Smart Battery
Delphi
Battery A

Battery B

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Executive Summary or Abstract

The world of vehicles is hindered by the ability of the battery to perform in many conditions. This leads to car breakdowns, which waste time, money, and resources. We analyzed statistics, customer needs, and methods of operation while deciding on a product. Also, we hypothesized a life cycle of the product. After taking into account all of our data, we found that our Smart Battery would be able to improve vehicles while being economically feasible.

Introduction and Problem Statement

Our group, in collaboration with Delphi, envisions a world where drivers do not have to worry about their car breaking down due to battery failure. We hope that within 10 years 50% of cars will be using our product.

Currently, the leading cause of car breakdowns is due to battery failure. A faulty battery causes 52% of car breakdowns (Buchmann), inconveniencing millions of people around the world. There is also an inherent danger that arises from restarting a car the conventional way, with jumper cables. Jumper cables threaten the safety of the driver and can damage the electrical systems of the cars attached.

By implementing a reserve battery we hope to drastically reduce the number of people inconvenienced by car breakdowns as well as improve car safety by eliminating the need for drivers to handle the car battery directly and instead implement a new user-vehicle connection through the driver’s cell phone. Our plan is to analyze the cost that the consumer is willing to pay for this new feature, how much weight affects the fuel economy, how easy it is for a consumer to install the battery, what is the overhead cost for installing the system and what is the appropriate delivery method for alerts.

Background

We did research into the battery technology relating to battery failure. Battery disconnect technology keeps people safe during crashes by decreasing the likelihood of a fire. The technology is capable of shutting off high currents or voltages in less than one millisecond after stimulated. Large power surges run the danger of causing high temperature short circuits that could start a fire after a crash. Battery disconnect technology protects against this.

We also looked into the indicators like text messaging, dashboard light indicator, and app that would be capable of notifying the car owners about battery depletion. A human machine interface is a graphic visualization of a machine process that a human can control. It is meant to make operation of the machine simpler and easier to use. Because most drivers do not know how their car systems work a simplified control scheme is needed so that they can operate the necessary features.

Customer Needs
We based our decision that the Smart Battery should not be a detriment to any of the other systems and should be an improvement on the normal battery. The end user is more likely to spend time with the car battery than the car manufacture, so most of the criteria was leveraged with consideration with the consumer in mind.

Safety is our main concern so we stressed that the consumer should not have any reason to touch the battery. We started by eliminating the need for the consumer to touch the battery by giving no reason to either jump a dead battery or mess with the wiring. Cars are becoming increasingly complex, and the likelihood that an owner could mess with the internals is more likely than older models. We also want to prevent the defect battery from being in the car for too long, because it could cause permanent damage to the car’s computer or wiring.

Portability was another concern that we stressed, because Delphi indicated to us that the new system cannot be a detriment to another system. It would not make any sense to make an extremely heavy battery that would affect its fuel economy, because the new system would be a detriment.

Ease of use is associated with the end user experience with the battery and how easy it is for the car dealerships to service the vehicle. The importance of the usability is closely associated to how easy and intuitive the product is to use upon first arrival. If a product is too complicated to use that end user gives up, it is very likely that the consumer might not opt for this feature the next time they buy a car. Not only is the driver of the car an important in the consideration of the usability of the battery, but how easy it is for a car to adopt this new battery and service the car. If the battery requires a long installation process or is very complicated, cost of a service at a dealership could rise.

Cost is an important factor in any new product, because it determines the accessibility to the public. If it is too expensive, the battery would only be available to the luxury cars. Incorporation of the battery into all cars was the goal of the battery, so the price must be cheap enough that the consumer might be enticed into trying or using the Smart Battery. It is possible to run a campaign that would give a major discount to the Smart Battery so that consumer could buy the battery the first time and end up buying the product year after year because of how useful the product is. We have no interests of only putting this car into luxury cars, so our battery should stress cost. Of course we don’t want to have the product to have a bad reputation for terrible consumer experience, so the cost is of lower importance than usability and portability.

Compatibility was a concern with older cars that might not have a cellular antenna capable of transmitting data. We wanted the car owner to be more aware of the car’s health, but some of the older car’s don’t have the capability to transmit information over cellular networks to a phone. Since our idea is based on connectivity, it is crucial to have access to an antenna. Note: There is a concept that didn’t involve connectivity.

Integration time is of lower importance, because it could take a while before the product is ready but it is better than having an inferior product. We hope to integrate all of the cars so that car manufacturers can better identify cars with defective batteries or problems. Although it can become a problem when the developers of the battery are outpaced by antenna technology and create the product on an outdated frequency or module.

