Autonomous Vehicles: A Solution to Facilitate Human Mobility and Increase Face-To-Face Interactions

A study inside a large campus organization.

by

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ABSTRACT

The world is and has been in constant change. Disruptive technologies have emerged and integrated into our day to day lives and have radically improved the way we live. Today, in our overly connected world technology is advancing at an incredible fast pace, firms have to change focus to keep up with the shift in the consumer behavior, megacities will continue to emerge; at the same time consciousness is growing towards more efficient and ecological solutions to solve the problems the world is facing what is leading to the redefinition of economic models. The automotive industry in particular is being disrupted to become mobility services companies instead of car makers.

With the unquestionable need of people interacting with each other and the imminent need for innovation for any firm to subsist, the next step is to identify the best way the organization can foster interactions and communication between individuals where they are able to continuously innovate to achieve the substantially higher performance every organization is seeking for.

Although Autonomous Vehicles are close to a production phase, there are still limitations to their deployment in the full ecosystem. This thesis provides a systems perspective approach by studying a large campus organization and offering a proposal to integrate Autonomous Vehicles technologies with the purpose of increasing face-to-face interactions while at the same time increasing productivity, innovation, and creativity to improve people's lives by facilitating human mobility staging a unique mobility experience.

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To my wife Mariana, who I love and admire, and who has walked beside me in this journey.

To my son Jerónimo, for complementing our family and teaching us a new way to love.
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PURPOSE AND MOTIVATION

1.1 Introduction

Today, our world is defined by connectivity, allowing us to be open to new ideas, products, and services—thanks to the democratization of information the Internet has provided. With organizations like the MIT Media Lab, devoted to creating disruptive technologies to radically improve the way we live (MIT Media Lab, 2015), we have seen a fast-paced advancement in the creation of new organizations. An increasing focus on companies to fulfill consumers’ needs and wants by providing a full consumer experience, rather than focusing solely on the product or service itself, is evidence of this shift toward the adoption of newer technologies.

When considering that the main objective of most organizations is to achieve substantially higher performance levels, the opportunity exists to analyze organizations from one common perspective, and by seeking to identify common elements that all organizations possess. In basic terms, an organization can be defined as a group of individuals interacting together toward a common goal. For this to happen, individuals within a group must interact and communicate with each other to ensure the achievement of a goal.

In today’s competitive world, characterized by continuous change, organizations are striving to achieve higher performance rates, which constitutes focusing on having the best talent, and promoting a culture of constant innovation. With the unquestionable need for people to interact effectively with one another, and given the pressing need for innovation for any organization to thrive, identifying the best way an organization can foster interaction and communication is essential. When clear communication and productive interactions take place, between individuals in a group with a common goal, the ability for an organization to continuously innovate and achieve substantially higher performance rates can take place.

Today, the automotive industry is in the midst of a disruptive phase, where a new business model for Original Equipment Manufacturers (OEM’s), could be developed regarding mobility. Integrating Autonomous Vehicles as a primary technology toward this end could serve to increase face-to-face interactions inside large populated areas, or within organizations. An additional benefit to promoting Autonomous Vehicles for OEMs could be an increase in productivity, innovation, and creativity to improve quality of life by facilitating more ease in human mobility.
1.2 Purpose

The purpose of this thesis is to provide a systems thinking approach on how new mobility solutions, enabled by Autonomous Vehicles technologies, can promote and strengthen face-to-face interactions when people are en route to a shared destination. The focus of this study will be placed in a case study framework, within a large campus organization, with the intention of later motivating broader usage of innovative technologies in other large campus organizations and cities. The ultimate purpose of this study is to expand networks, promote innovation, avoid silos, and ultimately increase productivity and gross domestic product (GDP).

1.3 Motivation

The need for human mobility to effectively move people from point A to point B is essential, and present solutions are not fulfilling current demands, suggesting that future demands will go unmet as well. Today, the vast majority of most vehicles sit parked throughout the day, making them an expensive asset that is basically underutilized. Furthermore, the trend of growing populations in urban areas are in resulting more congested and chaotic transportation systems.

In reaction to these transportation problems, the automotive industry is being transformed through the creation of new companies. These newer enterprises promote a shared use of resources to reduce costs, both to owners of vehicles and users of vehicles, in exchange for effective transportation. OEM's today are devising new strategies to appeal to buyers with car sharing programs, facilitating the rental service of personal vehicles, even for hourly and group leases. Furthermore, there is considerable opposition to the use of personal/individual vehicles. Opposition leaders mainly argue that cars have been responsible for city sprawl and a significant reduction of human serendipitous interactions that can occur when using a shared transportation system such as a bus or a train.

My principal motivation for this study is to be part of transforming the way the world moves, by proposing a transportation method that would both facilitate and promote human interactions in an organization. This system could also be deployed and adopted in other highly
populated areas, with similar environments, for the main purpose of promoting innovation and increasing productivity.

2 PROBLEM DEFINITION

Interactions between individuals have been an important topic for a large number of researchers, and has been analyzed from a wide array of perspectives. The focus of this thesis is to analyze face-to-face interactions taking place between employees working together on Ford Motor Company's large campus. The emphasis is on the way in which employees move from one building to another within the Ford campus.

Mark Fields, Ford Motor Company CEO in an internal video blog, has the following three main priorities: accelerate the Ford Plan, deliver product excellence with passion, and drive innovation in every part of the business. To successfully achieve these goals, the company is organized in many areas, which deal directly with each component. One of these areas is the Ford Research and Engineering Center, which is focused on working towards the design and development of current and future products. Employees who are a part of the Research and Engineering Center work closely together, and are subdivided into different areas such as Product Development, Research and Advance Engineering, Program Management, Purchasing, and Testing. (Fields, 2015)

However, like in any organization, Ford faces challenges in fully accomplishing its priorities, which could be better facilitated with more face-to-face interaction. Employees at the Ford Research and Engineering Center have low levels of interaction with other colleagues on a day-to-day basis. In many cases, employees have lunch at their desks, and some even have a personal microwave oven and coffee maker in their personal work area. In departments such as the Product Development Center (PDC), employees may have the convenience of a printer, or other work-related devices, located just a few steps away from their desks. This type of set up is not encouraging PDC employees to move around the office and engage in informal conversations with employees from other divisions, or to interact with employees in different buildings entirely.
Meetings do provide an opportunity for employees to engage in face-to-face interactions, however, most of the meetings have a virtual attendance format, encouraging individuals to stay in their own work areas and not participate in both formal and informal conversations. Factors affecting communication might also be stimulated by the length of the meeting, or that meeting participants often cover several items within the same meeting, making it difficult for employees to attend for the full duration of the meeting.

In this scenario, multiple questions arise; with one of the main ones being, “What causes employees to prefer to stay at their desks and attend meetings virtually, rather than attend in person?” This question can have different answers such as: (a) there are too many meetings taking place, (b) there are not enough meeting rooms, (c) it is difficult to move between buildings, and other reasons as well. Yet, if employees continue to interact mainly within their closed departmental groups, they could fall into what is termed by Pentland (2014) an “echo chamber” where no new ideas are discussed, minimizing innovation and diversity within their groups.

With this in mind, the question this thesis addresses is how an organization can promote a work environment, which spurs innovation and creativity. The main idea is that this should be done through promoting face-to-face interactions between employees belonging to the same area, as well as with employees located in different buildings. Perhaps if Ford were to provide a user friendly transportation method for employees to move more freely around the campus, this would encourage employees to engage in more face-to-face interactions.

3 CONTEXT
3.1 Megacities

At her presentation at the EmTech@MIT 2015, Erika Klampf shared that any city in the world that can hold 10 million people or more earns the title of a megacity. Today there are 28 so-called megacities globally. Some examples of these cities are Tokyo, Mexico City, Mumbai, Sao Paolo, and Shanghai. By 2030, experts are forecasting there will be at least 41 mega cities in the world. With these numbers of people living in the same city, it is safe to assume that the benefits they get from living in an urbanized area are higher than the negative impacts like traffic congestion, pollution, or crime. Nevertheless, these topics should be addressed to promote
healthier environments in congested areas. Speaking specifically about air quality, the World Health Organization in Chapter 4 of the 2002 The world Health Report has noted that urban air pollution is a serious social and public health issue, and is one of the ill effects promoted by so many vehicles operating within a confined area. Yet, this need not be the case as innovation can be used to mitigate these affects.

Another important consideration to address when discussing megacities is the expected growth of the middle class on a global level. For example, as Mark Fields comments to Forbes in 2015, this class will more than double in size from 2 to 5 billion by 2030, with most of the growth taking place in Asia. One of the indicators that signifies being a part of the middle class is owning a car. In urban areas people want to be mobile, and need an easy way in which to move around. However, as our cities grow, people are having more problems getting around due to traffic congestion and limited transportation options. Primary players within the automotive industry cannot keep putting more and more cars on the road, and there is a need for new solutions. Mark Fields, Ford Motor Company's CEO voices that there simply isn't enough room on the planet for all those cars. (Muller, 2015)

3.2 Sharing economy

We are living in an era that has been transformed by networks. As Alex Pentland (2014) comments in the book Social Physics, these networks are facilitated by both people and computers. It is this combination that gives people democratized access to an incredible amount of information, allowing millions of individuals to learn from each other and influence the exchange of ideas.

In an analysis of the digital data created by the digital bread crumbs we all leave behind as we move through the world, broadly known as Big Data, we can understand how experts have come to realize how consumer behavior patterns are shifting. Having this type of information can be used to create services that will improve the lives for many citizens. With examples like Nokia, and how they lost their market share to Apple and Google (Waber, 2013) it is clear that today building the best product is not enough; consumers are more focused on having the best experience they can with a product. Consumers are pushing companies to think first about the
type of experience an organization wants to create for consumers, and then to create and design the appropriate technology to deliver a usable product.

Facilitating the creation of better products and making our lives increasingly connected has led to a disruptive advancement in several industries. In today’s world it is simple to rent beds, cars, boats, or even homes directly from each other. Developments in technology have made this possible as transaction costs are now reduced. Additionally, the scope of the internet is so broad that it is possible to share on a larger scale than ever before. As the article *The rise of the sharing economy* (Economist, 2013) mentions, “The big change is the availability of more data about people and things, which allows physical assets to be disaggregated and consumed as services ... social networks provide a way to check up on people and build trust; and online payment systems handle the billing.”

The main idea of the sharing economy model is that access trumps ownership. Sharing in this manner first started with consumers buying expensive items that they were not fully utilizing—like a car or a room in a house—and through renting these assets people were able to profit from their underused possessions. The benefits this type of shared economy brings to the world can be perceived as influential in several areas. One of the main areas a shared economy is beneficial is in regards to the environment. From an owning to sharing model, fewer resources are needed for production, and the waste of disposing of a product, or its parts, is reduced.

In a historic evaluation of this shift in consumer behavior, thanks can be given to the internet’s value to consumers, probably strengthened by the entrance of the millennial generation (those who were born between the beginnings of the 1980s through to the 2000s) into the economic market system. The shift that has occurred has significantly impacted the economy, business, government, and politics. While a valuable tool, this emerging model creates concerns for regulators, due to regulatory uncertainty, and incumbent companies within newly disrupted markets. Both regulators and companies are waking up to this disruption and are making the changes they need to in order to keep up with the market, offer solutions to customers and consumers, and to guarantee their survival, at least at first.
3.3 Automotive industry

The consumer behavior seen in other industries, and discussed above, is also transforming the automotive industry. We are living in the most transformational era in automotive history, and there are a lot of well-known players in the game. A strong disruption is taking place within companies like Google, Apple, and Tesla, who continue to enter the market with new technologies. Luckily, OEM's have an opportunity to be right in the middle of this shift. As such, vehicle manufacturers need to change their mindsets to the idea of becoming mobility service companies, instead of companies that only manufacture vehicles and vehicle parts. Without question, the industry has to become engaged with the advancing technologies coming out of Silicon Valley today, of which the first and primary reason to do so guarantees survival.

