2006-543: INCORPORATING PUBLIC POLICY INTO AN ENGINEERING COURSE: VOLUNTARY PROGRAMS FOR MOBILE SOURCE EMISSION REDUCTIONS

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Incorporating Public Policy into an Engineering Course: Voluntary Programs for Mobile Source Emission Reductions

1. Introduction

A course in air pollution control engineering offers many opportunities to incorporate analysis of public policy because federal and state environmental laws affect many aspects of an engineer's work in ameliorating air pollution. Mastering landmark command-and-control legislation such as the Clean Air Act has traditionally been a part of air pollution control engineering courses. Voluntary programs, however, are gaining importance as innovative tools to reduce emissions beyond what can be achieved through traditional regulatory control strategies and deserve space on the syllabus. I therefore incorporated voluntary programs into an air pollution control engineering course through a course project that focused on mobile source emissions. Six of the eight students enrolled in the course were third and fourth year mechanical engineering students. Two graduate students from other engineering schools were also enrolled.

To formulate my ideas for the project, I collaborated with staff at the City of Chicago Department of the Environment, the Region 5 EPA office, and EPA headquarters. The resulting project had two elements. Both originally focused on Pilsen, a Chicago neighborhood that is both a trucking hub and a population center for working class families. As part of the first element, students assumed the role of fleet managers of small trucking firms in Pilsen seeking to join EPA's SmartWay Transport Partnership[1], a voluntary program aimed at reducing emissions from heavy duty diesel vehicles. Students assessed emissions reductions and economic impacts that would result from the company's membership in the program. They used EPA's Freight Logistics Environmental and Energy Tracking (FLEET) model, an Excel-based tool, for these calculations and provided feedback to EPA on the tool's ease of use. The second element was a student investigation of anti-idling policies for school buses in Pilsen. These policies would reduce school childrens' exposure to diesel exhaust and save cash-strapped school districts money. The eight students enrolled in the course divided into three groups. Two groups worked on the first element and one worked on the second. At the end of the semester, the students presented their work at the regional EPA office for an audience of EPA and City of Chicago staff. The next section describes the two elements of the project in greater detail. The balance of the paper discusses the students' results, the grading methodology, and the post-project assessment.

2. Project Description

To introduce the project to the class, I lectured briefly on the SmartWay Partnership and gave the following four goals for student participation in the project.

1. Gain insight into a voluntary emission control program
2. Become familiar with mobile source control technologies
3. Calculate emissions reductions and economic impacts from involvement in a voluntary program
4. Communicate project results effectively

ME/ChE 450 Course Project:
EPA SmartWay Program for Diesel Trucks in Pilsen

Goal: Present alternative technologies to reduce emissions from diesel trucks in Pilsen at the USEPA Midwest Diesel Corridor Workshop this April.

Task 1: Select an emission reduction technology from the list below.

Options for Task 1:
- Idling reduction technology (direct-fired heater, auxiliary power unit)
- Oxidation catalyst (retrofit)
- Idling policies (compare policies for different countries, states, etc.) especially relating to school buses*

Task 2: Investigate three types of your chosen technology. Questions to address include:
- How each technology works
- Advantages and drawbacks of each technology (better for long/short haul, high maintenance, work best under stringent operating conditions)
- How do the technologies compare economically?

Task 3: Compute potential emission savings with EPA spreadsheet for several different trucking companies (data to be provided by City of Chicago). If applicable, also calculate the payback period. Does the manufacturer of one of the devices that you are investigating claim a different emission reduction than the spreadsheet calculates? Identify potential improvements to spreadsheet - either technical or ease of use. (Spreadsheet is available on Blackboard.)

Task 4: Prepare final report (max 25 pages) and presentation (length to be determined). I will provide guidelines for report and presentation preparation later.

Resources

Smartway Website: http://www.epa.gov/smartway/
Other useful websites are listed in Blackboard.

