Hybrid Cars As a Way to a Cleaner Environment

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Table of Contents

Introduction

Since the advent of the internal combustion engine in the late 1800's, and particularly its installation in wheeled automobiles, motorcars have been creating pollution. The degree of this pollution has varied over time, as initially very few automobiles existed, which progressed to the hundreds millions of automobiles on the road today. In relatively recent years, there have been various attempts to control these emissions, such as the first auto emissions law created in California in 1960[1] and the creation of the EPA by President Richard Nixon in 1970[2]. However, it is clear that the internal combustion engine, fueled by fossil fuels, will continue to pollute to some extent regardless of the degree of emissions reduction. This fact, coupled with technological advances of the late 20th century and the 21st century, has caused corporations worldwide to pursue alternative means of vehicle power, in efforts to both reduce environmental harm and meet stringent upcoming emissions laws passed by national governments.

These means include, but are not limited to, fully electrical vehicles (such as GM's 1990 "EV1"), experimental vehicles powered by hydrogen, and gas-electric hybrid vehicles. If vehicle design is to follow a similar path in the future as it has in the past, then gasoline-electric hybrids (hereon in referred to simply as "hybrids") are likely the only feasible option out of these three developed concepts. Vehicles that depend on electric power only, for example, still require that power to be produced in bulk, and electric power in the US is still primarily created by burning fossil fuels (more than 50%

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[1]California Auto Emissions Law.
History of SAE and Automotive Industry (1905-2002) :
http://www.sae.org/sae100/history/timeline/timeline.htm

[2]Creation of the EPA.
EPA History Timeline
http://www.epa.gov/history/org/origins/reorg.htm

of the power created in the US is still based on coal-burning plants[3]). This means that, while an electrically power car will not produce any pollution itself, it will require a greater electricity consumption by its owner, and therefore will often increase overall pollution by an amount similar to a gasoline burning car. Hydrogen technology has promising benefits, but there are many matters of convenience to be dealt with before the technology becomes widespread, promising that it will not be used in quantities great enough to reduce global pollution for some time.

Gasoline-Electric hybrids, on the other hand, are not merely an aspiration. These vehicles are already being sold in (relatively) large quantities, and are very commercially feasible due to their engineering and design basis on popular vehicles. Close to fifty thousand hybrids were sold in the United States in 2003, and sales numbers have been shown to increase approximately twofold annually. In fact, projections have hybrids accounting for 10% of midsize sedans by 2006, and 5% of all cars sold by 2010[4]. These vehicles are the future of low-emissions automobiles as we know them, and they are available now.

Of course, the introduction and popularity of these models creates as many questions, if not more, than it answers. While some consumers are anxious to jump on the bandwagon of hybrid vehicles based on their emissions status alone, the majority of American drivers are hesitant to purchase these vehicles for various reasons; reliability of yet-untested technology, cost, and questionable performance as compared to gasoline powered vehicles are issues that arise quickly. The consumer perception of these

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[3] US Electricity Production
http://www.solcomhouse.com/electricity.htm

[4] 4. US Hybrid Sales Numbers and Forecasts
http://www.hybridcars.com/sales-numbers.html

vehicles is just as important as their true factual capabilities, and for this reason it is very important to consider how average people who are not technologically knowledgeable feel about this new advance in automobiles.

Another issues which is certainly influencing the sales of all automobiles sold in the US (and worldwide), and particularly the sales of high-efficiency vehicles such as hybrids, is the issue of fuel economy, and its relationship to rising fuel prices and a decreasing global crude oil supply. Interestingly enough, worldwide crude oil reserve estimates have been increasing at a rate greater than that of oil usage, according to the US Geological Survey in a comprehensive report published in 2000. However, regardless of the current oil reserve estimates, it is clear that at some point in time crude oil will begin to become scarce due to the fact that its usage is far greater than its natural production.

Based on this knowledge and gas prices that are rising, the public is beginning to become concerned with fuel economy (a far cry from the SUV boom of the 90's). What better technology to carry vehicles into the 21st century, than hybrid Gas-Electric powerplants? These vehicles, using a mix of new engines and new technology, are offering gas mileage increases of 50% or more, as compared to similarly sized vehicles with conventional engines. This has great promise for both fiscal savings of the consumer, and extending the life of worldwide oil reserves.

In order for this technology to be successful in meeting its true reasons for existence, those being the reduction of emissions and fuel consumption, these vehicles must be commercially successful such that they eventually account for a noticeable percentage of vehicles used on a daily basis. While limited production runs of low emissions vehicles do well to exhibit technological capabilities of the manufacturer, they

do nothing to help reduce the emission caused primarily by the sheer magnitude of gasoline powered vehicles in use, nor do they provide a perceivable decrease in nationwide fuel usage. For an appreciable reduction in emissions to take place, consumers as a whole must be satisfied with the performance of the hybrid automobile, and therefore willing to choose one instead of their favorite standard sedan when they are new-car shopping.

What does this mean for producers of hybrid automobiles, such as Toyota, Honda, and Ford? It means that they must build vehicles which perform (feel, sound, and drive) as though they are powered by normal gasoline-only powerplants. In recent years, this requirement has been sought-after, and in many cases manufacturers have had at least some degree of success in reaching it. For example, take the Toyota Prius. While not an extraordinarily fast vehicle, the Prius boasts acceleration numbers in line with that of Toyota's Camry[5], a very popular sedan sized similarity to the Prius, and utilizing non-hybrid propulsion. Similar performance has and will be attained by other offerings from manufacturers such as Ford, who is offering a hybrid version of their Escape SUV for the 2005 model year. The Escape (until now, powered by a gasoline engine) is the best selling small SUV in America[6], and the hybrid version of the vehicle is poised to perform just as well as the original.

Based on these examples, and many others both current and to come in the near future, it is clear that a solid market exists for the hybrid automobile. The only factor left

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[5] Prius and Camry Acceleration
Road and Track First Drives: 2004 Toyota Prius
http://www.roadandtrack.com/article.asp?section_id=6&article_id=828

[6] Ford Escape
Ford Escape Hybrid Manufacturer's Website
http://www.fordvehicles.com/escapehybrid/

now is the consumer, and their willingness to buy a new car offering this promising technology. Regardless of market projections and sales forecasts, the future of the hybrid hinges solely on the manufacturer's abilities to produce a vehicle that serves as a viable replacement (in all aspects) for the best-selling vehicles of yesterday.

Background

Since 1970 the amount of miles traveled per year by Americans has risen by 150 percent compared to a population increase of only forty percent[7]. In other words on average Americans travel more than three and a half more miles than they did in 1970. This is not to say that this is not happening in other industrialized nations as well, but for simplicities sake only the United States of America will be taken into account. America is a country that has truly become dependent private transportation.

Even more interesting than the America's dependency on private transportation, is its effects on the environment. Hybridcars.com claims that ninety percent of the "environmental impact" from cars occurs while the car is being driven[8]. The effects on the environment that should be looked at are those which are caused by driving a car. When a car is being driven there are only a small number of things that contribute to that effect the environment namely being the fuel used by that car and the emissions given off by that car.

Typically, for every one gallon of gasoline burned, twenty pounds of Carbon Dioxide are produced[9]. This adds up to eight point two million barrels of oil per day and three hundred metric tons of Carbon Dioxide goes into the air per year from automobiles alone[10]. Alone the numbers might not mean much, but according to the EPA in 1997 automotive emissions were the second highest contributor to greenhouse gases second only to Industry[11]. If the fuel economy of American vehicles on average was increased by five miles per gallon almost twenty percent less oil would be used and thus twenty

[7] (www.hybridcars.com/driving-trends.html)
[8] (www.hybridcars.com/totalcycle.html)
[9] (www.hybridcars.com/global-warming.html)
[10](www.hybridcars.com/global-warming.html)
[11](http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html)

percent less Carbon Dioxide per year[12]. Five miles per gallon is by no means an unreachable goal, in many cases better driving habits could help contribute to better gas mileage, when the EPA tests for their rated miles per gallon they do not take into account flooring it up hills and on ramps, and speeding can reduce gas mileage by thirty three percent on the highway[13].

According to the EPA thirty two percent of green house gas production is due to things that each person can help prevent[14]. The three specific areas that each person could contribute to, or rather not contribute to are[15]:

- electrical usage
- waste production
- personal transportation.