One of the most significant changes in consumer behavior disrupting the automotive industry today is the shift younger consumers are making from car ownership to car sharing. For them, owning a car is not a priority anymore; they are getting their drivers' licenses later, and prioritize having a smartphone over a car. They are more interested in having access to transportation, rather than in owning a vehicle. The prevalence of this shift is especially true in areas where people can get around without a car, or where it is inconvenient to have a car because of traffic congestion or not enough parking spaces. This phenomenon can, and most probably is, setting a trend in megacities where the exponential urbanized growth cannot bear the same rate of growth in car ownership.

Companies like Zipcar, Uber, Bridj, and Lyft understand the change occurring in consumer behavior and the implications of this rise of a collaborative economy. They have entered the transportation market as game-changing companies, offering mobility services focused on a type of experience that has resulted in the creation of an industry worth 5.4 trillion at market value. This new market has shaken OEM's and has made them begin to examine what role they could be playing to get a share of that market, rather than only providing the products for the service. (Fields, 2016)

At the 2015 EmTech@MIT Summit, Erica Klampfl, Ford's Global Mobility Solutions Manager, talked about what Ford Motor Company is doing to understand the transformation happening within the automotive industry. She suggested looking into different trends such as
consumers' attitudes, what is happening in communities, and new and upcoming technological
trends from which Ford can lever an advantage. Klampfl further noted that to build strategies to
become both a product and a mobility company, by helping people get from point A to B (even if
it is not by using a car) could make Ford one of the major players in today's technology-centered
world. Some of the companies already focused on this transformation are using connectivity,
software and sensor technologies, Autonomous Vehicles, Big Data, as well as digital experiences
and services. Today, the current focus on newer trends are flexible ownership and multimodal
urban solutions, which allows for seeing the car as only one node in the transportation ecosystem.

The automotive industry is highly conscious of the new need for mobility integration,
where the future is to remove the driver from the equation and deliver an autonomous vehicle that
will change the economy of mobility when taking people from point A to point B. The disruptive
portion of this equation changes the dynamics surrounding car ownership, energy use, fossil fuels,
public transportation, and planning for cities.

4 FACE–TO–FACE INTERACTIONS
4.1 Evolutionary perspective

Humans by nature are social animals. We have been living in societies for a long time. To
try to understand this fact, research has been conducted around the topic from different
perspectives. At the most basic level, we can assert that we are wired to connect with others,
primarily to ensure our own survival, and in a greater sense to contribute to the betterment of
humankind.

Ben Waber (2013) in his book, People Analytics, presents how our pre-human ancestors used
to work in groups, since this activity provided some fundamental advantages over individual
action. The most obvious one, the ease of better defending oneself from the dangers the
environment, examines how individual risk is mitigated simply by being greater in number when
being part of a group.

This initial manner of forming groups had survival at its core; our ancestors spent most of
their days hunting, hiding from predators, and sleeping. Although they did live in groups, we don't
know how large the groups were, or how exactly they behaved. As the author shares, the closest
idea we have gather regarding their behavior is by seeing how our other close relatives behave—like Gorillas, Bonobos, and Common Chimpanzees. Today, these primates form groups mainly to search for food and thus guarantee their survival. The groups can vary in size from 20 to 150, and the interaction the members have with each other is clearly defined, depending on the availability of food. Often this can even lead to the creation of a hierarchical dominance, still with a strong focus of survival (Waber, 2013).

Talking about the human species, John Medina (2008), a developmental molecular biologist, research consultant, and an affiliate professor at the University of Washington has something to say about brain development. In his book *Brain Rules*, he presents the theory that the strongest brains survive, not the strongest bodies. He asserts that it was the evolution of the brain that has allowed us to survive in first place and to evolve as human beings. He observes that is our ability to solve problems, learn from mistakes, and create alliances with other people that has helped us to survive. Medina proposes that we have played such a large role on earth by learning to cooperate and by forming groups. He supports his argument by explaining the human need to survive in the jungle at a point in time when our ancestors had two options: either develop bigger, stronger bodies that would enable fighting off the saber-toothed tiger or to become “bigger” in some other way. Medina clarifies that the solution to becoming bigger was found by forming groups with other individuals living in the same circumstances, other human beings, and to create alliances to increase the group’s chances of survival. Given this winning choice, our need to connect and interact with others became a survival tool.

The evolutionary perspective supports how we are wired as human beings, and how we evolved the need to connect with others to continue our survival. As we have persisted in evolving biologically, socially, and culturally, face-to-face interactions have evolved too. For our ancestors, face-to-face interactions were the only way possible to connect with others, and our ability to understand one another during that time was our chief survival tool. Yet, we are a nonetheless a social species, and learning from one another has made us smarter, in a number of different ways as well.
4.2 Social Physics: a lever to understand human interaction

The Merriam – Webster (2015) dictionary definition of social science is “a branch of science that deals with the institutions and functioning of human society and with the interpersonal relationships of individuals as members of society.” For decades, the information used in the social sciences was acquired by the direct observation of trained scientists, questionnaires individuals had to answer, and through longitudinal studies where a small group was followed for a number of years to try and understand a particular behavior. All of these qualitative methods have been useful, yet limited in the amount of information that can be gathered on a large scale. These methods are also limiting in their ability to generalize to other populations and individuals, since such studies can only describe the norms found in stereotypes, and have difficulty in reflecting the social complexity (and sheer numbers of humans) seen today.

Waber (2013), in People Analytics proposes that “today people analytics is poised for a revolution, and the catalyst is the explosion of hard data about our behavior at work” (p. 196). Previously, this data was only able to reflect the digitally recovered part of the story, since it was collected by all our digital activities such as email, messages, online searches, etc. However, today the rapid development of wearable sensing technology has allowed science to gather data from face-to-face interactions as well, since the provision of data on interaction patterns, speaking patterns, motion, and location, among other things are now available. Today, we have the advantage of leveraging these large data sets, that offer an impressive amount of objectivity, and continue to present quantitative information in a dense form; a form which is able to predict human behavior and how interactions shape behavior and habits.

As Alex Pentland (2014) further explains, Social Physics is a quantitative social science, based on reliable mathematical connections, which help us understand how ideas flow from person to person through the mechanism of social learning. Ultimately, this flow of ideas ends up shaping the norms, productivity, and creative output of our companies, cities, and societies. Using Social Physics, it is possible to understand the social fabric of a group or society from a new perspective, and beyond traditional economics. Such a perspective changes the view from analyzing independent people to analyzing people interacting who are capable of watching, learning from, and copying each other. By using Big Data to analyze personal and detailed
information about the behavior of each person, it is possible to build quantitative and predictive behavioral models, which include the analysis of individual behaviors, as well as the peer to peer relationships that take place.

As a new science, Social Physics offers definitions to terms related to human interaction. The basics of Social Physics are important to be defined for a common understanding of the vocabulary used in this thesis. The following terms are as they appear in Pentland’s work. (Pentland, 2014, p. 20)

- **Idea flow**: the propagation of behaviors and beliefs through a social network by means of social learning and social pressure.
- **Exploration**: the process of searching out new ideas, potentially valuable ideas by building and mining diverse social networks.
- **Engagement**: social learning, usually within a peer group, that typically leads to the development of behavioral norms and social pressure to enforce those norms.
- **Social learning**: refers to how new ideas become habits, and how learning can be accelerated and shaped by social pressure.
- **Social influence**: the likelihood that one person’s behavior will affect the behavior of another person.

One of the key finding in Social Physics is the rate of idea flow, which gives information about how fast ideas move from one person to another, and from one society to the next, thus creating a social network. What Social Physics allows us to do is to look at the Big Data of communication to better understand the interactions happening wherever there are human beings interacting. Based on Daniel Kahneman Fast Thinking Theory, 90% to 95% of social learning is based on experience and association. When observing our peers, people we identify as similar to us, and by experimenting with something that appears successful, we tend to incorporate what we have learned into our behaviors without a great deal of thought. This is why we are social species, we have a need to observe our peers and see what makes them successful so we can inherently adopt the same or similar methods. (Pentland, 2014)

Alex Pentland and his colleagues have also discovered that the use of Big Data and Social Physics can be used to increase productivity, as well as the functionality of companies and other
organizations. The starting point for this is to think about an organization as an *idea machine*. The author describes this “machine” as things that take in ideas, and bounce them off each other to observe the results in action. If an organization is able to make that flow of new ideas better; then the organization (or company) performs better. If we know how to make our organizations work best by encouraging individuals to work together in specific manners, we can solve complex large scale problems. (Pentland, 2014)

4.3 Interactions within the organization

Continuing with the basic definition of an organization as a group of individuals interacting with one another toward a common goal; organizations are a way to get people to collaborate with each other. We collaborate by passing information to one another. Since we, as we have learned from the evolutionary perspective, are wired to connect, it is logical to think that interactions that take place within any organization would occur seamlessly; however, this is not always so. It is precisely the interactions employees share with one another in a company that makes every company different from another, and what allows a company to perform the way they do. In having knowledge of this distinction, it is important to distinguish the specific communication methods and patterns of interaction used by a company that actually drive performance in that organization.

As Waber (2013) shares in *People Analytics*, after the industrial revolution complexity started to increase within organizations. Companies had the ability to manufacture their goods on a larger scale that required not only a defined manufacturing process, but also close coordination between colleagues to deal with the magnitude of production the process required. To this effect, the dependence on others made the importance of coordination extremely valuable, especially given that it became the main path to manufacture the product. Today we face bigger challenges with constant change, even more complex systems, and problems requiring immediate solutions. These societal shifts lead to the need for work groups, or teams, to change their approaches, and the parameters of their systems. When a team is working within a complex system, rich communication channels are needed to keep everyone working in concert and toward the same goal.
To understand the impact newer communication methods have had on the performance of present day organizations, we can look at the introduction of email to the organizational world. Clearly, this tool has fundamentally changed the way people communicate with each other in an economic setting and otherwise. In *People Analytics*, we can read about the results of a study conducted by Erik Brynjolfsson at MIT, in which it's been noted that the increase in productivity the email system has brought to companies from the late 1980s to the late 1990s changed the landscape of how organizations conduct business. At the onset of using this technology, it was found that every dollar a company spent on new IT systems, such as e-mail, the company's value increased by $12, simply by changing how people collaborated on a massive scale. Around the same time, the use of the Web for business was exploding. In today's business environment, these technological shifts have facilitated a wide diversity of communication tools like email, instant messaging, videoconferences, or with resources such as Yammer or Jive, which seek to enhance virtual interactions between employees. The Internet truly democratized information gathering, giving employees the ability to search through records to understand what was happening in their markets in real time. This capability was one of the major catalysts for the ever-accelerating changes that have occurred in the way companies work (Waber, 2013, p. 35).

As human interaction within an organization is any type of communication employees conduct within a company, the proliferation of mobile phones in the early 2000s, also allowed people to be consistently connected. In this manner, the separation from work and leisure was almost invisible, until the impact was obvious as people started spending more time on their cellphones, rather than talking to people face-to-face. Nevertheless, face-to-face interactions continue to have an important impact on an organization's performance, continuing to be a rich channel where colleagues are able to exchange ideas, and understand requirements and information needed for the company to achieve positive results. Not sharing information makes it difficult for people to support one another and to work with each other effectively.

A classification of the different types of information people share at an organization can be described as either work-related or personal. In *People Analytics*, the author states that both avenues have tangible benefits for the organization's performance in sharing that, "Work-related discussions transfer relevant information between employees to complete a task or even can lead to new innovations. Whereas social related conversations can be a powerful mean to create trust, build rapport, and relieve stress" (Waber, 2013, p. 75). It is also important to note that information
exchange can occur in formal or informal communication processes. The informal communication process can happen in an organization when employees chat at the coffee machine, while eating lunch together, or even at the beginning or the end of a meeting. This communication process gives individuals the opportunity to be involved, for people to informally touch base, and for social interactions to be coordinated. It is extremely important for organizations to allow space for social interaction, given that it creates social norms, which tend to keep behavior predictable and, ideally, optimized to achieve a desired end.