Schedule

Task	Due Date
1	January 24 (M)
2	March 4 (F)
3	April 1 (F)
4	April TBA

*For Task 2, the group that investigates policy will investigate at least one nationwide policy, at least two state policies, and at least two school district policies. Discuss reactions to the policies and financial and economic benefits (or drawbacks) stemming from the policies. You should also include a section on the health effects of emissions from the combustion of diesel fuel, especially on children. Finally, for Task 3, calculate emissions savings that will result from retrofits on CPS school buses and anti-idling policy using data provided by the City of Chicago.

Figure 1. Project assignment sheet

The students received the project assignment sheet in Figure 1. The project was divided into four tasks with deadlines. The first task was to select teammates and one of the project elements. If students chose the first element, they could select between the first two options under Task 1. These options related to two technology choices available to SmartWay Partnership participants: anti-idling technologies and aftermarket treatment devices. The third option under Task 1, which was associated with the second project element, was to investigate reducing school bus emissions through anti-idling policies. Students received about five weeks to complete Task 2, which was the research and information gathering stage of the project. In Task 3, students calculated the environmental and economic effects of participating in the three options. The groups investigating the SmartWay Partnership used a combination of the FLEET model and their own calculations to meet the requirements of Task 3. The school bus group relied solely on their own calculations with emission factors and fuel efficiency data. The assignment sheet (Figure 1) gave students specific questions to consider during Tasks 2 and 3. The final task was to prepare a report and presentation.

3. Challenges of Project Implementation

Several challenges arose as the students worked through the project. First, trucking firm data from Pilsen, such as average number of trucks per firm and annual vehicle miles traveled did not become available in time to be used in the project. However, a staff member from EPA headquarters was able to provide typical numbers for long and short haul fleets. Additionally, the city provided data for their garbage truck fleet. The students were able to use these data, which Tables 1 and 2 contain, to complete the project.

Table 1. Long and short haul truck fleet data

Combination	Number of Trucks	Annual Vehicle Miles Traveled	Total Fuel Consumption (gallons)	Average Payload (tons)	Total Idling Hours
Short Haul	700	50,000	10,000	3	210,000
Long Haul	1,500	100,000	16,667	3	1,500,000

Table 2. City of Chicago refuse hauler data

Technology	Number of Trucks	Annual Vehicle Miles Traveled	Total Fuel Consumption (gallons)	Average Payload (tons)	Total Idling Hours
CMX Catalytic Converter	75	7,226	13,169	4	450,000
DPX Catalyzed Particulate Filter	4	30,000	1,690	3	300

Another challenge of implementing the project was the process of learning the FLEET model. Students occasionally grew frustrated with confusing aspects of the model, but this type of confusion could arise with any tool used in a course project. As students raised questions about the model, I contacted EPA for clarification. As I learned more about the model, I communicated this new knowledge to students via email or in class.

4. Student Presentations and Reports

The final goal of the course project was for student groups to present their findings at the regional EPA office. As the presentation date approached, I took class time for the students to practice for each other and receive feedback. Eleven people (excluding course participants) attended the final presentations. They were from the City of Chicago Departments of the Environment and Fleet Management and EPA headquarters and Region Five. The students did well and received many positive comments from the audience members. EPA and the Department of the Environment received copies of the students' reports. All students therefore met the fourth goal listed in section two.

5. Selected Elements of Student Papers and Presentations

The next section of this paper presents portions of student presentations and reports that demonstrate students' mastery of the project goals. It has three subsections that correspond to the three student groups.

5.1 Anti-Idling Devices

The first student group studied anti-idling devices, the first option under Task 1. They considered direct-fired heaters, auxiliary power units, and truck stop electrification as technology alternatives for companies seeking to join the SmartWay Partnership. Their report contained detailed descriptions of each technology and demonstrated that they had met the second project goal. Figure 2 contains their comparison of these three technologies.

Alternatives to Idling

Technology	Benefits	Drawbacks
Direct-fired heater	Heat; small	Cannot supply cooling; requires battery power
Auxiliary Power Unit	A/C, Heat and power	Heavier, larger, more expensive than heater
Truck stop electrification	A/C, Heat and power	Only at limited locations; not commercial?