For this study the only aspect looked at was personal transportation.

Not only are the emissions caused by automobiles a growing problem, but dependency oil as well. The United States accounts for twenty five percent of the world's oil consumption, despite accounting for only five percent of the world's population[16]. The US is a country that is dependent on oil, especially for automotive use, ninety-seven percent of automobiles use petroleum based fuel[17]. It is projected that in forty years there will be no more oil to be use[18]. The problem is not that the oil will be gone in forty years; it is that the peak of oil production has now been reached[18]. As oil production declines prices will sky rocket, as they did in the 1970's when oil production

[12] (www.hybridcars.com/global-warming.html)
[13] (http://www.fueleconomy.gov/feg/driveHabits.shtml)
[14] (http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html)
[15] (http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html)
[16] (http://www.hybridcars.com/importance-of-oil.html)
[17] (http://www.hybridcars.com/importance-of-oil.html)
[18] (http://www.lifeaftertheoilcrash.net/)

and oil prices increased by four hundred percent[18]. Unlike the Oil Crisis in the 1970's oil prices will stay high and only get higher as time goes on and the oil supply continues to be depleted. We do not need to start developing alternative sources of fuel now, we needed to thirty years ago.

Emissions from private transportation can be reduced in four ways:

- travel less per day
- take alternate transportation
- improve gas mileage
- lower the amount of pollution per amount of fuel burned.

For many people it is not an option to travel less due to a fiscal situation or some other kind of need. Alternate transportation could consist of taking public transportation, riding a bike or walking, or car pooling. All three means of alternate transportation will reduce the amount of pollution a person produces per day. The third and fourth options can be fulfilled with one solution a *hybrid* car, a car that gets more gas mileage than any other passenger car on the road, and produces less pollution per fuel burned[19]. While a combination of all four would ultimately lead to the least pollution per person, the following report will concentrate on the last two.

Now that is has been shown that hybrids can potentially lower emissions from automobiles and decrease dependency on oil, it is important to see what hybrid cars are currently offered. To date there are seven hybrids on the market, to simplify the matter the following investigation will only take one hybrid into account.

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[19] (http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html)

The Toyota, Prius is a prominent hybrid in January of 2005 about five times more were sold than its closest competitor the Civic hybrid[20]. The Prius sales record alone makes one wonder what the other companies are doing wrong, or rather what Toyota is doing right. The 2004 Prius was named one of the ten best cars of the year by Car and driver, it was the first hybrid to ever do so[21]. Car and driver is a performance magazine and many of the cars that often wind up in the top ten best cars of the year are performance cars. For the Prius to be included in this list it would have to do what it is designed to do very well. The engine in the 2004 Prius was voted International engine of the year 2004[22]. One of the 51 out of 56 judges that voted for the Prius engine was quoted as saying, 'Toyota's hybrid system points the way to a world with eco-cars that deliver surprising acceleration, class leading fuel economy, and industry-leading emissions levels.' [23] This means the integral part of the hybrid platform, the engine was not only designed well, but it was the most innovative of those produced in 2004. The Prius is a good representation of current hybrid technology.

The Prius is not some car that was designed in some rocket scientist's back yard and rushed into production. The story of the Prius goes back at least twelve years, to Toyota's "Earth Charter" a program designed to promote environmental responsibility at all levels of production[24]. As part of the charter Toyota wrote, "Develop and provide products with top level environmental performance."[25] Here one can see the beginnings of a hybrid car, since the goal of a hybrid car is to get the best possible fuel efficiency,

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[20] (greencarcongress.com/sales)
[21] (http://www.caranddriver.com/article.asp?section_id=33&article_id=7582)
[22] (http://www.ukintpress.com/engineoftheyear/winners/winner.html)
[23] (http://www.ukintpress.com/engineoftheyear/winners/winner.html)
[24] (www.toyota.mo.co.jp/environment/plan/)
[25] (www.toyota.mo.co.jp/environment/plan/)

while still having a car that can keep up with others on the road. Soon after this the G21 committee was formed by Toyota, they decided and announced in late 1994 that a hybrid car was to be built[26]. The Toyota Prius first went on sale in Japan October, 27, 1997[27]. This means that the Prius has been on sale for over seven years now. The Prius arrived in the United States in August of 2000.[26] The Prius has been in development for over ten years and has been on sale for seven of those ten years, and the 2004 model has had only one recall, which is for a brake light switch, this has nothing to do with the hybrid aspect of the car, the Prius is a reliable car[28].

Not only is the Prius reliable, but it can keep up with the average car on the road, in a test preformed by Consumer Guide the Prius accelerated from 0-60 mph in 10.5 seconds[29]. Compare this to the Civic EX, and the Ford Focus ZX5 with 0-60 mph times of 9.4 and 9.3 seconds respectively[30]. The Prius can hold its own with two cars in its class designed with a sportier crowd in mind. Despite not being as quick as its competitors the Toyota Prius is still able to accelerate hard enough to satisfy the average drive when needed. Some thing to keep in mind is that hard acceleration means poor gas mileage and the Prius was designed to get good gas mileage 60 mpg highway and 51 mpg city[31]. The Prius was not built for performance it was built to deliver half the amount of pollutants of the average passenger car on the road[32]. Something very important to note the Prius is not only comparable to those in its class in performance, gets better gas

[26] (http://www.autofieldguide.com/articles/100302.html)
[27] (autos.msn.com)
[28] (http://www.recall-warnings.com/auto-content-53620.html)
[29] (http://auto.consumerguide.com/auto/new/reviews/full/index.cfm/id/37572)
[30] (http://auto.consumerguide.com/auto/new/reviews/full/index.cfm/id/37572)
[31] (http://yosemite.epa.gov/opa/admpress.nsf/0/25ca1f93cff978c185256dc800567f43?OpenDocument)
[32] (www.hybridcars.com/pollutants.html)

mileage, and pollutes half as much per gallon of gas, but it comes with a price tag of $20,000 MSRP, thanks to Toyota's subsidizing of the cost[33].

Hybrid technology is very interesting and if implemented in a large numbers it could help reduce passenger vehicle emissions, and reduce dependency of oil. If the public does not understand hybrid technology then the whole point is lost. To test to see how well the public knew about the hybrids a survey was designed to try to understand just what was known by the public. The survey was given to only engineering students, this was done to focus in on those who usually have more information than the general public, thus if engineers knew hybrids well, then the public could be tested to see how well hybrids were understood.

[33] (http://www.caranddriver.com/article.asp?section_id=33&article_id=7582)

Methodology

Due to the short amount of time that hybrids have been on the market, coupled with the fact that they depend on various types of new technology to operate properly, it is clear the average consumer may very well not completely understand the operation of these vehicles. There has been a lot of media concentration on some of the specific systems, such as Toyota's attempts to focus on their "Synergy Drive System," but it is likely that the majority of the public has either seen these and dismissed them, or not seen them at all. Additionally, there is always a stigma that accompanies new technology, which must be shed before the non-technical majority is willing to depend on it.

In order to gauge the public perception of these new technologies, we conducted a survey with questions carefully selected to hit on some of the more subtle (and likely more important) points of modern hybrid technology. For example, several of the questions focus on what the public deems as acceptable differences between hybrids and non-hybrids, in terms of cost and performance. It has yet to be clearly seen if, for example, the average consumer is willing to give up some acceleration capabilities in the name of improved gas mileage. Or, in another scenario, it is clear that the Prius' increased gas mileage (almost double that of the Camry, and over 50% more than the Corolla[34]) would save the vehicle's owner several hundred dollars within a year's use, based on annual passenger car mileage[35] and a gasoline price of two dollars per gallon.

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[34] 2005 Toyota Vehicles Gas Mileage
Edmunds New Vehicle Information: Toyota
http://www.edmunds.com/new/toyota/index.html?tid=edmunds.n.mainindex.content..0.*

[35] Average Annual Passenger Car Mileage
EPA Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks

However, whether or not a new car consumer has this in mind when making a purchase decision is a question that is yet to be answered. One of the goals of the aforementioned survey is to provide insight into questions such as this.

