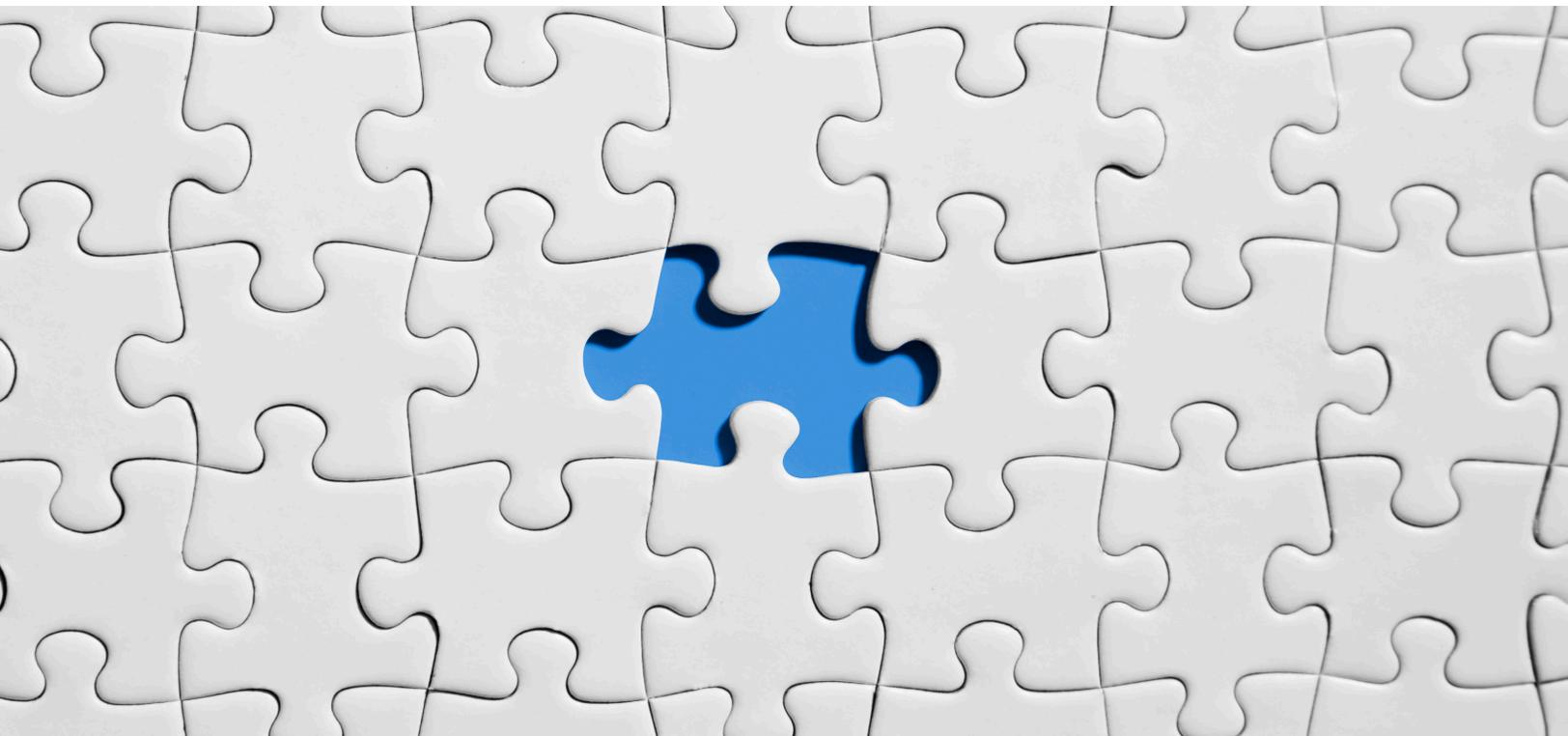


# DATA IN DRIVER SEAT OF MODERN VEHICLES



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## **Abstract**

Roughly 15 years back, renowned mathematician Clive Humby said, "data is the new oil". Humby termed it that way because both are valuable but neither can be used if not refined. Now, the term is literally becoming true as data and data analytics are powering and controlling the modern driverless vehicles to move people around the world. Unlike oil, data is powering bicycles too, helping to grow the number of bicycle users through bike-sharing programs. As more and more people adopt micro-mobility vehicles (such as eBikes and electric scooters) for their daily commute, companies are performing data collection and analysis to better understand their products and consumers. These types of analysis opened a huge opportunity for businesses to build their fortune and also started helping the world in a smaller way to recover from what oil did to our planet. By saying so we can state that "data is more than oil".

Even though self-driving or driverless cars are in the Automobile industry from 1980s, only in the last 4-5 years it took a steep growth. Main reason for the steep growth is not 'what is moving the car', but 'what is stopping the car' when needed. Data collection and Data processing done at an unimaginable speed is making it possible. With a lot of Machine learning and Artificial intelligence every move of a vehicle and its surroundings are recorded and processed. Through one vehicle's data, whole network of a vehicle learns a new procedure. This is a big lap in Automobile industry. On the other hand, People opt to use Micro-Mobility vehicles if it is available and placed at the proper location. Tremendous amount of analysis happens at the backend of every vehicle placements. No wonder why Car manufacturers and Bike manufacturers/providers have started calling themselves as a data-driven organization.

This article explores how "the data" is contributing to these two different modes of transport, starting with a deep dive into how a Driverless Car manufacturer is collecting, storing, processing, analyzing and doing a machine learning on Data gathered from different sources (cameras and sensors) of their cars. It also touches on how Data collection and Data processing is boosting the Bike-Sharing program which is enabling greater public use of "Green Vehicles" .

This article will also delve into how humans will benefit if both existing successful ideas come together. Future predictions of fully autonomous vehicles and the innovations that can be introduced in bike/car sharing programs are also discussed. This article clarifies what data can do for an industry where it was not considered at all a decade ago. Doing so may open opportunities for readers to think "out of the box".

