A Comparison of American and Dutch Engineering Students' Views on Safety and Sustainability for Ultra-lightweight Vehicles

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Abstract

This paper reports on one of three international collaborations on engineering ethics, which was the development of an ultra-lightweight vehicle ethics engineering ethics case that focused on potential ethical issues for safety and sustainability in design. The case focused on the efforts of a multidisciplinary design team consisting of undergraduate and graduate students from the Netherlands attempting to design a lightweight, sustainable car. In this paper we will present the ultra-lightweight vehicle case study, which focused on the possible design of a family car with a maximum mass of 400 kg, which is less than half of that of normal cars. This reduction in mass has generated a debate over safety concerns when building a lightweight car because heavier vehicles protect the driver and passengers in a collision, but are not as fuel efficient. We presented engineering students from both the Netherlands and the United States with questions about safety and sustainability for this case, and in this paper, we will discuss representative answers from both groups. These answers demonstrate the commonality of views between the two engineering cultures as well as the differences in attitudes towards safety and sustainability. From the results of this pilot study, a multimedia web-based engineering ethics case was developed that is available through the Online Ethics Center (www.onlineethics.org). This web-based case can be used to augment ethics and design instruction in engineering curricula. The online presentation details the ultra-lightweight vehicle design case, as well as the questions posed to the Dutch and American students concerning safety and sustainability, which could also be answered as part of a class assignment. In addition, on the web site, a comparison of the answers from the American and Dutch engineering students is presented to give insight into cultural similarities and differences, as well as to provide topics useful for classroom discussions.

Index Terms: engineering ethics, lightweight vehicles, safety, sustainability

Introduction

Through a SUCCEED grant (#0135585) designed to pair international junior scholars for engineering ethics case development, an ultra-lightweight vehicle ethics engineering ethics case was developed that focused on potential ethical issues for safety and sustainability. The case focused on the efforts of a multidisciplinary design team consisting of undergraduate and graduate students from Aerospace Engineering, Applied Earth Sciences, Industrial Design and Mechanical Engineering at the Delft University of Technology in the Netherlands to design a lightweight, sustainable car (Van Gorp & Van de Poel, 2001). The case was piloted to similar groups of engineering students at the Delft University of Technology (Aerospace) and the University of Virginia (mixed engineering disciplines), and their answers were used to develop a web-based case study to be used in engineering ethics forums. This paper will detail the case study as well as the answers from the two groups of students and conclude with a discussion of how the case can be used in engineering ethics instruction.

The Case Study

The American and Dutch engineering students were presented with the following case: The goal of the Dutch design team is to design a family car with a maximum mass of 400 kg. Mass is an important factor in the fuel consumption of a car, therefore a light car can be very energy efficient. The target mass is less than half of that of normal cars. (European family cars usually weigh about 1200 kg and the average American car weighs 1360 kg). Another requirement is that the car should be manufactured at affordable mass production costs (DutchEVO, 2004).

Safety Issues for Lightweight Cars

The goal of reducing the mass to 400kg has generated a debate over safety concerns when building a lightweight car. A car that is relatively light always has a disadvantage in collisions with larger cars; it will always experience the greater acceleration. Traditional automobile safety considerations have resulted in designs of very heavy and stiff vehicles, protecting the driver and passengers in a collision but at the same time constituting a hazard for other road users in lighter vehicles because of their significantly reduced stiffness and mass. In addition, heavier vehicles are not as fuel efficient.

Recent developments in automobile safety have led to the increasing use of passive safety systems[1] like different kinds of airbags and active systems like Anti-lock Braking System and night vision. Designing in the conventional way means that safety systems are included as much as economically feasible. In a car of 400 kg or less it is very difficult to include extensive active and passive systems, so the design of a lightweight car necessitates a reconsideration of the ideas of what constitutes adequate car safety. Is it a car that performs well in crash tests, or is it a car that helps the driver to brake suddenly and hard to avoid a crash?[2]

There is a theory within safety science that states that people have a target risk that guides their behavior, and this is called risk homeostasis. People will try to keep the perceived risk at the same level. A driver that feels safe and protected by her car will speed more. This could lead to accidents with higher speeds involved and therefore more injuries and damage. The same driver would probably not speed in a subcompact, as she will probably feel more vulnerable. Therefore, there might be good arguments to build a car with less active and passive safety systems. The Delft student designers have chosen to design a car with few systems, good handling, but one that makes the driver feel a bit vulnerable. This choice is inspired by the lightweight criterion and the risk homeostasis theory.

Safety Questions for the Case Study

1. Are the fundamental responsibilities of safety engineers compromised in the design of this lightweight car?
2. Risk and cost benefit analyses are critical components of any engineering process. Describe the ethical issues that a designer of a lightweight car faces when conducting these analyses.
3. If the theory of risk homeostasis is correct (there are debates about this, some studies indicate that the theory is empirically verified and others claim that the

[1] Passive safety systems try to minimise the damage and injuries when an accident happens, active safety systems help prevent accidents.
[2] For example Anti-lock Braking System (ABS) and break assistance.

theory is empirically refuted), is it ethical to design cars for perceived levels of risk? Why or why not?

