

Global Positioning System Based Intervehicular User Interface Wireless Communication System

AT&T Incorporated Final Design Report

Engineering Design 100
Section 004

Design Team Members:

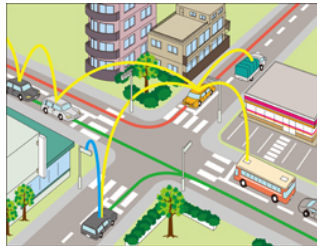
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Executive Summary:

The purpose of this design is to create an interactive car communication system that provides a radar-like map of all vehicles near the user. This new system would facilitate vehicular communication systems by developing the advanced car detection system through use of the internet and satellite GPS. In this case, the portable Wi-Fi hotspot provides the long-range connection between vehicles, making the interactions possible.

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1.0 Introduction

AT&T, one of the world's leading telecommunication and internet service providers, presented an opportunity to develop a new technology that would assist with daily life. The Internet of Things was to be used, a system that utilizes the ability to connect to, monitor, and interact with physical objects through communicative technologies such as the internet. AT&T offered three categories in which to work: wearables, smart home, and vehicle-to-vehicle. Wearables are devices that are integrated in clothing to monitor a person's health or personal habits. Smart home technology integrates all aspects of the home life together through the Internet of Things. Vehicle-to-vehicle focuses on facilitating car-to-car communication.

The first component in achieving a design was to develop an understanding of the project parameters. This included expanding general knowledge on communications, such as the internet, cell phones, GPS, and bluetooth, through online research. The project was narrowed to the vehicle category, and surveys were used to help form specifications. Ideas were brainstormed, and the pre-determined specifications, along with results from the surveys, allowed the brainstormed ideas to be narrowed down to a more specific idea.

See Appendix A for the Project Gantt Chart

2.0 Project Background

Summary:

For our project, we decided to focus on the connected car category. The problem we chose to address was difficulty communicating between drivers. We thought we could reduce accidents and awkward encounters while driving if there were a way that drivers could talk to each other, other than shouting out the window. We imagined a way that drivers could use their car to call to other nearby drivers.

Stakeholders:

Stakeholders are people, groups, or organizations who would be interested or affected by our project. The first stakeholder would be AT&T. This project was assigned by them and is intended to be profitable for them. The next group of stakeholders would be car manufacturers. Our product is going to affect communication between cars and we're going to need their help to make sure that we have all the appropriate technology integrated into the cars. One more group of stakeholders would be drivers all across the country. Our project is intended to help all drivers by making it easier to communicate.

Survey

We conducted a survey online to evaluate potential customer interest and needs.

