class. We need to design materials and activities to engage the students with less ability or experience while still challenging their more skilled peers.

Another concern is that the curriculum within these types of classes is already full. As discussed by Lidgren et al. (2006), instructors are often wary of adding new material or learning goals to an existing class. Our experience as instructors is that we are frequently asked to embed new requirements. Typically when a topic is added, other course material must be compressed, removed or de-emphasized to provide room. What can complicate the embedding process further is that the new topic must be well integrated with existing materials and teaching methods.

The last challenge we consider relates to the inherent nature of our classes. These courses deal with objective analysis and use data and models to support decision making. In order for sustainability to become an integral part of the class, and not seem a hastily grafted supplement, the material needs to be delivered in the same analytical context. As discussed previously, many mainstream textbooks, even ones that have substantive modeling and analysis, present only terminology and vignettes. Even pioneers such as Lourdel et al. (2005) measure engineering students' understanding of sustainability with respect to vocabulary recognition, not mastery of more complex concepts. Yet such a deeper mastery is needed, as shown by Hopkinsson and James (2010), who report on a survey of engineering professionals; respondents indicate that the most important task in education for sustainable development pertains to modeling and evaluating sustainable development performance, and the most valued skill is dealing with complexity.

Approach

Module Design

We create and deliver a stand-alone module that provides students the background and tools to objectively analyze a facet of sustainability for a product or

process. While many traditional topics in operations management, operations research, and other quantitative analysis classes can be taught with a sustainability approach, we select supply chain management (SCM). Others, such as Walker et al. (2009) and Drake et al. (2011) have used this topic to introduce ethical and environmental considerations. Supply chain management captures student interest and does not require extensive prerequisite knowledge or analytic skills, enabling such a module to have the potential to be embedded in a variety of classes. We select the graduate core operations class and the undergraduate concentration course in management science.

We next consider what facets of sustainability to embed within the module. As limited time precludes detailed coverage of the myriad of social and environmental sub-topics, we focus on energy usage and greenhouse gas (GHG) emissions, often referred to as "carbon footprinting" by popular media. We select this sub-topic because it is newsworthy, has a large impact within most industries, and requires no chemistry or other specialized background knowledge to understand. Compared to the other dimensions of a life cycle assessment, a basic GHG emissions analysis has simple data needs. As we shall see, results from such an analysis can be significant and can vary greatly with underlying assumptions, in turn motivating discussion.

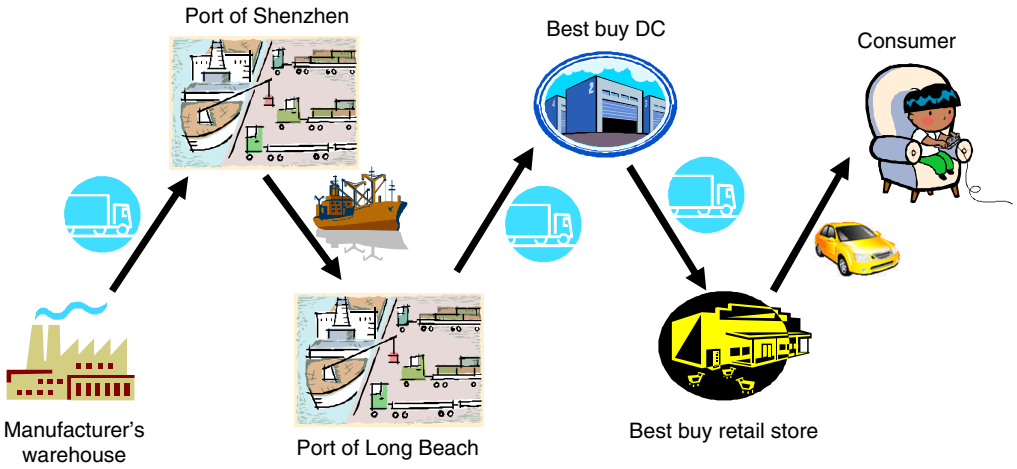
To be usable within different classes, the module must not only address the challenges presented previously, but also be self-contained. All student and instructor materials necessary to support the module's delivery must be available without great expense. These materials must not assume use of a specific textbook. Even across sections of the same class, instructors often use different textbooks. Given its topical nature and the large number of professional societies and consultancies that support it and compete for attention, supply chain management is rife with terminology and buzzwords, many of which are synonyms. Care must be taken to avoid confusing or overwhelming students with a barrage of terms.