## **Introduction**

### **Human Data**

Mankind has evolved over thousands of years, somewhere in the forest when there was no invention; our ancestors were wandering around for food and survival. Since that time, we've come a long way, making millions of discoveries and inventions. Life is easier compared to our ancestors. It is not just about food and survival. With the ability that we naturally possess, we developed ourselves as a better species on this planet, gaining and preserving knowledge from an incident and inventing out of the gained knowledge.

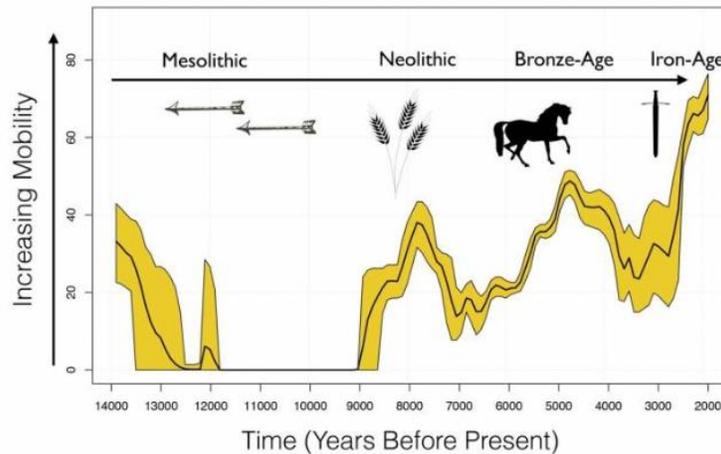
Where does the knowledge comes from? It comes from the information and skills we acquired through experience or through education. It is nothing but taking meaning out of the available data. Therefore, when we look at human history, our ancestors provided us with tons of data. Data that was transferred through generations by means of a gene or a meme. We are all about Genetic and Memetic data.

As a human race, we know more today because of the superior intelligence of every individual who lived before us. Only by understanding the importance of knowledge transfer through drawing, writing or vocal medium have we survived for thousands of years. The importance of data and knowledge transfer can be easily understood if we look at the research that we are doing currently at the sites of the Great Pyramid in Egypt. We still have many undiscovered mysteries due to missing information.

### **Human Mobility**

When the culture grew, we had kingdoms and empires. We slowly started communicating and commuting. Connectivity between one human to another became more important. This paved a greater path and provided opportunities to exchange knowledge that was gathered over generations. Mobility from one place to another became part of life for some humans, not just for food and survival but for the exchange of many other things. This is considered one of the most important stages which gave humankind exponential progress as a race.

Researchers from UCL (University of Cambridge and King's College London) recently conducted a study on mobility in Europe over the last 10,000 years. Results clearly show mankind's movement has influenced the race in many ways, be it evolution, ideas or technologies<sup>[1]</sup>



**Figure 1: Estimation of mobility through time from empirical data(Source: UCL)**

UCL Genetics, Evolution & Environment professors posit that the change that occurred during the Bronze age and Iron age dictates a strong link between technological change and human mobility.

We learned in history that naturalists used seaways for their voyage to discover the world and kings used ships to capture other kingdoms for a few centuries. But, for thousands of years, a major part of human mobility was by horses. They had the ability to run faster for several hours continuously which humans do not have naturally. Even up till the 1920s in the United States of America horses were a common means of transport. Throughout every point in time data played a major role. Humans either used data to invent something or they created data by their experience.

## **Transformation in Human mobility**

The 19<sup>th</sup> Century saw the revolutionary way to transport goods via railroads. This network carried an enormous amount of goods for various reasons. Governments slowly started introducing rail as a means for people to commute as well. While railways provided a great opportunity for industries to grow, it had its own disadvantage in network coverage.

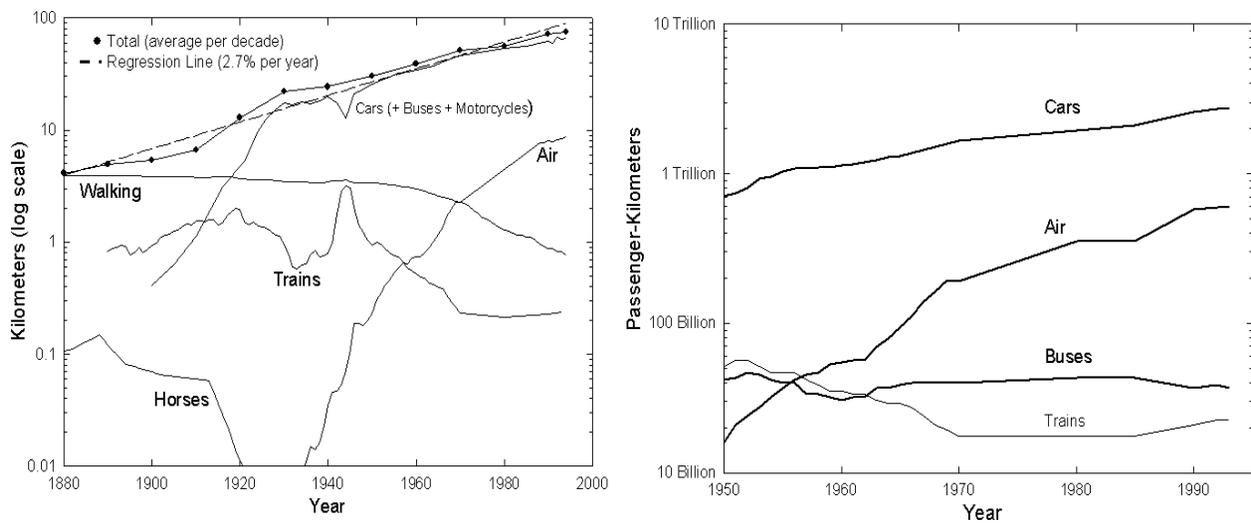
## **Road transportation – A Revolution in Mobility**

Near the end of 19<sup>th</sup> century and the beginning of 20<sup>th</sup> century humans accomplished groundbreaking achievements in mobility. Physically, we had the courage and potential to successfully complete the expeditions of reaching the South Pole and the North Pole. Mentally, we had already developed the intelligence to invent more affordable and compact vehicles that can operate with the help of a motor.