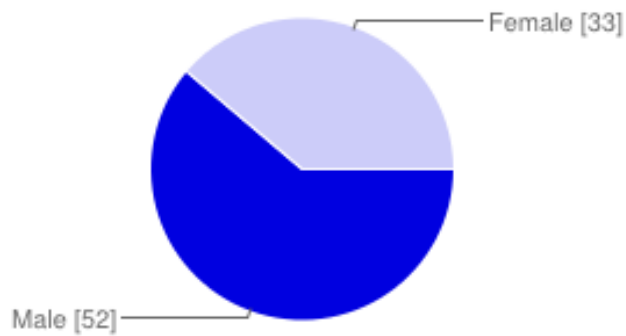


Figure 1: Gender Distribution of Pool

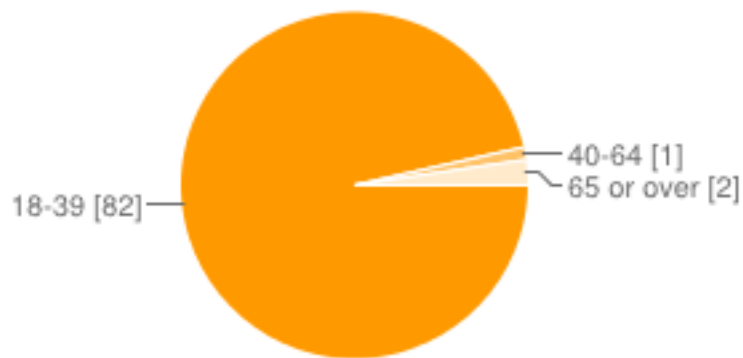


Figure 2: Age distribution of pool

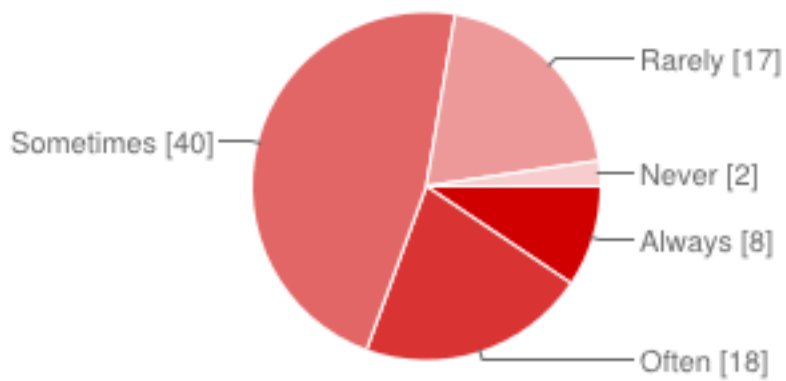


Figure 3: Frequency of inter-driver problems

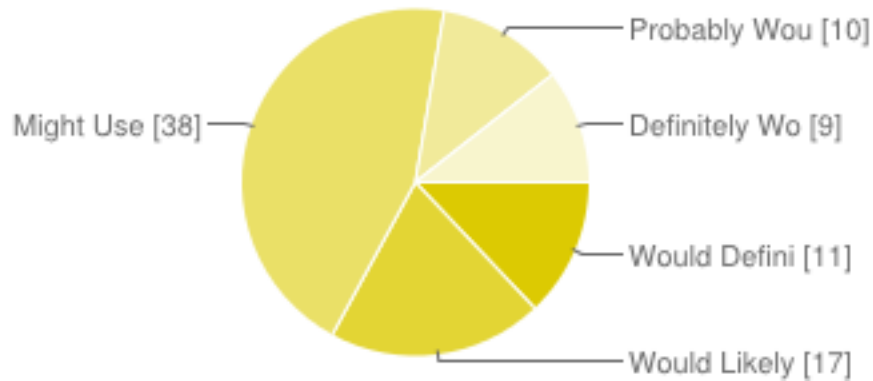


Figure 4: Likeliness to use technology

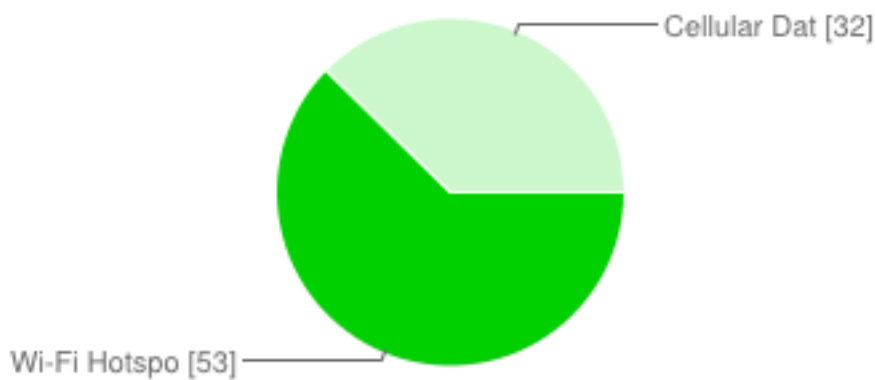


Figure 5: Wireless communication preference

The survey shows us that almost every person has encountered a problem with another driver while most people have experienced it multiple times (77%). Only 23% of people were likely not to use our technology. In terms of the internet connection, 62% of people prefer a Wi-Fi connection while 38% of people support using cellular data.

All the data shows us that our concept has some validity to it, however, we must improve and refine the specifications to make it more appealing for customers to use.