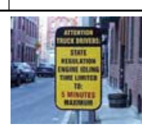

Figure 2. Qualitative comparison of three types of anti-idling technology

The students used the fleet data in Tables 1 and 2 and the FLEET model to quantify the benefits of using these three technologies, satisfying the third project goal. Figure 3 contains a screen shot of EPA's FLEET model. Figure 4 contains the results of the students' analysis for long haul trucks.

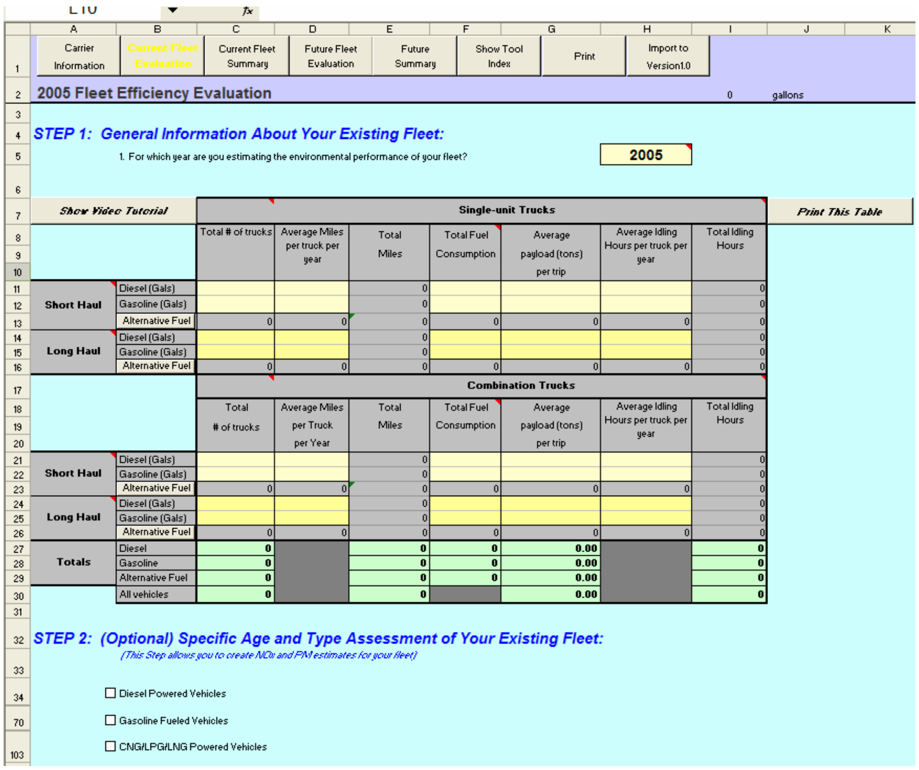

Figure 3. Screen shot of FLEET model

Long-haul trucks - Results

Technology	CO_2	PM	NO_x	Payback time
Direct-fired heater	-97%	-16%	- 8%	≈ 0.9 years
Auxiliary Power System	-98%	-16%	- 8%	≈ 5.6 years
Truck stop electrification	-99%	- 32%	- 16%	≈ 4.5 years

Figure 4. Environmental and economic aspects of anti-idling technologies for long-haul trucks

Although the students quantified these same benefits for the municipal fleet of garbage trucks, they found that the technologies were not feasible for that type of fleet, as described in the excerpt below. They also felt that the FLEET model over predicted CO_2 reductions. Their overall conclusions are presented in Figure 5.

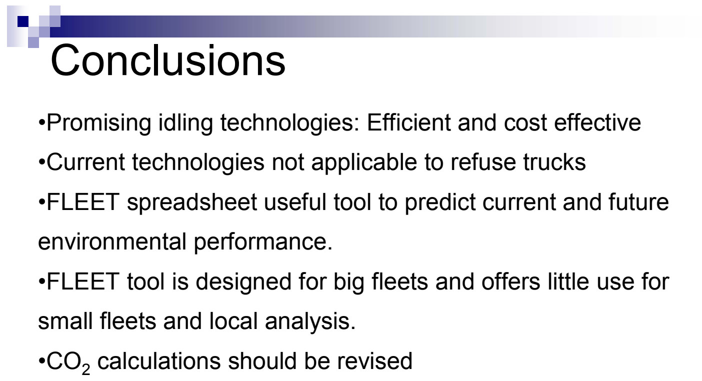

Figure 5. Student conclusions from investigation of anti-idling devices

The students appreciated that a company's approach to joining SmartWay is very dependent on the fleet characteristics. The following excerpt from the students' report summarizes this conclusion and demonstrates that this group met the first project goal. It also illustrates that the students investigated policy options to reduce idling from municipal fleets in addition to technological options.