With this focus on energy usage within the supply chain, the development of the module has been supported with the financial assistance of a SEED grant from the Leonard Transportation Center at CSU San Bernardino. These awards are bestowed upon select projects that enhance education in transportation issues. This grant facilitated the development of the documents described below, including user testing by student assistants.

Documents. We developed a PowerPoint presentation to facilitate the delivery of the material in the classroom.[1] It is comprised of five sections, each 10 to 15 slides in length. The first three sections provide an overview of supply chains, sustainability and basic modeling techniques. As students have differing levels of prior exposure to sustainability concepts, the second section provides an introduction to several environmental and social issues and serves to remind students that even though they will focus on one facet, energy and greenhouse emissions, they need to remember that their recommendations may have broader ramifications. Students with prior class experience in these topics may be able to skim the sections. However, even veteran model builders would likely benefit from a review of the third section, as it covers nuances such as the tradeoffs in setting the frame, differentiating between data and parameters, and in the setting of assumptions. Furthermore, the slides are developed to lead to classroom discussion. For example, in the slides covering metrics, we encourage students to reflect upon how overreliance on a simple metric may be misleading. Likewise, as conclusions from students' analyses may lead to recommendations for action, we mention environmental policy and discuss the levels of regulation that may be appropriate to certain situations. The fourth section delves into a more detailed explanation of logistics, the management of goods through the supply chain. It ties the material from the prior sections together, as the logistical aspects such as temperature control, transport mode, utilization, and backhaul rates are presented along with the implications for energy usage and the resultant GHG emissions. We also provide an overview of the relative impacts of the different transport modes. For instance, airfreighting will be the most expensive mode both in financial and energy/emissions terms, but it is the fastest for long haul routes. We call attention to utilization and backhaul rates, as improvements to either will likely increase supply chain performance economically and environmentally. The last section prepares students to analyze the transport and storage activities within a supply chain. It introduces students to a case study, described below. To highlight the critical importance of transparency and assumptions, we present the wide range of results from several internet carbon-footprint calculators with respect to a simple, well-defined situation: a round-trip cross-country commercial flight. This comparison is not intended to denigrate the value of such analyses, but instead to reiterate the challenges associated with even a seemingly straightforward analysis.

[1] Files that accompany this paper can be found and downloaded from http://dx.doi.org/10.1287/ited.1120.0087. Proof of instructor credentials will be required for access to the solution guidelines.

Figure 1 Push View of the Outbound Logistics for the Wii Game Console



As the module involves active analysis, hands-on exercises have been developed. We provide three case studies, each representing a different supply chain. The first analyzes the supply chain for Nintendo's Wii game console. It embeds a tutorial for using a web-based software tool within the directions for building the outbound logistical model for delivering the game console. In this "learning by doing" approach students are directed to build a model of all stages of the outbound logistics, as shown in Figure 1, including the transportation link between the retail store and the consumer. In the questions that follow, students interpret the model results and consider alternate configurations. Lastly, a section of discussion points leads students to consider open-ended questions, such as whether the last transportation link should be included in the modeling frame and who should be responsible for reducing the energy usage and resultant emissions.

