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Modeling the relationship between transportation-related carbon dioxide emissions and hybrid-online courses at a large urban university

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Abstract

Purpose – This paper aims to investigate the relationship between hybrid classes (where a per cent of the class meetings are online) and transportation-related CO_2 emissions at a commuter campus similar to San José State University (SJSU).

Design/methodology/approach – A computer model was developed to calculate the number of trips to campus for a student body similar to SJSU. Different scenarios considered the theoretical effectiveness of implementing a hybrid course system to reduce CO_2 emissions.

Findings – Increases in hybrid courses resulted in decreased student trips to campus and associated CO_2 emissions. The utility of such a relationship is demonstrated through a case study where the required increase in online class meetings needed to eliminate the need for an overflow parking lot is studied. Finally, preferential scheduling of online meetings can further reduce trips to campus.

Research limitations/implications – A limitation of the model is that student schedules are random. Future research could use actual student schedules to better model how online course delivery will affect trips to campus.

Practical implications – As today's universities struggle with financial pressure, online course delivery is being offered as a way to cope. This analysis provides an additional metric to evaluate online courses and includes other potential financial savings.

Social implications – Transportation contributes to local air pollution and emissions of heat-trapping gases. As universities move toward more sustainable behaviors, reducing automobile trips to campus can be seen as a priority.

Originality/value – To the authors' knowledge, this is the first attempt to model the relationship between hybrid courses and CO_2 emissions at an urban university. This information will be valuable to the SJSU community, as well as many other institutions.

Keywords Higher education, Online classes, Transportation, Carbon dioxide, Commuter campus, Hybrid classes

Paper type Research paper

1. Introduction

The increased use of online courses in universities has associated risks but can also be beneficial to the students, university and environment. Although students may enjoy

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the flexibility that online course delivery offers, questions remain about whether online learning environments can provide similar quality education compared to face-to-face courses. Past analyses of the quality of education and student satisfaction with online education systems have been varied (Parkinson *et al.*, 2003; Topper, 2007). However, it is clear that universities see the reduction in overhead costs associated with online courses as a strong benefit (Abdous and Yoshimura, 2010). One of the potential benefits of online learning, and the focus of this paper, is the reduction in student trips to campus and the potential reduction in local air pollution, CO_2 emissions and parking congestion (Tolley, 1996; Balsas, 2003).

In this paper, the authors will explore the relationship between online courses and transportation-related CO_2 emissions at a large urban university (i.e. San José State University) where the majority of students commute to campus. One of the trends in higher education is the availability of hybrid courses where some of the course meetings are face-to-face on campus and others are conducted online through use of computers at students' and professors' homes and some mediating software. The flexibility of course delivery offers options for course scheduling that may have implications for the frequency of student trips to campus. It is hypothesized that increasing the number of online meetings accompanied by a preferential scheduling (idealized student course scheduling to reduce trips) of those online meetings may produce a significant reduction in commuter trips to campus. This paper will explore this relationship and also discuss implications for the environment and other issues such as campus parking.

2. Background

The state of California has recognized the risks associated with global warming and increases in greenhouse gases. The California Global Warming Solutions Act of 2006 is designed to cap and reduce greenhouse gas emissions and to encourage the development of sustainable technologies (California Global Warming Solutions Act, 2006). On a local level, the City of San José, where San José State University (SJSU) is located, has implemented the "San José Green Vision". The main goal of this plan is to reduce greenhouse gas emissions through various means, including reducing energy consumption and encouraging clean technology industries (San José Green Vision, 2012).

In the San Francisco Bay Area, transportation is responsible for 36 per cent of greenhouse gas emissions (BAAQMD, 2008). The normal heavy traffic congestion not only contributes to local air pollution but also increases the average commute time and thus reduces worker productivity (Applied Survey Research, 2004). At SJSU, a concerted effort has been made to reduce trips to campus through incentives for both students and staff. Over the last ten years, the number of students driving solo to campus has dropped from 59.8 per cent in 2001 to 37.4 per cent in 2011 due to extensive measures made by the university (Zonobi, 2011). Although these gains are impressive, a large fraction of students still drive to campus, which requires extensive measures to accommodate parking and traffic congestion. For example, the South Campus Parking Lot (used for overflow parking) costs the campus nearly $1 million per year to operate. Because these measures do cost the university, in terms of both direct financial costs and indirect costs through air pollution and changes in climate, some administrators are strongly motivated to reduce the number of cars traveling to campus.