To further illustrate this, Waber (2013) shares about a widespread belief in the American culture that “time not spent at your desk is time wasted, and typically people found schmoozing by the coffee machine or eating lunch at a table with colleagues are viewed with disdain” (p. 197). This example is very powerful for understanding how social norms work, while also allowing us to understand the smaller amounts of strictly social conversations some organizations might encounter, which can potentially interfere with work-related interactions. Yet, many social interactions at the workplace often turn to work related matters.

When teams are working on big projects, they generally tend to focus on the big issues and pay less attention to the smaller issues. Meetings are a formal channel of communication, where the participation of most of the team members is mainly focused on solving critical issues. These meetings ideally serve to keep the whole team working together and focused on the desired outcome. The small issues are not taken into account until they become “big issues,” normally requiring a shift in focus and the allocation of resources to an issue that could have been solved earlier. As Waber (2013) states, this is where informal communication is critical. The small things may not come up in formal meetings, but they are important enough to be discussed informally around the coffee machine, and during those unexpected encounters. Sharing information about smaller issues so that they can be dealt with before they become future problems, gives the group time to focus on the more critical issues, and be proactive instead of reactive. Informal conversations can also help to reduce assumptions and make sure everybody’s thoughts and ideas are in alignment. One major, and much needed, benefit of a cohesive face-to-face network is the ability to build a common language.

For the purpose of understanding the importance of face-to-face interactions in a connected world, and with all of the tools that are available for telecommuting and distance
working, Ben Waber and his colleagues conducted research in a call center. The results of their work shows that by completely removing face-to-face interactions from the call center, employee performance decreased by 12.9% (Waber, 2013, p. 92). With this decrease in performance, there was a 13.1% increase in stress, which contributed to higher rates of turnover, thus increasing the cost of running the call center operation as a whole. Waber’s research provides quantifiable data to understand the impact face-to-face interactions have on the performance of an individual, which in turn has a direct impact on the performance of the whole organization.

Face-to-face interactions are also a rich channel of communication, given that it allows individuals to observe one another and to gain non-verbal information. Normally, organizations do not keep track of what takes place in face-to-face interactions, especially those in an informal setting. Yet, both the formal and informal processes that occur within a company relate to the way people interact and communicate with each other, and make up the social fabric of an organization. Changing the behavior of how people communicate with each other can result in a change in performance for the entire organization. Pentland and his team conducted research that shows that full engagement within a group (i.e. everybody is communicating) can be responsible for 30% or even 40% of the variation between groups, revealing which groups work well together and those that do not. Furthermore, 10% to 20% of group variability is related to creativity, which comes from exploration outside of the group (Pentland, 2014). Conversing with people from different groups, areas, or with those who perform different functions can allow for the exploration and learning of new habits. When new habits related to engagement are created, it can have an important impact on the whole group. Creating new patterns of communication and learning new habits are perhaps the largest factors in the promotion of the creative and productive output of companies; all of which can be achieved by the quality of the face-to-face interactions happening within a group. While electronic communication has also been studied, the research does not say much about productivity or creative output, because these results do not appear to affect behavior.

An example where engagement was observable is related to meetings. Recently I had a scheduled meeting in my work zone with people who work on the same work zone. The location for the meeting at the meeting request was stated as “my desk/WebEx”. The WebEx was sent so that a person from a different country could participate. Since there was a physical location stated I assumed that all the participants who were on the same work zone would attend in person.
When I arrived to the desk I was surprised to be the only one there, besides the desk owner. When the first person called in I naively asked him if he was out of the office (to understand if that was the reason why he was calling instead of showing up in person) when he said that he was actually in the office, the desk owner in a playful way invited him to join us. When other colleagues called in, they were immediately invited to join the in-person meeting. By the end, only one person who was at the work zone decided not to physically attend. During the meeting all the participants had the opportunity to interact and give opinions in an even way.

Later we had a manager review meeting, it is important to mention that hierarchies matter, so since the manager organizes, everybody attends in person. During this meeting participants started to joke around the past meeting as a “party” since we were all together in one same place. Even the manager asked us to be invited to these parties. In this case, we were able to change the behavior of a group of people to attend to this one meeting in person and encounter face-to-face interactions. Those who did not attend are able to watch what we did and the positive result we got from it. To get more people start working with this new behavior, we need to continue to engage and attend to meetings in person.

Another important part of face-to-face communication has to do with exploration, speaking with people from different groups, and outside of one's own group. The evidence shows that this type of interaction has a positive impact on productivity, since this will help the individual view issues in a broader context. By sharing information in this way, it is probable that it will have a positive impact on creativity and inventiveness.

When groups are rarely exposed to each other, and do not generally have interaction with other groups, they are only exposed to their own group's ideas and behaviors, leading to limited learning. When a group has interaction with other groups, they are exposed to other ideas that can change behavior, when shared within the group setting. As Pentland (2014) defines it, talking with the same people can create an echo chamber where the same idea bounces around and gets "recycled" within an organization, leading to an organizational rut. As described in People Analytics, this has happened to some organizations and they have lost their competitive advantage. Even market leaders like Research in Motion, the company that made the BlackBerry smartphone, have experienced getting stuck in this way. For example, this company made the assumption that everybody wanted (and would always want) a physical keyboard on their mobile phones. Their
assumption put them in an echo chamber where they were not capable of listening to ideas outside of their group. Ultimately, this caused them to plummet in their market shares from 43% to -12% (Waber, 2013, p. 67).

With this example in mind, the need for an organization to promote exploration, encourage a diversity of people to talk to each other, as well as to people outside the organization, is evident. Only in this manner can companies avoid being caught in an echo chamber that can be extremely costly to the organization’s survival. Another positive point to promoting exploration is that this activity can serve to spur creativity and innovation, especially given that creativity is about getting the right people to communicate, share ideas, and collaborate to create something new. Through the combination of different skills, backgrounds, knowledge sets, and decision-making tools, great innovation can be generated.

In continuing the discussion on creativity, Waber (2013) comments that it is the engine of the world economy. There are different types of innovation which impact company success as well. These can be divided into disruptive innovation and incremental creativity. Each of these require a completely different mindset and both are crucial to a company's success. “When a company is trying to move into a new area or break out of an unprofitable business model, the key to doing it is disruptive innovation. Incremental creativity is responsible for the long-term success of a company or product” (Waber, 2013, p. 123).

One important thing to consider is how each of these types of innovation require different types of interaction within a group. For disruptive innovation to occur, it is indispensable for the group to have a strong exploration mindset where they can remove common assumptions and gather new ideas from outside the group. For incremental innovation, it is important to build and strengthen the connections within a group working together to solve a problem. When an organization is able to foster both types of communication patterns among groups, and understand how to effectively mix them, they are on the path to success. Having this information about group interaction is extremely relevant for any organization, since creativity is an economic engine. In having knowledge about how to foster creativity, an organization can then offer the conditions needed to promote a creative environment. For instance, having this information can make room for engaging others in discussion, rather than people having to work out new ideas on their own.
MIT Professor Tom Allen (2007), as well as Ben Waber (2013) and other researchers, have conducted different studies on fostering communication by examining the role of the physical layouts, distances from place to place, and physical space, as it relates to the communication patterns found within an organization. The findings from the work conducted by both researches are closely related. One of the most important discoveries in this work is the likelihood of people using bigger sets of communication tools; (i.e. telephone, email, IM) with the people they have the strongest face-to-face communication with. One hypothesis to explain this might be that face-to-face interaction creates a trusting relationship, fostering the continuous use of other type of communication as well and a sense of not having to create solutions and new ideas in a vacuum.

Professor Allen (2007) suggests that building architects can play an essential role in arming organizational managers with the tool of physical space to help them plan and direct successful innovation processes. He further proposes that in engaging in this activity, managers and architects will no longer think about the tools of organizational structure and physical space in isolation. Along the same lines, Pentland (2014) and his colleagues support Allen’s theory by alleging that coffee machines, kitchens, cafes, and recreational areas provide an environment that serve a crucial social function where people can interact and enhance social connectivity in the workplace. One of the biggest benefits of company campuses is the possibility of starting a serendipitous conversation that will cause someone’s thinking to propel another in a completely new direction and possibly start a new collaboration.

Additionally, Waber’s study demonstrates how in two completely different organizations (one located in the Midwestern portion of the United States and the other one in Germany) the distance between desks appears to be one of the main drivers of interaction (Waber, 2013, p. 101). The length of the interaction also has a relationship with distance. For the promotion of short and serendipitous interactions, distance is inversely proportional to the probability of people interacting. However, in People Analytics, the author also proposes “If you’re going to spend an hour in a meeting with someone, the distance to his/her desk doesn’t matter. Walking over to him/her or finding a meeting room is worth your while” (Waber, 2013, p. 145). Coincidentally, Waber and his team have also discovered that an approach to interaction consisting of a large number of very long interactions decreases the number of short conversations. These results show that the probability of two people interacting is inversely proportional to the distance between their desks (Waber, 2013, p. 96).
When analyzing a large company with an extensive, multi-building campus, the concept of distance becomes more complex. Many large business campuses are made up of a number of buildings housing different parts of the organization, while frequently all grouped together in a single location. One issue on a large campus is that walking between buildings takes more time, which makes it less likely that people will have unexpected encounters leading to conversations that can influence innovation. By changing the focus on company campuses from the actual office buildings, to event spaces and central social regions, companies are creating physical spaces where people from different areas or buildings can meet, opening up the possibility for serendipitous interactions between people in different buildings. The role of individuals and leaders should be to create an environment so that these types of random encounters can be more frequent than and as useful as possible (Waber, 2013, p. 106).

For organizations with people in different locations and countries, it is difficult to have constant face-to-face interactions, and collaboration must occur with the use of all the technology possible to help minimize the impact of distance. Some of this can be done through video conferences, phone calls, and chat sessions. Another tool that organizations have is the use of people Tom Allen (2007) calls “gatekeepers,” what Pentland (2014) calls “charismatic connectors,” and what Waber (2013) refers to as “brokers.” Whatever the term used, their main function is to actively try to connect diverse groups, and then in turn share this information with their own core group. These are people who travel frequently to different locations, and act as the main point of contact for both locations to interface with one another. They are even more effective when they are in close contact with relevant stakeholders, as this helps to create congruence, which speeds up the development time for a particular project and can create relationships that span both distance and organizational boundaries. These aforementioned individuals act as the glue that holds companies together, and shapes the relationships and communication patterns the organization uses to function most effectively.

With the vast number of tools available today, people can work more effectively, communicate more quickly, and be more flexible with the way in which they spend their time. Companies today are organized to take advantage of these tools, which enables rapid change in the products and services that they offer. Still, the system used by a company to communicate plays an important role in attention paid to face-to-face interactions. Employees are having to make sure the organization is providing the correct environment to foster engagement and
exploration, and to allow ideas to be shared and spread across the organization with the focused objective at its core; to continuously strive to perform at a higher level.

4.4 Interaction within the City

In acknowledging our basic need to interact with others, Ben Waber (2013) shares in his book that sometime within the last one thousand years people began to create groups as a solution to getting their needs met. Groups offered some fundamental advantages over more informal means of associating. Later, and with technological advances in agriculture, groups became large enough to form cities. It was during this time that a group considered sufficiently close to an "organization" was formed. It was in the cities where a greater number of people gathered, and thus cities became a place where people were able to exchange goods and ideas within an "organization". It has been noted by Waber that this exchange led to a much more rapid period of innovation (Waber, 2013, p. 26).

In his book, *The Triumph of the City*, Edward Glaeser (2011) presents how cities are humanity's greatest creation, and our best hope for the future. He asserts that cities are the most enduring social networks, with the greatest possibility of using innovation to spur social and economy mobility. Considering that it was in cities where the first exchange of ideas occurred, leading to a rapid innovation period, cities are the clearest example of how face-to-face interactions can lead to the betterment of society. The author further describes in his book that "cities are the absence of physical space between people and companies. They are proximity, density, closeness. They enable us to work and play together, and their success depends on the demand for physical connection" (Glaeser, 2011, p.6). Since their creation, living in the city has presented a great deal of advantages by offering more possibilities to its inhabitants. Cities attract talented people, facilitate face-to-face interactions, offer a place to exchange ideas, and finally enable people to work together collaboratively.