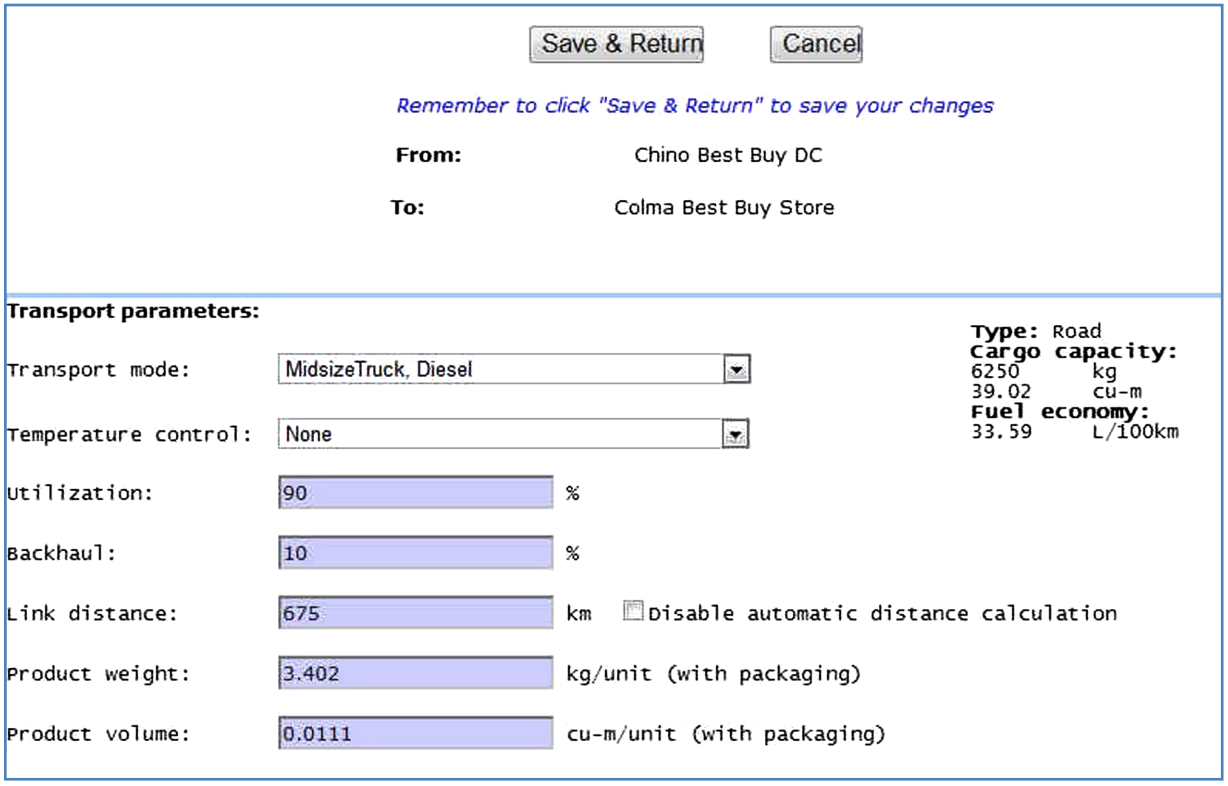
The slide deck is supported by a supplemental chapter of 15 pages, as some students may want access to the information in a textbook format. An additional annotated bibliography of relevant books, articles, and websites is provided for those wishing to delve further. Two other cases have been developed and tested by student assistants although they are not yet used in the classroom. One examines distribution methods for an imported bedding product. The other compares the relative emission profiles of local and global apple production and distribution, including dependence on seasonality, as discussed in Milà i Canal et al. (2007). All cases are supported by instructor materials, complete with solutions to questions when definitive answers are possible. As not every question has a single correct answer, suggestions for talking points are provided.

Software Tools. To analyze the energy usage and emissions from a supply chain, we needed to either create our own tool or use existing software. Given the limited timeframe, we opted for the latter and decided upon CargoScope, a web-based tool provided by Cleanmetrics (2011). CargoScope is available by subscription, at a per-student price equivalent or less than other simulation tools, such as those found at Harvard Business School's Publication website (HBSP 2012). CargoScope is not the only energy and emissions calculator available online, but it has the advantage of allowing for calculations to be adjusted by utilization and backhaul rates. It is also easily configured, reasonably transparent and well documented in both assumptions and architecture. CargoScope allows the user to create and specify a supply chain, with the model data residing on the user's computer in XML format for future reference and potential modification. Figure 2 depicts the Nintendo supply chain from a "pull" perspective: starting from the consumer and extending back towards the supplier. We depict this view, rather than the "push" view from Figure 1, as it is more appropriate for tracing the emissions impact of a single unit of the product.