4. Should lightweight cars be required to meet the same government safety regulations as regular cars? Why or why not? Is the government obligated to introduce any new legislation regarding the manufacturing of lightweight cars?
5. If some cars are significantly more safe than others, are engineers violating any ethical standards in designing cars that are not as safe as they could be? What other factors come into play in addition to ethical considerations when designing for safety?

Sustainability Issues for Lightweight Vehicles

The World Commission on Environment and Development, the Brundtland-commission (WCED, 1987) proposed the following definition of sustainable development:

Sustainable Development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

1. The concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given.
2. The idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs.

When following the Brundtland definition it is not clear what makes a car sustainable - should the car be recyclable, be lightweight, or should it not be built in the first place in order to be sustainable? Designers within the same design team interpret the term sustainability differently as can be seen in the answers given when asked what sustainability means. Some refer to the closing of the material cycle by recycling, others refer to energy and resource efficiency during production and use, and some focus on the energy consumption during the use phase (90% of the total life cycle energy is used during the use phase) of the car.

These different definitions are not always compatible. Lightweight materials are often difficult to recycle, but the energy consumption of a very light car is very low. European legislation requires that within ten years 95%[3] of the materials in cars should be recyclable. The design team does not want to comply with this percentage; they would rather build a very light "throw-away after use car" than a heavy steel car that can be recycled. Their argument for this choice is that most energy is consumed during use of the car and that mass is a large factor in energy consumption during use. A lightweight car would therefore require much less fuel than normal cars. This would also mean that, other things being equal, the CO_2 emissions of lightweight cars would be less than that of normal cars.

Sustainability Questions for the Case Study

1. Are engineers ethically obligated to consider sustainability in their designs? Why or why not?

[3] 95% of the total mass, so a heavy steel car that can be melted at once when interior, electrical wiring, battery and dangerous chemicals are removed will comply with this legislation. Steel is 100% recyclable. Complying with this legislation when designing a very light car is much harder because the interior, electrical wiring, battery etc will make up much more than 5% of the mass of the car and the relative mass of the easy-to-recycle body panels and cage construction is much lower than in the heavy car.

2. Defining sustainability is the first critical step in developing a plan for a sustainable product. This definition is not ethically neutral because such a determination implies a choice to include some aspects of sustainability, while ultimately rejecting others. Discuss the ethical dilemmas that could be faced by designers of lightweight cars attempting to define automobile sustainability.
3. Some elements of sustainability can be difficult to combine, for example lightweight materials are difficult to recycle or electric cars are very heavy but do not pollute the atmosphere. In your opinion do you think sustainable cars are feasible? Why or why not?
4. In the United States, there are no laws mandating that car manufacturers recycle any portion of automobiles, yet 97% of cars that reach their end of useful life are recycled and in general, 75% of the materials in these cars are recyclable. Recycled steel is very profitable in the United States, and in general, landfill costs are much lower in the U.S. than in Europe. Should the Unites States move in the direction that requires manufacturers make all cars 95% recyclable? Why or why not?

Discussion of Answers

In general the ultra-lightweight vehicle design case study was well-received by both groups of students, and the answers to the safety and sustainability questions provided interesting insights to both the similarities and differences in attitudes across the two student engineering cultures. For example, in regards to the question concerning the fundamental responsibilities of engineers in design of an ultra-lightweight car, the responses were mixed for both cultures. Establishment of and adherence to government safety regulations was important for the Dutch students in this regard. However, American students made no comment about governmental intervention for safety standards, but in general did feel that responsibilities of safety engineers were compromised. In drawing a distinction between American and other driving cultures, one American student said, “If this car design were to be implemented in the United States, this may pose more of a problem. Since the car is to be applied to Europe, where car designs in general are smaller, more compact vehicles, the lack of active safety features is not as big of a concern.”

In response to the safety question regarding the validity of designing for risk homeostasis, while the responses were mixed for both groups of students, the Dutch students tended to be more optimistic that designing for perceived levels of risk is ethical. One Dutch student said it is ethical “when the consumer is informed that he/she [will] not only feel more vulnerable but is more vulnerable in an accident. [This is comparable to] driving motorcycles.” In contrast, an American student said, “Assuming that the theory of homeostasis is correct, it is still unethical to design cars for perceived risk levels…the driver of a lightweight car would have no way of surviving, because his one and only defense was his perception, and he cannot perceive the negligence of others.”