Technical Information/Research:

Before any decisions could be made in regard to the project, technical research had to be conducted. Research was conducted into several different subtopics: Identification, location detection, and communication.

Identification was research conducted into how to identify each individual vehicle in the network, an important aspect of the internet of things. Our first topic of identification in this section was IPv6. IPv6 is the latest version of the Internet Protocol which is the primary communication protocol used today. It provides identification and location for computers. It does this by assigning each device connected to the internet a specific IP address, which in the case of IPv6 is combination of 32 hexadecimal digits. The advantage of IPv6 uses a 128-bit address system, over IPv4's 32-bit system, which allows

for more than 7.9×10^{28} times as many unique addresses as IPv4. Another advantage of the IP system of identification is the concept of the dynamic IP. Dynamic IP allows for a device to change its IP address every few days or weeks. This provides an additional level of security by making it impossible to track a specific vehicle over time because its IP address changes, so the secure server used to store that data can still identify the vehicle, but an outside individual cannot. After conducting this research, we decided the IPv6 identification met all the requirements we were considering, and we didn't need to conduct any more research into the identification aspect of the project.

Our next area of research was location detection. We wanted a system that could locate a vehicle's location and transmit that data to other vehicles, as well as to a centralized server. Our first subject of research was Global Positioning Systems (GPS). GPS is a space-based satellite navigation system that provides latitudinal and longitudinal data for the location of the device, as long as it can connect to four or more satellites. The GPS receiver calculates its location by receiving messages sent by the satellites that contain the time the message was sent and the satellite's location at the time of sending. The receiver uses this information to calculate transit time and distance from the satellite using the speed of light. This yields a position, which is then displayed on either a moving map or using latitude and longitude coordinates. This information yields only a position, but most common GPS devices can derive velocity from the position data. The reason that four satellites are needed is because four spherical surfaces rarely intersect, so when an intersection is found from the navigation equations, one can be fairly confident that it is the real location.

The next subject under location research was radar. Radar technology works by emitting radio or microwaves, which are reflected and scattered by objects in their path. The portion of the reflected wave that returns to the radar's antenna provides information on the object that reflected it. The time it takes to return to the antenna can be used to find the object's distance from the radar and if the frequency of the signal changed, that indicates the object is moving towards or away from the radar system, because of the Doppler effect. Radar systems suffer from a couple limiting factors. Firstly, they require line of sight to objects, so it provides no information further in a direction than the first object. Secondly, they are prone to interference and clutter from other signals such as noise.

Our last subject of location research was cell tower triangulation, also called multilateration. This technology is most often used for locating a mobile phone. This technique is based on the measurement of the difference in distance to two stations at known locations that broadcast signals at known times. Unlike measurements of absolute distance or angle, measuring the difference in distance between two stations results in an infinite number of locations that satisfy the measurement. When these possible locations are plotted, they form a hyperbolic curve. To locate the exact location along that curve, multilateration relies on multiple measurements: a second measurement taken to a different pair of stations will produce a second curve, which intersects with the first. When the two curves are compared, a small number of possible locations are revealed, producing a "fix". This technology could work with our project.

The next topic of research conducted was communication. We needed a way to connect two cars so that they can talk. We also needed a way to connect these systems to

the internet, a critical part of using the internet of things. The first idea we thought of was Bluetooth. Bluetooth is a wireless communication technology that transmits data over short distances. Bluetooth operates using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz. The transmitted data are divided into packets and each packet is transmitted on one of the 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz. Bluetooth 4.0 uses 2 MHz spacing which allows for 40 channels. Bluetooth is a packet-based protocol with a master-slave structure. One master may communicate with up to seven slaves in a piconet; all devices share the master's clock. Packet exchange is based on the basic clock, defined by the master, which ticks at 312.5 μ s intervals. In the context of our product, Bluetooth could be useful in communicating between vehicles, but would require an additional element to connect the vehicles to the internet.