Nodes in CargoScope represent either storage or processing stages, and the connections between nodes represent transportation links. For example, by

Figure 2 Pull View of the Wii's Outbound Logistics in CargoScope

Figure 3 Configuring the Transportation Link Between the DC and Store



checking the Chino Best Buy DC node and selecting "transport properties," the screen shown in Figure 3 will appear, representing the transport link from the DC (distribution center) downstream to the retail store. Figure 3 shows that this link has been configured so that a midsized diesel truck with no temperature control will travel the 675 kilometers to the store with a very high (90%) utilization rate, and that it then returns to the DC nearly empty (10% utilization). The student can opt to select a different transport mode or experiment with different rates. For example, were Best Buy to enter into the backhaul market with its trucking fleet, its backhaul rate should increase.

Once the student has created and customized the supply chain, CargoScope will calculate the energy usage and equivalent GHG emissions associated with a single unit of product. This analysis is presented for the overall supply chain and is also broken down by node and transportation link. For example, Figure 4 shows that the largest component of energy usage and resultant emissions from transporting a Wii game console is from the consumer making a short but dedicated trip to the store to purchase and bring home that console. Conversely, the long distance overseas journey from China represents a relatively small share of the total emissions.

Students are then asked to experiment with different aspects of this supply chain, and to observe the changes in the results. For example, if the consoles are air-freighted to California, overall energy usage

Figure 4 CargoScope's Calculation of Energy and Emissions

Analyze product network

Edit Node/Link Parameters

	NodeOrLink	Type	Mode	Time	Dist	Energy	F-Energy	Carbon
*	Colma Best Buy Store <TO> Pacifica Consumer	Transport	HondaAccord, Gasoline	0.01	10.00	67.71	0.00	4.689
*	Chino Best Buy DC <TO> Colma Best Buy Store	Transport	MidsizeTruck, Diesel	0.40	675.00	9.67	0.00	0.715
*	Port of Long Beach <TO> Chino Best Buy DC	Transport	MidsizeTruck, Diesel	0.05	80.00	1.21	0.00	0.089
*	Port of Shenzhen <TO> Port of Long Beach	Transport	Ship-LargeBulkCarrier, BunkerFuel	15.39	10260.00	3.16	0.00	0.244
*	Shenzhen Factory Warehouse <TO> Port of Shenzhen	Transport	MidsizeTruck, Diesel	0.01	20.00	0.30	0.00	0.022
*	TOTAL			15.86	11045.00	82.04	0.00	5.760

and emissions increases by a factor of 80. Likewise, if the consumer either combines this trip with hauling purchases from nearby stores or makes only a short detour to the store, the impact of that last link is reduced.

Module Delivery

Depending on the amount of class discussion generated, the slide deck should take two to three hours of class time to deliver, typically a week's worth of classes. In the three times this module has been used, it was presented within a 2.5-hour lecture. Students are then expected to follow the directions for the first case study and use CargoScope to build the Wii model, as well as address the additional questions before the next class, an exercise that typically takes at most two hours.

In the three classes where this module has been taught, students were either given time within a computer lab to work together, or the opportunity to do the analysis as an extra credit homework assignment. The next class would begin with an interpretation of the findings and a discussion of the more open-ended questions. The first part of the assignment is designed to test students' ability to comprehend and follow directions in building the base supply chain scenario and exploring alternate configurations. The open-ended questions, however, do not have a single set of right answers and require students to think analytically on their own and to defend their answer.

Once students have worked with a sample supply chain and have practiced using CargoScope, they form small teams, either through self-selection or as assigned by the instructor. The teams research and build the relevant portion of a supply chain for a product of their choice and then propose a realistic, cost-effective modification that is likely to reduce energy usage and emissions. We find students tend either to pick products from companies with which they have worked or have familiarity, or opt for a product that appeals to them as consumers; many teams investigate supply chains for coffee beans, beer, chocolate, apparel, and consumer electronics.

While CargoScope output is limited to energy and emissions analysis, we encourage students to estimate costs based on published rates for different modes of transport. It should be noted that such a cost analysis will be rudimentary. While reducing distance travelled or switching to a more efficient mode for a long-haul route will improve both the financial and sustainable aspects, there is not always such a direct relationship. Switching to an intermodal solution may reduce energy usage but typically entails additional links and increased handling costs. Negotiations, especially for high volume businesses or in regions with greater carrier competition, can dramatically affect costs. For instance, Drake et al. (2011) document that parcel delivery costs are determined by transit between somewhat arbitrarily defined zones and show how contracted rates can vastly differ. Drake et al. (2011) show that it is possible to define a delivery strategy that involves greater distances and entails more handling yet is still cheaper, although perhaps unethical. Such complications are not currently considered in our module.

