Achieving Smart Mobility: A Review

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Abstract

The purpose of this paper is to cover the many different pieces of research that have come out in the last six years. By classifying the topics covered in these papers, and then analyzing the contents and suggestions made by them, this paper offers a conglomeration of the information stored to help others plan future research in the field. Analysis of how certain proposed solutions work, and how their results are achieved is also done with some real-world statistics. Using all this information, examples of future research into smart mobility are given based on the information parsed in the making of this paper.

Keywords
Machine Learning, Electric Vehicles, Smart Mobility, Self-Driving, Artificial Intelligence.

1. Introduction
In our modern world, digital services have changed our lives by giving rapid access to a massive repository of information and tools. Be it knowing the traffic and routes you can take to get somewhere with up-to-date information, being able to see the seating available at a restaurant or movie theater, or even being able to request and pay for a ride or delivery service from anywhere with cellular service. These advancements exist to ease the potential stresses on the consumer and allow for easy access to useful resources. These innovations grow with each passing year with new services springing forth into the public space. With some advancements being used for private business (DoorDash, Uber, etc.) and other developments being used by public infrastructure (Weather Services, Safety Alerts, etc.). Thus, it is no surprise that one such idea looks to advance digital infrastructure in population centers to grant a plethora of benefits. Be it installation of mesh routing in cities to provide wireless internet throughout, or the use of online services to provide information such as bus routes and times, and much more.

There is a specific subset of this that has come to be known as "smart mobility", which is using the collection of electronic devices that exist everywhere (also known as the Internet-of-Things) in our world to collect data related to movement to find the most efficient route. Be it something as simple as active parking management so you can know how many spots are remaining in a parking lot, to something more complex as active traffic monitoring to help people plan their commutes through areas. This only scratches the surface of potential benefits, however these come at a cost. In some cases, it is at the cost of privacy alongside a cost of capital. These technologies and techniques are rapidly developing, and in some cases being implemented, creating new tools and benefits. Therefore, the important question is what is being done and where new potential advancements lie. The purpose of this research is to look at what others have done in the last eight years and potential smart mobility technologies to ease the day-to-day travel of everyone.

1.1 Objectives
To give recommendations to those wishing to help advance the field, this work exists as a general summary and primer on the topic. To serve this goal, multiple papers were gathered from various literary sources with the intent of summarization and recommendation. These papers were aggregated to best give a multi-faceted explanation of the potential future developments. With the objective of analyzing what is being done, what could be done, and the benefits and drawbacks of everything.

1.2 What Goes Into Creating Smart Mobility
Smart Mobility is the use of technology to gather data and use it to help make traversal of areas more efficient, a smarter way to get from place to place. However, there are many ways to achieve this ease of travel. It can be achieved by aggregating a massive amount of data for use in prediction, it can be achieved by using video cameras to detect dangerous driving to give a warning to other drivers, or it could be something as simple as having an active count of how many cars are in a parking lot that can be accessed easily online. At the heart of all these tools that enable smart mobility is the gathering of information to give those utilizing the system the full bevy of potential knowledge that can help them get from point a to point b with the smallest number of resources needed.

This is normally achieved through a combination of sensors which gather information, a device that sends that information, an aggregate center that processes it for use, and an access point which allows the public to access this information. This is how most public-facing smart mobility services work. For example, a traffic information system that would warn you about congestion on roads it would then be made up of: cameras on the streets that are gathering how many vehicles are passing by, a device connected to the cameras that send that information to a device that aggregates it, then that aggregator device processes the information, and then sends it to an online accessible host for consumer use. Depending on the service there can be more steps, such as processing the data for easier readability, but they usually follow a similar outline. There are other smart mobility technologies as well. Not all systems require an online presence as some instead focus on optimizing the vehicles used for travel. This is done by analyzing the information provided by the vehicle used, and either optimizing the runtime efficiency or another method that reduces the resources used in travel.

This is the surface layer of smart mobility, once you go past this point however things become more complex and numerically focused. Most smart mobility services are operating at a massive scale of data, so much so it is almost impossible for people to keep up. Thus, it has fallen to predictive algorithms provided by machine learning to rapidly analyze massive amounts of information. However, it is not as easy as simply feeding the data to your favorite machine learning algorithm. To create an efficient system that operates as intended, it must be customized and designed with the explicit purpose in mind to achieve the best results. The predictive algorithm that powers something like the estimated travel time on a GPS, will not work the same way for something trying to predict how full a car lot will be. These machine learning algorithms work by collecting data pertinent to the calculations required to get an accurate prediction. Estimating how many cars will be in a parking lot, in theory, is achieved by populating an algorithm with "features" that are pertinent to the calculation of the result. In this example, the features selected would be a combination of things like time of day, weather, day of the week, nearby events, and much more to calculate a reasonable prediction of how full the parking lot will be. The use of all these technologies and techniques are covered under the idea of smart mobility.