A product that isn’t green could get bad press and lead to no one wanting this product. This could kill the product’s future and lead to a great product that didn’t have a good execution.
Ease of Manufacturing (Ease of Mfg) was an addon that we thought was a good idea, because it could be impossible to manufacture and would be the end of the idea’s life span. It is of little concern, because engineers are always finding new ways to manufacture items.

Durability was a concern after Delphi consultants asked, but we quickly dismissed it citing that the battery would have to pass IIHS regulations before any car manufacturer would be willing to put on the car.

**Analytic Hierarchy Process (AHP)**

**Table 1. AHP Matrix**

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Cost</th>
<th>Portability</th>
<th>Ease of Use</th>
<th>Ease of Mfg</th>
<th>Compatibility</th>
<th>Integration Time</th>
<th>Green</th>
<th>Total</th>
<th>Weight</th>
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<td>Safety</td>
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<td>0.8</td>
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<td>0.4</td>
<td>1.25</td>
<td>1</td>
<td>5.33</td>
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**Table 2. Ranking based on weight**

<table>
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<th>Category</th>
<th>Ranking</th>
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<tbody>
<tr>
<td>Safety</td>
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<tr>
<td>Cost</td>
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</tr>
<tr>
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<td>Integration Time</td>
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<td>Green</td>
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AHP ranked portability to be the highest, because it was thought that the ability of the battery to not affect the other categories of the car was of great importance. We wouldn’t want the car to have a battery so heavy that the fuel economy would have been affected.
Portability was a concern that was tied to compatibility as the size of the battery could affect the ability of older cars to accept the new Smart Battery. Older cars have less space for their battery, because electronics in new cars have become more prevalent and this requires more voltage and watts.

Safety was supposed to be the most weighted, but the data shows that we were more interested in portability. Endangering the occupants and the driver was our main concern as Delphi emphasized that the new product can not endanger or harm other systems of the car. By making the car’s battery more intelligent, we were hoping to decrease the amount of breakdowns and leaving people stranded.

Compatibility was the 3rd highest in rank by weight and we were surprised that we had ranked the car’s ability to accept the Smart Battery would rank that high. We were not too concerned by a scenario where someone does not have a phone, because that person most likely would be too young if they didn’t have a phone. With the age of new technology, kids get phones far sooner than they are driving with some kids receiving their phones in middle school or elementary school. It would be highly unlikely for the adult responsible for the car to not be able to receive texts.

Ease of use was ranked 4th because we wanted for the product to be useable above all else. It would not be an effective product if we did not rank ease of use within the top 5 of the weight chart.

Cost was of a minor concern, because technology will always become cheaper and easier to manufacture. The smart battery could start in the luxury cars and trickle down to cars that are cheaper and more basic.

Green technology has always been a concern with new technology as it could ruin a product’s reputation and lead to bad sales. We wanted to have the product to be eco-friendly as batteries in cars rely on a very heavy acids. Any new technology should not impact car’s overall ability to be recycled.

Integration time and ease of manufacturing got the lowest weight as we determined that it wouldn’t be good idea to rush an idea. There should be the proper development time as well as the best materials to manufacturing the product. It wouldn’t be a good idea to recall the item after it was release because we rushed the integration time or we cut corners on the methods used to manufacture the Smart Battery.

Concept Generation
Our Smart Battery is all about keeping the driver informed on the health of the battery, so our main focus was on the method of notification, sensor and computer. The computer will be responsible for incoming and outgoing information so there should be a strong computer that should not be temperature sensitive.

There also are so many ways to code the computer to send notifications. Each language for the computer has pros and cons.
Notifications have so many different ways to notify from lights, app notifications and text messaging. Creating an app is more difficult because each operating system has a different language and Delphi would want each app to be the same to not create confusions among the consumer.

The capacity of the battery is directly correlated with the chemical composition. There is also the ability to increase the capacity just by increasing the size of the battery. All of these will have to be factored in the compatibility with the car. Some car’s will require more voltage so changing the composition of the battery might be necessary.

**Concept Selection**

Design 1 was based on the connectivity that the battery brought to the owner of the vehicle. It would be capable of sending notifications to the phone and there would be an indicator for the battery’s health and percentage remaining.

Design 2 was a low tech idea that was meant to be indestructible and not rely on the new technology. There were also concerns over virus infecting the car’s computer and wreaking havoc. We were thinking that this concept would have manual switches that could have overridden some of the features but there were to be no connections with a cellular network. This could have also been fitted on the older cars that aren’t have size constraints for the battery.