This project further challenges the students, as they need to research their chosen product's supply chain. Detailed supply chain information is not always publicly available, and parameters such as utilization rates may not even be known by the company. Students are allowed to make assumptions; we require that assumptions must be explicit and reasonable. Lastly, teams give a brief class presentation about their supply chain and their recommendations for improvement. A side benefit is that students are exposed to many different supply chains and proposed solutions.

In total, the material and activities occupy two to three weeks of class time. While significant, the module's inclusion did not displace material from the existing class topics or create significant additional workload for the instructors. For example, the graduate operations class typically includes a team project with a classroom presentation, so the student-led supply chain analysis merely substituted for a different operations project. In the undergraduate class, the case study also substitutes for a previously used one. In short, our experience is that embedding the material is simple and nondisruptive.

Research Questions

As this is an experimental module, both instructors desired to measure the module's effectiveness and garner feedback for potential improvements. There are many dimensions to success for such a module. The most basic is whether students' awareness and recognition of sustainability issues increased. Lourdel et al. (2005) answered this through testing for vocabulary recognition. A more specialized measure would assess whether students improve their abilities to recognize and analyze a problem and determine a viable solution. Yet another facet would consider whether student behavior or attitudes towards sustainability have changed, as Ryu and Brody (2006) consider.

While we ultimately aim to develop and implement more sophisticated assessment of students' analytical skills, our present assessment efforts are modest and are restricted to capturing student perception of the module's usefulness and objectiveness as well as their prior exposure to the topic. Our concern with student perception is motivated by the challenges presented earlier: a class of students will have diverse

prior exposure to sustainability and perhaps different attitudes towards it. We first consider whether students perceive this module as useful.

One of the inherent attributes of a quantitative class is that students need to be able to perform an objective analysis and avoid or at least recognize bias. Our intent was to enable students to realize that supply chain sustainability issues rarely have a simple, single answer; often the desire for environmental improvement must be balanced with fiscal concerns. This philosophy is similar to that of Stubbs and Cocklin (2008) in their presentation of multiple frameworks to enable students to understand others' viewpoints. Thus, our second question pertains to whether students found the module's presentation to be balanced.

The last question concerns students' reported prior exposure to sustainability in their other classes. We ask this not only to better understand our students' background but also to get a ground-level view of where sustainability might be taught within the curriculum. We then combine these last two questions to record how students perceive our module's level of advocacy as compared to that of other classes that have significant sustainability content.

Survey Instrument. To address our research questions we administer an end-of-term survey, an assessment technique used by Boks and Diehl (2006) and Walker et al. (2009). While the survey instrument varies slightly between the two classes, the questions relevant to both are shown in Appendix A. These questions are purposefully kept brief to encourage survey participation. The default wording is for the graduate operations class (BUS786); different wording for the management science class (DS601) is bracketed. The survey was not formally pre-tested; we solicited informal feedback from three student assistants. Rather than asking students directly "was the module useful," we query indirectly through the question relating to the amount of class time dedicated to the module and the approach taken. We expect that if students perceived the module as less useful, they would have indicated that too much time was spent or that a different approach would have been appropriate.

Survey Implementation. We have delivered this module three times; twice by the same instructor in the graduate operations class, BUS786, in Spring 2010 and Fall 2010 and once in the undergraduate management science class, DS601, in Fall 2010. We administered the survey near the end of each class. In BUS786, the survey was distributed during the final exam, and students were asked to fill out the survey. In DS601, it was distributed during the formal course evaluations done at the end of the semester.

Given that this survey measures student opinion, we took the following precautions to minimize response bias. In both sections of BUS786 (75% response rate), students completed the survey after finishing the exam. Although some may have opted out for other reasons, it seems that most of the nonresponders simply ran out of time. While we might have avoided nonresponse bias by administering the survey at another time, one advantage of this timing is that student interaction is minimized during an exam period, increasing the likelihood that survey respondents are not influenced by their peers. In DS601, we obtained a 92% response rate. The advantage of administering the survey at the same time as course evaluations is that the instructor is absent and classroom interaction is minimal, so students are able to provide opinions without peer pressure or fear of professorial disapproval.