"The idling habits of refuse trucks make it hard to use existing technologies in a relevant and effective way, mainly due to the fact that the refuse compressing device requires an amount of power that nothing but the truck engine can provide. Even if the total amount of idling minutes is high, it might consist of many short periods of time, each of them being hard to minimize. Looking at Californian legislation, the "working idling" for refuse trucks seems to fit within regulations, which are a maximum of 5 minutes of idling [ref]. Within this field, other technologies such as particulate filters, or catalysts might prove more efficient. This has partly already been implemented by the City of Chicago [ref]. It is also possible that future technologies might be able to fulfill requirements.

As for the question of suitable equipment for long-haul trucks, it is clear that it is very important that a thorough investigation is made for each fleet (or even for each truck); to decide what functions and services are required and/or desired. The FLEET evaluation shows small differences in emissions savings, despite the different idling hour input to the spreadsheet. For example, a DFH cannot provide enough power for cooling, which makes it inadequate for use as climate controller; on the other hand, if the truck cabin is not used overnight, these functions might unnecessary. This must also be evaluated on an economical level, something that can be done using the FLEET Performance Model described earlier."

5.2 Aftermarket Treatment Devices

Students in the second group studied aftermarket treatment devices for heavy-duty diesel trucks including diesel particulate filters (DPF) and diesel oxidation catalysts (DOC). Their report included a summary of how these devices work and the benefits and drawbacks to using each technology type. Figure 6 is a slide from the students' presentation cataloguing the advantages and disadvantages of using particulate filters. Their report contained a detailed description of each technology type complete with diagrams, proving they had met the second project goal.

DPX Catalyzed Diesel Particulate Filter

Advantages

- Effective in reducing the total mass of particulate matter created by vehicles
- Effective in reducing engine noise and may replace muffler
- No operator attention required
- EPA approved

Disadvantages

- Formation of solid sulfates over the platinum catalyst.
- Engines may not produce sufficient exhaust temperatures
- High cost technology
- Lower sulfur fuels must be used

Figure 6. Merits and drawbacks of diesel particulate filters

Students in this group also used the data in Tables 1 and 2 for their Task 3 calculations. They used EPA's FLEET model to gauge emissions reductions that would occur if the fleet adopted various technologies. Figure 7 provides an example of a FLEET model-generated graph detailing reductions in PM emissions.

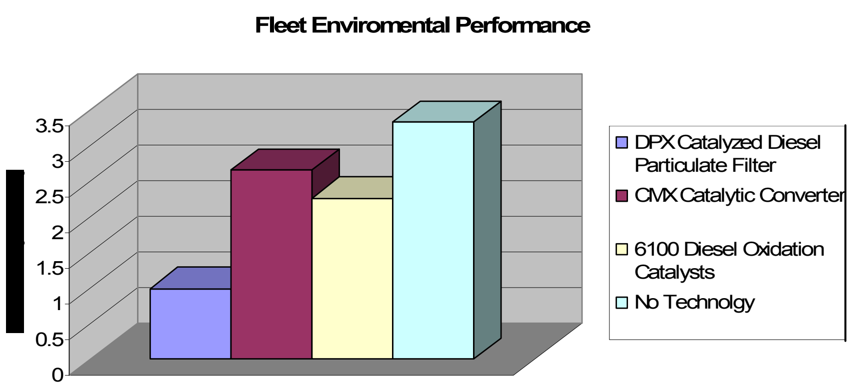

Figure 7. Reductions in PM emissions (tons/truck) resulting from different aftermarket treatment technologies

The students summarized the cost to the fleet to adopt these technologies in the slide contained in Figure 8.