Design 3 had some connectivity that would allow for the battery to access the cellular network, but it was meant to be a one way communication so there would be no infecting of the onboard computer. It would have been a compromise between the design 1 and 2.

**Table 3. Design Matrix**

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<thead>
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<td>Design 1: Connected Battery (App)</td>
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<tr>
<td>Design 3: Connected Battery (Text Message)</td>
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<td>2</td>
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<td>5</td>
<td>4</td>
<td>3.753</td>
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</table>

Design 3 won because of its ability to reach phones that might not have been smartphones like feature phones as well. This could appeal to a greater audience and allow the battery to be more effectively used. We know that it would cost more to add a antenna to the battery, but we think that the ease of use will greatly increase. We have also increased the car’s safety by not asking the driver to open the car’s hood in order to restart the car.

**Final Design Section**
The final design was decided to be a mix of all the ideas and to have two separate models. We felt like it wasn’t a good idea to alienate cars that might have been older or had size constraints, so we created a model that housed an antenna capable of establishing a link with the outside world for cars that didn’t have an antenna. It would have all of the computers that the other model had but with an additional chip, new smartphones could interact with their battery.

The second model wouldn’t have an antenna to save money and space. We envisioned new cars to have antennas built in for the car’s onboard computer to receive information. we would simply tap into the existing antenna and piggyback a signal to the phone.

All model could be unhackable from the outside (without plugging into the Smart Battery’s computer), because there would be a mode that would only send text messages or phone notifications through the app creating a one way interaction with the outside world. All of the models would come with the same computer designed to shut off at 15% and/or 5%.

**Systems Diagram**

![Systems Diagram](image)

**Figure 2.** Systems Diagram

**3D Model/Prototype App/Images of interface, process, etc:**

In order to maintain a relative ease of use for the Smart Battery we decided to make a smartphone application to operate it. In figure 3, the overall layout of the app is displayed. There is an opening screen with a terms and agreement warning drivers to avoid using the app while operating the vehicle. Upon accepting the agreement, the next screen is a menu that leads to three options: battery percentage, estimated maintenance date, and diagnostics. Diagnostics would display whether
or not the battery was functioning correctly and also if the battery is on or off. Each of the three options have a back arrow in the upper-left hand corner that leads back to the menu page.

![Figure 3. Layout of app interface](image)

As for the model of the battery itself, it will come in two options. Battery A is our standard battery. This will be used in modern vehicles with cellular antennas already in the vehicle. By attaching the battery to the antenna we will be able to connect to the battery without requiring any more materials to utilize it. Battery B will be used in older vehicles lacking a cellular antenna. Battery B has an antenna built in that will allow classic cars to have a Smart Battery without changing the exterior. Both models have the same methods of operation.
Concept of Operations (Scenarios)

All operations are the same for both of the models released but the consumer can change the setting with the car’s onboard computer to one way or two communication. Then there is also the ability to negate the communication ability using the switches. Blue switch allows for only one way direction communication and the green switch negates the batteries ability to communicate to the cellular network. The red switch over when switched on negates both blue and green switch. The red switch is responsible with two way communication. All of the following scenario are only responsible for the red switch constantly on (two way communication).

Setting up the battery with the app or with your phone should be very simple. We would include an QR code on the battery itself that would lead you to the app store that would let you download the app. (Below is an example of a sticker that would attached to each battery to give
Instructions.) Upon opening the app, the phone should prompt you for a red code (unique to each battery) that would allow you to link the car to the battery and allow for your phone to receive updates. The app will also ask you to make an account with the company so that a person may receive updates on computer or tablet. They may also check the status of their car’s battery through the company website.

**Figure 6.** Example of sticker that will be placed on every battery.

If a person does not wish to receive app alerts or their phone might not have the capability to download the app, right next to the QR code there is another option to setup the Smart Battery. There would be instructions on what to text to the number the serial number located in green. After it verifies the code is correct then the phone will respond with an “Battery Operational” like the picture below. Now the owner’s phone can communicate with the battery.

**Figure 7.** Setting up text message interface.
The following scenarios are after the initial setup. If the battery chooses not to accept the codes or doesn’t respond please call our customer service (1-800-BATTERY).

The first scenario is where the interior lights or radio are left on all night draining the battery. This would normally drain the battery and leave no charge in the morning. The new Smart Battery would send the car owner(s) a text or app notification letting them know that the car is sitting idle (with the engine off). The notification will then bring them to the app (below left) where it will show the estimated battery life. The text messages will tell you that your car is idle and battery is being drained like the photo on the right.