A number of studies have examined the relationship between transportation modes and CO_2 emissions. It is clear that reducing single-occupancy automobile trips in preference for other modes (i.e. bus, train and bike) or carpooling can significantly reduce per capita emissions (Najafi, 2010). Further studies have compared emissions of online courses with standard face-to-face courses. As expected, these suggest that significant reductions in CO_2 emissions can be realized through online course delivery (Takahashi *et al.*, 2006; Roy *et al.*, 2008). However, relatively little work has been done to determine the effects of hybrid-mode course delivery (i.e. where a course includes both online and face-to-face meetings) on CO_2 emissions. Thus, the goal of this research is to explore how a campus-wide hybrid course structure would affect the number of student trips to campus for a typical urban university.

3. Methods

A computer model was developed using the interactive data language programming language to simulate the effects of varying combinations of hybrid courses and online meetings on student trips to campus. Here, the authors define a trip to campus to be from the student's home to campus, and then back home (a round trip), driven alone, and in a standard passenger car. In the model, 30,236 students (SJSUOIR, 2011) and 5,012 courses (SJSUOIR, 2012) were used to roughly represent the SJSU system. A simplified system of courses was also assumed, where 80 per cent of the courses in the model met twice a week for 1 hour and 15 minutes, while 20 per cent of the courses met once a week for 2 hours and 40 minutes. Students were randomly placed into these courses, between three and six courses, each to represent the mix between part-time students (about 25 per cent) and full-time students (about 75 per cent) as seen at SJSU (SJSUOIR, 2012). Students who take different numbers of courses are assumed to be the same in the model other than their course differences. The model calculated 3.79 trips to campus per week per student using the parameters above, which is close to the campus survey value of 3.91 (Zonobi, 2011). These trips include only those associated with official class meetings, and are not affected by events or special circumstances.

The primary model calculation is the number of student trips per week for a given percentage of hybrid courses and online meetings in those courses. The model calculates the number of student trips for all possible scenarios, ranging from 0-100 per cent of courses being hybrid and 0-100 per cent of course meetings being online. For each of the scenarios, the total number of student trips to campus is then calculated. Using the totals for the student trips to campus, estimates of CO_2 emissions are then made based on average distances driven to campus [13.7 miles each way (Zonobi, 2011)] and national statistics for the average miles per gallon of a standard passenger car [23.8 miles per gallon (DOT, 2011)] and CO_2 emitted per gallon of gasoline burned [8.92 kg of CO_2 per gallon (EPA, 2011)]. This analysis focuses on CO_2 emissions associated with transportation and neglects other components of energy use such as electricity used at home and on campus.

It is important to note that students' schedules are randomly assigned, and thus no coordination of course schedules occurs, although that may happen in reality. The authors also assign hybrid courses and online meetings in a random manner. In both cases, the authors expect their estimates for the number of trips reduced through online course delivery to be conservative, as students' preferences may be to schedule courses

on fewer days per week. As will be discussed later, the scheduling of hybrid courses and online meetings could be optimized to further reduce trips to campus.

4. Results

4.1 Trips to campus

To study the utility of the model developed in other applications, three case studies are presented. The primary case study focuses on the projected reduction in student trips to campus given a certain scenario of online and hybrid courses. The second will discuss the influence of the reduction in student trips to campus on parking. The final case study will examine the effects of preferential scheduling of classes on combined with modeled student trips to campus.