Cost Analysis

- CMX Catalytic Converter
- Equipment Cost =$1840
- Installation Cost =$360

- 6100 Donaldson Diesel Oxidation Catalyst
- Equipment Cost = $1,800
- Installation Cost = $400
- Replacement Filters = $100

- DPX Catalyzed Diesel Particulate Filter
- Street Sweeper - $9,675
- Refuse Truck - $8,450
- Fire Truck - $11,750

Figure 8. Aftermarket treatment device cost comparison

After considering cost and environmental implications, satisfying the third goal of the project, the students presented the conclusions outlined in Figure 9.

Conclusions

- The technology that collected the most pollutants was the DPX Catalyzed Diesel Particulate Filter
- The most cost efficient technology was the CMX Catalytic Converter Muffler
- EPA approved Technologies
- The EPA spreadsheet was user-friendly, but not helpful in calculating CO and HC emissions

Figure 9. Student conclusions from investigation of aftermarket treatment devices

The students realized that the device with the highest environmental performance was also the most expensive and therefore may not be a feasible technology for every company or municipal fleet. The following excerpt from the students' report demonstrates their grasp of the requirement for flexibility in the voluntary program and their achievement of the first project goal.

"There is no one "best" device for any and all situations. The choice of an optimal device is dependent upon the context of the situation that one is in. People who have compromised immune systems or who are weak and infirm must not be exposed to a high level of pollutants. In this case, the highly effective DPX catalyzed Diesel Particulate Filter is recommended. Hospital

and other healthcare facilities generally have a small number of vehicles, therefore the additional cost of a DPX catalyzed Diesel Particulate Filter would not be excessive.

The CMX Catalytic Converter Muffler and the Donaldson 6100 Diesel Oxidation Catalyst are both highly recommended for use by a city or by a private business with a large fleet of trucks. This recommendation is made due to the fact that any establishment with a large fleet of trucks would find it economically unfeasible to install a DPX catalytic converter. However, any of the two technologies listed above provide quality pollution control at an affordable price.

In regards to the SmartWay program it is recommended that CMX Catalytic Converter Mufflers are installed onto the current fleet of trucks and as new trucks are purchased, the Donaldson 6100 DOCs are installed. This course of action is recommended despite the fact that the Donaldson 6100 DOC is a better choice for the Pilsen fleets than the CMX Catalytic Converter Muffler. The reason for this is due to the fact that the performance of the Donaldson 6100 is age dependent. It does not perform as well on older vehicles as it does on newer vehicles. "

5.3 School Bus Idling Reduction in Pilsen

The final group of students elected to complete the third option of Task 1, which was associated with the second project element. Their final report included information on school bus idling policies in California and Connecticut in addition to summarizing federal idling guidelines, demonstrating that the students met the first project goal listed in section two. The report also summarized the health effects of diesel exhaust and how aftermarket treatment devices could be used to reduce emissions from the buses. The students, using Pilsen area school bus fleet data that the city provided, calculated emission reductions and fuel savings from implementing an idling reduction policy. Data on the idling behavior of the Pilsen neighborhood school bus fleet would have been helpful in analyzing fuel cost and emission savings, but this information was unavailable, so students made assumptions to facilitate their analysis. Figure 10 displays the PM emission reductions that would result from reducing idling by 60%. Through their report and presentation, the students demonstrated that they met goals one through three listed in section two.

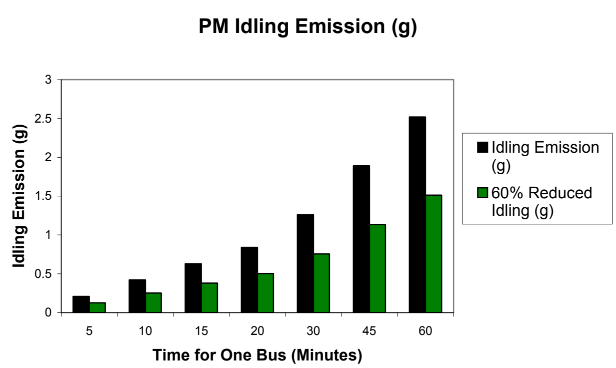

Figure 10. Reduction in PM emissions from idling as a function of idling time

6. Grading

Figure 11 contains the document students received outlining how their reports and presentations were to be graded. The document was meant to alleviate student concerns about what to include in the report and presentation and to make the instructor's expectations explicit. Figure 12 contains the scoring mechanism and criteria students used to develop the participation element of the grade. I found that this framework for grading worked well.