1.3 Why is Smart Mobility
With an understanding of what smart mobility is, the next question is why? The answer is simple, to ease stress on the consumer and make the act of getting from place to place easier alongside reducing the number of resources needed to achieve it. Alongside these are a bevy of other potential benefits, such as reduce pollution by optimizing the driving routes, the replacement of fossil fuels in service of using electrical power in automobiles, creation of better public transportation, and many more things related to travel. There are many more potential benefits, and the ones listed are ones commonly mentioned in other smart mobility literature. The end goal of smart mobility, in theory, is making it easier for everyone to get from where they are to where they wish to go. With this knowledge in hand, now comes the question of what could be, what is, and what should be.

2. Literature Review
The literature analyzed for the purpose of review could be divided into any number of categories, as done with topics covered later in the review. However, an even broader distinction can be made simply due to the split nature

of the papers used. The works either reviewed other literature much like this paper, or they gathered data to analyze trends or use machine learning techniques to get predictions from said data. These papers focus more on classifying and extracting information from data gathered to achieve a goal. So, the papers read can be split into two clean groups review papers and test papers.

In the test group all papers analyzed and put into this group used machine learning methods to test machine learning methods that could be used to increase the efficiency of travel. Stolfi et al. (2019) used machine learning methods and six different classifiers on parking data collected from major urban areas in the United Kingdom. By using this data, they found that they could predict the number of cars in parking areas at a given point in time. Filjar, Sklebar, and Horvat (2020) did something similar, except instead of analyzing car parks and the number of cars at any given time, used smartphone location data to track where people were and how they were travelling. Another study was done by Semanjski and Gautama (2015), who used a gradient boosted tree classifier to predict similar information about methods of travel. Another machine learning experiment was Kostic et al. (2021), in which they used data provided by SHARE NOW Copenhagen, a car share service, through a linear and neural network classifier to predict the time used and changes over a rental period. They used this information to predict the time rented and where they were most likely to go. They suggested that this information could be used to help expand the service by analyzing the congregated data. Magalhaes et al. (2019) applied a similar technique, using traffic data gathered in Fortaleza, Brazil over the course of 2014. They used their machine learning techniques to predict traffic on a city-wide level, and a more localized cluster level as well. They found this cluster style used at a micro level while feeding data to a higher city level authority was effective and should be investigated further. Another paper by Fadi Al-Turjman (2019) proposed a framework for ITS implementation that used IEEE 802.16 to analyze QoS metrics on IoT devices.

While the prior examples used machine learning techniques to predict traffic flow, these papers instead directly focused on using these techniques to optimize engine efficiency. Zhou et al. (2021) used their techniques to optimize hybrid-engine efficiency. By using deep reinforcement learning and heuristic rules, they found that they could get performance better than using other similar methods. Chemali et al. (2022) followed a similar path, however they used it to estimate the health of a lithium-ion battery using thirteen features in the classifier. They used a convolutional neural network method and found that it could be used alongside other information to predict the health of the batteries. Finally, Mawonou et al (2020) did something similar, however they used an ensemble classifier with twenty features and found it "produced excellent results when using extensive data".

Then some papers were surveys, which analyzed the populace's responses to the inclusion of smart mobility technologies. Such as Sato and Hashimoto (2023) analyzed the use of MaaS in many different regions in Japan and analyzed the changes after a year in how it impacted each region's life space assessment. They found there was no direct correlation between the two but did note that residents were quick to accept MaaS as a new transport option. Another paper that did something similar was Walczak et al. (2023) which surveyed residents in Warsaw and found that most of the residents were fine with IoT devices collecting information if it was anonymized and used to benefit others quality of life. They, however, disliked any use of the data beyond such means, such as if the data were to be used for advertisement