As Alex Pentland (2014) explains in *Social Physics*, one of the most reliable methods for learning is proximity because it facilitates transmission by observing what other people are doing, and by paying attention to the outcome of their actions—whether positive or negative. When people observing others identify a successful outcome, then that behavior is more likely to be
repeated and adopted by others. Later, this also serves to create social pressure for other individuals to change their own behavior. This process of social learning has been key to innovation and the advancement of cities. As Glaeser comments in his book, “many of the biggest innovators acquired their knowledge not through formal training but by being close to the action.” (Glaeser, 2011, p. 5) The idea presented here is closely related to how MIT professor Thomas Allen (2007) explains innovation as the results from collaboration, collective intelligence, and sharing knowledge, as the most common areas that allow for communication. Allen further asserts that “Success in today's complex innovation process depends upon getting the right information to the right people at the right time,” (Allen, 2007, p. 127) which leads us to understand that being close to the action and being open to observation, can have a positive impact that can lead to innovation.

Even with the rapid development of new technologies, which enables bringing people in different locations “together,” and being able to interact in virtual environments, proximity still plays an important role. As Glaeser comments, “Proximity has become even more valuable as the cost of connection across long distances have fallen” (Glaeser, 2011, p. 4). We can observe the phenomenon of greater face-to-face interaction in cities happening in places like San Francisco, New York, Paris, Boston or London, in which inhabitants are being offered a fun and engaging place to live, without the need of commuting for long hours to more distant locations. Everything that is needed is available within a very small radius. Furthermore, with the efficient public transportation systems that many cities now have, the opportunity to interact and connect with people from different backgrounds, and having different interests, allows for the exploration and exchange of ideas from one group to another, increasing the diversity within individual networks. Today, living in these types of cities is considerably expensive, yet, individuals are willing to pay a higher price to be close to the action, as the benefit of being there is still greater than the cost.

Thanks to big data, it has been possible to analyze people's habits, and to even go beyond the individual to understand behaviors on a larger scale, like in a city, where subgrouping can be observed. What is interesting about is the city dynamic is that normally subgroups, or tribes as they are sometimes called, typically do not interact with each other, and they often end up learning the same habits from each other by learning through example. The habits and patterns learned in this manner often can identify certain qualities of specific group, such as a general attitude towards risk, or even to the susceptibility of developing health problems.
Recent work by Wei Pan and his colleagues at MIT have shown that the rate of innovation in cities is directly related to population density, which provides a clue as to why these early civilizations were so successful. Through more work in analyzing city dynamics, Alex Pentland and his team were able to predict different things like GDP in cities (Pentland, 2014). The key factor in this study of GDP was to locate the different communities and to analyze the rate of idea flow, to gain greater understanding about where different communities within the city are able to interact and come together. The mixing of ideas between the subgroups is the source of creative output and innovation. These findings allow us to understand that who we are is not just about our level of education, our class structure, or even a specialization that may have been part of the development of a city, but rather the interaction and flow of ideas from different communities that can result in innovation. In Pentland's study, it was found that this mixing and blending of ideas between communities is what raised the city's GDP.

To ensure effective social interactions, cities need to evaluate if they are providing opportunities for social encounters to occur or whether the city is promoting a more individualized lifestyle. Transportation infrastructure plays a key role in determining how groups within a city relate to one another, as the possibility of running into a variety of different people, with different ideas, is more possible when city members are sharing modes of transportation. The more people are able to serendipitously interact with each other in a city, the greater the chances for more innovation, which can do a host of things such as positively impact GDP, lesson infant mortality, or even affect the crime rate. It is vitally important to make it easy to get around in different areas of a city to increase the random exposure to new ideas that can be shared among groups. Knowing this helps to engineer cities that have better transportation and infrastructure systems, which support the sharing of ideas between people to help societies become more creative and innovative.
5 AUTOMOTIVE INDUSTRY

5.1 Automotive Industry System

The Automotive Industry is one of the world’s most important economic sectors by revenue of the industrialized world creating a mobility market worth of over a $5.4-trillion (Fields, 2015). The automotive industry has much evolved since the XX century, since it has been able to leverage from the development in technology and information to introduce it to both the product development and to offer the customer a greater comfort and safety. Currently, the automobile is the primary mode of transportation for many developed economies.

As a system, the industry does not move alone. Any change in other parts of the system has a strong influence over the other. The Automotive Industry is a century old ecosystem, currently in the middle of a disruptive phase. One reason this is happening is due to changes in the consumer behavior system moving from car ownership to car sharing and who are actually more interested in having access to transportation than owning a car; which has open space for industry’s outsiders interested in solving user mobility needs. These outsiders entered and created a 5.4 trillion mobility market where they are profiting by providing additional services to users taking advantage of the current products/vehicle solutions manufactured by Original Equipment Manufacturers (OEMs).

Another reason to explain the stage the industry is involved in is the tighter emissions regulations and strong media coverage about negative environmental effects of car mobility. This has pushed the industry to adopt novel technologies faster than anticipated. The paradigm has shift the trends in the sector to electrification of the powertrain and consideration of different car ownership models. The two most important technological trends in automotive transportation are the sharing economy and the autonomous driving, which are expected to fuse into shared autonomy into robotic taxis as new technologies become available.

The software and digital technologies systems are developing rapidly, the advancements are being introduced in other industries to improve product features and are becoming a feature every customer is expecting to have. Currently, auto manufacturers globally are competing for the auto market, the use of software in the vehicle is still minimal accounting for less than 10% of the value of an automobile. It is expected that over time, people will give up control of the automobile
to a computer, using steering wheels and pedals less over time allowing emergence of the shared autonomy. At the same time, society will benefit of improvement in vehicle safety and efficiency, additionally to the air quality improvement. Today, the disruption is coming from software incumbent firms who have identified the opportunity and are entering the auto market to speed the inclusion of automation technologies to the transportation system.

Lastly, megacities system is impacting strongly the transportation system. With the high density, heavy traffic congestions and insufficient parking solutions, megacities inhabitants are demanding a better transportation system. New services have entered the mobility market including car-sharing services, and even a booming of taxi services, having a high acceptance in the megacities market since they are offering a viable solution to their needs.

5.2 Transportation System

The transportation system is a complex system with a vast amount of actors from diverse fields interacting to ensure the main objective of moving a person or a product from A to B is accomplished, ideally in the most effective way. As a complex system, it is important to consider all the components and the interaction between them in order to understand the impact they have on each other. This will give access to relevant information to all the actors, allowing them to make the best decision focused on the development of new mobility systems.

The Automotive Industry has a variety of stakeholders who can affect or be affected by the business as a whole, the detailed stakeholder network and their interactions can be seen in below figure 01. The system boundary depend upon the stakeholder perspective leading to differences between each type of stakeholder.

In the figure 1, the relationships between stakeholders are distinguished by colored arrows describing the type of relationship divided by the primary values: policy, money, information, technology, safety, services, and labor.
Some important considerations shown in the figure are:

- The major entities driving technological development in the automotive ecosystem used to be the OEMs; in the current disruptive phase with fast development timing of electronics and computing, the industry has had a shift of technological development to Auto Suppliers and Tech companies introducing disruptive technologies like Autonomous Vehicles technologies and in-vehicle computing technologies.

- New policy and regulation will be required as emission standards become stricter and new technologies become available with the sole purpose of maintaining the system capable of handling any impact on its stakeholders.
- The vehicle user is the direct beneficiary with the primary benefit of safer transportation and additional benefits as efficiency, speed, convenience, availability, and free time while commuting.

- The main value flow of the value network is safety, having government, regulators, Autonomous Vehicles Technology companies, vehicle users and road users as the primary stakeholders.

Below figure 2 shows the Stakeholder Value Network Design Structure Matrix (DSM) presenting the relationship between stakeholders with a focus on the good or value it's being exchanged between stakeholders. The matrix is based on horizontal vs. vertical axis, the intersection show the type of value being traded by two particular stakeholders.

We can observe the main values revolves around policy, money and knowledge. This information is relevant in order to create strategies focused on designing specific incentives to enhance those interactions between stakeholders, identify possible roadblocks or conflicts in order to move the system forward towards improving people lives.

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Figure 2 Stakeholder Value Network Design Structure Matrix (DSM)
Advances in vehicle technology, with an augmented use of sensors and faster computing processing in vehicles have enabled increased levels of functions to be operated by the vehicle, rather than the driver. Vehicles that can drive themselves without human intervention are those referred as Autonomous Vehicles.

Autonomous Vehicles represent a major innovation for the transportation industry, they can also be described as self-driving, driverless or automated cars. Autonomous Vehicles technology should not be confused with Autonomous Vehicles, same as highly automated driving should not be confused with fully autonomous or driverless cars.

"Automated vehicles are those in which at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. Vehicles that provide safety warnings to drivers (forward crash warning, for example) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation (e.g., the necessary data are received and processed, and the warning is given, without driver input). Automated vehicles may use onboard sensors, cameras, GPS, and telecommunications to obtain information in order to make their own judgments regarding safety-critical situations and act appropriately by effectuating control at some level. Accordingly, for purposes of this discussion, vehicles equipped with V2V technology that provide only safety warnings are not automated vehicles, even though such warnings by themselves can have significant safety benefits and can provide very valuable information to augment active on-board safety control technologies. In fact, the realization of the full potential benefits and broad-scale implementation of the highest level of automation may conceivably rely on V2V technology as an important input to ensure that the vehicle has full awareness of its surroundings". (NHTSA, 2013)
6.1 Crowdsourcing for Autonomous Vehicles Development

Crowdsourcing is a practice which has grown with the pass of years adopted by governments and entities to obtain needed services, ideas, or content by soliciting contributions from large groups of people and especially from the online community rather than from traditional employees or suppliers. (Merriam-Webster, 2015)

Enterprises are also matching these systems to their new culture of innovation, using the crowd (employees, customers, and partners) to co-create and implement ideas, processes and efficiencies to invent new products, identify new markets, improve customer experiences, streamline processes, and increase employee engagement with innovation management.

The beginnings of crowdsourcing for Autonomous Vehicles development started back in 1987 when the first project in the field of Autonomous Vehicles was launched in Europe (Eureka PROMETHEUS); in 2004 DARPA launched the Grand Challenge in America to accelerate the development of autonomous vehicle technologies. Since then, Auto OEM's have launched similar projects including Ford Innovate Mobility Challenge Series in 2014 and 2015.

6.1.1 Eureka PROMETHEUS 1987

The Eureka PROMETHEUS Project (Programme for a European Traffic with Highest Efficiency and Unprecedented Safety, 1987-1995) was the largest R&D project ever in the field of driverless cars. It received €749 million in funding from the EUREKA member states, and defined the state of the art of Autonomous Vehicles.

The Eureka PROMETHEUS project was launched in cooperation with several European car manufacturers, suppliers, electronic producers, institutes and universities. The project aimed to elaborate the technical base for advance in the development of road transportation with the objective of creating concepts and solutions which would make traffic perceptibly safer, more efficient and less detrimental to the environment. The project also aimed to remedy the deficiencies of the present road traffic system by developing new information control and management systems. (Eureka, 1995)
This project intended to fully exploit the potential of information and communication technology, micro-electronics, sensors and actuators to adapt progresses in technology to the capabilities of human beings in order to create an optimum interaction between man and machine in road traffic (Panik, 2007).

The Daimler-Benz group made a number of driverless prototypes that culminated with a re-engineered S-Class that technically drove almost entirely by itself over 1678 kilometers (1043 miles) from Munich to Copenhagen back in 1995 (Oagana, 2013).

Developed with input from the University of Munich, the autonomous car was using saccadic computer vision, a range of microprocessors and probabilistic approaches to react in real time to road and traffic conditions. The steering, throttle and brakes were controlled through computer commands based on a real-time evaluation of image sequences caught by four cameras with different focal lengths for each hemispheres. The main idea behind the project was to prove that accidents could be prevented by means of computer vision.