Wi-Fi is the most common type of wireless internet connection these days. Wifi is a technology that allows an electronic device to exchange data or connect to the internet wirelessly using 2.4 GHz UHF and 5 GHz SHF radio waves. To connect to a Wi-Fi LAN, a computer has to be equipped with a wireless network interface controller. The combination of computer and interface controller is called a *station*. All stations share a single radio frequency communication channel. Transmissions on this channel are received by all stations within range. The hardware does not signal the user that the transmission was delivered and is therefore called a best-effort delivery mechanism. A carrier wave is used to transmit the data in packets, referred to as "Ethernet frames". Each station is constantly tuned in on the radio frequency communication channel to pick up available transmissions. To work in a mobile setting, like in a car, it would require a wireless hotspot. A wireless hotspot connects to 3G/4G cellular networks, like a smartphone does, and then shares its connection with other nearby devices. Wi-Fi could definitely work for our project.

The last topic of research in regards to communications technology was 3G/4G/LTE. These are different generations of mobile telecommunications technology. 4G is the direct successor to 3G and is more stable and provides faster data transfers. 4G is different from previous iterations because it is IP-based, utilizing the IPv6 format. Data is sent in packets from a base station (aka cell towers) and is received by the mobile device. There are numerous different methods to establish a link between the base station and the device, including CDMA2000, HSPA, 3G LTE, EV-DO Revision B, DO Advanced, and Mobile WiMAX, to mention just a few. LTE is short for Long-Term Evolution, and is a standard for wireless communication of high-speed data. It feature high connection rates, low latency, improved mobility support, and increased spectrum flexibility.

Benchmarking:

In this year February 3rd, Obama administration is finishing an analysis about car communication system and is going to require the automaker to equip this technology, which will largely decrease the traffic problems. This communication system uses radio signals for detection of the car's position and transmitting information with vehicles around. This new technology might increase the price of a new car by \$100 to \$200. The

research indicates that safety benefits would be seen with as few as 7% to 10% of the vehicles in a given area equipped with the technology. In this report it considers the cost, feasibility, security, privacy and the necessary legal and regulatory framework.

The paper named Securing Vehicular Communications by Maxim Raya, Panos Papadimitratos, Jean-Pierre Hubaux, discusses the basic requirements for the design and build of vehicular communication protocols. In this paper, it discusses the vulnerability, like jamming, forgery, tampering, impersonation, and challenges of car communication systems and how to solve these problems. These potential problems, like security and privacy are some aspects that could be the specifications in this project.

3.0 Project objectives (Specifications)

The project objective is to create an Interactive Car Communication System that would be standard on most cars and display a radar-like map of all vehicles near the user. This would reduce numerous traffic problems and increase the road safety awareness among drivers.

From the background research, the specifications are classified in 3 groups: technical requirements, customer needs, and stakeholders. By searching the properties of existing wireless technology, five important conditions are considered for the selection of the best wireless carrier: range, compatibility with the user interface, compatibility with the smartphone, compatibility with existing data plans and speed. Since the car detection system is better to be incorporated in the smartphone and the wireless carrier needs to be fit in the data plane for the lower cost, the compatibility is crucial for reduction of the cost.

From the survey, the customers for the product of this design are basically all drivers falling in every age range. Therefore, the communication systems need to satisfy variable customers. The result of the survey shows that around 40% of people encounter problem when driving and they are willing to use the car communication technology. The online research of the drivers indicates that there are number of things that other drivers do that can be extremely irritating and dangerous. Bad Tailgating, poor lane discipline, not indicating and undertaking are just a few of the bad habits that frequently and are very annoying. Aside from the inconvenience to other road users, this kind of inconsiderate driving is also very dangerous.

From the benchmarking research, security is the primary consideration for the specifications. Privacy of drivers is the essential aspect in privacy. It should not be user-traceable. In this way, it would be low risk for driver to lose the individual information. In the survey proposed by Obama administration, it indicates that the car communication technology will increase the cost of a new car in \$100 to \$200. Therefore, the cost should be affordable for customers and the automaker and AT&T should also make money.