Then there were the review papers, these focused on gathering other research and analyzing it alongside other information gathered from public records and other sources of information. These were often generalized instead of focused and covered many topics under one umbrella. Fayez Alanazi (2023) reviewed the implementation of smart mobility in South Korea, Singapore, and Japan which have put a lot of effort into updating their cities with such technologies. They then explained what things were implemented and how, to give examples to the Kingdom of Saudi Arabia and their own smart mobility initiative. Another similar work was that done by Vrščaj, Nyholm, and Verbong (2019) which analyzed the Dutch smart mobility initiative, finding that the intended user-centric advancement did not occur and breaks down what went wrong. Tundys and Wisniewski (2023) analyzed the electromobility options and demand, arguing that its effect of reducing CO2 pollution makes it uniquely positioned to help major urban areas have cleaner air. Lee et al. (2023) investigated other research, analyzing how the data was used to achieve smart mobility in other tests. They suggest the development of intelligent transport systems (ITSs) that could utilize machine learning techniques to optimize traffic. Tang et al. (2022) followed a similar approach; however, they focused explicitly on using the techniques to upgrade railway systems. Porru et al. (2019) analyzed public transportation much like Tang et al., however they focused on other means of public transportation and analyzed the different circumstances between enabling rural smart mobility and urban smart mobility. Lyons (2018) analyzed the use of smart mobility terms and warned that the terms are vague and can be used in ways that undermine the goal of smart mobility. They argue that smart mobility is the provision of efficient and useful travel for everyone in a sustainable way, and that others can use the term even if part of that definition is not reached(efficiency without sustainability or vice versa). A similar thing was noted by another team, Noy and Givoni (2018) which noticed several entrepreneurs led businesses would claim they were innovating smart mobility but did not align with the smart mobility initiatives outlined by research in the field when questioned. Finally, Butler et al. (2020) took a more critical look at "Mobility-as-a-Service" (MaaS), which is services like Share Now, Zip Car, Uber, etc. They saw potential in providing quick access to a mode of transport but were skeptical about the potential issues of private companies dominating shared transportation in urban environments. They argued that it has potential for local governing bodies to rely on these services in lieu of providing their own which could lead to a disparity in use and potentially inelastic demand which could lead to unfair pricing.

3. Methods

To the goal of being a good representation of the current work and potential developments in smart mobility, a handful of recent articles from the last eight years have been gathered and read. The content inside the articles have been analyzed for specific key topics. Topics such as automated transport, traffic flow control, resource optimization, and other terms that commonly appear in research about smart mobility. These results allow for a numerical count of the potential ideas that are being investigated or mentioned. By knowing these numbers, topics that are commonly pursued and topics under-represented will become clearer. With this knowledge one can see where they can best help forward research or see where current interests lie alongside giving an understanding of what is being used to potentially achieve these goals.

4. Data Collection

The articles gathered were collected from a multitude of sources, among them Eastern Michigan Universities' Halle Library, Google Scholar, and other similar repositories. These articles were then read and checked for relevance to the topic and works from before 2015 were excluded for the sake of focusing on newer developments. In further research looking further into the past may better help classify and understand the research going forward however the focus of this paper is recent developments.

5. Analyzing the Research

5.1 The Archetypes of Smart Mobility

Upon analyzing the research done, all the information put forth can be broken down into 7 generalized categories, these categories are as follows: Intelligent Transport System (ITS) / Intelligent Infrastructure, Intelligent Vehicles, Transportation Share, Smart Parking, Automated/Assisted Transportation, Optimized Foot Traffic, and Resource Optimization. Some of these have been grouped together due to covering very similar topics or due to their interconnected nature.

Intelligent Transport Systems and Intelligent Infrastructure have been combined due to the first's reliance on the second. Intelligent Infrastructure is underlying technology that can communicate information to each networked device about what is going on in each area it is a part of. This is done by the inclusion of different sensors that can gather data and report to a centralized source. By using this information, the location can know how many cars are on the road, the speed at which they travel, the different types of pollution, and much more. By having this infrastructure, a location can then develop Transport Systems that use this information to automate and report certain data. This allows for areas to utilize the information gathered to increase the efficiency of travel for all involved. This can be anything from traffic light control allowing through traffic longer when no cross traffic is detected, to detecting older people and stopping traffic for longer so they may use the crosswalk (Alanazi 2023).

Intelligent Vehicles are any form of transportation that can connect and share data with a local system. A smart vehicle, to use the common nomenclature. This is usually achieved by having sensors inside the transport that gather information such as fuel efficiency, speed, and relative position which are then utilized by the vehicle or are sent to an ITS which can use this information to optimize traffic. This can be anything from a bike to a bus, the importance is that it can gather data relevant to operation and inform a local system what it is gathering for advisement or other services. This category usually works alongside resource optimization; however, it is considered separate from intelligent vehicles as a topic in this paper as the term focuses more on interconnected networking capabilities, rather than the inclusion of sensors for internal data collection and status.