The start of this revolution facilitated the transport of people easily by road instead of relying on huge trains which suffered from insufficient coverage. The vehicle was named the *Car*.

Though steam engine vehicles were invented well before, their usability were more difficult when compared to petrol/gasoline powered motor vehicles. Back then, fossil fuel was affordable and available hence people slowly adopted using cars, which enabled them to look at the world differently.

The Rockefeller University published an article [2] about the evolution of transportation in which two graphs clearly depict how people in the United States used transportation over the last century. For domestic intercity travel people prefer the car more than any other means of transport.



**Figure 2: US passenger travel per capita per day and US domestic intercity passenger travel (Source: Rockefeller University)**

As road transport became more affordable and easy to use, the need for cars increased exponentially. This provided a huge market opening for the car industry and they have rightly made use of it. Human mobility saw a huge change, but all through the change the human mind and body had to work. Even though machines or animals were used, humans had to handle and operate them. Road transport has been with us for more than a century, but these vehicles still require assistance from humans in many ways.

There is one powerful statement about the Human Race; “we are powerful as a Race but not as individuals”. Though on this planet for thousands of years, not all humans are good at using maps and navigation. There is always a need to rely on others for something that we are not aware of. The same is true with locating and navigating unknown areas. In fact, even machines and computers were not

powerful enough in this aspect until the 1990s. Only then was GPS(Globa Positioning System) was successfully implemented.

Making GPS available to the public is a landmark in human mobility, enabled us to move around the planet without help from others. Also, GPS data collected and computed is considered to be the enabler of self-driving vehicles.

### **Last Few Years of Road Transport**

After the innovation of GPS and other technological developments, in the last few years the road transportation industry saw a massive difference in how we handle and operate the vehicle. Indeed, it can be said we are moving away from 'handling and operating' them. We are making huge progress in finding a smarter way, moving towards just needing to board the vehicle and say where we want to go; the vehicle will take care of the rest. We call them *Autonomous vehicles (AV)*.

Why is this century-old invention changing? It is because of the data and data analysis that we are doing. We will look at how and why these autonomous vehicles are disrupting the automobile industries and explore how machines are serving humans in the mobility industry.

Experts opine that we are in the midst of a fourth industrial revolution and data is driving this revolution. Data that we feed to computers. Also, Cloud, Big Data Analytics, and Internet of Things (IoT) have their own share. But, integral to this revolution is artificial intelligence (AI). Data along with AI is going to change the world. Let's look at how data is driving the Vehicle.

### **Self-Driving Vehicles**

Before getting into the technical aspects of Self-Driving or Autonomous Vehicles, let's look at what is meant by Self-Driving and why we need them now.

PCMag defines Self-Driving Cars as a computer-controlled car that drives itself<sup>[3]</sup>. In simple words, self-driving cars are on-road supercomputers. It also states that predictions of these self-driving vehicles were made in 1939. But, commercial use of these vehicle was not legalized in the US until 2011 – more than 70 years after initial prediction to become commercial. As said before these are supercomputers, having one supercomputer on a confined space like a data center or a lab differs completely from having them run on road. It took all those years not just because of the delay with legalizing it, but because of the challenges that in inventions of hardware and software components.

## Levels of Automation and Its Market

Even after a century, we cannot say that we have reached the level of what we aimed for. However, many car manufacturers reached half-way with what are called Semi-Autonomous cars. The biggest advantage that we have is the government and professional organizations like SAE (Society of Automotive Engineers) got more clarity on the “Levels” of automation [4]. Now we have a good roadmap for companies and research scientist to clearly understand where they stand. Below are the five levels of automation that are defined by the US Government.

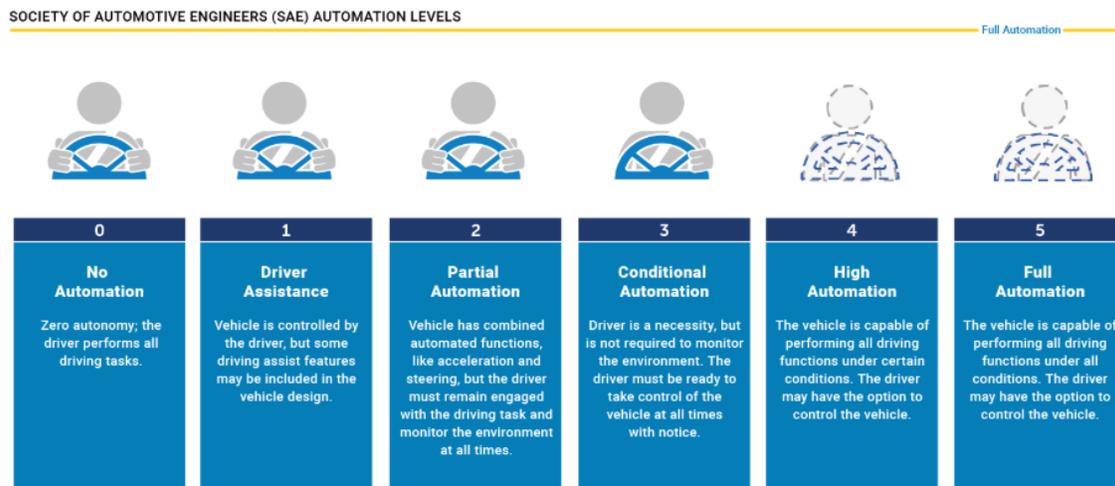


Figure 3: SAE Automation Levels (Source SAE)

Looking at the players in the market will give us further clarity on where we are heading. Below snapshot from Liberty Advisor Group study [5] shows the original equipment manufacturers (OEMs) and new entrants. This clarifies that the Autonomous Vehicle market is a completely a different ball game.