Figure 8. Display of battery life via smartphone application

Figure 9. Text notification that the battery is drawing power despite the car being idle

The owner of the car could go into the app and shut off the battery to anything except for starting up the motor. They could also send it a text message and the car will recognize this as command, but it will only shut off the battery to anything except for the motor starting up.

If occupants leave the car alone and ignore all notification, the car’s Smart Battery will drain until it reaches 15% where the Smart Battery will send another text like the picture on the bottom left that warns of the impending shutdown of the battery (only to functions outside of starting up the
engine). At 5% level, the battery will send another text notifying that the shutdown process will begin.

![Figure 10. Alert text sent when battery reaches 15%](image)

![Figure 11. Alert text sent when battery reaches 5%](image)

The second involves a defective battery that is recognized by the internal computer or the on-board battery. If the car is driven the battery will only give notification through the dashboard, because drivers could be distracted by the phone. If the car isn’t being driven, the battery will send a notification directly to the phone like the image on the left. **Figure 12. Battery malfunction alert**
The phone would then indicate that battery was defective and the car must be brought to a dealership to be replaced. There could be a massive drain that would give 15% indicator. All warning should be in place from scenario one. If the battery ends up dying without warning, the third scenario would play out.

The third scenario is where the car’s Smart Battery has failed altogether without warning. Customer could use the app to find the nearest dealership or tow truck company. There would be a tab within the app that would bring the end user to a map. If clicked on the pins that corresponded to the location of the dealership, there would be the option to call the service.

The fourth scenario is driver might be concerned about the battery being drained and is unable to check the car at that moment in time. There is an option within the app that would allow for the battery to respond with a percentage. The text messaging option could also do the same by asking the battery a specific line of questioning like the one on bottom left. The driver could also use the app to check the status of the battery. This option is the tab in the app and it will give data like percentage and the estimated battery life (like the image on the right). The second tab will give

![Figure 13. How to view battery percentage via text](image)

![Figure 14. Battery percentage display in application](image)

**Cost and Feasibility Analysis**

The total cost of our product as an accessory in a new car would be about $215. This total includes the cost of the raw materials, the assembly, the labor, the non-recurring engineering costs, and the manufacturers costs. This kind of technology requires a buyer who is
willing to spend a little extra money on their vehicle. However, the cost of the battery is well worth the reliability it brings. A normal car battery lasts, on average, for about 6 years before it needs to be replaced (Buchmann). If your car battery fails just once during this 6 year period you are looking at a towing cost of anywhere between $100 and $300 dollars to get your car to a repair shop. For this reason, our battery could actually save our customer money while also eliminating the hassle and expense of a failed battery. Furthermore, the cost of a replacement battery when your first battery reaches the end of its life cycle is only slightly more than half the accessory cost. So, not only is our product a more reliable alternative to the standard battery, but a smart economical choice as well.

We predict that our battery will be most popular among people who live in remote areas and people who live in colder climates. People living in remote areas have the most to lose from a battery failure, and people in colder climates run a higher risk of battery failure than those in more temperate climates. These are the people who will value our product the most and therefore make a good target consumer base.

Because our product merely improves convenience, there would be no reason for it to be required to be in a car by law. For that reason we will have competition to deal with when trying to market our product. For example, there is already a patent for an auxiliary battery that serves the same function as our product. However, our battery has a couple advantages over the auxiliary battery competition. First, our battery includes a communication system between the battery and the driver that improves the connectivity of the car. Secondly, by bundling all of our technology into one battery we save space and cut material costs.

These are all qualities that car manufacturers will appreciate. We expect that auto companies will adopt our product quickly because improvements in car battery technology has been relatively static in the past decade and our battery adds a significant level of convenience to a car that could be a real selling point for any new vehicle. Especially in an industry that is all about who has the newest technologies, a progressive product like ours can grab a foothold in the market quickly. For example, as soon as Mercedes starts using it BMW will have to follow or risk appearing as if they are behind the times. Such is the way of the automobile industry.

Life Cycle Analysis

By nature, batteries have the potential to cause a lot of harm to the environment and other people. When batteries are not disposed of correctly they can cause soil contamination and water pollution that can cause brain damage, kidney damage, hearing impairment, and learning problems in children. Thankfully, the government has recognized this risk and implemented a very successful battery recycling program. Between the years of 2009 and 2013 99% of all battery lead was recycled in the United States (Kusibab).
Although the environmental impact of a car battery is rather meek, nobody is going to buy a car without a battery. So our product is not adding to the footprint of the car except in the materials we add to the battery so that it can monitor its own charge and communicate with the owner. We designed our product so that the amount of material used and what will eventually end up as waste is minimized. This means adding a small circuit board that can communicate and read the charge on the battery but does not have any superfluous features that would raise costs and create more waste. The materials we are adding, a circuit board and wiring to the car antenna, should only add a minimal burden to the footprint of the car. Because Delphi has voiced a commitment toward going green, we could add a refundable deposit to the cost of the battery as an incentive for consumers to recycle their battery when it reaches the end of its life. Also, since the lifespan of the battery is shorter than the lifespan of the circuitry, we could reuse the circuitry on recycled batteries in our new batteries. An example of the lead-acid battery recycling process by Gopher Resource Corporation is shown to the right. Notice how they are able to recycle the lead, the plastic and the acid.