Transportation Share is, as the name implies, a method to create shared transportation for easy mobility in a location by sharing means of transportation. This has a couple of variations that operate similarly with differing end goals. This includes things such as public transportation methods which allow for anyone in the local area to access a shared method of transport at a cost or free depending on local policy. This includes public buses, subways, trains, and other shared methods of publicly maintained transportation. There are also private shares, this includes things like car share and bike share services. These services are privately maintained transport that can be rented for mobility in an area. Car shares exist internationally and have seen growth over the last couple of years(Butler, Yigitcanlar, and Paz 2020) and other similar initiatives have found themselves in many cities across the globe. These services are maintained by private companies and have GPS systems to keep them only active in the areas assigned as well as working as an anti-theft system.

Smart Parking is the intelligent monitoring of parking lots to note the occupancy and help car commuters find parking. This is commonly done by maintaining an active count of cars that are in the parking space and having a list of open spots. This is usually accessed through a publicly available website, that allows drivers to plan where they wish to park in advance. It can also be done by using machine learning methods to estimate the number of cars parked at any given time if enough data is gathered as seen in Stolfi et al.'s work (2019).

Automated or Assisted Transportation specifically refers to transportation that without intervention from the pilot can transport them to their location or assists the pilot requiring less interaction than if they were to drive themselves. This can be classified on a 6-point scale as defined by SAE, with level 0 being no automation/assistance and level 5 being fully automated driving. In theory, these systems would combine with an ITS to find the best route and reduce potential for accidents keeping all people involved safe.

Optimized Foot Traffic, while not mentioned often, is the use of sensors to help keep people walking safely and quickly to their destination. This can be achieved by including uninterrupted walkways, using sensors to increase or decrease the time allocated for pedestrian crossing, or simply including a way to queue up pedestrian crossing. This part of smart mobility is often overlooked as more focus is placed on public transportation and motorized vehicles, but some have analyzed phone GPS data to predict walking traffic and assist with walking mobility(Semanjski and Gautama 2018).

Finally, there is Resource Optimization. This is the use of technology to help reduce the amount of energy needed for anything to get anywhere and is an important part in ensuring the sustainability part of smart mobility. This can be achieved using machine learning(Chemali et al. 2022)(Mawonou et al. 2020)(Zhou et al. 2021) to optimize energy gain from breaking and other methods of optimizing the number of resources used. It can also mean doing the same for gas powered vehicles, or even with people to help them get from place to place with less exertion of force. The key idea behind all of this is that by using whatever techniques resource costs can be reduced.

All these things in theory come together to create the most optimal way to travel using the least amount of energy. This works by having all the information sent to a centralized system (an ITS) which then can use that information to direct all travelling in that location(Al-Turjman 2019). This is the common endpoint that many see to be the current future of travel in cities, removing potential dangers from human error with a theoretically more perfect automated transportation system. Some places have already made strides in these fields such as Singapore, South Korea, and Japan (Alanazi 2023). With others looking to update their urban areas for more efficiency like the Netherlands(Vrščaj et al. 2019).

5.2 Numerical Results

With this understanding of the archetypes commonly found in smart mobility research, these are the number of times found in each of the works surveyed. In table one this has been broken down into the number of appearances and the research cited in the calculated number.

Table 1. Appearance of Key Ideas in Surveyed Research

Key Term	Numbers of Appearance in Surveyed Research	Review	Test	Names of Research
Intelligent Transport System (ITS) / Intelligent Infrastructure	14	8	6	(Alanazi 2023), (Lee et al. 2023), (Tang et al. 2022), (Magalhaes et al. 2019), (Porru et al. 2019), (Butler et al. 2020), (Lyons 2018), (Tundys and Wisniewski 2023), (Sato and Hashimoto 2023), (Al-Turjman 2019), (Noy and Givoni 2018), (Vrščaj et al. 2019), (Walczak et al. 2023)
Intelligent Vehicles	7	5	2	(Alanazi 2023), (Lee et al. 2023), (Tang et al. 2022), (Butler et al. 2020), (Lyons 2018), (Sato and Hashimoto 2023), (Noy and Givoni 2018)
Car-Share/Bike-Share/Public Transport	6	3	3	(Alanazi 2023), (Kostic et al. 2021), (Porru et al. 2019), (Butler et al. 2020), (Sato and Hashimoto 2023), (Noy and Givoni 2018)
Smart Parking	3	2	1	(Alanazi 2023), (Stolfi et al. 2019), (Butler et al. 2020)
Automated/Assisted Transportation	7	4	2	(Alanazi 2023), (Lee et al. 2023), (Tang et al. 2022), (Butler et al. 2020), (Sato and Hashimoto 2023), (Noy and Givoni 2018)
Optimized Foot Traffic	2	1	1	(Alanazi 2023), (Semanjski and Gautama 2015)
Resource Optimization	10	5	5	(Alanazi 2023), (Lee et al. 2023), (Tang et al. 2022), (Zhou et al. 2021), (Chemali et al. 2022), (Mawonou et al. 2020), (Butler et al. 2020), (Lyons 2018) , (Tundys and Wisniewski 2023), (Noy and Givoni 2018)

As you can see, the most analyzed archetype is ITS/Intelligent Infrastructure at 14 papers covering the topic. ITS/Intelligent infrastructure gets the position due to its nature as the lynch pin of many automated future initiatives. Having a centralized transport authority makes it much easier to ensure all data is received and acted upon in a way that optimizes travel and safety(Alanazi, 2020)(Lee et al. 2023). Alongside these many other potential innovations rely on having a system that can process the massive amount of data needed for such decisions to be made. Resource optimization comes in second place with ten papers covering the topic in some regard. This is likely because resource optimization can be done by itself without the need to communicate with other external devices, instead focusing on optimizing a singular vehicle rather than every vehicle at the same time. There were also specific papers talking about explicitly optimizing resource performance using machine learning and only that topic, such as Chemali et al. (2022) and Mawonou et al. (2020). That is not to say that these advancements cannot benefit from a centralized information system, but that they can work without it and later be updated to take advantage of said technology when it becomes readily available.

Following this was Automated/Assisted Transportation and Intelligent Vehicles which both had 7 mentions. Automated/Assisted transportation is likewise a newer innovation growing more popular as many car companies offer similar services to Tesla’s “Autopilot”, such as General Motor’s “Super Cruise”, and many more. A commonly dreamed of future is one where a centralized authority system will direct fully automated cars in a way that will help optimize travel, while also limiting accidents that could potentially cost human lives. This hope for a safer future, alongside a mass of market ready assisted driving solutions have undoubtedly caused a bigger focus on it especially as it rapidly advances with each passing year getting more efficient and safer(Lee et al. 2023). Alongside this, intelligent vehicles are investigated as much as it is the underlying condition that automated/assisted transportation needs to work. The intelligent capabilities being what allows these vehicles to analyze their surroundings and make the correct choice when piloting/assisting to pilot themselves. Transportation share also had a sizable number of mentions at 6 and is different than the others, as the papers were focused on having public transportation run on a similar intelligent vehicle standard as mentioned in the prior section, but also on the currently growing private car share scene. Companies such as ZipCar and CarShare are growing in their respective territories offering rentals in certain areas(Butler et al. 2020). These services pride themselves on being eco-efficient often using electric vehicles that move from charging spot to charging spot keeping them constantly usable in theory. This burgeoning market has grown rapidly in the last decade, which undoubtedly caused this spike in interest. Other topics such as Smart Parking and Optimized Foot Traffic, which were 3 and 2 mentions respectively, had less investigations done in general but were niche and useful enough to have a small amount of dedicated works from Stolfi et al. (2019) and Semanjski and Gautama (2015) for the respective topics.

This information can be viewed more simply in figure 1 which breaks down the number of key topics mentioned to show the distribution of mentions across the twenty papers reviewed. This shows that there is a lot of focus on ITS and Resource Optimization, while little effort is being allocated to studies such as foot traffic and smart parking. Furthermore, in figure 2 you can see the breakdown of tests to reviews, which is a 45/55 with 11 test papers and 9 review papers. This shows an almost even split of testing papers and review papers, meaning that for every paper testing something another is reviewing it as it occurs. This is undoubtedly due to the large amount of research and resources required to test many of these methods alongside the necessity of access to large amounts of public data. For those that can overcome these issues, an entire section of study is open for new research.

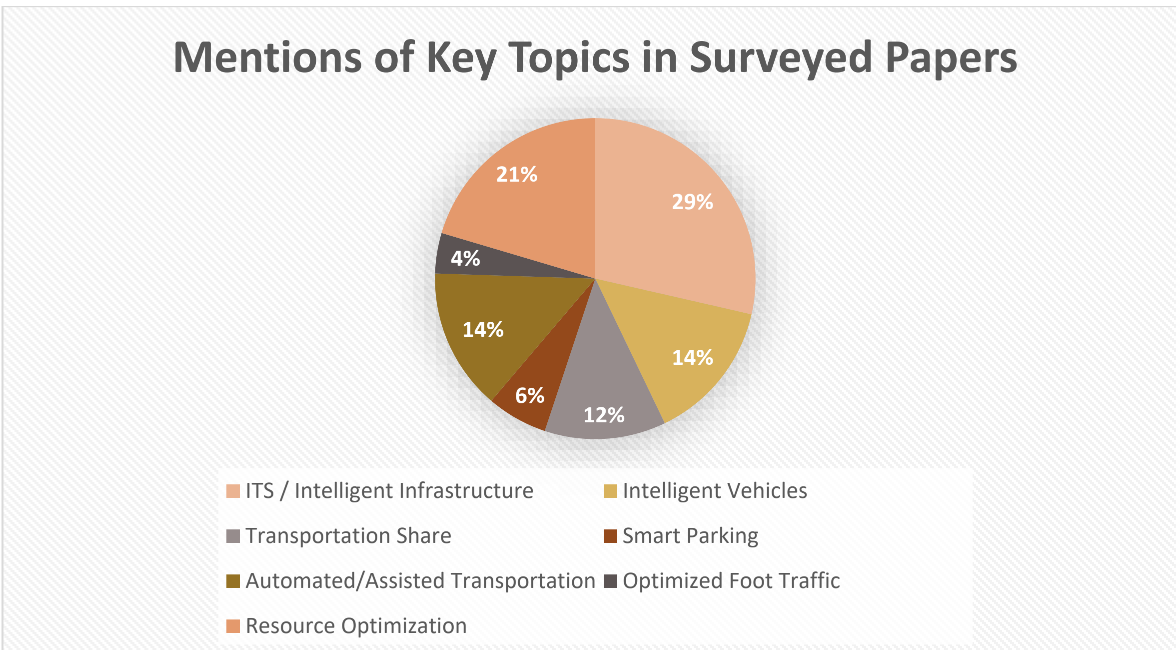

Figure 1. Mentions of Key Topics

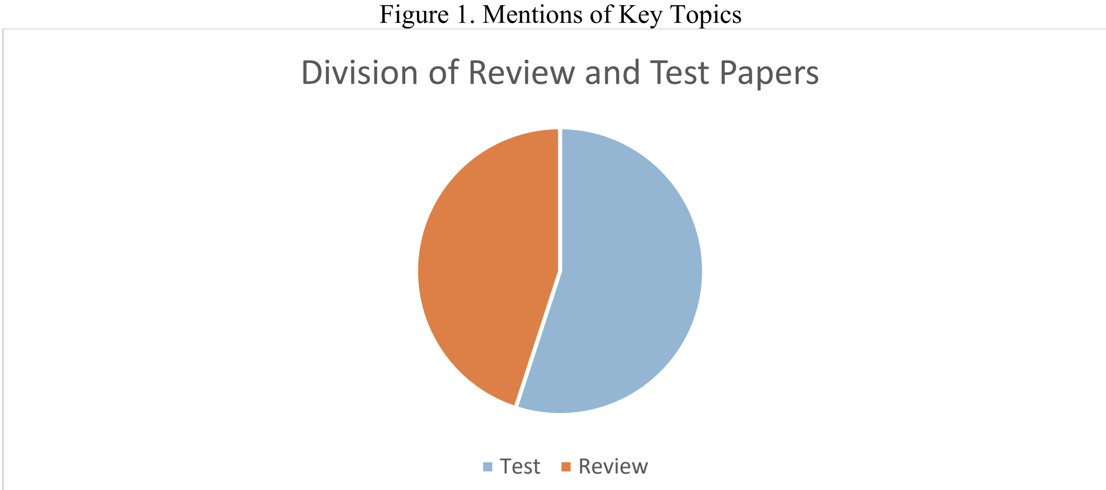

Figure 2. Division of Review and Test Papers

5.3 Benefits and Drawbacks

Smart mobility theoretically offers multiple ways to optimize our travel time and safety. Implementation of an authoritative ITS that connects all vehicles on a road can respond and direct traffic, which will help people get from point to point. It can also be used to detect dangerous behavior from vehicles, such as impaired driving and speeding to notify others nearby to help avoid dangerous accidents. Japan has it so in certain areas dangerous driving warns pedestrians ahead to lessen the chance of fatal accidents (Alanazi, 2023). These protections are mentioned in several papers, due to the high number of automobile accidents each year internationally. In the United States of America alone, according to the National Highway Traffic Safety Administration (NHTSA), an estimated 42,915 people died in vehicle related accidents (National Highway Traffic and Safety Administration 2022). Such numbers likely influence the focus on driver safety in smart mobility research.

This has also led to a growing demand for self-driving cars, with the theory behind it being that an automated vehicle connected with an ITS will avoid situations where such accidents can occur and stop dangerous driving behaviors such as speeding, driving while intoxicated, and others that can risk the lives of occupants and pedestrians. Alongside this the call for even intelligent vehicles can help by connecting to an ITS so dangerous behaviors can be detected, even if they are not automated. Another benefit of automated driving is for those that may not be able to drive on their own. People that have disabilities that prevent them from driving could keep their mobility if an automated driver or driving assistance for those with minor disabilities. This could allow them to still travel when needed without relying on other people to assist them.