Figure 4: Market players (Source: Liberty Advisor Group)

Nearly all the new entrants are computer/chip/data based companies and not related to vehicle manufacturing [6]. These new entrants do have connection to the components that are part of Self-Driving vehicles, being either manufacturers of key technologies used in these vehicles or mobility providers who look to explore opportunities to get driverless cars to benefit their vehicle fleet.

## Need for Self-Driving Vehicles

As the name says, a self-driving is it is self-driving or driverless vehicle means removing humans and, in the process, eliminating human error and distraction. Consider the human error rate on roadways. The below graph from the World Health Organization's study Global status report on road safety-2018<sup>[7]</sup> states, "The number of deaths on the world's roads remains unacceptably high, with an estimated 1.35 million people die and 50 million injuries each year". That converts to one human dying every 23 seconds in the world. Road traffic injuries rank 8<sup>th</sup> in leading causes of death.

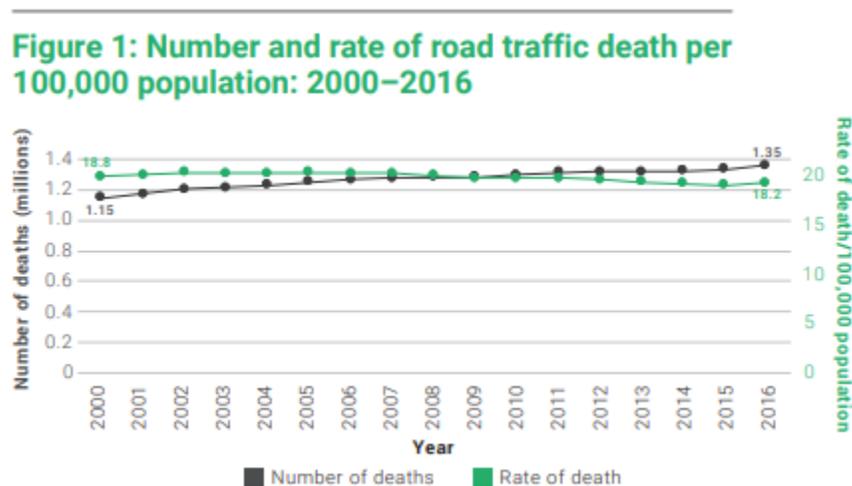


Figure 5: Global Status Report On Road Safety 2018 (Source: WHO)

The main reasons for Human error on wheels are considered to be drunk driving, speeding, distracted driving (mostly due to mobile phones) and drowsiness. Taking steering wheels out of the hands of humans can easily avoid all these. Unfortunately, we cannot avoid the bad behavior of other road users. Driverless cars not only avoid crashes and saves lives; it has several other advantages.

- Fully autonomous vehicles enable differently-abled people to commute on their own which makes a huge psychological difference for our race.
- Better for seniors as they don't need to indulge themselves in driving activity when they don't feel well.
- Assists people with slower reactions. As per the neuroscience study, human consciousness lags 80 milliseconds (for example when we touch our toe, we feel that only after 80 milliseconds)<sup>[8]</sup>. This latency in us is unbelievable because we are used to living like this naturally. For a driverless car,

anything over a hundred milliseconds of latency is going to disrupt vehicle operation<sup>[9]</sup>. Vehicle data processing power is almost close to human conscious power; this is expected to reduce but not the human consciousness lag of 80 milliseconds.

- Apart from these major advantages there are other social and economic advantages, namely the loss of economy when life is lost or when they have decreased life quality due to accidents. Recently WHO (World Health Organization) reported that road traffic crashes cost most countries 3% of their gross domestic product.
- Autonomous vehicles could free up 50 minutes of driving time each day, avoiding 6.9 billion hours spent in traffic delays in the US.

### How do Self-Driving cars work?

Recently Apple CEO Tim Cook stated, “Self Driving Cars are the mother of all AI projects”. These super computers with wheels have some key technologies to get data for AI to process. Technologies like sensors, cameras, radar, and LiDAR generate data at unimaginable speed and capacity. These technologies function in tandem with state-of-the-art GPS and inertial measurement unit sensors (IMU) to pinpoint the location of the car down to a quarter of an inch. Additional radar control will kick in whenever an obstacle comes within about 15 to 30 feet of the vehicle. These sensors exist to keep the car running .



Figure 6: Depiction of Key Technologies in Sel-Driving Car (Source: autonomoustuff.com)

Each component mentioned above plays a crucial role in moving and stopping the vehicle. Artificial Intelligence with cutting-edge algorithms, Machine Learning, Deep Learning and Deep Neural Networks perform the job of data analysing and processing. These advanced hardware and software components are networked together to make decisions that are similar to human decision.

To understand how the vehicle and human mind differs, let's look at this famous invisible triangle illusion which is an example of *Gestalt perception*. We might see triangles but the fact is there are no triangles, the human mind is capable of filling up the things that doesn't really exist. But, typically a machine will not do that. If we want a machine to do that we need to train it and feed it tons of data in a continuous process which will become accurate over the period of time.

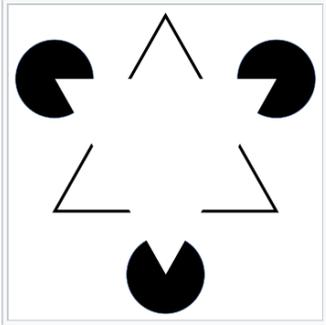


Figure 7: Illusion of Invisible Triangle (Source: Wikipedia)

Emulating human behaviour is what we do in self-driving vehicles. To do that we need data that is similar to what our brain needs. Data is an integral part of the whole cycle which flows from end to end. Data is what fuelling the car. Just as fuel is used to operate the engine in a traditional car, self-driving cars use data to operate the vehicle. Let's take a closer look to understand how the data is generated and what data flows from end to end to emulate human behaviour in driving.

The table below shows the difference between a human-driven vehicle and a self-driving vehicle. Exact human actions are emulated by the machine; this is only possible because of data.