It is remarkable to comment that over 30 years after the start of PROMETHEUS, in September 2015 Daimler-Benz presented an autonomous vehicle prototype and suggested plans to develop premium driverless cars in a future market catering people who, while not keen on car ownership, are interested in premium transportation.

6.1.2 DARPA Grand Challenge 2004

The Grand Challenge launched in 2004 by the Defense Advance Projects Agency (DARPA) with the mission to make pivotal investments in breakthrough technologies for national security working with innovators inside and outside of government.

The main purpose of the Grand Challenge was to leverage American ingenuity to accelerate the development of autonomous vehicle technologies, being the first-of-its-kind race to foster the development of self-driving ground vehicles. The Grand Challenge was designed to reach beyond the traditional defense performer base and tap into the ingenuity of the wider research community. It was DARPA’s first major attempt to use a prize-based competition to attract novel performers and ideas and encourage collaboration across diverse fields. The first
team to pass a series of qualification tests and then complete the course in less than the prescribed ten-hour time limit would receive a $1 million cash prize.

None of the teams finished the course, the top-scoring vehicle traveled only 7.5 miles—and the prize went unclaimed. The competition wasn't a loss however; it offered a promising glimpse at what was possible.

“That first competition created a community of innovators, engineers, students, programmers, off-road racers, backyard mechanics, inventors and dreamers who came together to make history by trying to solve a tough technical problem,” said Lt. Col. Scott Wadle, DARPA's liaison to the U.S. Marine Corps. “The fresh thinking they brought was the spark that has triggered major advances in the development of autonomous robotic ground vehicle technology in the years since” (DARPA, 2014).

Just one day after the first challenge ended, DARPA announced it would hold a second Grand Challenge in the fall of 2005, 18 months after the first. This time, after analyzing lessons learned, five vehicles out of the 195 teams that entered successfully completed a 132-mile course in southern Nevada, the first finisher made it in 6 hours and 53 minutes and won $2 million prize.

To further raise the bar, DARPA conducted a third competition, the Urban Challenge, in 2007 that featured driverless vehicles navigating a complex course in a staged city environment in Victorville, California, negotiating other moving traffic and obstacles while obeying traffic regulations. Six teams out of 11 successfully completed the course.

Although it isn't easy to quantify the effects of these DARPA challenges on the development and deployment of autonomous vehicle technology, ten years later defense and commercial applications are proliferating. The rapid evolution of the technology and rules for how to deploy it are being driven by the information technology and automotive industries, academic and research institutions, the Defense Department and its contractors, and federal and state transportation agencies.

Today, DARPA has three other challenges built on the Grand Challenge, and expects that, like the original Grand Challenge before them, these challenges will encourage new waves of research and development that will spur continued innovation, encourage commercial investment, and lower the cost of advanced technologies.
The DARPA Grand Challenge led to new technologies and invigorated the prize challenge model of promoting innovation using crowdsourcing.

6.1.3 Ford Innovate Mobility Challenge Series 2014, 2015

Ford Motor Company is also using global crowdsourcing platforms to identify solutions to local mobility needs. In 2014, Ford launched the series 1.0 with ten challenges, and in 2015 the series 2.0 of the Innovate Mobility Challenge series with 4 global challenges. The main purpose of the Ford Mobility Challenge Series is to obtain mobility ideas, services, and/or content by soliciting contributions from the global supply of application developers, accessory makers, and problem solvers to identify solutions to local mobility needs, thus helping make people's lives better. Each of the 14 Ford Mobility Challenges have been related to unique mobility needs from a different part of the world. The latest challenge, the “Mexico City Mobility challenge,” seeks to mitigate traffic congestion by effectively increasing vehicle occupancy while giving commuters a pleasant and safe commute (Devpost, 2015). The Mexico City Mobility Challenge looks to find under-utilized assets and repurpose them to people that have a need for those assets, while enjoying the use of them (while commuting). The goal is to find not only a way of matching resources to needs, but also to gather ideas about user interests and desires. The information gathered here will shed light on the preferences that will direct what is required in the new technology, and the activities that will likely be engaged in, while transporting people from point A to point B.

Global crowdsourcing has created novel links between Ford and developer communities, which promises to yield rich tech and business data. The Innovate Mobility Challenges have allowed Ford to understand that mobility means different things to different people, and that there is no one single solution, since there is so much variance between regions and in preferences. These types of crowdsourcing projects have also allowed Ford to increase interactions, not only with the developer communities, but also with clients who have the intention of positioning Ford as a leader in technology research and development.
6.2 Autonomous Vehicles within the transportation system

As seen above, Figure 3 represents the transportation system, including the different actors involved in such a system. The main purpose of this model, and the system as a whole, is to transport people or products from point A to point B. For Autonomous Vehicles, the primary actors identified within the system boundaries include vehicles, infrastructure, regulators, insurance companies, and users.

Currently, there is a strong debate concerning the connectivity and communication required between infrastructure and vehicles, and whether this communication should be bidirectional, from infrastructure to vehicle and vice versa, or simply unidirectional as a means to identify if the infrastructure is adequate for transportation. Furthermore, it is important to take into account if vehicles should communicate with other entities as a means to promote higher safety in the system; for example, with cyclists or with people walking by.

Regulators play an important role in the system, since they will be able to define whether an autonomous vehicle can be driven with or without a passenger. Many agree that the debate should be around the use of a particular vehicle. If the vehicle is intended to be a shared mobility
vehicle, it could be driven without a passenger, whereas a private vehicle could only be without a passenger in specific circumstances, such as looking to avoid an increase in traffic congestion, limiting an unnecessary waste of resources, or having vehicles circling around waiting for the owner so he/she will not have to pay for parking. Ultimately, regulators will be challenged by these questions and need to determine specific vehicle use purpose from the onset.

6.3 Levels of Automation

Vehicle automation ranges from "no automation," where driver intervention is required to be fully automated" where no driver intervention is required. The U.S. National Highway Traffic Safety Administration (NHTSA) defines five levels of vehicle automation, while the U.S. Society of Automotive Engineers (SAE) has outlined six. These are outlined below in Table 1.

<table>
<thead>
<tr>
<th>Level</th>
<th>NHTSA</th>
<th>SAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>No Automation</td>
</tr>
<tr>
<td>1</td>
<td>Function-specific Automation</td>
<td>Driver Assistance</td>
</tr>
<tr>
<td>2</td>
<td>Combined Function Automation</td>
<td>Partial Automation</td>
</tr>
<tr>
<td>3</td>
<td>Limited Self-Driving Automation</td>
<td>Conditional Automation</td>
</tr>
<tr>
<td>4</td>
<td>Full Self-Driving Automation</td>
<td>High Automation</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Full Automation</td>
</tr>
</tbody>
</table>

*Table 1 NHTSA and SAE Levels of Automation*
6.4 How could society benefit from AVs

As part of the transportation system, Autonomous Vehicles will have a societal impact upon mobility features. Even though the market is shifting, today a car makes a statement about the owner; however, it does not define who a person is anymore. Accessibility, convenience, and experience have trumped ownership. Almost in every industry, consumers are shifting the focus of their demands from product to experience. With the future trends of the vehicle industry moving from car ownership to car sharing, competition between OEM’s will be more intense in order to secure sales. The key growth will come from unit sales that operate at a fast phase and service level.

The other opportunity for growth as an OEM will be the additional services and consumer experience this new transportation method will be able to create. With this in mind, it is relevant to consider the role the transportation system plays in facilitating face-to-face interactions between citizens by allowing the different forms of transportation to influence interaction.

Commuting is an incredible opportunity for social interaction. In thriving cities like Boston, New York, Paris, and London commuting is often done on foot or by public transportation, allowing social interchanges to happen. Interchanges between people can be merely looking at the book another passenger is reading or listening to a conversation between others to find a solution to a problem you, or someone you work with, have been thinking about. Social exchanges can also be as simple as talking to a regular commuter. With this perspective in mind, it is imperative to ask the question: how can Autonomous Vehicles be a solution to facilitating human mobility and to increasing face to face interactions. And, by doing so, can they stimulate the thriving of a city instead of contributing to its decline, which takes place when the possibility for social interaction is minimal, essentially isolating the user from the outer World?

On the one hand, Autonomous Vehicles will enhance the probability of developing a transportation system that will take commuters from nearby areas to hotspot areas, where encounters can take place. However, on the other hand, the use of Autonomous Vehicles could lessen the possibility of social interactions during the route, or from the closest destination hub to the final destination, as it occurs today in semi-Autonomous Vehicles. Therefore, it is
imperative to find a mobility solution to address both the ease of transportation and to increase the possibility of social encounters while transporting.

Additionally, regarding ownership, automobiles use a large amount of space when parked (and when looking for parking). Yet, for a shared autonomous vehicle, parking issue would not be a considerable, since the vehicle will return to the loading or charging station (if charging is required). Otherwise, the autonomous vehicle can move on to the following destination without the need of parking. In the event of a shift to mainly these types of shared vehicles, the current space taken up for parking cars today could be used to promote flexible spaces for social encounters and innovation to occur. Autonomous Vehicles could also reduce traffic congestion by deciding on varying routes, based on traffic information and the demand for transportation by users.

6.5 Autonomous Vehicles Technology

To analyze the technology used by Autonomous Vehicles, it is useful to break down the process by the internal functions of: “sensing,” “controlling,” and “navigating.” The “sensing” process allows for vehicle decision-making based on data, this process can happen on-vehicle, through sensors and cameras, and/or within the infrastructure, using Vehicle-to-Infrastructure (V2I) and/or Vehicle-to-Vehicle (V2V) communications. As such, Autonomous Vehicles could be deployed with or without the capability to share information with anything in its surroundings as well (V2X).

The “controlling” process defines the algorithm needed for the vehicle to operate. There are two alternatives for setting the control, (a) separating roads for AVs from all other traffic in exclusive roads/lanes, or (b) integrating them to respond to the changing environment by interacting with any type of conditions. The latter alternative is directly dependent on the level of autonomy of the vehicle. The “navigating” process can be performed by sensors and cameras, although it is already assumed this is already being performed by GPS technologies, and the mention of it is for the purpose of clarity in this analysis.
For clearer interpretation, Autonomous Vehicles alternatives are represented below on the OPM diagram (figure 4).

The solution neutral statement of primary functional intent can be stated as: "A system to enable sensing, controlling and navigating of a self-driving car transporting users," and that is what such a system intends to do. Furthermore, a morphological matrix can be created to represent the different alternatives for Autonomous Vehicles Architectural Choices, including mixed usages divided by the sensing, separating and responding processes below.
Multiple architectural options are required to satisfy current real-world scenarios, as seen on the above morphological matrix (Figure 5). Different entities, enterprises, and areas where Autonomous Vehicles will be deployed have unique requirements and expectations. It is possible to see these in detail in Table 2, “driving Scenarios considered to build morphological matrix.”

<table>
<thead>
<tr>
<th>Driving Scenarios considered to build morphological matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHTSA</td>
</tr>
<tr>
<td>Interstate (Highway/Freeway)</td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Google Car</td>
</tr>
<tr>
<td>City</td>
</tr>
</tbody>
</table>

Table 2 Driving Scenarios considered to build morphological matrix

The Driving Scenarios presented represent aspects of each area where the Autonomous Vehicles will be used. The need for base level entity or enterprise expectations; in order for the AVs to be deployed, must consider the current infrastructure and type of road on which the vehicle will be driven. For example, for some type of roads, the AVs deployment could be simpler than others, resulting in situations where autonomous vehicles technologies are being mostly used on interstate highway models because in cities it may take longer, due to the high complexity of traffic patterns and driving speeds.

The variants from the morphological matrix can be mapped in an Architecture Diagram as shown in Figure 6 below, where the self-driving system is in charge of the sensing, planning, and controlling functions through the data provided by sensors, maps, GPS, and other vehicle controlling capabilities —depending on the level of autonomy.
6.6 AVs Architectural Criteria

The Architectural Criteria for designing Autonomous Vehicles helps to broaden the scope of the solution by defining minimum requirements and goals. The systems' architectural requirements can be seen on the following table (Table 3. AVs Architecture Requirements) where the most relevant variants are taken into account considering both internal and external factors.