Another beneficial technology investigated is that of intelligent vehicles in general. Even if the vehicles cannot operate themselves, they could connect to a local ITS which can help manage traffic in an area by allowing the system to manage them. Alongside this it gives traffic controllers a better numerical understanding of the streets that they oversee. By having the data and being able to see what cars are where doing what, operational decisions become much easier as more information that is useful for the decision-making process involved becomes available. It can also help manage foot traffic in theory, allowing for traffic to be managed to make it easier for pedestrians walking in the city. It can also help reduce potential threats to pedestrians from reckless driving behaviors.

By having a functioning ITS it also allows for other smaller technologies that can help alleviate traffic congestion in large population centers. Using an ITS, parking data can be sent to those traversing these areas to help them find parking and alleviate potential congestion caused by people trying to find a parking space. ITS can also help co-ordinate with public transportation which can help keep the street traffic to an optimal level. Finally, using these methods can also help monitor resources such as energy charge in electric vehicles and gas in oil-based vehicles. This has the benefit of increasing fuel efficiency in theory and can also help with the management of carbon emissions which can make living conditions in cities worse if not kept in check. Alternative transport methods also can assist in this as they are often electrically powered and provided in major cities to help alleviate such concerns. This is why many of the carshare companies use all electric vehicles, alongside other traversal options such as electric bikes, and electric scooters. Bikes, scooters, and other similar transportation could also help alleviate congestion.

There are, however, some issues when it comes to smart mobility. These issues can be broken down into three major blocks: cost to implement and maintain ITS, legal challenges, and the issue of adoption.
When it comes to cost, it comes down to the simple issue that updating the infrastructure anywhere to support IoT will be costly, and updating and maintaining a system like that will be so as well. The city of Bellevue, Washington, United States of America released their plan for their smart mobility initiative and estimated the capital expenditure from 2019 to 2023 to be 3.6 million United States Dollars (USD), and an upkeep cost of 1,925,500 USD for those same five years (Transpogroup 2018). That combines to a total cost of 5,525,500 USD over the course of five years. Bellevue in 2020 had a reported population of 151,864 people and covers around 33.46 miles with an estimated 4,538.2 people per square mile according to the 2020 census(United States Census Bureau, Bellevue 2023). This cost may change due to other factors such as availability of the technology, and the number of changes needed to allow the location to achieve an ITS system. These numbers provided by the City of Bellevue help give a real-world example of the theoretical cost needed to maintain and create such a system at that population and can be used to extrapolate the cost of similar initiatives.

The next issue is that of legality, of which there are many. If a fully automated ITS fails and causes an accident which harms or kills someone, who is at fault? What about data privacy? An ITS, in theory, operates best with up-to-date location services and connections with vehicles on the road. What if people do not wish to share their location? That can undermine the intent of an ITS especially one designed around only using fully automated transport. Are you at fault when your fully automated vehicle that you are having pick you up in front of a store causes an accident even if you were not in the car? What happens when a fully automated car exists without a human safety measure and causes an accident? What about ensuring that the intelligent capabilities of a car are secure from cyberattacks that could cause accidents or death in worse cases. Such things will need to be codified in the future to enable smart mobility to its fullest, and these questions are very important questions to ask.

Past that, there is still the question of adoption. New technology often takes years, or a decade or longer, to gain mass market use. Most markets do not wish to ban legacy technology, so any solution implemented in these areas will require accommodating legacy cars that lack intelligent capabilities. That however circumvents the intent of modernized ITSs, as older cars that lack intelligent capabilities will only be detected by roadside sensors which can decrease the efficiency of such systems. It could also potentially lead to cases where the ITS, lacking information on a non-connected vehicle, accidentally advises a car in a way that causes an accident.

These issues are not insurmountable: legally codifying rules to help the implementation of ITSs and automated driving systems, public sector and private sector working together to implement smart solutions in areas, offering tax breaks to those that buy in to ITS and intelligent vehicles. Moving forward, these questions must remain in our mind as implementation of smart mobility initiatives move forward.

5.4 Handling Big Data

Another big question is how can all the data needed in these smart mobility initiatives be stored and accessed? When it comes to storing the data there are three potential answers: on premise storage, hybrid storage or cloud storage. On premise requires there to be a shared data storage that all devices connected would send their data to that is located physically in that area. This would cost a lot in initial setup, as the amount of data would undoubtedly be massive requiring a equivalent amount of storage. A cloud solution would offload the job of hosting and storing the information on a cloud service provider such as AWS, Azure, Alibaba, etc. This would still be costly as monthly upkeep would then be required to keep the service active and working and has other issues in the case that the data cannot be accessed which could thwart the planned operations of these ITSs. Finally, there is hybrid which would have some data stored on premise and other data stored on a cloud-based service. Optimally, data needed for immediate actions such as car location, pedestrian information, and road hazards would be stored in a locally accessible data cache while data not immediately needed could be offloaded to cloud services to keep the system enabled even in the case of a cloud service outage. However, the solution used will change on a case-by-case basis depending on what needs each location has.