With sustainability in mind, as well as cost, we chose to make our Smart Battery from a lead-acid battery rather than lithium-ion. A new lead-acid battery typically is made up of between 60% and 80% recycled lead and plastic (Sullivan). Whereas almost all battery lead is recycled and reused in a new battery, almost no lithium is recycled. This is because lithium is so hard to extract from a dead battery that it is easier, and cheaper to mine new lithium. To put it in perspective, recycled lithium costs about five times more than new lithium. This makes recycling lithium an economically inviable option.

Production of lead-acid batteries is actually more efficient when they are built out of recycled materials rather than new materials. The two graphs below show us a comparison between the production energy needed to build the lead and plastic components of the battery based on whether the material used is recycled or not. We can see from the lead comparison that new lead requires almost three times as much energy as the recycled lead to produce the same part. This can make a significance in the footprint of the battery because lead makes up about 60% of a lead-acid battery. We see the same trend
with plastic material which constitutes another 10% of the battery. It takes about five times more energy to build the battery shell out of new polypropylene than it would to build it out of recycled polypropylene (Sullivan).

**Figure 16.** Amount of energy required to produce recycled lead vs. new lead

**Figure 17.** Amount of energy required to produce recycled plastic vs. new plastic

Data courtesy of Argonne National Library

Lead-acid batteries also compare well against other battery competitors. Notice the three graphs presented below. These graphs analyze the total production energy, carbon dioxide emissions, and criteria pollutant emissions for four commonly used car batteries. Criteria pollutants are government monitored chemicals that can harm your health and environment. Although there is a fair amount of variation in some of the data, lead-acid batteries (denoted PbA) clearly have the lowest production energy, carbon dioxide emissions, and criteria emissions.
The materials in our battery should be able to see several useful lifetimes since the majority of our product is recyclable. In conclusion, our Smart Battery should not significantly increase the carbon footprint of the car because we are using the most environmentally friendly battery on the market and putting an emphasis on minimizing waste in our product.
Conclusions

In conclusion, the Smart Battery shows promise as a product. Since batteries are responsible for the majority of vehicular breakdowns, the Smart Battery could be able to prevent car difficulties, that as a society, we have been dealing with for generations. While that was simply our inspiration, this battery goes above and beyond this problem.

As a part of Delphi, making vehicles more environmentally friendly was part of our guidelines for designing this product. While the Smart Battery does not necessarily make vehicles more environmentally friendly, it certainly does not negatively affect that aspect either. Based upon the life cycle analysis, one can see that there is no point in production where the environment is not taken into account. We made sure that our product will be both sustainable and reusable. Not succeeding in these categories would not only be detrimental to our product’s success, but also to the well being of our planet.

While we did not actively make the product more environmentally friendly, we did succeed in improving Delphi’s other two categories: connectivity and safety. The two are related in our product as safety was improved by connecting the driver to the vehicle. What we mean by this is that by providing a new interface that connects the driver to the battery, safety was also improved because someone can fix their battery with a push of a button, rather than risking electrocution via jumper cable. With society becoming increasingly dependant on technology, we were able to integrate an interface that uses a cell phone -- the technological centerpiece many people cannot go an hour without using -- to effectively provide a way to restore the battery to working condition.

Although many people already own a smartphone, ignoring the part of the population that owns a basic cell phone would not be feasible. To accommodate for this, we decided to make two systems of operation for the Smart Battery. The alerts can be selected to send through text messages or through the smartphone application. This allows for a wider range of targeted customers. We did not want to force people to use a system they are not comfortable with. Either system of operation was designed to be easy to use. The last thing someone wants in a situation where his or her battery failed would be to deal with a difficult to use interface. Both methods of operation display clear instructions on how and when to use it.

Only trials could reveal if the Smart Battery can effectively succeed as a product. Looking at the final design, we are confident in its ability to change the world of vehicles. The data shows it would work, and be able to generate revenue. Most importantly, the Smart Battery would improve the safety and connectivity of vehicles.
References:


