
Understanding the Opportunities and Challenges of Alternative Sustainable Transportation



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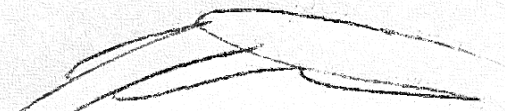
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Abstract

In the last few decades, sustainable transportation has simultaneously gained traction in three, often polarized, sectors of the macro-environment. A flood of sustainable transportation research from academia, large scale investment in the private sector, and significant policy change in the public sector suggest that this topic has gained widespread prominence. These groups are independently progressing in many ways; as cities begin implement transportation alternatives, private companies are racing to develop alternative power sources, ride sharing options, and light-electric vehicles. Like any large-scale change, the progression of sustainable transportation is made up of endless opportunity but littered with challenges. A lack of collective information may be restricting large scale progress in the field of sustainable transportation. This paper aims to synthesize the knowledge from disparate domains with an aim to develop a holistic view of the sustainable transportation field.

Introduction

Just a century ago, civilization was on the brink of a radical shift that changed the entire world, the birth of the motor vehicle. At the time, this alternative mode of transportation was faced with endless implementation challenges and uncertainty. Over 100 years later, car ownership has still not reached its peak. With large populations entering the middle class, more and more people around the world are now able to own the famed symbol of success and freedom, the car. To put this growth in perspective, “the world was home to around 670 million vehicles in 1996” (Chesterton 2). Though today's specific vehicle count is difficult to obtain, industry analysts believe that a total of 1.4 billion vehicles exist on our roads today (Chesterton 1). Our cultures and economies have developed a radical relationship with motor vehicles and the adverse effects are quickly accumulating.

With a seemingly endless amount of scientific research confirming the negative affect of CO₂ and pollutant emissions on the climate and the general population; this article does not set out to make a case for or against climate change or fossil fuels. Instead, this paper attempts to only analyze what is to come using the most relevant information available. Instead of raising awareness, this paper aims to analyze the potential opportunities and challenges of how people will move in the future. The high demands and expectations of a mobile population has put great pressure on transportation methods and transportation infrastructure. Sustainable Transportation has become a central focus for systems across the world as the century-old method of producing more cars and building more roads is exhibiting indications of maximum capacity in many urban communities. With limited success in sustainable transportation implementation, academics, governments, and industries must collaborate to better understand products, strategies, technologies, methods, and policies that make a positive large-scale impact. It is necessary to gather a foundation of information regarding sustainable transportation and analyze the intersections of diverse existing knowledge to better understand the future of sustainable transportation.

I. Context

Sustainable Transportation in practice is difficult to define indefinitely because we do not yet know how it will exist and function in its final form. There have, however, been many attempts to define sustainable transportation as a concept. Without a universally accepted definition, simplicity takes priority. For the purpose of this article the concept is defined as “satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs” (Black 151). Understanding this definition is of key importance to this paper, as researchers, companies, and governments alike become obsessed by a single mode of sustainable transportation, through usage of light electric vehicles, hydrogen cars, bicycles, public transportation, policy change, or technology advancement. The current focus has not yet inspired or demanded large-scale change.

The 2012 Harvard Business Review Article ‘Saving the Planet: A Tale of Two Strategies’ effectively boils the sustainability dichotomy into two core pursuits; Innovation vs. Restraint. All potential sustainable transportation solutions can be placed into these two families. The theory of restraint stems from the Anglican political economist Thomas Malthus who believed “Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio.” (Martin & Kemper 4). In more modern terms, Malthusianism makes the logical case for restriction; Eventually, economic growth will result in a depleted ecosystem that can no longer support the world’s population. In direct contrast, Nobel Prize winner in economics, Robert Solow explains “If it is easy to substitute other factors for natural resources, then there is in principle no ‘problem.’ The world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe.” (5). Solow’s thinking in practice suggests that the power of innovation and technology can indefinitely extend human dependence on its resources. These opposing theories help diagnose the growing number of steps towards sustainability that currently exist.

Though the dichotomy of the innovation and restraint pursuits cannot be erased, it is possible for the two beliefs to work together. Technology entrepreneur Elon Musk and his many endeavors are unquestionably centered around sustaining human existence. Both the aerospace manufacturer SpaceX and the automotive company Tesla are transportation companies. Tesla is constantly pursuing electric car innovation which would not exist without acceptance of Malthusianism thinking. Admission of the inevitable threat recognizes that our finite resources that will eventually be exhausted. In contrast, the admission of this Malthusianism thinking is absolutely what has driven Tesla's desire to innovate and disrupt outdated and destructive technology. The case can be made that Tesla's resilience and success found its opportunity in thinking aligned with Thomas Malthus, however, its solution is grounded in Solow's line of reasoning. As indicated by this example, the future of sustainable transportation will be made up of both restriction and innovation. Though the two methods seem to work in opposite directions, they are both pursuing the same goal. Restriction and innovation must be encouraged because in practice, they seem to be co-dependent.