Finally, for the stakeholders, it should be profitable and low running cost for both AT&T and automakers. For automakers, the car communication system should also be easy to implement and appealing to customers.

In summary, the preliminary specifications for these three groups are summarized in the following table.

Table1. Specification for stakeholders:

Categories	Specifications
Technical specifications	long range(>1km)
	compatible with user interface
	compatible with smartphone
	compatible with existing data plans
	highspeed
Customers	low cost
	easy to use
	secure
	variable identity (not user-traceable)
AT&T	low running cost
	profitable
Automaker	easy to implement
	appealing to customers

4.0 Conceptual Designs

4.1 Brainstorming:

After deriving the stakeholder and technical requirements, concepts are generated based on those specifications. For the car communication system, the accurate positions of cars near the driver will be displayed on the screen, basically a radar-like map. In this way, the driver would be able to recognize the situation around him/herself and get effective contact with drivers around him/her. In large extend, it can connect independent carts effectively and reduce some potential traffic problems.

The precise locations of vehicles play essential role in this car communication system. For car detection system, GPS (Global Positioning System) is considered to be the first choice, which will give the accurate longitude

and latitude positions of individual cars. It works with satellite, which can monitor things all around the world. The second choice is radar, which uses radio waves for the detection of range, altitude, direction, and speed of objects. The third one is cell tower triangulation.

For the connection of cars, some common wireless connective technologies are proposed, like Wi-Fi, bluetooth, internet, and 3G 4G LTE. The third aspect of concept is application implementation. User interface and smartphone are considered

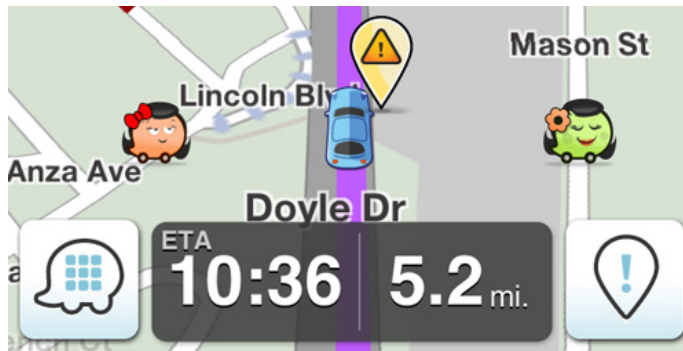


Figure 8: Concept example by Waze Navigation

With concepts in these three aspects, a concepts matrix are generated as following, which summarizes $2 \times 3 \times 3 = 18$ possible solutions:

Table2 Generation of concepts:

Implementation	Location Detection	Communication
Car User Interface	GPS	Wi-Fi
Smartphone Application	Radar	3G, 4G, LTE
	Cell Tower Triangulation	Bluetooth

4.2 Evaluation and Selection:

Table3: Decision matrix for communication methods

Requirement	Weight	Bluetooth	WiFi(Mobile hot spot)	3g	4g	LTE
Long Range (>1km)	7	-	+	+	+	+
Compatible with User Interface	9	-	0	+	+	+
Compatible with Smartphone	5	-	+	+	+	+
Secure	10	+	-	-	-	-
Not tracable to user	4	-	-	-	-	-
Compatible with existing data plans	7	-	0	+	+	+
Cost	9	+	0	0	0	0
Speed	7	-	0	0	+	+
Total		-20	-7	14	21	21

We decided to use 4G/LTE technology as our communication method because it is fast, has good range, and is compatible with existing data plans.

Requirement	Weight	GPS	Radar	Cell Tower Triangulation	
Speed	7	+	+	-	
Accuracy	8	+	-	0	
Capability of sharing information	5	+	-	+	
Cost	6	0	+	0	
Total		20	0	-2	

We decided to use GPS to find and map the location the vehicle because it is fast, accurate, and is more easily able to share it's information with the central server.

Given these rankings, we were able to decide on our final design. It will utilize GPS technology to give the position of the vehicle, and 4G LTE technology to communicate with the central server.