Another aspect of public perception is the understanding (or in many cases, the lack thereof) held with regard to some of the technologies used in hybrids. As an example, Toyota's power system uses high voltage wires running from the battery to the engine bay which can have up to several hundred volts of electrical potential energy contained within them (compared to twelve volts in a standard system). Toyota has set the system up such that it does not pose a risk to the consumer, but once again perception may differ from reality.

Issues such as these will have an effect on the sales and success of hybrid vehicles for a reasonably long time into the future, and if these vehicles get off on the wrong foot then it may not be possible for them to ever make a full recovery. It is this facet of the youthful hybrid market which the survey will concentrate on.

The survey is composed of six multiple-choice questions, followed by one demography question for classification purposes. The following is a brief outline of the questions, including information detailing why the question was selected, as well as intentions and desired information that we hope to be able to withdraw from the results.

1. If you were purchasing a hybrid car, and there were two choices where the only difference was aesthetic, would you purchase:

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http://www.epa.gov/otaq/consumer/f00013.htm

A. *The vehicle that looked like non-hybrid competitors.*

B. *The vehicle that looked different as a hybrid, as compared to non-hybrid competitors.*

C. *I am not concerned with how the vehicle looks*

The basis for this question is very simple, and is in part drawn from two of the competing hybrids available on the market today. Some manufacturers have been marketing vehicles that use hybrid technology in a body that is identical to that of models powered by standard engines, while other's hybrid offerings look decidedly "futuristic." Until this point the more futuristic model has been outselling its competitors, but it is unclear is this is due to aesthetics or other features.

2. I would be willing to spend ____ percent more on a hybrid vehicle with the same features as a similar non-hybrid.

A. *zero*

B. *1-5%*

C. *6-15%*

D. *I would buy the hybrid regardless of price difference*

This is more of a market analysis question than anything else, but it is also a factor often underlying all else. Many consumers, even when faced with a vehicle that they like more than the second option, will choose the cheaper vehicle due to financial feasibility and the

impression that they got a better "deal." This question will allow the survey results to be classified by which people are willing to spend extra money on a hybrid, and which people are shopping under their financial obligations before all else.

3. Does the fact that hybrids have only been on the road for several years, and therefore there has not been a long time to quantitatively assess reliability, bother you?

Please answer with a number from 1 to 5, with 1 being "not at all" and 5 being "a lot."

Answer: ___

This question focuses on the aspect of average technological understanding, as mentioned above. From an engineer's standpoint, it seems apparent that a manufacturer such as Toyota or Honda would have done as much, if not more, development in order to ensure that these vehicles would be reliable. However, most consumers are not familiar with practices such as these, and therefore will often wish to see several years of successful vehicles before they take the financial obligation of owning one.

4. Do you feel as though the high voltage hybrid system poses a threat to you (such as in the case of an accident)?

A. Yes

B. No

Yet another public perception question; similar to the third question, this focuses on the difference between a potential buyer's perception of automotive design, and the truth. It is very likely, and almost a distinct requirement, that the high-voltage power transfer system be designed with redundant safety measures, to render it harmless in the case of an accident. Regardless, the plausible threat of this system could potentially hurt sales.

5. *I would be willing to buy a gasoline-electric hybrid car, so long as the acceleration was no more than _____ slower than a non-hybrid competitor.*

   A. 5%

   B. 10%

   C. 20%

   D. Does not matter

In order for hybrids to be competitive with conventional vehicles, they must feel for the most part as a normal vehicle (except for when the bill is being tabulated at the filling station). Consumers may be able to give up a slight bit of acceleration in order to be able to achieve extraordinary fuel economy numbers, but it seems unlikely that they are willing to sacrifice more than that.

6. *What is the primary reason for your interest in a hybrid automobile?*

(Please circle only one answer)

A. Environmental

B. Economical

C. Technology

D. Pop Culture Interest

In some ways, this may well prove to be one of the most interesting questions on the survey; as a matter of fact, it may prove educational to perform a more psychological study, in order to determine if the answers given here match up with the consumer's true reasons for buying the vehicle. Since their introduction, hybrids have attracted quite a following, although different groups of people have been buying the vehicles for different reasons. Some financially motivated owners are concerned merely with saving money on fuel, while others are excited at the chance to drive some of tomorrow's technology. In addition, based on that fact that many public figures (such as Hollywood movie stars) have been seen driving vehicles such as the Toyota Prius, some consumers may buy theirs simply expecting it to be the next fad or status symbol.

Before the full survey was done, all of the questions were pre-tested on a small number of students and friends, in order to get useful feedback about the survey. Some slight modifications were made in wording and options, resulting in the questions shown above.

These surveys were given to various groups of WPI students, in order to gauge both public perception and common knowledge of hybrids. The results of these surveys,

as well as direct and indirect conclusions, will be drawn in the next section. However, there are some points of interest to be made, before continuing on.

One of the groups which the survey was given to was the WPI Motorsports club. This club is organized for all WPI students, faculty, and alumni who are interested in forms of motorsport, from off-road trucking to go-kart racing. Based on these interests, it is clear that this group of students will have a different outlook on a new car purchase, as compared to the average majority that the rest of the surveys were given to.

The rest of the surveys were given to a wider group, representative of the average WPI student who is much less inclined to be interested in motorsports, and automotive technology in general. This wider group consisted of a large lecture class, held by the project advisor, Professor A. Gerstenfeld of WPI[36].

[36] (http://users.wpi.edu/~ag/Gerstenfeld/index.htm)

Analysis

One interesting initial conclusion from the survey results can be found by comparing the results from the Motorsports Club survey to the rest of the data. It was initially expected that those surveyed who were interested in auto racing would have certain views that differed from those of normal technical students. For example, they may be less likely to accept performance shortfalls in the name of slightly improved gas mileage, and they may be more informed in the way of vehicle operation and therefore less likely to fall into the trap of several questions intended to uncover hybrid misinformation.

However, the extent to which all of this appears to be true is much less than one might expect. For example, the Motorsports students, who are intimately familiar with both strong points and shortcomings of modern automotive engineering, were actually only 4% less trustworthy of the new (and relatively untested) technology used in hybrids (an average 2.6 out of 5, instead of 2.5). As another example, these students were interested in hybrids for almost exactly the same reasons as the rest of the students surveyed; the breakdown across environmental, economical, and technological influences was very similar.

So, this means that the initial predictions were wrong; however, there are possibilities abound for why this could be true. For example, it is somewhat likely that the rest of the students (due to their nature as technologically-advanced WPI pupils) are actually much closer demographically to students involved in Motorsports than they are to the general public, in matters such as these. As members of a technical university,

WPI students will have a tendency to have a greater understanding and knowledge base of new technologies.

This same WPI environment, unfavorably, also creates a situation where it is difficult for survey results to be judged based on demographic criterion such as sex and age. With a dismal male to female ratio, and a very narrow range of ages, surveys such as this taken at WPI are guaranteed to only be applicable within their own category. In fact, this group of surveys may actually be very useful, to form a small pack of numbers that could be compared to other small and specific packs, such as retirees or working single parents. The point to be had here is that the survey group taken is a small part of a large overall majority, and as such some of the normal breakdown techniques do not apply.