<table>
<thead>
<tr>
<th>Level of Autonomy Allowed/ Required</th>
<th>NHTSA/ SAE Levels of Autonomy (Table I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation between Autonomy Levels</td>
<td>Mixed (Various Levels on the same road)</td>
</tr>
<tr>
<td>Infrastructure requirements</td>
<td>None (all data is sourced through on board sensors and cameras)</td>
</tr>
<tr>
<td>Level of human supervision</td>
<td>Human must always be present</td>
</tr>
<tr>
<td>Car ownership</td>
<td>Personal</td>
</tr>
<tr>
<td>Transportation mode</td>
<td>Mixed (private/public)</td>
</tr>
<tr>
<td>Operator requirements</td>
<td>Same as current norm for licensing</td>
</tr>
</tbody>
</table>

Table 3. Autonomous Vehicles Architecture Requirements
The System Architecture Goals set the expectations and tone of the proposal for vehicle type and capabilities. In this case, this is based on the idea of a fully Autonomous Vehicle ecosystem where the goals are presented in relation to the user, and society's expected benefits in relationship to the development of AVs.

<table>
<thead>
<tr>
<th>Autonomous Vehicles Architecture Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
</tr>
<tr>
<td>- Minimize the number of crashes of vehicles with each other</td>
</tr>
<tr>
<td>- Increase pedestrian safety and visibility</td>
</tr>
<tr>
<td>- Cost effective mix of safety features</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
</tr>
<tr>
<td>- Optimize manufacturing, operations and lifecycle costs</td>
</tr>
<tr>
<td><strong>Environmental Efficiency</strong></td>
</tr>
<tr>
<td>- Increase fuel economy</td>
</tr>
<tr>
<td>- Reduce greenhouse emissions</td>
</tr>
<tr>
<td>- Decrease traffic congestion</td>
</tr>
<tr>
<td><strong>Convenience</strong></td>
</tr>
<tr>
<td>- Reduced Travel effort and time</td>
</tr>
<tr>
<td>- Use of travel time with other activities than driving</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
</tr>
<tr>
<td>- Increased travel time predictability</td>
</tr>
<tr>
<td><strong>Acceptance</strong></td>
</tr>
<tr>
<td>- Safety and cost focus</td>
</tr>
<tr>
<td><strong>Facilitate impaired and Shared Mobility</strong></td>
</tr>
<tr>
<td>- Decrease traffic congestion</td>
</tr>
<tr>
<td>- Provide mobility to a larger group</td>
</tr>
</tbody>
</table>

*Table 4: Autonomous Vehicles Architecture Goals*

6.7 Risks for System Goals

Below, the diagram represents how the transportation system is evolving as improvements are made in autonomous vehicle technology. Ultimately, it is expected that these improvements will spark a chain of events that will have ripple effects throughout the transportation network. To help understand this chain of events on a conceptual level, the analyzed work was conducted by the mobility team in the MIT Media Lab's MAS.552 City Science in the Fall of 2014, and further developed by the System Design and Management "Autonomous Vehicles" team from ESD.413 during the spring of 2015. These developments led to adapting the System Dynamics model to develop a mental model using a Causal Loop Diagram.
Below, the Causal Loop (Figure 7) is able to detect any risks to the system goal by identifying the key stakeholders and by evaluation the exchange of value throughout the network.

The Causal Loop diagram identifies 7 key customer needs that Autonomous Vehicles must satisfy (System Architecture Goals). These consist of: safety, system cost, environmental efficiency, convenience, reliability, acceptance, and facilitate impaired and shared mobility. This System Dynamics diagram represents the reinforcing and balancing loops between the expected goals for deployment of Autonomous Vehicles and the consequences of each task once deployment takes place. The diagram allows a visual analysis of goals accomplishment and the opportunity to avoid certain areas that may block the goal. To highlight the importance of this, customer goals are then classified into the following 3 categories, noted below in Table 5:

<table>
<thead>
<tr>
<th>Customer Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Important (red)</td>
</tr>
<tr>
<td>Safety is the foremost attribute.</td>
</tr>
<tr>
<td>Important (orange)</td>
</tr>
<tr>
<td>System cost, efficiency, and convenience</td>
</tr>
<tr>
<td>Less important (green)</td>
</tr>
<tr>
<td>Reliability, acceptance, and the need to facilitate impaired and shared mobility.</td>
</tr>
</tbody>
</table>

Table 5 Customer Goals
One of the most important factors noted in Table 5, and clearly seen on the loop diagram, is the System Safety portion. Given that AVs have a negative impact on accidents (reducing them), the overall system is safer and at the same time more reliable. Yet, it should be noted that the items in green on the causal loop diagram are derived, in part, from the items in red and orange; making all aspects important in creating and stabilizing the requirements depicted in the loop. Certain additional requirements remaining would follow for greater adoption of Autonomous Vehicles. For example, as stated on the system goals, convenience is an important attribute for AVs. Because AVs increase the utility of time spent in the vehicle, as the convenience of using them is a major positive.

Here there is cause for caution, however, in that if AVs are used by more drivers, as a means to do business or complete tasks while “driving” the appeal of “driving” could result in an increased number of cars on the roads, possible increase the total driving trips, and potentially create more traffic congestion. These results would be the antithesis of the work being done on this thesis by reducing system efficiency and impairing mobility. If this were to occur, it would go against the original goal of using AVs to lessen traffic and environmental problems and increase passenger interaction.

Although Autonomous Vehicles have the potential to transform the existing transportation system, it is not well defined exactly how such a large complex system will evolve over the next several years. Additionally, it is plausible that people may find ways to use Autonomous Vehicles in manners we may not be able to currently imagine, and contrary to the AV use suggested here. Therefore, this type of analysis enables actions to be taken before deploying AVs –like adding regulations, fees to pay, and making room for any requirements needed for specific conditions.

6.8 Autonomous Vehicles Potential Growth

In an effort to look beyond today’s rapidly changing predictions on AVs penetration into the market, McKinsey & Company (Bertoncello and Wee, 2015) conducted research on potential implications of self-driving cars focusing on the following three eras:
Era 1 Before AVs are commercially available to individual buyers.

Era 2 When AVs are in the early stage of adoption.

Era 3 When AVs become the primary means of transport.

Table 6 Autonomous Vehicles Eras

In line with Table 6, the figure below shows how the year 2020 will be a tipping point for AVs, although it is expected to take over a decade to become the primary means of transportation in developed countries. Most of the OEMs have already announced their plans to develop Autonomous Vehicles during this timeframe, and OEMs like Ford, General Motors, Toyota, Volkswagen and Daimler are expected to create alliances with tech companies like Google, due to the OEMs expertise in engineering and car building (Priddle, 2015).

During Era 1, the new models that are expected to emerge could be a solution for commuting inside large campus organizations and serve to increase face-to-face interactions between employees. Potentially, this could be done through a form of pay-per-use, such as the dynamic car sharing program, which could then potentially be available for the communities surrounding large campus enterprises as well.
Ben Waber (2013) says that especially in modern organizations, managing workflow has become critical. With people working on ever more complex projects, it is necessary to set regular meetings and milestones and to use reporting tools to make sure that everyone is coordinated. To ensure this coordination happens in a timely manner, an organization needs a defined set of people who can make decisions about how these tools should be used.

The Ford Motor Company organization uses a matrixed management system. However, depending on the stage of development in a project, a particular feature can be managed as that which is merely functional (beginning of design) or like the way a project is organized during a launch. As the author of People Analytics comments, the time devoted to communicating in a matrixed organization is considerably higher than in other types of organizations. This creates considerable formal processing that has to occur before an initiative can start, since diverse areas, and managers, have to come to an agreement. The ultimate implication is that people from different areas must be on the same page and approve the initiative. (Waber, 2013, p. 47)

Waber (2013) also talks about the influence the organization chart poses on the formal communication process in any organization, where seemingly, if you do not directly connect with someone, you do not need to talk with that individual. Considering the concepts of engagement and exploration, presented by Pentland (2014), is the communication that happens outside of whatever is on the organizational chart that embraces and promotes creativity and innovation. These alternate communications are what lead to an increase of up to a 40% in performance, these interactions allow people to explore what is happening outside their group, gather different perspective on their work, and perhaps shift or broaden their world views as well. It is then useful to communicate what has been learned to their inner group, thereby creating new habits and behaviors that ultimately are reflected in behavioral changes in the whole group. This process is what constitutes social learning.

As Pentland (2014) reveals in Social Physics, the first step to achieving good idea flow within a group of people is to make people aware of their patterns of interactions. Understanding how organizations work today can be achieved by measuring and analyzing patterns in the connections that emerge from a social network. Seeing these patterns is extremely important
since it shows how information flows, how work gets done, and what has an impact on the outcomes that people care about, such as productivity and job satisfaction.

Having access to this research, which has also been noted in People Analytics, will provide Ford Motor Company information with which to make employees aware of their current patterns of interactions. In achieving this awareness, it can also grant employees the ability to propose a new business model that can be applied—not only within an organization—but also for city deployment. In this manner the idea of promoting encounters, while using Autonomous Vehicles, can foster face-to-face interactions.

7.1 Current Interactions inside a large campus organization

To analyze the current interactions inside a large campus organization, I studied Ford Motor Company. In Dearborn, Michigan Ford owns over 100 buildings with 26,000 local employees (for details see Figure 9). The Research and Engineering hub “Product Development Center (PDC) campus” has about 14,000 Ford employees in a mix of buildings and laboratories (for details see Figure 10) (Pinho, 2015).

Each of the laboratories in the Research and Engineering Center are in separate buildings, yet, the distance between one building and the next is less than 0.5 miles. Every building hosts several functional teams. Depending on the developmental stage, employees of a specific program need to gather in different locations, such as in the Research and Innovation Center, Benchmarking, Purchasing, the New Models Plant, or in visiting suppliers. The manner in which individuals are stationed in their particular building take place in this way, except when a new launch is taking place. In this situation, all the employees involved are temporally relocated, depending on the plant and the need. Another reason an employee may have to move to another building or location on the campus is for training or to attend to a meeting. Ford, as many other organizations surely claim, have an excessive amount of meetings, employees even jokingly call the company the “Ford Meeting Company.”

The primary method of transportation within the campus is walking, either outside or through underground tunnels. At times people will also use the company shuttle or a personal car to move around the campus. On average, it takes 10-20 minutes to walk from one building to
another. It is relevant to comment on the extensiveness of the parking lot as well, where the 14,097 employees can park their cars every day. On average it takes 5 minutes to walk from an employee's home building to their personal car (and other 5 minutes from the new parking space to the host building). In order to use the company shuttle, employees need to make a reservation, which can take anywhere from 2 to 10 minutes to make. Additionally, employees generally need to wait for about 20 minutes before the shuttle arrives, because considerable time is needed to ensure the routes are correct.

The map below (Figure 9) shows the Dearborn Ford Buildings Map, including the PDC campus, all seen inside the red square. It is easy to identify how the buildings are widespread and distances are considerable when walking from building to building.

Figure 9 Ford Buildings – Dearborn Buildings Maps
The main stakeholders (shown per building) related to Product Development at Ford Motor Company are the Research and Innovation Center, the Product Development Center (Studio, Part I of Engineering, Program Management), Engineering Electrical Systems Division, and Purchasing.

![Figure 10 Ford Research and Engineering Center – Product Development Center (PDC) Campus](image)

Focusing on the PDC in the map below (Figure 11) is presented in zoom view where the buildings are marked in black. The white space is either parking or natural areas.

Regarding the layout inside the buildings, every employee has an assigned workspace. However, the meeting rooms are scarce and generally in use. Areas where employees could randomly meet one another, like at the printer, coffee machine, or even on the way to the bathroom are scarce. The reason behind this is because approximately every 20 employees share a printer, every main building has its own cafeteria, and a great number of employees have lunch at their desks, and some employees have coffee machines and microwave ovens at their desks to avoid using the shared appliances. Many employees sit at their desks for most of the day having WebEx
meetings with colleagues, and even have lunch at their desks. All of these factors reduce the chance of having casual encounters with other employees.