Figure 1 shows the per cent reduction in number of trips to campus for different scenarios ranging from 0-100 per cent of hybrid courses and 0-100 per cent of those courses having online meetings. As expected, the number of trips to campus made by students was found to decrease with an increase in online meetings. For example, if 80 per cent of SJSU courses adopted a hybrid course structure, with 32 per cent of these course meetings online, then a 10 per cent reduction in trips to campus would be achieved (denoted by the circle in Figure 1). Also, it should be noted that the lines are not uniform; rather, they are slightly jagged because of the random allocation of courses for each individual scenario.

One of the general features of this analysis is that reductions in trips to campus become larger only when the percentages of hybrid courses and online meetings become greater. This means that with greater numbers of hybrid courses and online meetings, there is a more rapid decrease in student trips to campus. It also means that at the lower end of the graph, even relatively large increases in the percentage of online courses provide only modest changes in trips to campus. For example, if a campus that normally

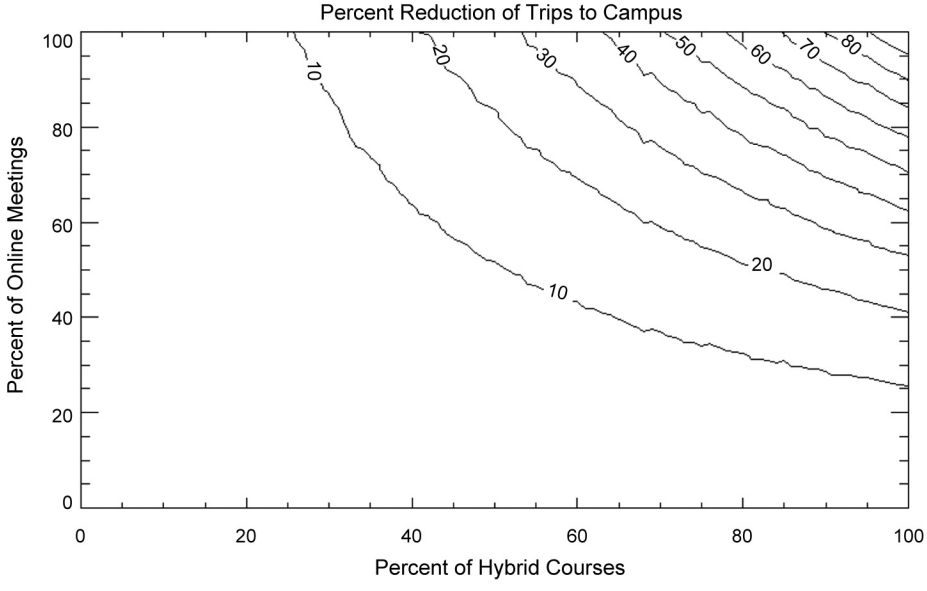

Figure 1.
The reduction in student trips to campus per day varying with hybrid course and online meeting availability. The contours are per cent decreases from the maximum (no online classes)

has 10 per cent hybrid courses (with 50 per cent of meetings online) were to double their hybrid courses to 20 per cent, this would only reduce trips to campus by 1.8 per cent. However, if 50 per cent of the courses are already hybrid, but then increased to 60 per cent, the reduction in trips to campus is 3.2 per cent.

To further illustrate the accelerated decrease in trips to campus and associated reduction in CO_2 emissions with increasing online meetings, ten scenarios, including a baseline, are studied as shown in Figure 2. For each scenario, the percentage of online meetings per day is increased by 10 per cent, so that 10 per cent of all course meetings are online in Scenario 1 and 20 per cent of all course meetings are online in Scenario 2, etc. The related CO_2 emissions are then calculated for each scenario. So while only relatively small differences in CO_2 emissions are achieved when fewer courses are online, these differences become much larger when there are larger percentages of online courses.

4.2 Case study: the South Campus Parking Lot

Parking at SJSU is very challenging, and most campus lots fill up by the middle of the morning. To accommodate extra cars, offsite parking (i.e. the South Campus Parking Lot) was established in combination with a bus shuttle service to the main campus. At present, the South Campus Parking Lot serves about 800 unique vehicles per day at an operational cost (for the buses and drivers) to the university of nearly $1 million (Yau, 2011).