4.3 Summary

According to the summarized decision matrix, the final concept is selected and the basic principle is summarized as following. This device will utilize existing GPS and internet connections to connect users on a common server, most likely operated by AT&T. Other vehicles using the device will appear on an overhead map, and vehicle-to-vehicle communication can be initiated by touching another vehicle's icon on the screen. Implementations such as variable IP will ensure user security, and muting and call rejection abilities will allow users to avoid harassment or exploitation of the system.



Figure 1: Tesla User Interface: The technology will be implemented in locations convenient to the drivers.

5.0 Detailed Design



Figure 3: Systems Flow Diagram

The selected concept for Car-To is an application that operates on a vehicle's user interface, and is also compatible with smartphones and tablets. The software utilizes built-in GPS and internet connections via the user interface. A map of surrounding vehicles is generated on the GPS display, and drivers can initiate voice conversations with each other by pressing vehicle icons on the touchscreen.

5.1 Servers

Multiple geographically allocated servers are run by AT&T. The exact area coverage of each server depends on how heavy the traffic usage is, but can be even as wide as cross-country. Typical coverage for one server would have at least a 500 kilometer radius.

1. Communication

Car-To will utilize existing internet connectivities via its operating platform; this will either be a WiFi hotspot, or a cellular data plan such as 3G, 4G, or LTE. Vehicles use this to communicate to the server through the internet.

2. Mapping:

Every vehicle running Car-To sends its GPS coordinates to its allocated server. The server generates a map with a display of every vehicle and sends the data back to each user. The software in each application generates a view of this map from a bird's eye view above the user's vehicle. The map can be zoomed out using the touchscreen.

3. Security:

Users are only able to observe and communicate with vehicles on the same server. This avoids the potential for individuals to use the system to track or stalk users across states, nations, or the entire world.

IP addresses are not visible to other users. The only information users will see of others will be the icon of their vehicles. Features such as tracking are exclusive to Friends lists entered by the users.

5.2 User Interaction

1. User Profile: Each unique vehicle will have a separate profile, identified by the license plate. Users will be able to access and change profile settings from the internet, or directly through the application.

a. Vehicle icon: Every user will have a vehicle icon selected from a given database in order for drivers to be able to easily differentiate between or locate desired vehicles. If the software is purchased with the vehicle, the vehicle's identifier will be pre-loaded with a selected icon. For users downloading Car-To for existing vehicles, or if changes to the vehicle are made (i.e. painting a different color), then it will be up to the user to update the icon in the profile settings. This information will be verified through the vehicle's registration to maintain accurate representations of the vehicles.

b. Communications Settings: It is crucial to avoid the potential for harassment through abuse of the system and any form of driver distraction. User settings will include only allowing other selected users to initiate calls (see Friends List), or allowing any other user except for certain blocked users (see Block List) to do so. Different settings will be available for ringtones, including various volumes, a completely muted setting, and having all calls temporarily blocked.

c. Friends List: Friends can be added online from a remote location or directly through the application. Entering a license plate adds that vehicle as a friend. There will also be an option to add a friend by pressing the icon of a vehicle on the map.

The people on a friends list have exclusive permission to track the location of or contact the list holder at any time.

d. Block List: Adding users to the block list is identical with the friends list. Blocked users will not be able to initiate calls to the list holder. As with any user who is not on a friends list, blocked users are not able to track the list holder's location.

2. Initiating Calls: Voice communication is initiated by pressing a vehicle's icon on the touchscreen. The call must be accepted, and settings such as automatic rejection and muting are available.

3. Trips: This is a feature that is created between multiple vehicles. Vehicles on a "trip" will always have GPS routes leading to each other, no matter how far apart the vehicles are. This enables users travelling together to avoid getting separated. Voice communication is also available in a group call for a trip.