![Figure 11 Product Development Center Building](image)

With the information presented above, my first diagnosis of the pattern of interactions between the PDC Campus employees is that the layout is not fostering random encounters to occur. At the same time employees are more comfortable moving as little as possible, and seem to prefer having social encounters virtually, whenever the possibility is offered. Face-to-face interactions with people in other areas are rare, since moving from one building to another requires considerable effort, which the culture does not promote.

To deepen knowledge of this topic, I conducted formal interviews with several employees, using the survey form below, and informally talked with over 50 employees from the Vehicle Components and Systems Engineering group. This group has over 3,000 employees on the Dearborn PDC campus. The main focus of the interview was placed on attendance and preferences surrounding formal, in person meetings on the campus. The main findings were the following:

- 90% of the interview employees stated they participate in-person to their scheduled meetings.
- 75% stated their peers do not participate in-person in their scheduled meetings.
Employees noted that most of their peers' preferred method of participation at a meeting is virtually, through Webex.

The reasons employees gave to explain why their peers do not attend in person are:

- Conflicting schedules
- Concern about losing their parking spot
- The idea that time not spent at your desk is time wasted (cultural).
- Their participation at the meeting is too short and the time and effort required to get there is not worth it.
- Heavy workloads requiring employees to “multitask” and therefore not being able to pay undivided attention to one meeting.

20% of all employees invited to a meeting do not attend at all. If their participation is required, they might call a key employee during the meeting to solve the particular issue, if needed.

7.2 Employee badge access log

To gain an objective perspective of the pattern of interactions between different buildings, I analyzed the information from the employee log to identify employee movement between buildings. Even though this information only gives a cursory first glance of the pattern of interactions between employees located in different buildings, it provides interesting insight worthy of analysis.

Some observations/facts important to note are:

- There are 14,097 employees working within the area analyzed.
- The analysis is based on the home building\(^1\) model, as cross referenced with the buildings the employee may access within a timeframe of 23 working days (Oct 12\(^{th}\) – Nov 9\(^{th}\) 2015).
- There are 30 home building areas and generally the employees have access to 89 different buildings during the period of time specified above.

---

\(^{1}\) Where the employee's work space is located.
The number of monthly transactions that occur between PDC Campus employees are 78,095.

The average number of transactions per day is 3,395.

The average of employees accessing different buildings is 24%.

The average distance between buildings is 0.5 miles.

The log access shows one transaction per employee to one accessed building, without registering if the employee entered more than once to that same building.

As shown in Figure 11, inside the PDC building the 5,245 employees can easily walk from zone to zone, allowing interactions to occur. Of note, the badge access log only shows transactions happening when accessing a different building, than those occurring in the home building. It does not show the interactions within the same building.

The average temperature for the timeframe was 53°F with a high of 77°F, allowing people to walk outside (Weather Underground, 2016)

As a final note, it is worth mentioning that this analysis only includes employee visits to buildings where the employee has approved badge access to the building. There may be additional unregistered visits to the host buildings via registration as a visitor.

<table>
<thead>
<tr>
<th>Home Building</th>
<th># Transactions</th>
<th># Employees at Home Building</th>
<th>% Transactions per employee per Home Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development Center</td>
<td>16,451</td>
<td>5,245</td>
<td>14%</td>
</tr>
<tr>
<td>R and E Area Facility Svcs Bldg</td>
<td>10,223</td>
<td>523</td>
<td>85%</td>
</tr>
<tr>
<td>Building 5</td>
<td>7,547</td>
<td>1,258</td>
<td>26%</td>
</tr>
<tr>
<td>Building 3</td>
<td>7,019</td>
<td>986</td>
<td>31%</td>
</tr>
<tr>
<td>Building 2</td>
<td>5,340</td>
<td>868</td>
<td>27%</td>
</tr>
<tr>
<td>Advanced Electrification Center</td>
<td>4,730</td>
<td>801</td>
<td>26%</td>
</tr>
<tr>
<td>Experimental Vehicle Building</td>
<td>3,600</td>
<td>660</td>
<td>24%</td>
</tr>
<tr>
<td>Research and Innovation Center</td>
<td>3,550</td>
<td>1,582</td>
<td>10%</td>
</tr>
<tr>
<td>Personnel and Admin Building</td>
<td>3,074</td>
<td>318</td>
<td>42%</td>
</tr>
<tr>
<td>Research and Engineering Center</td>
<td>2,285</td>
<td>115</td>
<td>86%</td>
</tr>
<tr>
<td>Safety Innovation Laboratory</td>
<td>2,133</td>
<td>129</td>
<td>72%</td>
</tr>
<tr>
<td>Dynamometer Building</td>
<td>2,000</td>
<td>466</td>
<td>19%</td>
</tr>
<tr>
<td>Building 4</td>
<td>1,727</td>
<td>265</td>
<td>28%</td>
</tr>
<tr>
<td>Building 6</td>
<td>1,485</td>
<td>325</td>
<td>20%</td>
</tr>
<tr>
<td>Fuel Cell Center</td>
<td>1,231</td>
<td>83</td>
<td>64%</td>
</tr>
</tbody>
</table>

*Table 7 Home Buildings with most transactions with other buildings*
In Table 7, it is easy to see the Home Buildings with the most number of transactions, meaning where and when employees move from their work spaces to different buildings. Even though the Product Development Center Building has the greater number of transactions, 16,451 in one month, it also hosts the greatest number of employees, really leaving only a 14% of its employees moving to a different building. The second Home Building with the largest number of transactions is the R & E Area Facility Services Building, with 10,223 transactions in one month. It is important to mention that this building hosts only 523 employees, giving it a rating of 85% of transactions taking place. This high number of employees moving to different buildings might be related to the location of the building, as it is located in the center of the PDC campus.

<table>
<thead>
<tr>
<th>Home Building</th>
<th>Building Accessed</th>
<th># Transactions</th>
<th># Employees at Home Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 5</td>
<td>Building 3</td>
<td>3,445</td>
<td>1,258</td>
</tr>
<tr>
<td>Product Development Center</td>
<td>Experimental Vehicle Building</td>
<td>2,026</td>
<td>5,245</td>
</tr>
<tr>
<td>Product Development Center</td>
<td>Rouge Complex</td>
<td>1,747</td>
<td>5,245</td>
</tr>
<tr>
<td>Building 3</td>
<td>Building 5</td>
<td>1,481</td>
<td>986</td>
</tr>
<tr>
<td>R and E Area Facility Svcs Bldg</td>
<td>Product Development Center</td>
<td>1,197</td>
<td>523</td>
</tr>
<tr>
<td>Product Development Center</td>
<td>New Model Programs Dev. Center</td>
<td>1,187</td>
<td>5,245</td>
</tr>
<tr>
<td>Product Development Center</td>
<td>Building 2</td>
<td>1,077</td>
<td>5,245</td>
</tr>
<tr>
<td>Product Development Center</td>
<td>World Headquarters Building</td>
<td>1,053</td>
<td>5,245</td>
</tr>
<tr>
<td>Building 2</td>
<td>Research and Innovation Center</td>
<td>1,005</td>
<td>868</td>
</tr>
</tbody>
</table>

Table 8 Transaction between buildings

Figure 12 Transaction between buildings
Table 8 shows the largest transactions between buildings, and is also represented in Figure 12. This information indicates that the greatest number of interactions happen between Buildings 5 and 3, with over 3,400 transactions in one month. These findings are significant, even though the number of employees assigned to Building 5 is only made up of 1,258 employees. At the same time the 986 employees with Home Building 3 accesses Building 5, 1,481 times in one month, making the interaction between Buildings 3 and 5 the most recurrent. The reason might be due to the closeness of location between these two buildings.

Focusing on the transactions happening between employees who use the Product Development Centers as a Home Building, compared to employees of other buildings, it is interesting to note the strongest interaction takes place with employees working in the Experimental Vehicle Building, with 2,026 transactions per month. This building is the closest building to the PDC and could be the reason for hosting the greater amount of transactions. It is also important to mention that when it is required, employees will move between their Home Building to the required building, without any consideration regarding the distance. These findings are evident when looking at the transactions that take place with the Rouge Complex (1,747 transactions) or the New Model Program Development Center with 1,187 transactions. Still, it is remarkable that 14% of PDC employees move to different buildings, leaving 86% of employees remaining at their Home Buildings.

<table>
<thead>
<tr>
<th>Home Building</th>
<th># Accessed buildings</th>
<th>% Accessed buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Development Center</td>
<td>75</td>
<td>84%</td>
</tr>
<tr>
<td>Personnel and Admin Building</td>
<td>72</td>
<td>81%</td>
</tr>
<tr>
<td>R and E Area Facility Svcs Bldg</td>
<td>65</td>
<td>73%</td>
</tr>
<tr>
<td>Building 3</td>
<td>60</td>
<td>67%</td>
</tr>
<tr>
<td>Research and Innovation Center</td>
<td>60</td>
<td>67%</td>
</tr>
<tr>
<td>Advanced Electrification Center</td>
<td>58</td>
<td>65%</td>
</tr>
<tr>
<td>Building 2</td>
<td>55</td>
<td>62%</td>
</tr>
<tr>
<td>Building 5</td>
<td>55</td>
<td>62%</td>
</tr>
<tr>
<td>Building 6</td>
<td>54</td>
<td>61%</td>
</tr>
<tr>
<td>Experimental Vehicle Building</td>
<td>54</td>
<td>61%</td>
</tr>
<tr>
<td>Dynamometer Building</td>
<td>47</td>
<td>53%</td>
</tr>
<tr>
<td>Gas Turbine Lab</td>
<td>41</td>
<td>46%</td>
</tr>
<tr>
<td>Research and Engineering Center</td>
<td>38</td>
<td>43%</td>
</tr>
<tr>
<td>Building 4</td>
<td>37</td>
<td>42%</td>
</tr>
</tbody>
</table>

*Table 9 Number of accessed buildings*
In examining Table 9, it is easy to see the number of buildings accessed by the employees from different Home Buildings. The relevancy of this information shows the diversity of interactions between buildings. Within the specified timeframe, PDC employees’ log they accessed 75 out of 89, or 84%, of the buildings in the Campus, allowing those employees to gather information from a wide variety of areas, and giving them the exploration advantage mentioned by Alex Pentland (2014). In truth, it was expected that the PDC would be the Home Building with the highest number of employees accessing different buildings, since it hosts the largest amount of employees. Not surprisingly, those buildings mentioned above, with the highest amount of transactions, also show they interact with a large percentage of buildings within the campus – like the R&E Area Facility Services Building, Building 3, and Building 5; giving them all a higher exploration rate.

7.3 Transportation within the Ford Research and Engineering Center

Ford Motor Company has a Shuttle service available for employees to move between 129 buildings/plants in Michigan, using 21 vans through a call-in number operated by a dispatcher who connects employees with rides at an average of 300 trips per day (Martinez, 2015) (6,900 during the analyzed timeframe). The 78,095 total transactions made during the analyzed timeframe are made by employees using the different transportation methods available as follows:

<table>
<thead>
<tr>
<th>Transportation Method</th>
<th>Employees per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company Shuttle</td>
<td>6,900</td>
</tr>
<tr>
<td>Walking or personal car</td>
<td>71,195</td>
</tr>
</tbody>
</table>

*Table 10 Transportation method used by employees to move between buildings*

For the 71,195 employees commuting by walking, or using their personal cars to move from one building to another, and considering the average distance between buildings is 0.5 miles, an estimated total of 8 minutes’ average time is spent walking from a Home Building to another building. Essentially, this is the same as the time spent walking from the Home Building to one’s parked car, and from the new parking spot to the accessed building, without considering the commute time while in the car.
The estimated cost associated with the 71,195 transactions between buildings is 9,492 hours per month, accounting for $257,093 USD per month. These figures equate to an average cost of $27 USD per hour, based on a Ford USA internal document Salary Ranges, or as a yearly economic impact of $3,085,117 USD. The loss of productivity in moving from building to building costs the company over $3 million dollars annually, which might be the reason to use virtual tools such as WebEx that can save time and money by not commuting. Nonetheless, opportunities for formal or informal face-to-face interactions to occur, while on the commute or inside the accessed building, is compromised. Of note, the use of the shuttle does save time, since employees do not spend the average 8 minutes walking to the building or to their parked cars, while at the same time the shuttle transports employees to the required building, allowing face-to-face interactions to occur, and being a good solution for large campus organizations.