A case study was performed to determine how many online course meetings would be necessary to eliminate the need for the South Campus Parking Lot. Based on the total number of trips to campus, from the model it was found that a 7.6 per cent decrease in

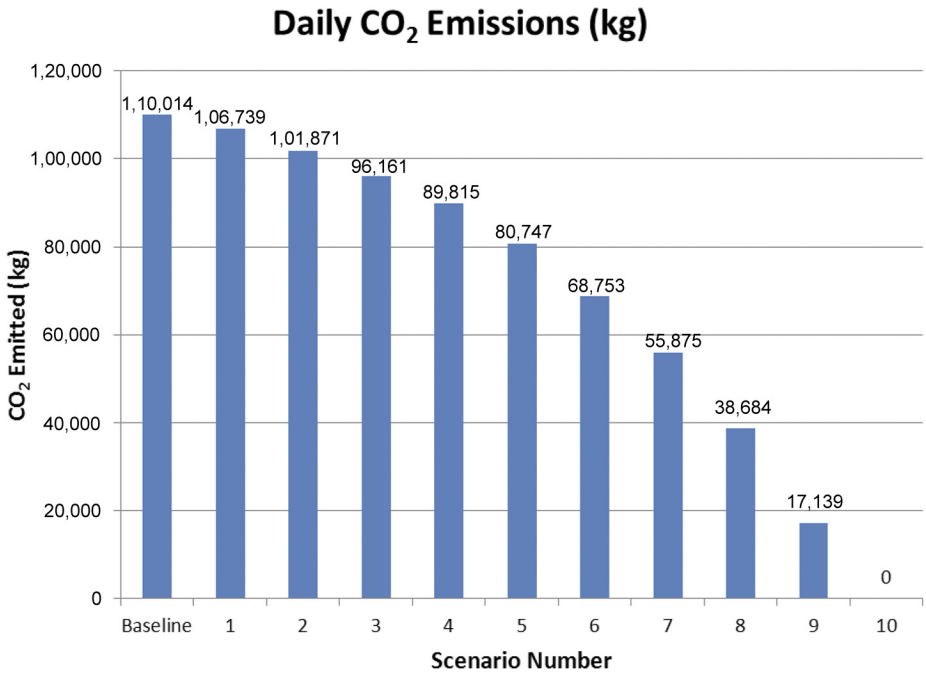

Figure 2.
CO_2 emissions associated with each scenario. Values above the columns are modeled CO_2 emissions (kg). For each scenario, the percentage of online meetings is increased by 10 per cent (i.e. Scenario 1 has 10 per cent online meetings and Scenario 2 has 20 per cent online meetings)

trips to campus would be required to eliminate the need for the South Campus Parking Lot.

Figure 3 illustrates the minimum percentage of online meetings required for given percentages of hybrid courses at SJSU to allow the removal of the South Campus Parking Lot. At < 10 per cent hybrid courses, there is no situation where the total number of trips to campus can be accommodated without the extra parking. However, at higher percentages of hybrid courses, there are ample opportunities to achieve a 7.6 per cent reduction in trips to campus. For example, if 40 per cent of courses use the hybrid model and about 45 per cent of those meetings are online, this should be sufficient to eliminate the need for the off-campus parking and the bus shuttle service.

4.3 The role of scheduling

As described earlier, the analysis performed here assumes a completely random distribution of online course delivery. It is assumed there is no coordination in scheduling the online course meetings. However, if reducing trips to campus were the goal, one could imagine that schedules could be optimized to reduce trips to campus to serve various needs. If parking were the goal, then scheduling could be optimized to reduce trips to campus each day of the week. If reducing campus energy were the goal, then focusing on a particular day of the week would allow for less energy to be used at the building level. In practice, university schedules are complicated, and individual faculty members tend to operate in a fairly autonomous manner. Although there is value in studying the role of such optimization, that is beyond the scope of this current study.