5.3 Implementation

1. Software Download: Car-To will be available for download in standard online application/accessory stores.

2. Purchase with Vehicle: Vehicles that include user interfaces will have the option of having Car-To pre-downloaded.

6.0 Conclusion

Car-To utilizes existing communication technologies such as GPS, WiFi, and cellular data. User interaction takes place through a touch screen, where features such as voice-to-voice communication between vehicles and advanced route plotting exist. Comprehensive security and privacy settings ensure that users both feel and are safe using the system, and that there is no room for exploitation by users. AT&T servers use data transmitted by each vehicle to create a map including every vehicle, and sends this data back to the users. Because of the utilization of existing technologies and simple communication systems, Car-To is a cost-effective technology that can be easily incorporated into the Internet of Things.

Appendix A

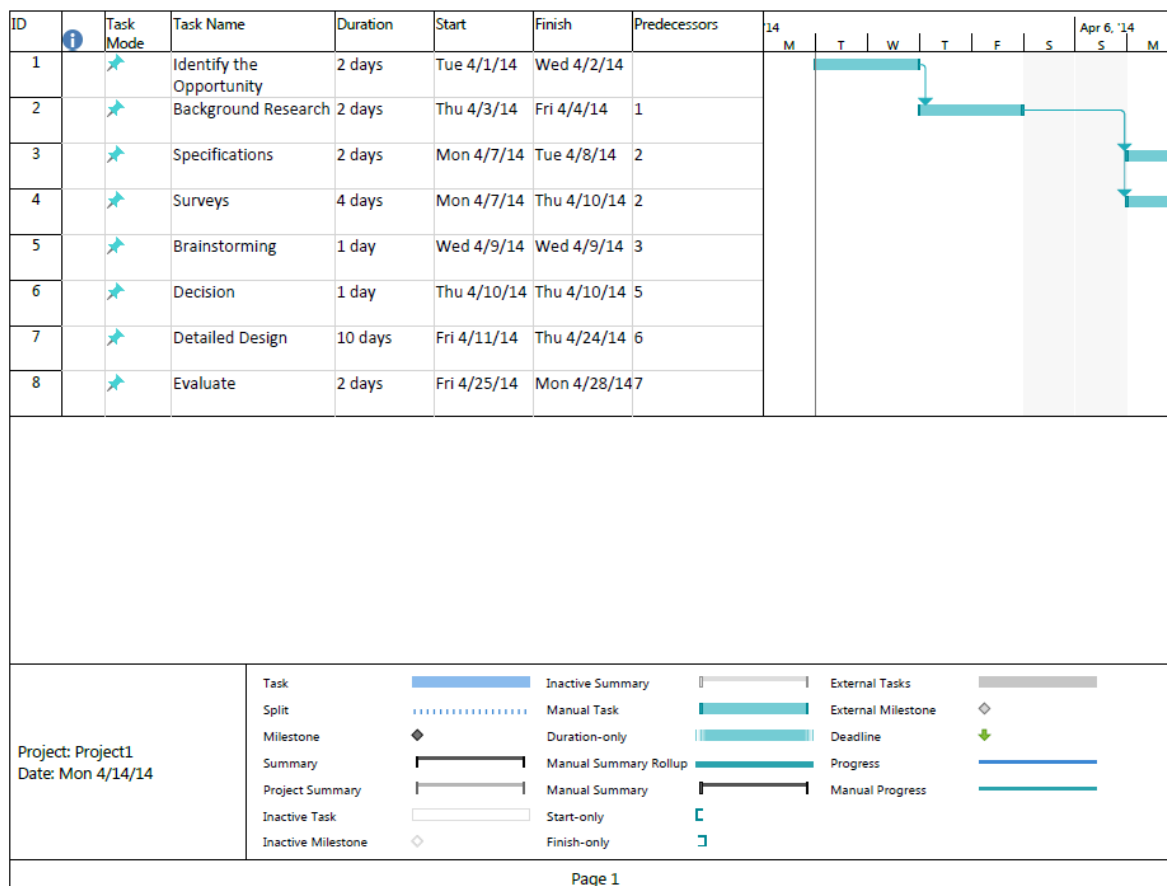


Figure 9: Project Gantt Chart