In January 2015, at the Consumer Electronics Show, Ford announced a series of experiments to be performed by the company as part of the Ford Smart Mobility initiative, including an internally developed on-Demand Dynamic Shuttle (Ford Motor Company, 2015). On December 2015, the Dynamic Shuttle moved from an experimentation phase to the pilot phase-allowing employees at the Dearborn campus facilities to use smart-phone-based software to request a shuttle ride. The software works with an algorithm determining the best shuttle to provide the service without altering the travel time of the passengers. Using a Ford Transit van, the Dynamic Shuttle will be adapted to carry six to eight passengers, offering interesting features like sending the proposed pick up time and the maximum duration of the trip, so the employee can have a clearer picture of time spent not officially working and to accept or decline amenities, including complimentary Wi-Fi, USB charging ports for each seat, and personal storage space.

This internal experiment is a progressive action Ford is taking to change the way the world moves- starting at their very own facilities, while at the same time promoting the possibility of having of face-to-face interactions. Face-to-face interaction would then have an opportunity to occur first inside the Dynamic Shuttle, while sharing the ride with up to seven other employees, and secondly by encouraging commuting from building to building inside the campus. At the same time, increasing the number of trips and the number of employees using the Dynamic Shuttle, the other transportation methods used to go from building to building, and most specifically with the use the personal car can be reduced. Adopting the use of this shuttle can reduce what will ultimately impact the current total loss of productivity of 3 million dollars per year.
Following the series of experiments of the Ford Smart Mobility initiative, a proposal to go even farther would be to join the Autonomous Vehicles and the Dynamic Shuttle teams to work together. Collaborating in this manner can create an opportunity to attract more employees to use this shared transportation method, and to provide employees the opportunity to experience their commute in an autonomous vehicle. In attempting such a collaboration, the possibility exists for Ford to gauge insights surrounding the interest, and hopefully acceptance, of the over 14,000 employees working on the Research and Engineering Campus.

7.4 User experience

The time people spend while driving as commuters can be perceived as futile, however as Prasad, member of the Ford Technology Advisory Board at Ford Motor Company remarks, “There is one thing that automobiles can deliver which consumers cannot find enough in their homes and places of work – time. Seating in the comfort of an automobile consumers have time – time to spend.” (Prasad, 2006)

Viewing the interior of a vehicle as a stage for user experiences, especially when coupled with autonomous driving technologies, allows for the possibility of the passenger to spend the time in transport in endless opportunities. Therefore, for AVs to be successful, it is necessary to understand users' needs, interests, and requirements while moving from point A to point B. Furthermore, safety requirements also need to be addressed to ensure the experience does not create a risk for the passenger; as well as any of the in-vehicle technologies being used. Some ideas of activities that can be performed by passengers while transporting from point A to point B are resting or sleeping, engaging in physical activities, experiencing any sort of entertainment with visual and interactive content such as reading, watching a movie, playing a game, learning a new skill or gaining knowledge through e-learning training or through any Massive Open Online Course, or any work-related activity related to the use of computers and similar devices.

With the case study presented in this thesis, the discussion revolves around how to stage the vehicle interior for a user experience that focuses on the needs and requirements of an employee being transported from building to building within a large campus organization. The benefit of transporting people in this way while providing continuous connectivity, and at the
same time promoting interactions with employees from other areas to engage in social interactions, can serve to create new networks that will spur innovation and lead the organization to achieve higher performance levels.

On a larger scale, and considering the shift in consumer behavior, promoting interaction and comfort must be taken into account in vehicle development. The intention of benefiting users, when offering mobility solutions by transportation providers, auto suppliers, and tech companies involved in the transportation industry, can serve to successfully impact the need of moving people from point A to point B. All of this can take place while increasing and promoting interactions, connecting a diverse range of people, that, as explained by Pentland (2014), will foster creativity and innovation, as well as increase performance and productivity. The potential to use such a system can attract more clients, allow companies to thrive as players in the mobility and transportation field, and increase GDP.

Ford Smart Mobility group has conducted research to gain insight about customer preferences regarding mobility solutions, and reported on the following needs people have (based on priority) when selecting their primary mode of transportation. These consist of: saving time, saving money, making transportation easier, being safe, being comfortable, giving freedom and control, allowing for productivity, allowing for fun, and keeping fit. With this information gathered by the Ford Smart Mobility group, the following proposal is presented to offer a mobility solution that can both address customer requirements and allow for face-to-face interactions to occur.

7.5 Proposal: how could AV impact/facilitate face to face interactions in a campus

In Mexico City there is a place called Xochimilco, which is considered by many to be the “Venice of Mexico.” Xochimilco is famous for its canals, which are left over from what was once an extensive lake and canal system that connected villages in the Valley of Mexico over a 110 mile area (Visit Mexico, 2012). These canals attract city residents and tourists, and people can ride on gondola-like flat shaped boats called “trajineras.” These boats have a large table sitting in the middle of them with chairs surrounding it. They are navigated by a driver who pushes the boat
along by using a large wooden oar to push off from the bottom of the canal while traversing at low speeds.

The trajineras are commonly used by city residents for family reunions and by young people to get together and have parties. One thing that is unique about these boats is that their shape and construction allows other boats to be attached to the sides, as well as to the front or back. The attached boats are often used for mariachi bands, foods, or other groups of people who would like to join in. Within the younger community, using the trajineras is generally a means to find other boats with young people, looking to interact with others in their age group, and drivers will often string the boats together—allowing passengers to move from one boat to another freely. The moment the passengers want to detach a boat or boats, it is simple to do so, giving an enormous amount of flexibility to this versatile transportation method.

With the possibility of having a transportation solution with the flexibility of attaching and detaching units when needed, like with what the trajineras offer, it is essential to engage in exploration. Using this idea could allow Autonomous Vehicles to have the potential feature of hooking up to, or chaining to, each other almost seamlessly with other vehicles, on all sides. Using something like the trajineras model would allow greater interaction to take place between passengers travelling on the same route. Ultimately, this would promote unexpected, or unplanned interactions with others, potentially bringing together people who have similar interests. This is akin to classmates meeting at a subway station on their way to a class on a University campus or families going shopping and bumping into other families while out. The possibility of using such a system to match up people who “speak the same language” would further the possibility of later getting together to learn from each other, do something together, or simply share an experience.

With the big shift in consumer behavior impacting the transportation system, it is imperative to think about how a “hookable” feature in an Autonomous Vehicle could provide a user friendly experience that would keep the passengers safe, while at the same time offer the possibility of promoting interacting by giving the vehicles the ability to attach like “Soap Bubbles” creating one single shared space. The “Soap Bubbles” type feature would be similar to what takes place in current interactions when people are walking from one place to another. For example, initially a person may start walking alone and along the way is joined by another or others for part
of the journey; akin to students going to a classroom, employees going to a cafeteria, or tourists taking a walking tour. The possibility of using this system to even transport large items when needed, as shown in the Figure 13, could be enabled by this technology.

Along another line, and relating to another important feature to consider, is what consumers are looking for in customization. Being able to tailor a service or a product is a common element offered today with mobile phones, computers, or even seen in the virtual customization happening in social media environments and with gaming. Customization is an important part of the vehicle market as well, and can be tied to the online business portion of the automotive parts and accessories market, which is expected to become a $20 billion business by 2020 (Singh, 2015). With the emergence of the shared economy, it may not possible to customize a shared vehicle in
the same way, and might be a less important feature for the customers the market is attracting. However, any OEM that could offer this feature will stage a more personalized experience for the user, or the larger buyer, and captivate customers more effectively.

Learning from the gaming industry, it is possible to adapt to a business model where customers can create “skins” to personalize their game character, and adapt this to the transportation industry as a means to stage a preferred experience. The use of “skins” could even be through holographic projections used to modify the vehicle exterior, or for the use of interactive content in the interior. On an individual level, these customizable features could allow a user to communicate their interests, personality, or other characteristics to other users, creating a space to build trust through transparency while promoting an increase in human interaction.

This idea can be further explored as a Ford Smart Mobility initiative, for implementation inside the Research and Engineering Campus facilities, where employees using the Autonomous Vehicle to commute could have the opportunity to personalize their mobility solutions. Any feature that could support engaging in serendipitous interactions with other people traveling along a similar route to another building inside the campus (for example by using external holograms to communicate information regarding a project they are assigned to, skills, or specific knowledge a person has, or they are looking for) would lend the commute itself to serving multiple beneficial purposes.
8 CONCLUSION

The research presented in this thesis confirms the perception that buildings located closer to together allow more interactions between employees, simply because it is easier to go from one to another. Currently, and with an average of 24% of employees interacting with employees located in other buildings per month on the Ford Dearborn campus; it is clear that the company could benefit by promoting more interaction. Increased interaction to ensure the mixing together of ideas within a more diverse network, could result in more innovation and productivity for the organization. With the launch of the Dynamic Shuttle, there will be data to analyze the new and more accessible transportation system, undoubtedly showing greater interaction between employees located in different buildings.

So the question is, what does the Ford Motor Company need to offer its employees as a means to promote more face-to-face interactions and movement between buildings? Employees could be given many reasons have to go to other building. For example, there may be a meeting room available with special features, a new cafeteria, the showcasing of a new vehicle, or having to meet one on one with a top executive. The promotion of movement could even be constructed through social network creation incentives where it would be possible to obtain a reward of some sort. Another idea is around the transport itself; guaranteeing a fast, convenient, and easy to use solution, where an employee will not feel that movement between buildings is wasting his or her time. Either way, employees must be encouraged to move between buildings, mostly as a means to promote interaction. With features like the ones offered by the Dynamic Shuttle, or even going one step beyond to allow the employee to stage the experience they require by being involved in testing a vehicle part, system or component, could have great appeal. The allure of having the opportunity for the company to continue experimenting on its own campus the newest technologies like autonomous driving, could encourage more employees to use exciting new transportation methods to go to different buildings, fostering more participation in informal interactions.

As has been discussed throughout this thesis, face-to-face exchanges are a rich channel that strengthens interactions, communication, and innovation, ultimately having a positive impact at the individual level as well as for the group. Both communities and society can benefit
from increased social engagement. These interactions are vital to thriving in the new era, where we are connected to our virtual networks, yet disconnected from our present networks. As Alex Pentland remarks “face-to-face connections are still most important in changing minds and making us smarter.” We need to create environments that promote face-to-face interactions to occur in every possible scenario; transportation being one of them.

With current demands on society and our environment, a mobility solution is needed; one that provides efficient transportation, improves current and future traffic congestion, uses green energy, while at the same time focuses on improving the way the world moves and the way we live. Autonomous Vehicles will allow the task of driving to alleviate the driver, permitting the passenger to spend 100% of the time invested in the commute in activities that can be beneficial for that person; be they recreational, work-related, social interactions, or even sleeping. A flexible Autonomous Vehicle like the “Soap Bubble” proposed in this thesis can be a solution that warrants further investigation, especially since it provides the flexibility today vehicles offer, while allowing vital social interchange to take place.

Car sharing has the potential to become a winning game for automotive OEMs, individuals, communities, megacities, and the environment because the overall distances driven will not change, yet, fewer vehicles will be on the roads. Space that was used for parking will be opened up, there will be reduced emissions. Time spent in searching for parking will be eliminated as well. As we move into an even greater technological age, OEM Business models are expected to change from a product focused manufacturer base to a Service manufacturer base, or even an experience focused manufacturer base. Mobility providers will be expected to fully integrate mobility services and become mobility service and experience providers. OEM’s that are able to foster social interactions through newer technology will thrive and shift society as a whole; ultimately towards improving people’s lives.
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