Human-Driven Vehicle	Self-Driving Vehicle
Data of surrounding gathered through eyes and ears	Data of surrounding gathered through cameras, sensors, radar and LiDAR
Brain to compute the data from eyes and ears.	Artificial intelligences enabled through computing power processes the data
Brain signals hands and feet to act on the decision that it took	Computer signals Control electronics to act on the decision it took.

To achieve this, all self-driving or fully autonomous cars use data collection and data processing inside the car. The block diagram shown below from Chalmers University of Technology is the simplest representation of the flow of data and processing modules for autonomous driving<sup>[10]</sup>.

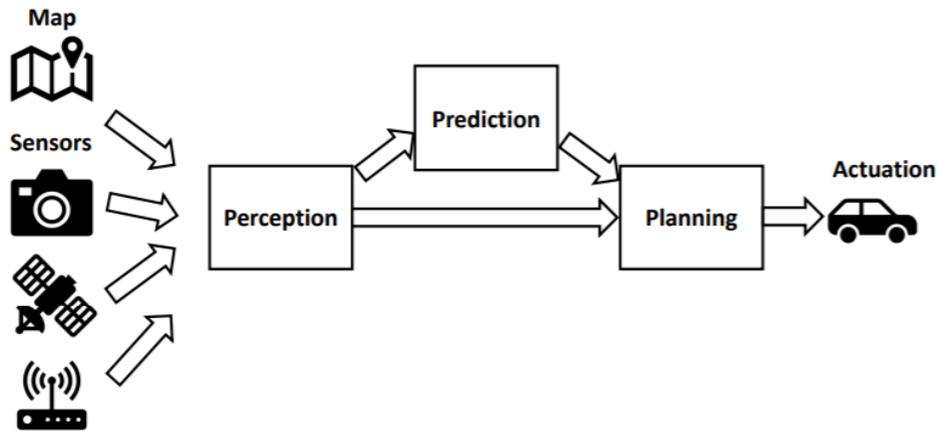
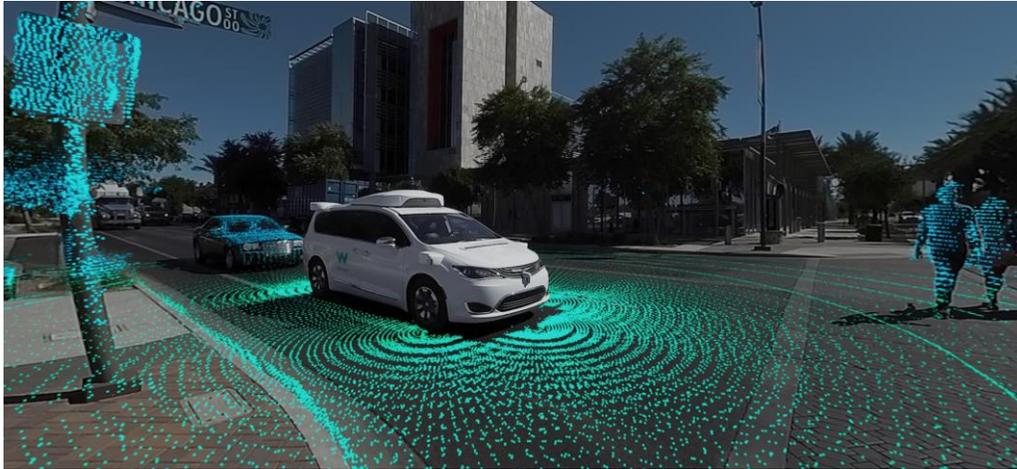


Figure 8: Flow of data and processing modules for autonomous driving (Source: Chalmers University)

Any self-driving cars will have as having five core components

1. Computer vision is nothing but an eye of the car. It's how we use images captured through camera and figure out our surroundings. Humans are able to identify and describe what we are seeing/hearing within a millisecond. Similarly, with tons of data processed through Artificial Intelligence and Machine Learning, computers understand the image and identifies what is in the image. To achieve this the computer is fed with tons of data, learning each image as data and data points. It is a continuous process.
2. Sensor fusion – how machines incorporate data from sensors like lasers and radar – is the next level of understanding the environment in a better way. Using data from camera image (computer vision) machines cannot calculate the distance between two objects. The vehicle processing system is designed for variety of scenarios and different environments gathering data from lasers, radar and LiDar and combines it to develop meaningful information. Data from each technology is important as some of the components don't work or give proper output in specific weather or environmental conditions.
3. Localization is used to determine the precise location after understanding the environment using sensor fusion. This is the most important step for the car to decide when to move or stop. Car manufacturers use recorded data from the sensors and build a map of its surrounding. GPS is not enough to perform this kind of localization; centimeter-level precise localization is needed which GPS does not provide. In the above diagram, Localization comes in the perception module. this is achieved with mathematical algorithms and the high defintion map data. Currently, we have

centimeter-level accuracy which is still not enough. The picture below shows how Waymo (Google's Autonomous car) sees the world using the data that it collected through the various technologies mentioned above.



**Figure 9: How Waymo sees the world (Source: Autopilot Review)**

4. After building the localization map, vehicles use path planning methodology to chart a course and drive around, finding a way to navigate without hitting any static or dynamic obstacle. For this, information such as roads and lane connectivity also complements but this needs internal massive computational power as it is done on the go.
5. The final step is to control parts of the car, i.e. steering, accelerator and brake. A computer transmits control data to controllers by means of electronic commands. For a fully autonomous car, these real components are actually not needed as everything is controlled internally.

### **Data in Self-Driving Vehicles**

Operation of an autonomous car is full of data and data processing, so it is necessary to understand how much data is generated and what kind of solution we have to store the data.

Data Storage Capacity - As per a prediction from Intel in 2016, it was estimated that self-driving cars would generate 4 TB/day on average, more or less equal to the data generated from a connected airplane. This is now estimated to reach 30 TB/day<sup>[16]</sup>. It is already understood that data generation has grown exponentially for fully autonomous vehicles like Waymo.