7. Assessment

This section discusses the post-course assessment that I conducted to gauge the students' impression of the project and what they had learned from it. Seven out of eight students completed the evaluation. The assessment aimed at answering five basic questions:

1. Did students think they had gained technical knowledge from completing the project?
2. Were instructor expectations for the project clearly communicated?
3. Was student time and task management successful?
4. Did students gain oral and written communication skills?
5. Did students enjoy the project?

First, I present the results of the evaluation in Tables 3 to 5 and then discuss their implications for the project. I also discuss how the assessment could be improved.

Guide to Preparing Report and Presentation

Report (55% of overall project grade)

Use the assignment sheet as a guide for what to include in your report. The report should have the following sections, which will be worth the noted amount of points:

- Introduction (10 pts)
- Comparisons (of technologies or policies) (25 points)
- Calculations (25 points)
  - State the numbers/parameters that you used in calculations and/or spreadsheet (e.g., engine type, idling hours, etc.)
  - State assumptions that you made and why they are valid
- Conclusions and Recommendations (20 points)

Note: You do not have to use the above as section titles.
The report should not exceed 25 pages.

You will also receive points for:

- Spelling and grammar (5) – Of course, your paper should have absolutely no spelling mistakes
- Clarity and organization (15)

Presentation (30% of overall project grade)

Your audience will be members of the staff of the City of Chicago Department of the Environment and the EPA. They will also receive a copy of your reports. You will be graded on:

- Clarity of your presentation – can you present with clarity your ideas and results to people unfamiliar with your work? (40 points)
- Organization (logical flow, well-organized tables and charts) (40 points)
- Preparedness – did you practice? (10 points)
- Question answering (10 points). It's OK to say "I don't know" or explain that you are making a best estimate based on the information that you have.

Participation (15% of overall project grade)

Your group members will be asked to rate you on the following criteria:

- Contribution of original ideas
- Participation in calculations/working with spreadsheet
- Participation in group discussions by email or phone and in person
- Contribution to report and presentation preparation
- Overall percentage of the project that you did

Figure 11. Explanation of grading

Name of group member ________________________________

Please rate your group member on the following criteria on a 1 to 5 scale (one is lowest amount of points, five is highest).

_____ Contributed original ideas

_____ Found relevant data/information

_____ Participated in calculations/working with spreadsheet

_____ Participated in group discussions by email or phone and in person

_____ Contributed to presentation preparation

_____ Contributed to report preparation

______ Overall percentage of the project that this member did (from 0 to 100%)

Figure 12. Participation grade sheet

Table 3. Student responses to agree/disagree style questions

#	Question	Strongly Agree	Agree	Disagree	Strongly Disagree
1	The project helped me learn about pollution control for mobile sources.	57%	43%	0%	0%
2	The project objectives were clearly laid out in the assignment sheet.	57%	43%	0%	0%
3	I followed the deadlines for the four tasks.	71%	29%	0%	0%
4	If intermediate steps were graded at the deadlines, I would have changed my approach to the project.	14%	43%	43%	0%
8	I had enough technical knowledge when the semester began to start work on this project.	0%	29%	71%	0%
9	I gained technical knowledge from working on this project.	40%	60%	0%	0%
10	I did not have enough time to do this project.	0%	40%	60%	0%
11	I gained knowledge about how to find information I need to complete a technical project.	0%	100%	0%	0%
12	I had fun working on this project.	0%	100%	0%	0%
13	I am proud of my accomplishments as a result of this project.	40%	60%	0%	0%

Table 4. Student answers to Question 6: "How did presenting your results for a professional audience affect you? (circle all that apply)"