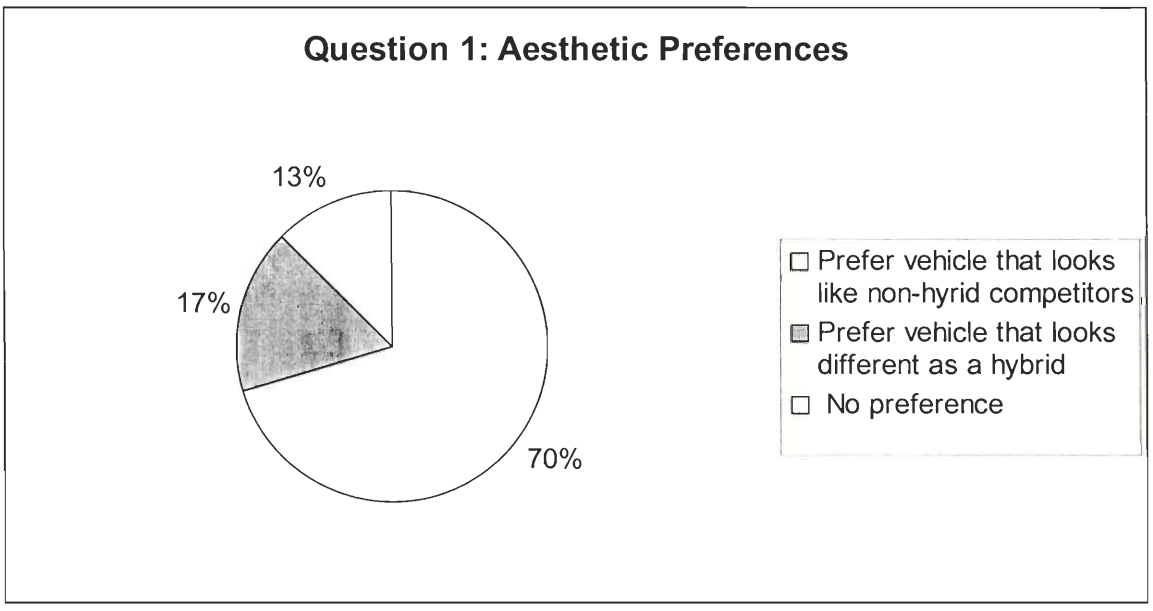
Due to these modified comparison criterion, the comparisons to be made and the conclusions which are to be drawn will be based primarily on the raw distinct numbers that are results of the direct questions asked by the survey. Rather than percentages of females who chose A for one question, B for another, and live in a certain region (as might happen with a wider survey), the results will concentrate simply on the breakdown of answers on each question, and how the results for each individual question maybe be comparable to other questions.

Question 1:

The first survey question is concerning people's preference, in terms of aesthetics, when it comes to hybrid automobiles. The question asks whether the consumer would prefer a vehicle that looked distinctly different, or a vehicle that looked as though it was a standard (non-hybrid) automobile. In addition, an option was given for those who were not concerned with this aspect of the vehicle.

Now, thus far in hybrid sales history, the distinctly different-looking Toyota Prius has been outselling the Honda Civic hybrid by about five to one; the Honda looks almost exactly like every other Civic that is sold annually, besides the fact that it has a small hybrid badge on the rear trunk lid. Considering that Honda and Toyota are both very successful and well-renowned Japanese car manufacturers, it would appear as though the Prius has a distinctive feature which makes it more attractive to customers; for a majority of US consumers, the appearance difference is going to be the most distinct, if not the only noticeable, differing initial feature.

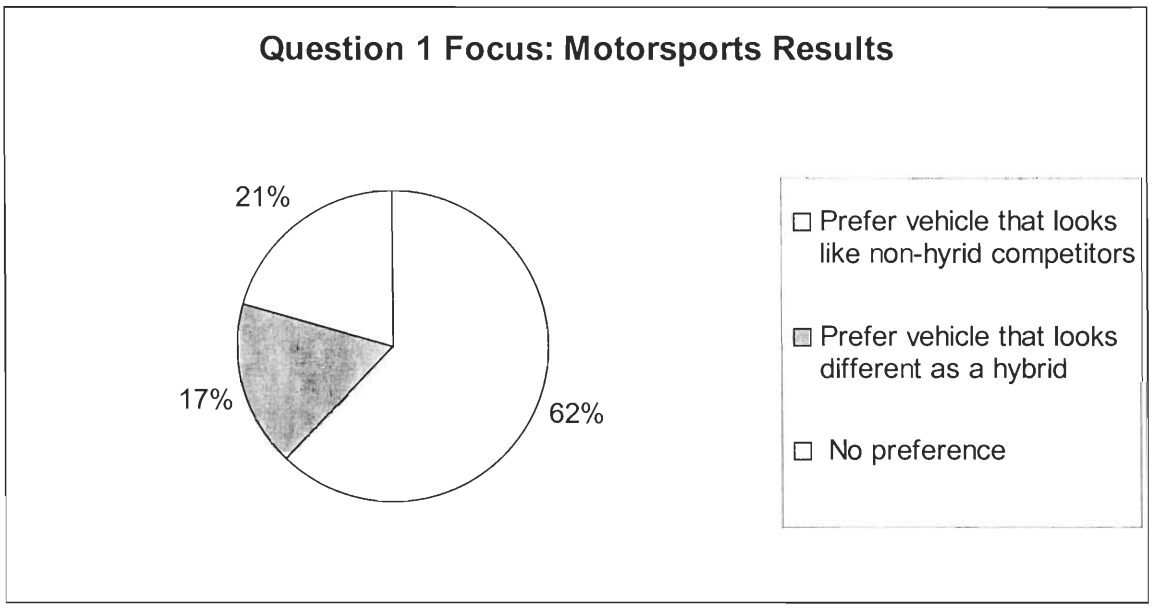
Based on these assumptions, it would appear logical that the subtle futuristic looks of the Prius, which set it apart from other offerings, are attractive to consumers. This is certainly not the only factor in such a decision, but it also is certainly a key one. So, we have thoroughly expected that the survey would show the majority of consumers desiring to have a vehicle that looked different as a hybrid.

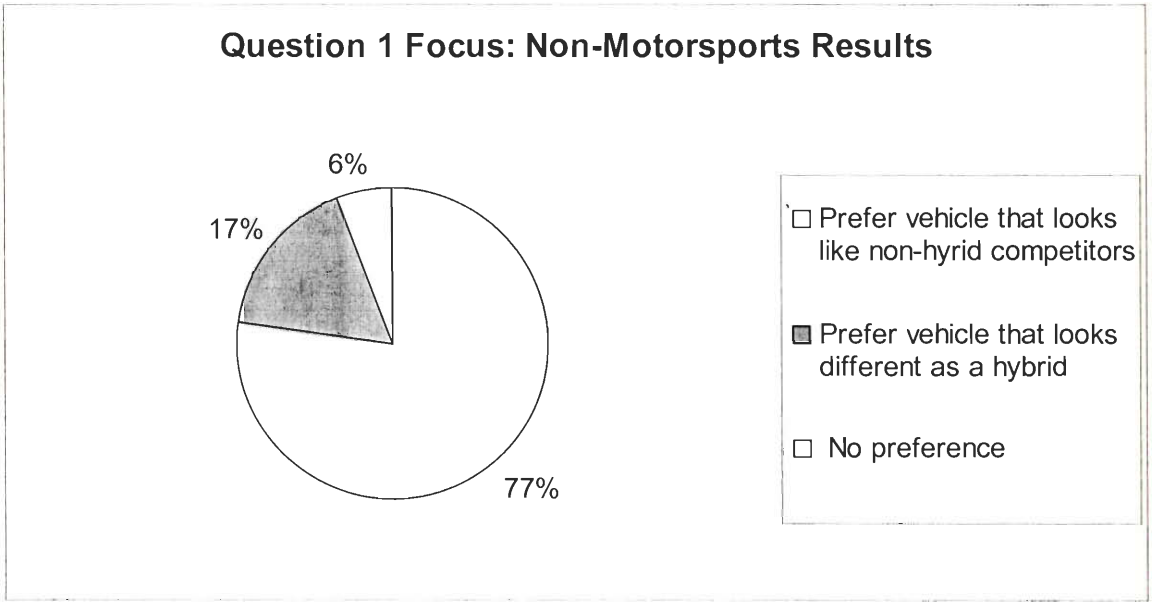


It very quickly becomes clear that not only were our suspicions not true, but that survey results were the complete opposite of what we expected. The vast majority of the students surveyed felt as though they would prefer a vehicle that looked like non-hybrid competitors, completely belying the assumption that all consumers were interested in the Prius's looks.

The question, at this point, becomes a matter of the true meaning of these results: are WPI students (once again) different than the majority of Prius buyers, or are aesthetics truly not a motivating factor in new car purchases (and therefore, other reasons must exist for Toyota's exemplary sales numbers)? We feel as though the first case is unlikely; the possibility of WPI students differing that greatly from the majority is an unlikely proposition at best.

A mildly interesting comparison exists in the comparison of the Motorsports Club survey results to the cumulative outcome of the surveys.