Data generated by cameras and sensors in the car contributes to this exponential growth because of the capacity of each sensor. As per the study that was published at a Flash Memory summit found that the following amount of data generated per sensor<sup>[11]</sup>

- Radar: 4-6 sensors 0.1 - 15 mbit/s /sensor
- LiDar: 1-5 sensors 20 - 100 mbit/s /sensor
- Camera: 6-12 sensors 500 - 3500 mbit/s /sensor
- Ultrasonic: 8-16 sensors <0.01 mbit/s /sensor
- Vehicle motion, gnss, imu: <0.1 mbit/s /sensor

Anticipating such data growth, data storage companies have developed solutions like scale-out file systems which will be useful for data processing.

With all these data, as of now only semi-autonomous vehicles are running on the road, with humans in the driver seat to control the vehicle only when needed. Once machines start doing the work some humans might become lethargic and might miss controlling the vehicle. Hence, to monitor and understand human behaviour, car manufacturers included cameras and sensors for them as well. Data collection and data processing is done for human drivers along with the data collected and computed for the operation of the vehicle cameras and sensors.

### Fully Autonomous Vehicles

Fully autonomous (Level-5) is more difficult than what was predicted or imagined. To be clear, the hurdle is not with machine learning or artificial intelligence; the problem is predicting human driver behaviour. Even though it was highly challenging, machines are very close to filling the gap with respect to technology. As proof, Waymo (a car which is closer to SAE Level 4/5) completed their 20 million miles on public roads. This means multi Petabytes of data has been gathered, analysed and processed.



**20** million miles: Waymo CEO [@johnkrafcik](#) just announced at [#FortuneTech](#) fireside that we've exponentially increased our miles driven on public roads - it took 10 years to drive 10 million miles and just 1 year to drive another 10 million! [#CES2020](#)

Figure 10: Tweet from Waymo (Source: Twitter)

Below is experimental research from MIT. While the vehicle is driving itself it also precisely monitors what the person in the driver seat is doing. If all cars become driverless we do not need to solve the problem of predicting human behavior. But we cannot change this overnight. At the same time, without changing this we cannot get driverless cars on the road. Somehow, this challenge must be solved.



Figure 11: (Source: MIT University)

## Moving to Easy and Sustainable Mobility

As humans evolved, we also greatly disrupted nature and are now paying the price for the disruption with the threat of global warming. This is mainly driven by the Industrial Revolution of the last 150 years. We forgot to think about sustainability. So, to address use of non-renewable energy which emits carbon and destroys the planet, it is wise to move to renewable energy.

Reducing the use of fossil fuel and increasing the use of renewable electric energy is highly important. Already, the car industry is moving to electric energy, with companies like Tesla pioneering that. Apart from cars, using green vehicles like bicycles and micro-mobility vehicles will further reduce carbon emissions. In this case, can the data help? Yes, with proper data collection and analysis, data is already helping increase the use of green vehicles. It is already proved that data analytics has helped grow the number of bicycle users through bike-sharing programs all over the world. Let's look at the kind of data collection and analysis done to improve the adoption of micro-mobility vehicles.

## Micro-Mobility Vehicles

Data is not just powering the self-driving cars, it is driving the micro-mobility vehicle industry as well. These vehicles are mainly used for first and last mile connectivity. Just as human mobility changed over the years, now people in urban areas started segregating the modes of transport depending on the distance that they travel. Similar to the surge in car use after the 1920s, the 2020s will experience a good amount of progress in people using micro-mobility vehicles.

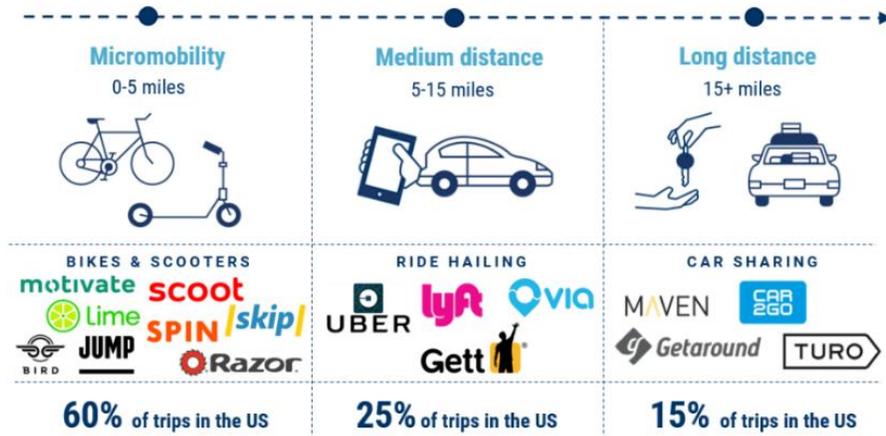


Figure 12: Alternative to Car ownership (Source: NHTS)

Recently NHTS (National Household Travel Survey), the authoritative source on the travel behavior of the American public, released data on “alternative to car ownership”. It clearly indicates where micro-mobility placed itself in the market. This kind of survey shows the advantages of Micro-Mobility for its users.

## Success of Micro-Mobility

Global Micro-Mobility market is anticipating CAGR of 11.95% during 2019-2029. It is helpful to understand what is making these services a huge success. First, what is micro mobility and why do people opt for it? Micro mobility vehicles include bicycles, electric scooters, skateboards, etc. Though bicycles have been around longer than cars, it was not considered the go-to vehicle for daily commute, mainly because of its nature of operation. Also, the ubiquity of cars and other transports overtook bicycle use long ago.

Ironically, the same exponential popularity of cars and other vehicles has created greater interest in using micro-mobility services. Below are the common reasons driving people to use these services.