Response	Percent of Respondents
a) I am used to presenting my work before professionals (either industrial or academic) and so this element of the project did not affect me much.	43%
b) I gained knowledge about how to prepare for and give a professional presentation.	86%
c) I learned nothing about preparing for or giving a professional presentation.	0%
d) I have never presented for a professional audience before.	14%

Table 5. Student answers to Question 7: "How did preparing a report for external review affect you? (circle all that apply)"

Response	Percent of Respondents
a) I have written reports that have been read outside the university environment before this project.	43%
b) I gained knowledge about how to prepare a report.	71%
c) I learned nothing about preparing a report.	0%

From the responses to questions one and nine (Table 3), it is clear that all respondents gained technical knowledge from completing the project. Because this course is in an engineering department, mastery of technical content was one of the primary objectives of the project. The answers to question two indicated that all respondents also understood the project objectives (in terms of what they were to complete) that were articulated on the assignment sheet (Figure 1).

In designing the project, I aimed to set clear project milestones to avoid a last-minute rush to complete the project. Although I gave each task in Figure 1 a deadline, I did not grade intermediate steps. I adopted this strategy to provide flexibility and to reduce time spent grading. Questions three, four, five, and ten aimed at assessing the degree of success of this approach. All respondents agreed that they adhered to the schedule on the assignment sheet. Although 57% said they would not change their approach to the project if the intermediate steps had been graded, 43% said they would have. Question five read, "If you agreed with question 4, how would your approach change?" The three respondents indicated that they would have put more effort into the project either through producing higher quality intermediate steps or better coordinating with their teammates earlier in the project. Somewhat surprisingly, 40% of students felt they did not have enough time to complete the project although it was assigned during the second week of class. From the assessment, it is unclear whether these students felt the project was too difficult or whether the traditional difficulty of balancing the workloads of several courses contributed to their responses to question ten. In general, these questions indicated that students may have put forth more effort if I had graded the intermediate steps although the task deadlines helped them stay on track to complete the project on time.

Questions six and seven (Tables 4 and 5) were included to asses whether students gained communication skills while completing this project. Presenting their work to an external audience with an interest in their findings prompted students to take perhaps more than the usual amount of care in preparing reports and presentations. 86% of the respondents felt that they had gained oral communication skills. In fact, one student had never prepared for an presentation outside the university before this project. Further, 71% said that they gained skills in report writing.

Finally, it was my hope that students would enjoy this project, which was very applied. The responses to questions 12 and 13 assured me that the students had enjoyed the project and were proud of their work.

Although I was able to learn a good deal about students' perception of the project from this evaluation, it lacked some elements that would have helped me better assess the project's success. First, the evaluation did not inquire whether students had gained any insight into voluntary programs and whether their interest in public policy had increased as a result of the project. Second, in retrospect I regret not asking students for general comments on the project.

8. Conclusion

This project was, according to the assessment results, enjoyable and educational for the students. It is my hope that students will be more aware of voluntary strategies to reduce emissions when they become practicing engineers and would be able to help their companies assess participation in those programs. Alternatively, if the students were to enter the government sector, they may have a better foundation for working on voluntary programs.

I learned a number of lessons from implementing this project. First, it is better to use existing data or those which students will generate rather than relying on external sources to generate data. It was difficult to proceed with the project when Pilsen truck fleet data from the city were unavailable. Substitute data from the city and EPA, however, made it possible to continue but shifted the first project element's focus away from the Pilsen neighborhood. Second, it may have been better to grade the intermediate steps to provide greater motivation for the students.

If I were to implement a similar type of project again, I would place more emphasis on its policy aspect. I focused on ensuring that students learned about mobile source controls because they were enrolled in an engineering course, but it may have been worthwhile to more closely examine the policy implications of the SmartWay Transport Program. For example, the students could have studied the design and development of the program, program alternatives, the role of engineers in designing the program, and barriers to companies joining the program. Nonetheless, in light of the evaluation results and after witnessing the students' well-received presentations, I believe this project was successful.

9. Acknowledgements

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