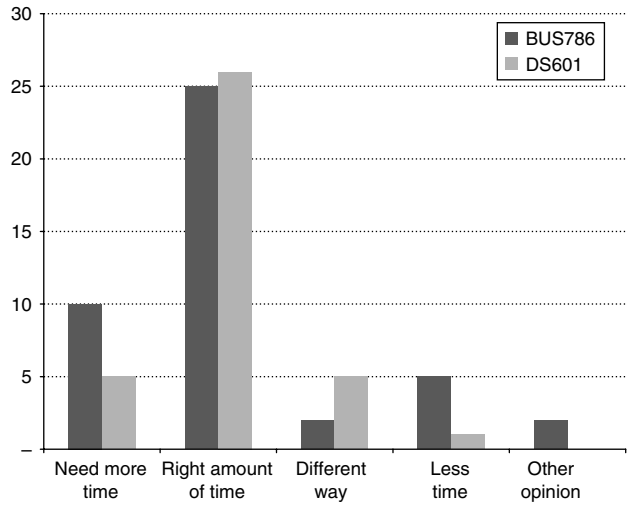
Results

We have 76 responses: 33 from DS601 and 43 from the two sections of BUS786. We aggregated the responses from BUS786; a comparison of the two sections showed only minor differences between sections on the dimensions that we consider below. Like Walker et al. (2009), we measure student perception of the module. We first ask about the level of coverage as we consider students' attitude toward sustainability. As this module represents material that was previously not covered in these classes, we were initially concerned that there might be some student resistance. Other BUS786 instructors are not currently using the module, and as course syllabi are a matter of public record, students could discover this lack of uniformity. As students in both the graduate and undergraduate degree programs are required to take a class focused on ethical and sustainability topics, might they perceive the module as redundant or unnecessary? We also explicitly ask whether sustainability should have been covered in a different way and provided an additional option for a write-in comment. Students could pick more than one answer to this question, although only a few did.

Figure 5 suggests that such concerns can be put to rest. The most common response from graduates and undergraduates alike is that the level of coverage is appropriate. Indeed, about a quarter of the graduate students desired more coverage. In both classes, under a fifth of the responses indicate either that the topic should be addressed differently or take less time. Students appear to agree with experts such as Shriberg (2002), who argue that this topic needs to be addressed beyond the mandatory ethics and sustainability class.

When we examined student perceptions on whether the material appeared to be taught with bias (Figure 6), students responded overwhelmingly

Figure 5 Student Perception of Amount of Coverage



that the material was presented in a neutral manner. We next compared our module to what students experienced in other classes. We asked students whether they have taken a class at SFSU that discussed sustainability issues, and, if so, to list the class(es). This is the first question where we observe significant differences between the graduates and undergraduate; while 65% of the graduate students report experiencing such content, only 30% of the undergraduates do. This divergence may be due to timing issues. The required ethics and sustainability course (BUS784) is a foundation class for the MBA program, and graduate students are likely to take foundation classes earlier. By contrast, the undergraduates often enroll in concentration classes before they take their required ethics and sustainability course (BUS682), a seminar that is typically taken in the final term.

We next tally the total number of reported exposures to classes with substantial sustainability content.

Figure 6 Student Perception of Presentation Bias

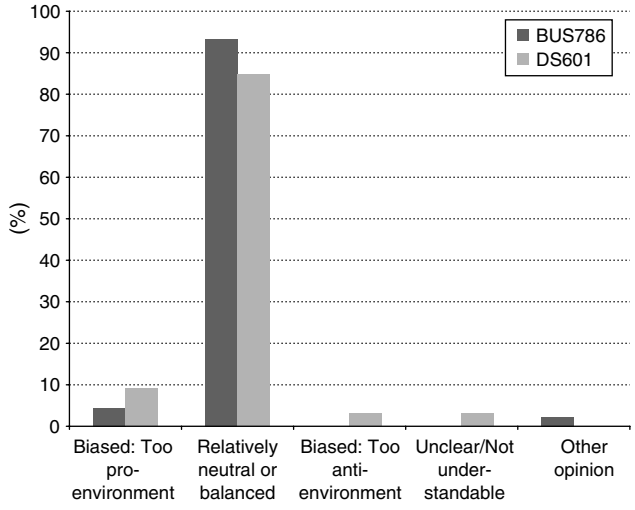


Table 1 Student Perception of the Degree of Advocacy for Sustainability in Graduate Business Classes