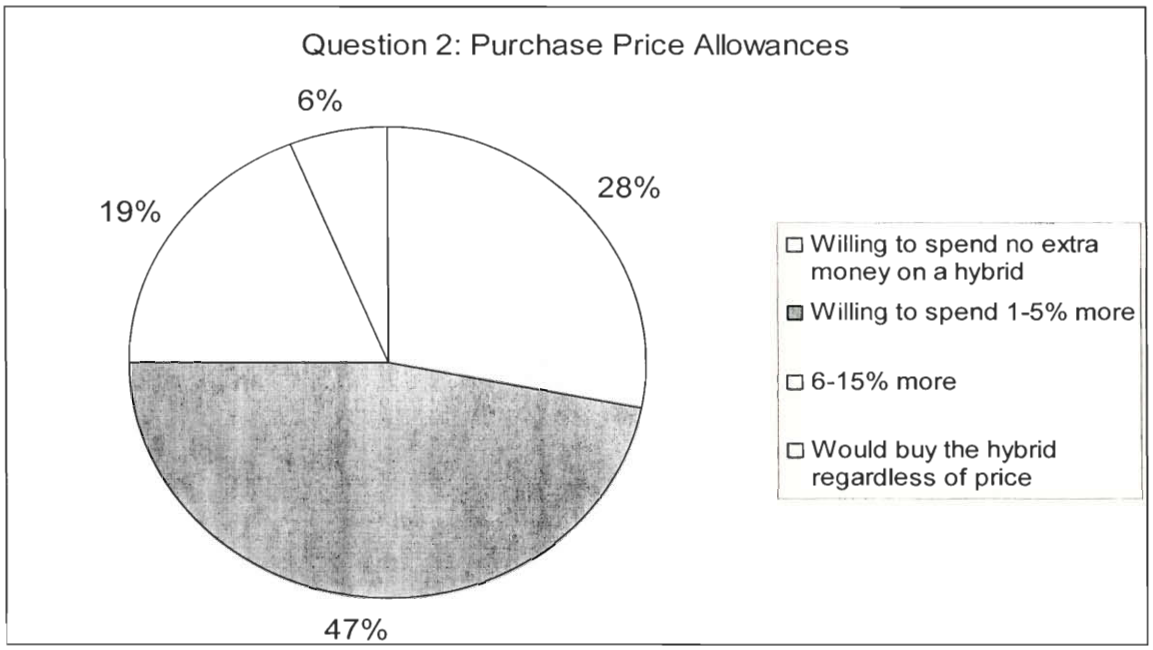
Initially, it is clear that in both cases the breakdown is along approximately the same lines; both groups have the same initial preference, as well as the same hierarchy of choice. However, the distribution is different enough that subsequent analysis shows a key point.

Primarily, it appears as though the same percentage is interested in the appeal of a distinctly hybrid vehicle, while quite a few more Motorsports students are unconcerned with appearance at all.

Question 2:

The second question has a very simple and direct inquiry: how much more are people willing to spend on a hybrid?

Based on available EPA suggested fuel mileage figures and average annual mileage (as discussed earlier in this report), it is clear that a hybrid could save the owner several thousand dollars in fuel costs alone over the course of a couple years of ownership. In addition, governments are proposing tax breaks as well as other perks (such as HOV lane use, among other things) for owners of hybrids, sweetening the deal financially. As such, one would expect that consumers would be willing to spend more money when buying an automobile if the vehicle was a more economical hybrid, as opposed to a less efficient standard vehicle. However, the extent to which they are willing to increase their spending is another point entirely.

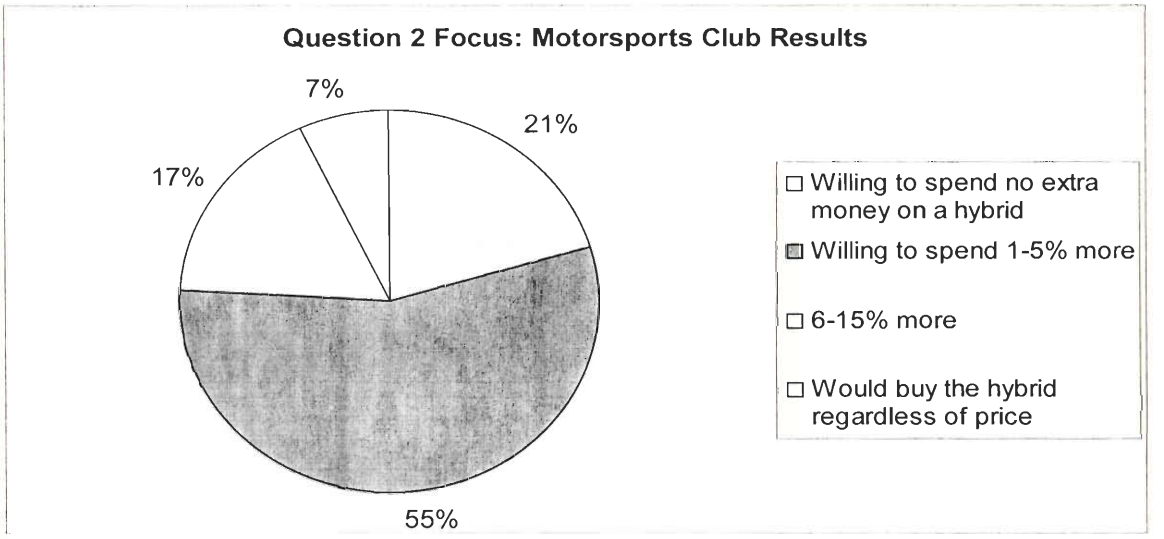


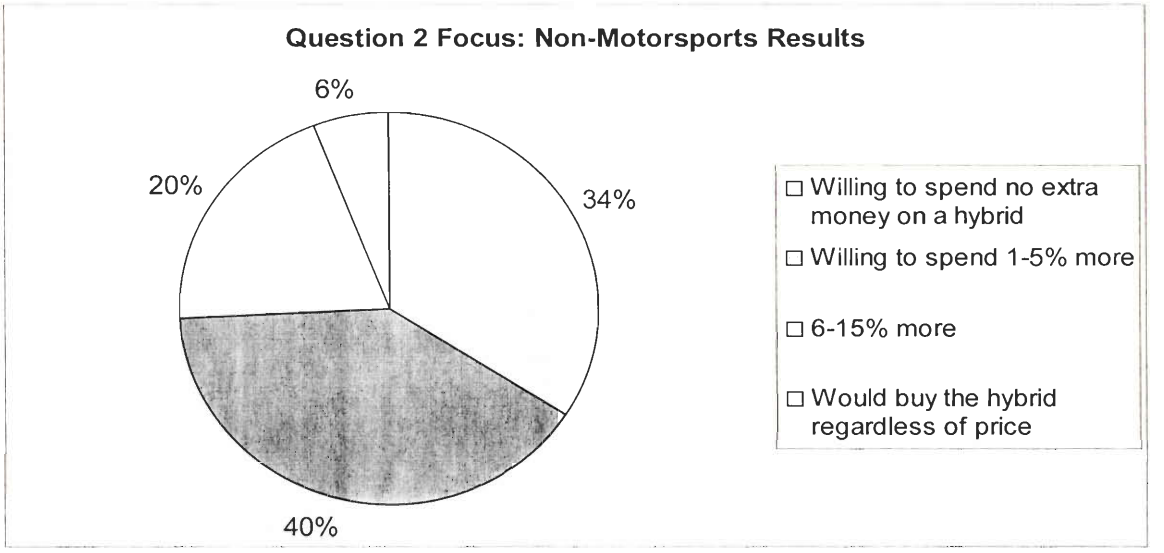
The results of this question are much more in line with expectations; the largest percentage of votes were from people willing to spend 1-5% more on a hybrid, likely primarily due to its more economical fuel usage. The second most popular option is an unwillingness to spend any additional money on a hybrid, which is very reasonable considering the normal tendency for car buyers to have an ultimate budget cap regardless of the vehicle's fortes.

These two choices, combining to form a plausible spending range of zero to five percent, combined to form a large 75% of all of the surveys received; it is very clear that consumers do not see a justification for spending much more money on a hybrid than they would on a standard vehicle. Based on current estimations of fuel savings, as well as the possibility of expensive repairs that would not be needed on a standard vehicle (such as battery replacements), this is completely legitimate, and probably mathematically true for optimal value. A couple students were willing to pay any cost for

a hybrid, which raises interesting questions that are not capable of being answered with this small data base.