In this analysis, the authors explore the role of scheduling based on a fairly simple adjustment to the delivery of online courses. The authors model the impact on student trips to campus when faculty members are asked to preferentially schedule their online

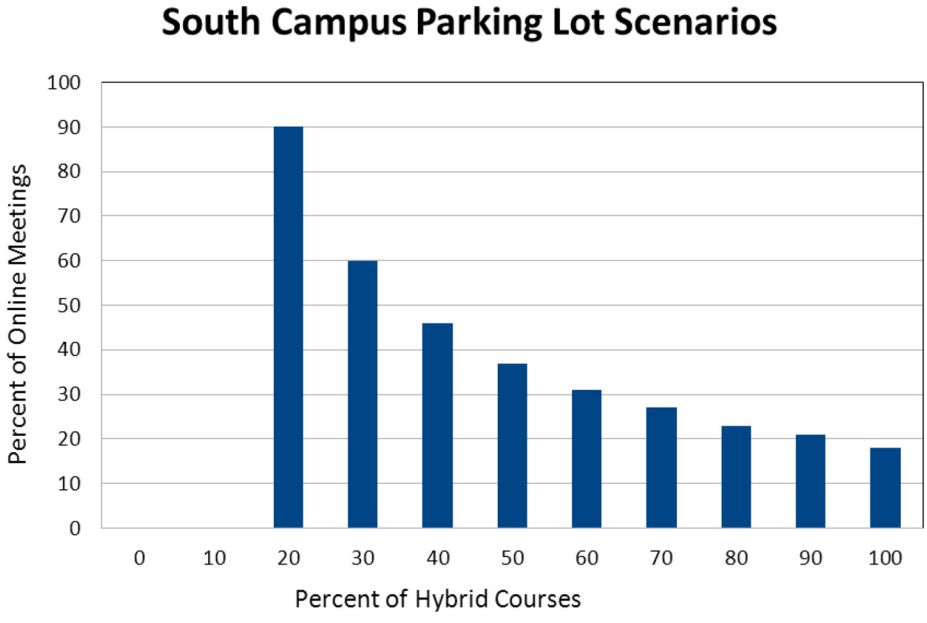

Figure 3.
Online meetings required to eliminate the need for the South Campus Parking Lot

meetings toward the beginning of the week (i.e. Monday and Tuesday). In this case, the odds that online course meetings might be aligned to reduce student trips to campus would improve. This is modeled by varying the percentage of online courses while assuming faculty compliance to be 100 per cent.

Table I shows scenarios where 0, 20, 40, 50, 60, 80 and 100 per cent online meetings are considered (all courses are hybrid). The total number of courses that were adjusted from either Wednesday or Thursday to Monday or Tuesday is shown (courses adjusted) in the following row, with a peak of 955 courses adjusted under the 60 per cent column. The following four lines show the decreases and increases in courses adjusted for each day, with the net weekly change also shown. The greatest decrease in trips to campus again occurs under the 60 per cent column and a further reduction of 19,994 kg CO_2 from the baseline. This corresponds to a 5 per cent decrease from the weekly baseline, as seen in the final row. Beyond 60 per cent, it becomes likely that online meetings are scheduled for both days for a twice-a-week course, and therefore cannot be switched in favor of the earlier day.

The changes observed in trips to campus under this relatively minor scheduling adjustment are significant. A further 3-5 per cent reduction in trips to campus suggests that additional reductions could be found with an optimization of scheduling. In the model, the random allocation of courses and online meetings limits the potential for online meetings to occur, so these results may be considered a conservative estimate of the potential to reduce student trips to campus.

5. Conclusions

Overall, the authors' results are similar to those of Takahashi *et al.* (2006) in that student trips to campus, and therefore CO_2 emissions, decreased with increasing online meetings. However, it can be seen from Figure 1 that decreases in trips to campus, and correspondingly decreases in CO_2 emissions, became more rapid with higher percentages of hybrid courses and online meetings. For example, it is not until Scenario 3 (i.e. 30 per cent of all meetings online) that at least a 10 per cent change in CO_2 emissions is projected to occur. Analysis has determined that relatively large percentages of hybrid courses and online meetings are needed to achieve similarly large decreases in trips to campus and CO_2 emissions.