Compared to other classes, BUS786 had	BUS784 Specifically	All classes
MORE prosustainability	5	7
Same level of promoting sustainability	5	7
LESS prosustainability	14	17
Not sure	0	1
Other opinion	0	1
	24	33

A total of 33 such instances were reported by 28 graduate students, and only a few experienced more than one such class. Not surprisingly, the most cited class is the aforementioned BUS784, "The Political, Social, and Legal Environment of Business." Only a few other classes were recorded, and none received more than two mentions. While it is likely that sustainability may be featured in more advanced core and elective classes, most MBA students enrolled in BUS786 are still early into their studies. Table 1 shows the breakdown of the graduate students' assessment of the degree of advocacy in BUS786 compared to other courses; these students report that BUS786 has less of a prosustainability emphasis with respect to presentation of the material or recommended action. We might expect a dedicated class on sustainability and ethical issues to strongly promote them. We feel such advocacy has less benefit in our classes, which focus upon objective analysis.

Only 10 of the undergraduate students report experiencing substantial sustainability content in another class. Our small sample size and use of a concentration-specific elective precludes generalizing the experience to that of all undergraduate College of Business students, but we would have expected to find more undergraduates learning about sustainability in other classes at San Francisco State. One possible explanation could be the presence of a large number of transfer students who would have missed most of the lower division classes.

Conclusions

Pedagogical Implications and Benefits

Our exploratory survey results lead us to believe that this module can be viewed as a success. There are some differences in responses between students within the different classes, levels of the program, and instructors; however, students are engaged overall. Indications are that the module is delivered in an appropriate manner and timeframe, and that the presentation is perceived as balanced. Less than a third of students in the undergraduate class reported any significant classroom exposure to sustainability. Two thirds of the graduate students had experienced such content, although overwhelmingly only within

the one mandatory ethics and sustainability class. If these respondents' experiences do indeed mirror those of the student population, instructors in the College of Business may consider revisiting their class curricula. Given that many sustainability experts recommend the topic should also be embedded in core courses, not addressed solely within a dedicated course (Shriberg 2002, Holt 2003, Lourdel et al. 2005), we would be doing our students a disservice not to reconsider the curriculum.

Aside from the survey results, we also report the following ad hoc observations from teaching the module and interacting with the students. Students seemed more engaged with the sustainability-related course materials than with other topics. Within the graduate operations class, students appeared to put more effort into preparing and presenting the supply chain project than in past terms, when the final project comprised of analyzing and presenting a predefined case, even though the project's contribution to the final course grade remained unchanged. Certainly, the written deliverables evidenced more research and care. Some of the sentiments expressed by students mirrored those found by Walker et al. (2009); namely, the value students perceived from the module was not from gaining absolute knowledge about sustainability issues but acquiring the ability to make a difference at the margin, by performing a relevant analysis and suggesting appropriate changes. Students felt that they had been given the tools to make a difference, however incremental.

A concern for faculty in adding a new topic to a course is that other course material may have to be removed to make room. However, a common theme in quantitative modeling courses is the need to state assumptions and specify a modeling frame. The topic of sustainable supply chains interests students and does not require significant technical knowledge to analyze. As a consequence, it can be used to engage students and teach them the fundamentals of modeling and model framing. Furthermore, the process of developing a formal model forces students to consider many aspects of the system being studied. Making changes to the supply chain will have ramifications, sometimes unexpected, elsewhere within the chain. Situations are often multi-faceted. For example, it is undoubtedly a desirable goal to try to reduce greenhouse gas (GHG) emissions, but students must recognize that this may not be as easily done in countries experiencing strong economic growth and rising living standards.