Following this, how the data is processed and what methods are used is the next pressing question. In many studies a lot of focus is placed on the use of neural network classifiers such as convolutional neural networks (Chemali et al. 2022), while other studies use ensemble classifiers such as random forest(Mawonou et al. 2020). The algorithm used will change heavily based upon the task needing classification. An ensemble method such as random forest is often faster and mostly accurate which lends itself to quick training and classification at a lower processing cost compared to more advanced neural network classifiers. Neural networks often require more computational power and are slower to train while being more accurate than linear and ensemble methods depending on the task and given enough data. Each method has its own benefits and drawbacks and will require case-by-case decision making depending on the specific task. For long-term learning it may be more useful to use deep learning methods, while in other cases it may be more efficient to use linear algorithms. In the studies reviewed multiple different methods were analyzed from Support Vector Machine to Particle Swarm Optimization(Chemali et al. 2022). One thing is for certain, for handling massive amounts of data at scale few things are more efficient than a well-designed artificial intelligence for rapid classification. This technology will undoubtedly find use in the achievement of smart mobility, and further optimization of machine learning methods will help assist in the achievement of said smart mobility and should be investigated to find which classifier performs best for what tasks.

7. What Comes Next?

Now comes the question, what are the next steps? The end goal is adoption of smart mobility frameworks to increase efficiency in travel in urban areas and rural areas, and to decrease the amount of resources needed for such mobility. Urban areas are easier to start with as a lot of the infrastructure is closer to being compatible or is compatible depending on the location. While rural areas can be underdeveloped and need more effort to update due to the different nature of said areas as covered by Porru et al.(2020). Further development of these frameworks could also help governing bodies implement working solutions to help ease travel for the populace. Alongside this, research should be done into the best ways to optimize smart solutions that allow for fast decision making.

Further research should be done into optimizing classifiers for traffic control and to optimize automated/assisted driving technologies. Developing these technologies further could reduce the needed input from drivers and theoretically work alongside ITS systems to co-ordinate with other intelligent vehicles on the road. There should also be simulated urban areas to test potential ITS systems, alongside eventually working towards the creation of a physical version of said system as suggested by Al-Turjman(2022) and Lee et al.(2023).
Further research should also go into the optimization of engines to lower the number of resources used. By using machine learning classifiers studies have shown further potential to make engines more efficient and reduce extraneous resource use. Developing this alongside ITS that can create optimal paths that use less energy as well will help reduce carbon emission or energy drain depending on the type of transport used.

Finally, more investigations should be done into local smart mobility initiatives. Papers by Alanazi (2023), Vrščaj et al.(2019), and Magalhaes et al. (2021) offer insight into other countries' smart mobility initiatives which helps show the different approaches taken by each region. By seeing where each initiative succeeds and fails more information can be disseminated, which could help in future implementations by giving a fuller understanding of the process of implementation.

8. Conclusion
Smart mobility is a term growing in popularity as an increased demand for more efficient modes of transportation increases. No one wants to be stuck in rush hour traffic, or in the middle of a city with everyone trying their best to move through the crowded streets. ITSs offer a theoretical fix, by receiving and analyzing all data received through a series of connected devices they can help optimize travel time either by directing traffic or offering routes to those traversing the areas covered. Other potential smart mobility initiatives also are looking into ways to reduce resource consumption of fossil fuels and energy, alongside making it easier to get from place to place. These techniques have real world implementations that are useful. The biggest issue is getting everywhere to the same level to reduce potential hazards and to make life easier when it comes to transportation. Alongside these issues are questions of legality, logistics, and adoption. These questions must remain in the forefront of all designers creating plans to implement smart mobility concepts. Countries like South Korea, Japan, and Singapore have made massive steps with other countries such as Saudi Arabia, France and Spain looking into using this framework to make their own urban areas more friendly for traversal. To help develop these methods and technology, more studies should focus on designing frameworks for locations to use for planning out these updates. By creating easy to understand and apply frameworks can help with adoption and development of key infrastructure needed to achieve smart mobility. Alongside this further study should be done into automated driving tools and finding ways to optimize travel. Finally, legal frameworks should be developed to help ease the growing pains of these new technologies.

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