For the question concerning whether or not ultra-lightweight vehicles should meet the same safety standards as regular cars, many students in both countries felt that while the lightweight cars should be required to adhere to some governmental regulations, these vehicles should not have to meet the same safety standards as regular cars and should be assigned to a separate category like that of motorcycles. Another opinion in both student groups was that the lightweight cars travel on the same roads as regular cars, and should therefore meet the same safety standards.

Answers to the question about engineers violating ethical standards in the design of ultra-lightweight vehicles often refer to informed consent of the public in both American and

Dutch societies. An American student formulated the informed consent issue as follows, "Engineers are not violating any ethical standards by designing 'unsafe' automobiles provided that the safety successes and failures are disclosed to the customers at the time of purchase." In addition, some American students also addressed socio-economic and legal liability issues. For example, one student wrote, "One ethical consideration is whether or not people of all income levels have the option of choosing a risk level acceptable to them, or whether those of scarce means are relegated to driving cars with higher inherent safety risks." Perhaps reflecting the litigious nature of American society, one student wrote, "If the cars are produced in the United States, one thing can be assured, lawsuits will be filed against these companies for the lack of safety features."

When reflecting on the responses to the questions about sustainability issues, it is important to keep in mind that all the Delft Aerospace engineers take a required course on sustainability. Students from Delft thought that including sustainability considerations in design was apparent as exemplified in the following quote, "According to me it is obvious that engineers should take sustainability into account in their designs. They should look at the consequences of a design for environment and society. Especially in designing mass products like cars it is absolutely necessary that these consequences are investigated." For American students it was less or not at all obvious that sustainability should be a significant consideration, "The consideration of sustainability should not be burdened on the design engineer. Instead the consideration of sustainability should be with those who are responsible for protecting the environment and its resources…to consider sustainability might limit the creativeness of the design. Sustainability in engineering is typically a by-product of the need to be economical. The only obligation of an engineer is to consider sustainability as if it was a specification of the design."

In regards to the question of the feasibility of sustainability, in general both groups of students thought that this would be difficult. A Dutch student wrote, "It will be difficult to create sustainable cars because very different aspects need to be compared. I think, however, that the question is wrong. I think that it is impossible to find an ideal and perfect sustainable solution for cars, this does not mean that we should not try to attain such a solution. I think it is possible to improve existing cars with existing technology and this process should be repeated. The question is not sustainable or not sustainable, but to what extent a car is sustainable." In a similar vein reflective of an American attitude, a U.S. student answered, "In my opinion, the market for sustainable cars is very small relative to the market for big trucks and SUVs (sport utility vehicles). Sustainable cars are not feasible, especially in the United States. Generally the consumers' attitudes towards cars are that bigger means better, stronger, and more durable. Sustainable cars do not have the market for mass production."

Highlighting the perceptions that the two cultures have about one another, when asked whether or not the U.S. should make all cars 95% recyclable an American student answered, "The U.S. should follow the Europeans' example because the average American buys more cars in his lifetime that the average European," and a Dutch student answered, "In the U.S. cars are heavy and consumers probably do not want lighter cars, therefore it is possible to require 95% recyclable without cars getting heavier. This makes the choice for recyclability a good idea."

The Web-based Case Study

The previous discussion of the American and Dutch responses to select questions from the ultra-lightweight case study is only representative of a small group of answers. To both provide a venue for disseminating the case study and questions, as well as provide a more in-depth comparison of the two student engineering cultures' answers, a web-based case was

developed. Found on the Case Western Online Engineering Ethics Center website (www.onlineethics.org), the ultra-lightweight vehicle design web-based case is titled, "Where Should The Line Be Drawn Between Fuel Efficiency And Safety?"

This online case presents the same background material and questions as detailed above, as well as provides forms for entering answers to the questions and allows users to send the answers via e-mail to any relevant party. This capability was included so instructors of ethics or engineering design courses could use the website case study as an assignment in addition to using it as a tool for discussion. Furthermore, a representative comparison of all Dutch and American responses to the pilot case study is included on the website to provide an additional discussion component as well as to allow students from any discipline or country the ability to compare their answers to the American and Dutch engineering students' responses. The comparison of American and Dutch engineering student responses is not meant to be representative of the two cultures in general, merely an example of ideas and opinions that were generated by two closely related cohorts from two different cultures.

Conclusion

In an effort to promote international collaboration between junior doctoral candidates through a SUCCEED grant, an engineering ethics case was developed that focused on the safety and sustainability issues in the design of ultra-lightweight vehicles. The case was piloted to similar groups of engineering students at the Delft University of Technology and the University of Virginia, with some enlightening and sometimes surprising results. The case study along with the student responses to the safety and sustainability questions were used to develop a web-based case study which is available through the Case Western Online Engineering Ethics web site. The interdisciplinary web-based ultra-lightweight case study, questions, and comparison of student responses are designed to be used by instructors and students in ethics and technology classes, as well as management, public policy, and engineering design classes

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