Next Steps

There are several steps for future work. The first is to continue teaching the module in various courses at San Francisco State University. In addition, we are actively promoting the use of the module outside the University. A second goal is gathering more information about the students themselves. To gain insight into how students may encounter sustainability within the core business curriculum, we need to know how many semesters they have been enrolled and whether they transferred to SFSU from elsewhere. If we indeed find that undergraduate students do not generally learn about sustainability in courses outside of the one mandatory class taken in the final term, the College of Business should consider revising its core curriculum to give sustainability a more prominent presence across functional areas, a cause championed by both Shriberg (2002) and Cotgrave and Alkhaddar (2006).

Beyond investigating students' perceptions of the module, we plan to assess the module's efficacy. Such an assessment can be done on two fronts. The first is determining whether students are able to complete the analysis. The second is by administering paired surveys before and after the module to track changes in skills and attitudes, a modest version of the multi-year longitudinal study performed by Holt (2003).

In the longer term, we plan to improve the functionality of the underlying tools. While CargoScope has been a convenient solution, allowing us to develop and deliver the module without a huge investment in time or development costs, we would like to customize the functionality to better meet our pedagogical goals. The current web solution does not allow for the adding of new modes or adjusting the parameters. Additionally, we envision embedding cost functionality, so that students can compare financial as well as emissions differences between transportation solutions. We plan to develop and migrate to a spreadsheet-based solution. Not only will this allow for direct developmental control, including the opportunity for linkage to Excel's LP solver, but students could use the tool after course completion for future modeling endeavors without paying further access fees.

Lastly, we are encouraging others to embed similar modules in their courses. To this end, documents are available free of charge on the ITE website. Even if an instructor uses an alternate energy and emissions calculator, many of these materials can still be of use. While the absolute answers between different energy and emissions analyses will likely vary, the more general questions about building a model, making assumptions and interpreting results will continue to be relevant. Other courses focused on analytical methods could benefit from emulating our approach through developing and embedding modules that consider other aspects of sustainability. Just as quantitative models should be considered in context, especially when there may be significant ethical or environmental ramifications, the converse relationship holds: the understanding of and solution

to sustainability issues can be enhanced through effective use of quantitative analysis.

Supplementary Material

Files that accompany this paper can be found and downloaded from http://dx.doi.org/10.1287/ited.1120.0087.

Appendix A. Student Feedback on *Operations Analysis*: *BUS786* [Applied Management Science: DS601]

This is an optional, anonymous survey that will be used for considering improvements to the class. This is separate from the official San Francisco State survey you filled out earlier, and results do not go to the administration. It has *no* impact on your grade!

1. Two class periods focused on an aspect of environmental sustainability (the lecture and then the team presentations on doing a carbon footprint). What most closely matches your opinion about learning about sustainability in BUS786 [DS601]? *Circle ALL that match your opinion*

(1) We needed to spend **more time** on sustainability in *BUS786* [DS601]

(2) We covered sustainability in **about the right amount of time** in *BUS786* [DS601]

(3) We should have approached sustainability in a **different way** in *BUS786* [DS601]

(4) We should have spent **less time** on sustainability in *BUS786* [DS601]

(5) Other Opinion? Write in _____

2. Sustainability can be a more controversial topic than, say, *Capacity Planning or Inventory Management* [Linear Programming]. Opinions in the business and political world range widely on GHG Emissions/Global Warming concerns. In your opinion, was the material covered in class presented . . . . *circle* 1

(1) Biased: **too proenvironment** in presentation and/or recommended action?

(2) Relatively **Neutral** or **Balanced**

(3) Biased: **too anti-environment** in presentation and/or recommended action?

(4) The material was **Unclear**/Not Understandable

(5) Other opinion? Write in _____

3. Has sustainability been covered in any other classes you have taken in *the SF State MBA program* [at San Francisco State]? (Coverage means at least 20 minutes of class time was involved . . . i.e., it was not just mentioned in passing.)

circle 1 **YES NO**

If Yes, which classes? _____

If you answered "Yes" above, compare how sustainability was presented in *BUS786* [DS601] against the other class(es) *circle* 1

(1) *BUS786* [DS601] was **MORE prosustainability** in presentation and/or recommended action?

(2) *BUS786* [DS601] had about the **same level of promoting** sustainability

(3) *BUS786* [DS601] was **LESS prosustainability** in presentation and/or recommended action?

(4) **Not Sure**

(5) Other opinion? Write in _____

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