- More efficient during peak hours – Car-aggregator, Uber indicated that rides on Jump electric bikes (shared e-bike platform) easily crosses Uber’s car rides during periods of high congestion.
- Most cost-effective transportation – It is much cheaper and more convenient than hiring a cab or owning a car and fighting for parking space in cities.
- More awareness of environment conservation leading people to use small electric vehicles rather than fossil fueled cars.
- Apart from these common reasons, the most important reason for the surge in use is because companies made micro-mobility a shared service wherein vehicles can be picked up in one place and dropped off at the destination. This service is simple to use, requiring nothing more than a tap on a mobile device.

### **Mobility as a Service (MaaS)**

In the IT era, it seems everything has become “as a service”. Now, even vehicles are provided as a service – called Mobility as a Service (MaaS). Done through vehicle sharing programs, a major contribution for these services comes from micro-mobility vehicles as they are sustainable and complement the private and public transportation in a larger way.

Considering the scope of this now billion-dollar industry, investments are pouring in from around the world. Normally, this kind of micro-mobility sharing is done through a mobile app. Though it is very easy for users to book and ride through these kind of applications, a tremendous amount of data collection and analysis takes place in the background. We will look into how data is enabling MaaS.

### **Data and Bike-sharing Programs**

It is understood that data is the most important factor for any decision making. However, when it comes to transport we have so many data available but they are scattered, and arrive in structured and unstructured format. Companies who refer to themselves as a "Transportation Data Company" aim to perform data collection (which is spread across the world in different formats) and analyse the same. These companies provided software through SaaS (Software as a Service), and proved to be a huge advantage in areas such as city planning.

Making use of the service provided by Transportation Data companies, micro-mobility services are enhancing their products. It is a cycle where data from micro-mobility service is much more useful to understand the first and last mile commute of the public.

Micro-Mobility data has three major sections

1. Already available data – With the help of GPS and Maps we now know how the street looks and what we have in that specific street. With modern Maps we can look from a remote location at the world as is. Also, some developed cities publish their traffic data regularly. With the help of Big Data Analytics, companies are doing extremely well in understanding the people’s mindset. This is mainly useful during the initial phase of deployment.
2. Data gathered from Users – Apart from the data that we already have, companies do collect good amount of data from users – mainly from the mobile application that they use to book their micro-mobility service. As Smartphone use has increased in last few years, data companies are making use of this growth to the extreme. Mainly, the GPS data for these kind of mobility service is very important. Companies collect data such as location, time and traveled distance which helps the company develop deeper understanding on people's needs. Through mobile apps they also push small surveys to get answers to questions which cannot be analysed using the collected data. Coalescing the already available data, companies are trying to understand the multiple aspects of the user’s mindset. Knowing this will help the economic balance of the company in a larger way.
3. Data gathered from their own bikes/scooters – Every vehicle manufactured now is an Internet of Things (IoT) device, with fixed GPS that provide real-time data. Data from these devices are the real fuel for the company and what is powering their service. Accessing the real time data is very important for vehicle monitoring, pricing and incident/accident management. Combining all these three sections of data, bike-sharing companies manage their fleet dynamically. Positioning and re-positioning of the vehicle happens based on people's requirement. For instance, the following graph shows the pattern of shared usage along with the member type<sup>[12]</sup>.

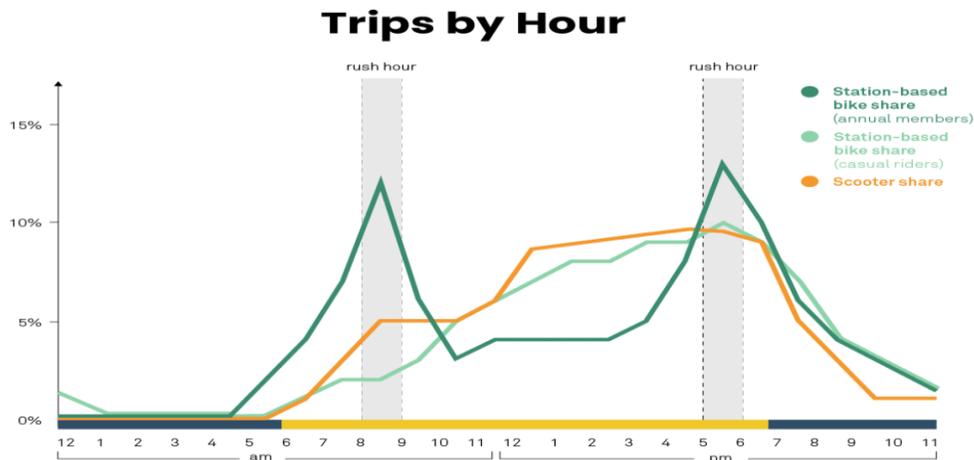


Figure 13: Shared-Ride Usage (Source: NACTO)

### Brief Case Study on Shared Micro-Mobility Service

In India, bike-sharing company "Yulu" which was launched in 2017 used data to propel their service and the immediate result was mindblowing. The company CTO updated that they saw a jump of up to 35% more use of their fleet. The power of data analysis started giving them output immediately. What did they do to have this kind of growth? They took decisions based on data. They use real-time data to predict need and balance/re-balance their vehicles depending on demand spikes in certain areas or at certain times. It is now their everyday job. The initial few months of operation was just about collecting data to understand usage pattern and slowly they constructed their own prediction model. They are able to proactively manage their vehicles and now make sure that their vehicles are always in great condition. They act quickly on vehicles that move outside their best operational zone and simply bring them back to high demand areas.

### Micro-Mobility Data Standards

As mobility data increases day by day, the need to address the standard has also increased. To standardize that, local governments in the US created the Open Mobility Foundation(OMF), an organization that mainly supports scalable mobility solutions for cities. OMF derived a project named Mobility Data Specification (MDS), an API to transmit unidentified information about the rides. The definition of MDS from OMF states "It is a set of Application Programming Interfaces (APIs) that create standardized two-way communications for cities and private companies to share information about their operations, and that allows cities to collect data that can inform real-time traffic management and public policy decisions to enhance safety, equity and quality of life."