Table I.
Changes in trips to campus by day when preferential scheduling of online meetings is set for early in the week (i.e. Monday or Tuesday)

Percent online	0%	20%	40%	60%	80%	100%
Courses adjusted	0	621	946	955	626	0
Monday	0	−807	−2,063	−3,109	−2,626	0
Tuesday	0	−796	−2,067	−2,870	−2,642	0
Wednesday	0	+552	+1,323	+2,097	+2,096	0
Thursday	0	+577	+1,330	+1,935	+2,030	0
Net change		−474	−1,477	−1,947	−1,142	
Percent change from baseline (42,852 trips)		1.1	3.4	4.5	2.6	

Notes: For each scenario of percentage of online courses, the number of classes adjusted and the changes in number of trips to campus are shown, where negative numbers denote decreases in trips to campus and positive numbers denote increases in trips to campus

A case study was examined to determine the scenarios that would allow for the elimination of the South Campus Parking Lot. As an example of one scenario, it was found that if 40 per cent of courses used a hybrid model and, of those courses, 45 per cent of the course meetings were online, this would sufficiently reduce the trips to campus to allow for the removal of the off-campus parking lot. The benefits of this, including reductions in air pollution and CO_2 emissions, as well as financial relief (nearly $1 million in annual operating costs eliminated), are noteworthy. Further, this land could then be used for other purposes and, because land values in the Bay Area are high, additional financial rewards could be made. However, it is also noted that the model is idealized and does not include actual student preference for classes (based on when classes are offered), which can alter the results.

Preferential scheduling made a moderate difference in CO_2 emissions in the idealized scenario of 100 per cent hybrid courses and 100 per cent faculty compliance. Assuming 60 per cent of meetings were online meetings, 1,947 additional trips to campus were eliminated weekly (5 per cent from the weekly baseline), and a decrease of 19,994 kg CO_2 emissions was projected (Table I).

The generality of the model as well as the ability to customize key parameters allows it to be potentially useful at other educational institutions. For more complex environments, some manipulation of code may be necessary to yield meaningful results. Therefore, the code will be available to those who wish to use it by contacting the authors.

Although the model provides a good estimate of the relationship between student trips and hybrid course delivery, there are some important caveats. First, this model is highly idealized because it assigns courses to students in a random manner. In reality, students often choose course times to best suit their own busy schedules (work, family, etc.) and often have a preference to come into campus on few days per week if possible or to come on additional days outside of class for social reasons. In either case, the availability of a collection of online courses may affect their choice of campus courses to ultimately alter classroom trips. To better estimate how student trips would be influenced, one could use actual student schedules to better represent the studied changes and study actual parking data. However, the model developed does present a logical approach to studying the theoretical relationship between hybrid course delivery, trips to campus and CO_2 emissions. Because the analysis used very conservative values and assumptions, it is expected that actual reductions in student trips and CO_2 emissions would be greater in practice.

One final perspective on the practical value of this analysis is given. When these results were presented to campus administrators, in addition to the potential environmental benefits, there was a special interest in the potential financial gains that could be realized by implementing online course delivery. For example, one dean suggested that hybrid course delivery in their college could be used to schedule entire days where all classes would be online, thus significantly reducing energy use for those buildings in the college. Although this would require significant buy-in from faculty, some deans thought a gradual approach, starting with one or two online days per semester, might be a good way to start. Additionally, the idea of eliminating the South Campus Parking Lot through additional online courses was also initially popular in different budgetary discussions, until it was understood that any additional resources gained by parking and transportation, which is a distinct unit on campus, could not be

used by the main campus budget office. In both cases above, further study would be needed to better understand how online course delivery would affect the environment and campus finances. These examples do illustrate the potential opportunities and challenges that can result from such analysis.

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