Once again, one bit of analysis which can be done is the same comparison between the Motorsports results, and all the rest of the results. These two aspects of the survey are shown below.





Once again, we have a similar options and results hierarchy between the results sets. Both the Motorsports club members and the rest of the survey participants were most willing to spend 1-5% more money on a hybrid, and the second most popular

category was an unwillingness to spend anything more. Also, in both situations, these two options accounted for approximately three-quarters of all of the surveys taken, an overwhelming majority.

However, interestingly enough, this shows that students who are more knowledgeable about motorsports and automotive technology are actually more likely to spend additional money on a hybrid. There are several possible reasons for this, two of which we feel have primary significance on these results. First of all, these students will tend to have a greater understanding of both the significance, and the technological ramifications, of hybrid technology (such as the complex drive system). This understanding allows them to see the additional work that went into these vehicles from an engineering standpoint, making them more valuable.

Second of all, as most WPI students, there is a large interest in new technology. However, due to these pupils' interest in automobiles, they will be particularity interested in automotive technology. Hybrid automobiles carry new technology in spades, and (good or bad) this may be attractive.

Question 3

In the third question was designed to directly ask how much confidence people have in hybrids. The first hybrid to be sold in the United States was the Honda Insight, which was introduced in December 1999. At the writing of this report that means that hybrids have only been sold in the in the United States for a little over four years.

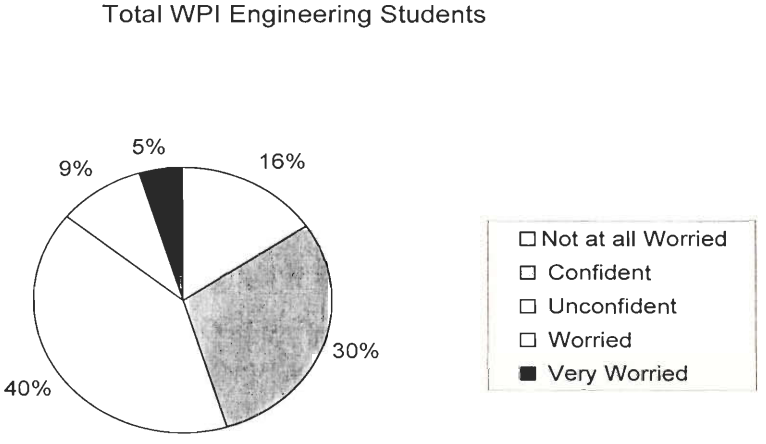
Typically many people will stray from buying a new model of a car for at least the first few years the model is out. This reasoning comes from the fact that many times when a new model comes out there are certain bugs in the product, which sometimes can be costly. If this were a normal internal combustion engine car it four years would be plenty of time for companies to work out the bugs in their products. However, since hybrids are not the typical new model and the technology in them has never been put to use in passenger cars it would be understandable if most people we weary of this new technology. It is also good to note here that Honda and Toyota are two of the most trusted car companies in terms of reliability. Also the Toyota Prius was introduced in Japan three years earlier than it was in the United States, meaning the Prius has been in production for seven years.

A breakdown of what the gradient between "not at all" and "a lot" worried about a hybrid's reliability is needed to help analyze trends in the answering of the question. People who were very worried about the cars reliability have most likely not done their homework, as was shown earlier in this report the Prius for example has been engineered for over ten years and has had no recalls on it's 2004 model, these people would pick five. Those who answered in the middle were mostly likely moderately informed about the Prius, and probably have actually read articles about testing of the Prius, these

peoples answers would be three. People who familiar with engineering practices, Honda, and Toyota's reputation and facts like the Prius has been on the market for seven years should have chosen not at all, which would be one.

This question was designed to see how informed the public was about hybrid technology. Those who are informed would be most likely chosen that they are not at all worried about the reliability of a hybrid. It was not simply asked are you familiar with the hybrid because questions like this are analogous to handing out a test and asking one question, "do you understand the material?" People would be more likely to say yes even if they didn't understand the material fully, what was done here was to gauge the level of understanding those who were surveyed had of the Prius and other hybrid cars.

All of the surveys were given to engineering students at WPI and about half of those students were from the Motorsports club one would suspect that most of the answers should be closer to not at all. Also one should not expect there to be many answers of five.



As expected most students chose from 1-3 so most student had at the very least some confidence in the engineering of a prospective hybrid. What was not expected was that forty percent of the students surveyed were unconfident. One would think that engineering students would be very well informed, and likely would have picked either one or two. It is possible that many of the surveyed students were not very well informed and instead of having blind confidence in the product chose three because often time products have problems when they are first introduced.

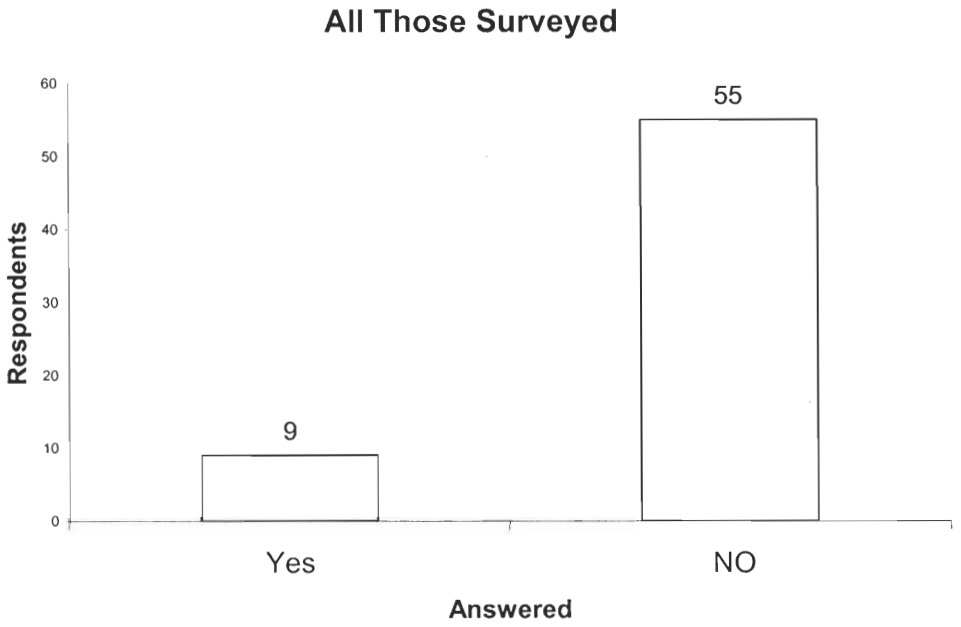
Something that may correlate to the large number of unconfident is that only sixteen percent of the all of those surveyed were not at all worried. All who were surveyed were engineers so it seems that if they were informed about this technology most would have chosen not at all concerned, but since very few did it begs the question where these engineers informed about the product. It is very likely that if they were many would have chosen one.

Question 4

Question four like question three attempts to answer how familiar those surveyed are with current hybrid technology, but it asks something more, it asks whether or not they understand safety regulations for cars.

It is true that the hybrids need to contain a large amount of battery voltage to run the car for any extended period of time. If one were discharge the battery it could be very dangerous. However, that is not really what the question asks, it asks if one might think it were at all probable that this battery may be allowed to harm them. Simply put there is no way that a car would be allowed on the road if it were at all possible for that battery to

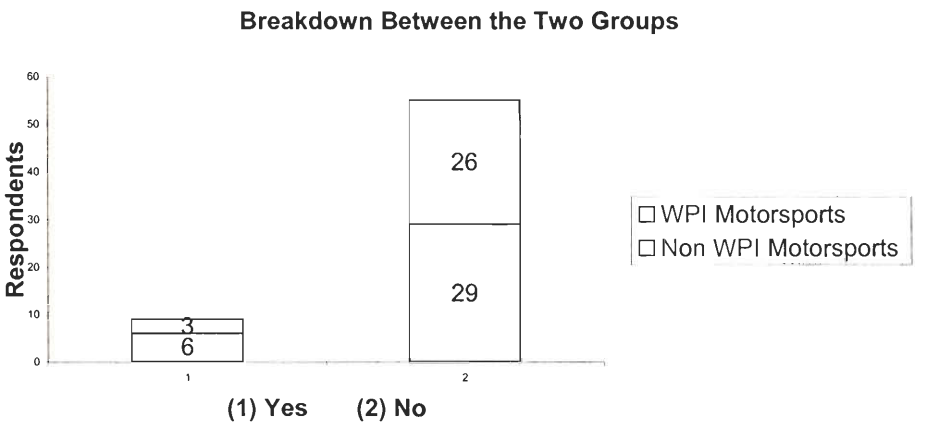
cause harm to a person under any normal circumstances, including most automobile accidents.