This started in Los Angeles and now has been adopted by more than 50 cities in the US alone. As it is an open source project anyone can contribute to the development and anyone can benefit from it. Its purpose is to make people's lives better. MDS is built upon a basic API which was already available and used to get basic information from the General Bikeshare Feed Specification (GBFS) bike-sharing system. This is being used by bikesharing companies to describe the status of their system to customers.

### **Using Micro-Mobility Data for a Better Life**

Deriving information from the available data and harnessing the power of micro-mobility data will benefit humans greatly. Below are some key points on how progress is being made in using these data.

- By leveraging the data from people's first and last mile commute, local governments and companies get more insight into identifying under-utilized street parking, over-utilized parking, pickup-drop zones of vehicles and people movement data.
- When planning and building city infrastructure, government, citizens and micro-mobility companies working together offers a path to improve quality of life by avoiding congested traffic.
- Benefits of Micro Mobility vehicles are not just for the people using them. This service gives economic advantage to those who can rent out their parking space from their shop or residence.

### **Autonomous Vehicles meet Sharing Platform**

There are signs that vehicle ownership is trending down, particularly among Millennials. As the transportation industry becomes more data-driven, there is a noticeable shift from owning the vehicle to hiring a taxi or sharing the ride. This is driven largely by convenience and cost-effectiveness. The cost of autonomous vehicles has also increased due to installation of essential features such as sensors and LiDAR's. This pushes even more people to opt for vehicle sharing rather than owning.

Though higher cost is a disadvantage, companies like Uber are finding opportunities to reap the vehicle/ride sharing advantage. It is predicted that by 2030 there will be close to 11 million driverless shared vehicles on the road<sup>[13]</sup>. Currently, autonomous cars are now available as-a-Product or as-a-Service. As-a-Product is simply owning the car which is the traditional way and As-a-Service is a ride-sharing service.

2019 was a landmark year for the automotive industry because Waymo (Google) and GM Cruise (General Motors) positioned themselves as ride sharing vehicles. IT giants like Apple, Cisco, Amazon and

Microsoft are also getting into this market, making this segment more competitive and innovative. A few small-scale startups like May Mobility and Drive.ai are also providing shuttle services.

When “Level-5” autonomous cars arrive, automakers will no longer manufacture pedals and steering wheels, rendering human control of the car obsolete. Data collection of human behavior will still be done, not as a requirement but rather as an added advantage, i.e monitoring passengers for their comfort and so forth. Passengers will become more productive instead of doing the same job of driving up and down. Notably, this is going to take one person out of the transportation equation – the driver, whose seat can then be occupied by another passenger. This is a main reason why companies like Uber place their mark in the autonomous car industry; they are aiming to move away from managing drivers.

### Conclusion: Data and Our Future in Mobility

Already data is ruling the world. Without the data even a simple human statement is considered just an opinion rather than fact. Some years back, data was driving just the IT business but now data is driving every business. This article discussed about the role that data plays in Autonomous vehicles and Micro Mobility vehicles.

Though we have come a long way in human mobility, looking at it from the data perspective, this is just a starting point. Now we are in an era where vehicles generate a lot of data, sometimes more than what that machine could analyse. A KPMG survey states that we are yet to get all the benefit from data analytics, we are still lagging behind<sup>[15]</sup>.

Autonomous and Micro-Mobility vehicle's main source of data and the only sources of real time data is from IoT devices. The below graph shows the numbers from 2015 predicting through 2025 <sup>[14]</sup>.

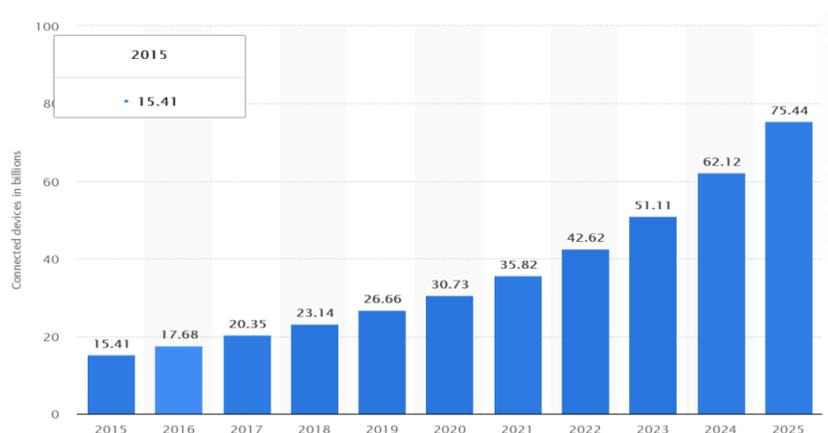


Figure 14: Number of connected devices worldwide 2015-2025 (Source: Statista)

Each IoT-enabled device produces tons of data, daily. Hardware gets more efficient and produces more accurate data while software also becomes more accurate with machine learning algorithms and precise data analytics. This gives a richer, more diverse experience. As the amount of data grows, so does the accuracy of Machine Learning and Deep Learning.

A recent prediction from Ericsson states that by 2025 the number of connected cars will increase to more than 700 million and very soon connected cars will be sending 100 PB of data to the cloud every month<sup>[17]</sup>. Today's 4G network provides good flexibility for connected cars but it is significant to have 5G for the autonomous cars. With higher data transfer rate and lower latency 5G technology will make things faster for autonomous vehicle industry. This will also help vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity.

The exponential increase in the number of cars obviously results in traffic congestion in developed cities. Road authorities are seeking new ways and technologies to solve the problem. Micro-Mobility vehicles offer a partial solution to traffic congestion. In addition, electric vehicles helping to decrease carbon emissions. However, existing roads are not very safe for Micro-Mobility users as not everyone follows the rules of the road. If every vehicle becomes autonomous, passenger safety will likely improve overall.

Instead of making everything autonomous, governments and large organizations are planning for better infrastructure, building cities that are smart and sustainable. To do that, the data being collected and analyzed now is very important. ***In essence, today's data decides tomorrow's future.***

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