As was expected most of engineering students surveyed did not believe that the high voltage in the batteries would cause them any harm. Being engineering students they are obviously very must have been exposed to engineering regulations. It is curious that any of those surveyed would believe that hybrid manufacturers would or would be allowed to put out a product that would be potentially harmful to those who drove it. Perhaps further inspection of the results will provide reason as to why so many were worried about a potential threat from the batteries.

The previous chart shows that three out of the nine responses for yes the battery would be harmful came from the Motorsports Club, which means that ten percent of the

of the Motorsports Club thought that it would be harmful while seventeen percent of the



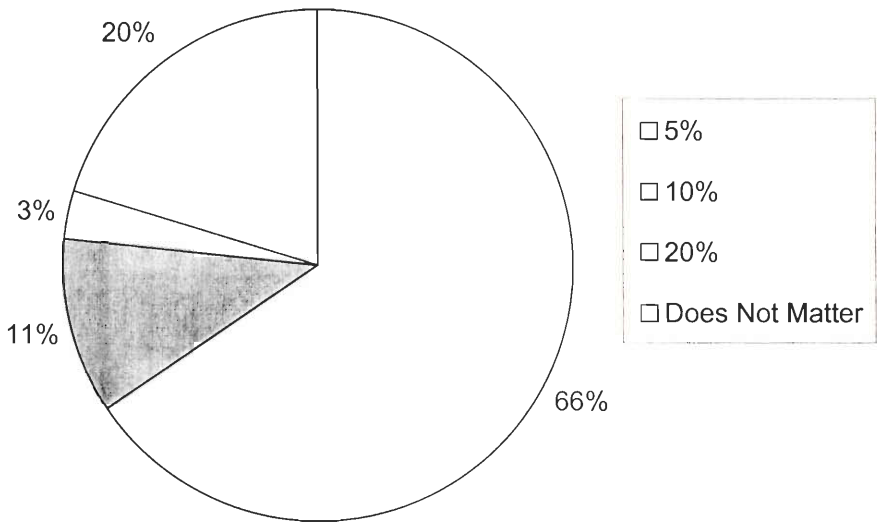
Non Motorsports Club engineers thought it would be harmful. Although this difference is relatively small it would seem that those in the Motorsports Club were more informed on such issues, these are people that are into the modification of cars and many have spent time working on cars and are probably more familiar with them then the typical engineer. The percentage of Non Motorsports Engineers who chose no is still relatively low, so it would reasonable to say that engineers at WPI are generally well informed about engineering practices.

Question 5

Our fifth survey question intends to decipher the precedence of acceleration to our sample group of potential hybrid vehicle consumers. While initially a quantifiable measure of acceleration may be difficult to substantiate in one's mind, the options given suggest towards clear differentiations in opinion on the subject.

A consumers interest in acceleration will certainly vary greatly dependant upon which market the consumer is in. For example, acceleration will be much more important to an adult entering a mid life crisis, then a parent looking to drive their children to school each day. In the case of current hybrid vehicles, the given markets do not lend themselves to be power crazed, something that is no doubt a large consideration for the manufacturers of hybrids. Current hybrids offer near matching acceleration to their non hybrid counterparts at this point in time, and as such, this question is intended to measure over all importance of acceleration, not necessarily only considering existing hybrids. The market is expanding rapidly and such data will be of importance to manufacturers as they expand hybrids into other vehicle markets. At this point we believe that while acceleration is a concern, hybrid manufacturers have done a sufficient job in not allowing the difference to be substantial enough to be a purchase consideration.

Question 5



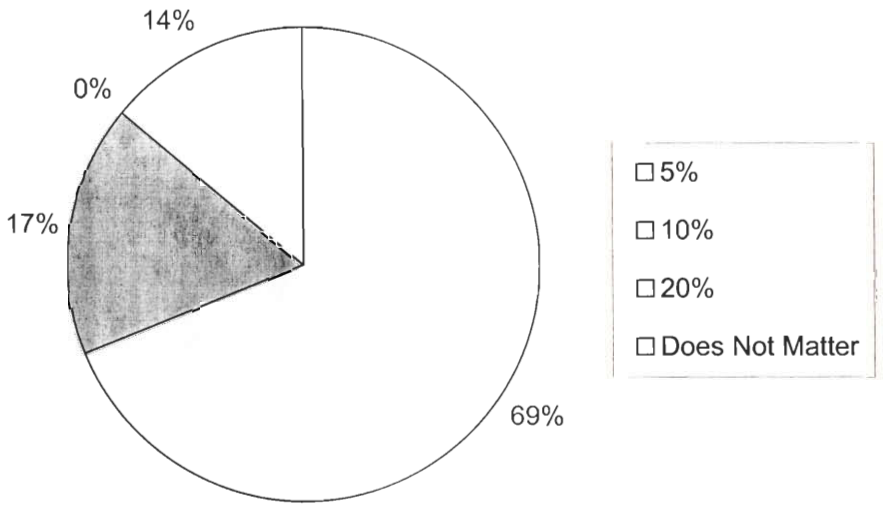
Our initial results indicate that our hypothesis was correct in that acceleration does appear to be a significant factor in consideration. Over half of our respondents stated that they would accept a maximum of five percent difference in acceleration. We did not provide an option for those surveyed to chose zero percent, as we felt that five percent was small enough to be considered as a slight change. About one out of ten people said they were willing to accept a ten percent slower vehicle if it were a hybrid. This certainly represents a group prepared to allow a noticeable change in acceleration, but only to a point. A small portion was willing to accept a twenty percent increase as well.

One out of every five people questioned stated that the difference in acceleration does not matter to them. About one third of these respondents were from the Motorsports Club group, while the remaining two thirds were average WPI students. This group

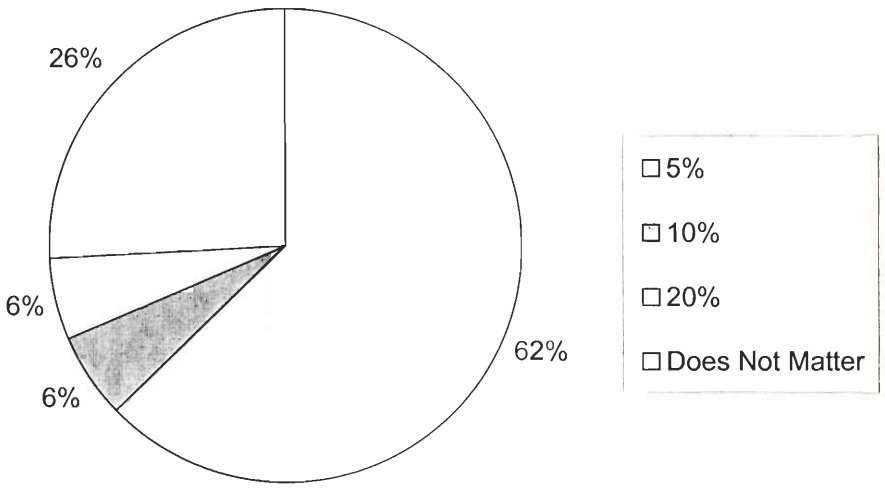
demonstrates a thought-provoking response. These subjects are saying that regardless of the difference in acceleration, they would choose the hybrid option.

There are two possible answers for why this is true. One could initially say that this group is so adamant about purchasing a hybrid vehicle that any change in acceleration will be offset by the gains from the hybrid system. A second outlook would suggest that this represents a group not concerned with acceleration, regardless of if the vehicle they are interested in is a hybrid or not.

Question 5 (Motorsports)



Question 5 (Non-Motorsports)



Upon further analysis of the group specific data; one can see that in the Motorsports group, about fourteen percent of those surveyed are not concerned with a difference in acceleration. Given that this is a group of informed automotive enthusiasts, it is likely that the technological advances and other gains make this a suitable option as a commuting car. This is a group which will often own multiple cars, doing so allows the owner to have a vehicle which need not provide any level of performance, only functionality as a vehicle.

One can see that in the group of general students, one out of every four students said that acceleration was not a concern. This is likely the case where the vehicle simply serves as a utility, and acceleration is not a consideration in the vehicle choice.

Question 6

The final question offered attempts to isolate the main motivation for interest in a hybrid vehicle. It is possible, and likely the case that for most consumers some or all of the choices appeal as points of interest, however respondents were asked to choose the option which represents the most significant aspect for them.

Hybrid vehicles without question offer many levels of benefit in different areas. One of the main initial reasons for development in hybrid vehicles is based on environmental concerns. Pollution has been increasing steadily as a mainstream concern over recent years. Not only are harmful pollutants exhausted by internal combustion engines, but the manufacture of fuel produces more harmful pollutants to the environment. These pollutants are causing irreversible damage to our ozone layer and general ecosystem. A second issue becoming extremely prevalent to our country in recent years is the dependency on foreign oil supply. We are currently heavily dependant on trade for petroleum products to produce gasoline. Hybrid vehicles utilize a zero emissions electric engine during a significant period of usage. During this period, no fuel is being consumed, and as such, no exhaust is being expelled.

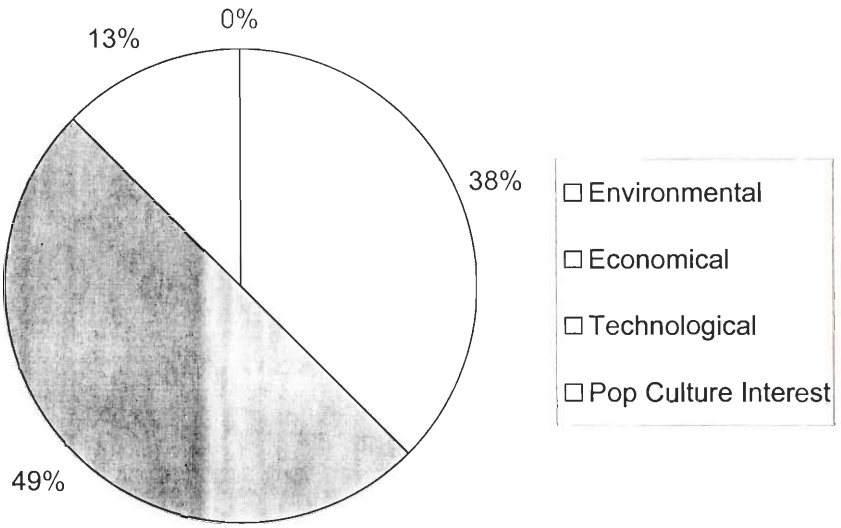
As a direct result of our foreign oil dependency and current war crises, gasoline prices are at an all time high. Hybrid vehicles can offer an owner a substantial, sometimes as high as one hundred percent, increase in fuel economy over non-hybrid competitors. These differences equate to substantial savings on fuel costs. In addition to decreased fuel consumption, hybrid owners may soon be able to receive tax breaks for owning their

vehicles. Other financial incentives exist through dealerships for hybrid consumers as well.

A third viable option for interest in hybrids spawn from the technological advances found in these vehicles. Many successful marketing campaigns for new vehicles are based on technological advances first found on certain vehicles, and hybrids are no exception. Hybrids have been suited with advanced systems for navigation, regenerative braking, power distribution among others. Continuously variable transmissions are available on certain models as well.

Every day we are force fed ideas, styles and products based solely on whomever is selling the products. As a society we are focused more now than ever on our popular image, and even something as significant as hybrid cars is not left untouched by this phenomenon. Celebrities are always the pioneers of fashion, including accessories such as vehicles.

Question 6



Given that our results were obtained from a technologically based environment, one would suspect that the technological advances present on these vehicles would be of high interest, however that does not appear to be the case. Both our of sample groups showed only a small focus on technology as the primary motivator. The groups demonstrated a fourteen and eleven percent choice of technology for the motorsports and general groups, respectively. Being an audience of students who are in general very intelligent, informed and aware, it comes as no surprise that no respondents chose pop culture interest as their primary motivator. Three out of every eight students asked demonstrated that their primary interest was environmental. It is likely these students are very aware of current issues, and while there are many potential benefits to owning a hybrid vehicle, these

issues are of highest importance. Half of all the students surveyed replied that economic reasons are the driving factor for their interest in hybrid automobiles. Being a group who will likely be purchasing a vehicle while repaying a substantial amount of loans and beginning to establish an important life style, it is important for these students to have such benefits as tremendous fuel economy and potential tax benefits.

Conclusion

As we have discussed, there are many positive reasons one might consider a hybrid vehicle. While there are certainly compromises to be made, as there are with all vehicles, the current line of hybrid vehicles offer many compelling bonuses and the sales numbers are reflecting their increase in popularity accordingly.

The federal government has issued a tax deduction to those who purchase hybrid vehicles, offering a $2000 one time deduction for anyone who has purchased a hybrid vehicle in 2004 or 2005. The deduction is even larger for owners of full-electric vehicles.

In addition to the federal incentives, many states are offering personal incentives to hybrid owners in their respective states.

California is leading the movement to allow hybrid owners solo usage of HOV lanes, previously dedicated to commuters traveling with at least one passenger. Currently owners of 100% emissions free vehicles are granted HOV lane usage, and even free tolls during rush hour traffic.

In Colorado, owners are offered a state tax incentive, similar to the deduction currently offered federally.

In Connecticut, purchasers of vehicles with an EPA fuel economy rating of higher than 40mpg, with the original design of dedicated natural gas, LPG, hydrogen or electric power are exempt from sales tax completely.

Florida hybrid owners can purchase a decal for $5 which allows them to travel in HOV lanes at any time, regardless of occupancy.

The same is true for owners of hybrid vehicles in Georgia.

In Illinois, automobile owners willing to convert their vehicles to alternative fuels are being offered a rebate of 80% of the conversion cost, up to $4000. This includes natural gas, propane and electric vehicles. Currently hybrid gas-electric vehicles are not included.

Maine is offering buyers a deduction of $500 for vehicles which do not have a comparable non-hybrid counterpart, such as the Toyota Prius and the Honda Insight. For vehicles such as the Honda Civic and Accord hybrid, a $300 deduction is available.

In Maryland, the Clean Energy Incentive Act is currently offering a tax credit of up to $2000 for full electric vehicles, and half that for hybrid electric vehicles. Also available through this act is a tax break on excise tax.

In New Mexico, vehicles with an EPA rating of higher than 27.5mpg are able to receive a one time exemption from excise tax. In Albuquerque, New Mexico, owners are exempt from paying parking meters.

In New York, tax credit is available for hybrid owners of up to $3000 depending upon the fuel economy of the vehicle.

Currently Oklahoma is offering a state tax deduction of $1500 for qualified hybrid vehicle owners.

In Oregon, a residential tax credit of $1500 exists for qualifying hybrid vehicle purchasers.

In Utah, the state is offering an income tax credit for up to 50% of the incremental cost of a vehicle purchased through a manufacturer, or up to 50% of the cost of conversion for a personally converted vehicle.

In Virginia, hybrid vehicle owners can don their car a 'Clean Special Fuels' license plate. This plate allows usage of HOV lanes regardless of vehicle occupancy.

In the state of Washington, qualifying vehicles are exempt from state emissions inspections. (http://www.hybridcars.com/incentives.html)

Many people are unhappy with these incentives being offered. In regards to the HOV lane usage, many people feel that as hybrid vehicles increase in popularity, the HOV lanes will no longer offer any type of commuting benefit, as they will be overrun with traffic. Also, many consumers feel that while hybrid vehicles do offer increased fuel economy, that is irrelevant to the purpose and execution of the HOV lanes in their original design. Some consumers are upset by the mass incentives being offered to hybrid vehicles because as the market expands, the term "hybrid vehicle" becomes less clear in terms of performance and emissions. While the compact hybrids offer extremely high fuel economy, an owner of a non hybrid Volkswagen Golf TDI will drive with over 50mpg and no incentives, compared to an owner of a Ford Escape Hybrid, who receives only 26mpg.