II. A look at Sustainability and Efficiency

Quality transportation maximizes efficiency and productivity for both daily commuters and the commercial transport of goods. Whether you're a multi-national company like Coca-Cola distributing your products across hundreds of international supply chains or a commuting family, efficiency is valued. Efficiency in transport is the reason one might speed up to make a green light, the reason people pack subways trains full, and the reason companies allocate significant resources to transport good via plane rather than ship. Thankfully, sustainability often benefits from efficiency improvements in the transportation sector. For example, leaving 30 minutes earlier for work to avoid major traffic buildup on the interstate cuts commute time from 40 minutes to 30 minutes. Avoiding traffic, in this way, is commonplace especially in growing cities with deficient infrastructure. Saving just 10 minutes on your way to work everyday results in at least 50 less hours your car is running annually, saving you money on gas and wear on your vehicle. For context, if Canadian motorists alone made this efficiency improvement in their daily commutes over 4.5 million tons of CO₂ emissions could be avoided. That is equivalent to removing over 1 million vehicles from the road for a year (NRC-Transport Initiatives). A

driver's decision to cut 10 minutes from their morning commute was not made as an effort to be more sustainable, but in a decision to be more efficient because the driver simply wanted to spend less time in traffic every morning. Efficiency and sustainability are often co-dependent and allow collaboration towards a common goal.

Maximizing transportation efficiency on a large scale is an extremely complex task. Typically, these issues exist in developing urban areas and large cities experiencing growth. Infrastructure and transportation improvements require a significant monetary investment, usually from a highly scrutinized public budget. This aspect adds a unique challenge for investment in sustainable development, as investing in alternative transportation initiatives is inherently riskier. A 2018 Article brought together knowledge from numerous academic fields in Chongqing, China to develop a simulation approach to assessing potential transportation strategies to help overcome emerging transportation challenges in growing Chinese cities (Shen, Du, Yang, Wang & Hao 35). This is a highly valuable tool in promoting sustainable development as an improved ability to test and determine the efficiency and effectiveness of alternative transportation methods will minimize risk. Improved ability to simulate transportation methods will “assist decision makers in assessing the effectiveness of different transportation strategies and selecting one that can support the sustainable development of emerging cities in China (Shen, Du, Yang, Wang & Hao 35).” During the study, the group was able to suggest sustainable transportation investments for the ever-expanding city of Shenzhen. The article was able to conclude that improved efficiency could be achieved through three main development strategies: urban road construction, public transportation investment, private traffic restrictions. This conclusion reinforces the general framework of sustainable transportation development. It is important to note, the study failed to consider emerging conditions such as renewable energy vehicles and light electric vehicles. The simulation approach has proved to be effective in gauging development strategies and the future efficiency gains. With this knowledge, investment in simulation all potential sustainable transportation investments should be assessed to maximize efficiency gains.

III. Analyzing sustainability intention and perception

Large cultural movements require a shift in social beliefs and values. Future development of sustainable transportation will be driven by the perceptions and intentions of the majority. Environmental sustainability is still a contested and debated topic for many which explains the limited progress most environmental initiatives have made. Sustainability perceptions and intentions are well studied in the context of understanding the growing importance of corporate social responsibility. Two key people groups have been identified as focus points. Both college students and employees are heavily studied and researched in motivational fields. These two people groups represent different age groups, this difference can represent current perception and how it differs from emerging perceptions. Analyzing existing research regarding employee and student views will provide a better understanding of the future of sustainable transportation.

A. Employee Perspective

The private sector plays a large role in influencing the future of any sustainable initiative. Companies have a large influence on both the supply and demand sides of the transportation sector. As the importance of corporate social responsibility continues to grow there is reason to believe that this will be a major driver of sustainable transportation. Analyzing current research on employees' perceptions and intentions of corporate responsibility can provide insight to the current climate. Employees can give an accurate and current picture of corporate social responsibility within companies as they are more directly exposed to the real actions of companies. Though consumer demand is what eventually controls and demands responsible actions, customers are less prone to marketing bias. Beginning with a look at current employee perceptions of corporate responsibility to set the current climate stage. Corporate Social Responsibility is defined as "context-specific organizational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance" (Aguinis 855). Over the last few decades companies who investment in CSR have often experienced improved competitive advantage and profitability. A 2018 article in the Journal of Management developed a scale for rating employee perceptions of

CSR within their organization (Akremi, Gond, Swaen, Roeck, Igalens 626). This study was conducted using data primarily collected from employees of a few French firms. The 39 scale items distributed through questionnaires were split into six different factor types (620). Natural environmental-oriented CSR is the most closely related to sustainable transportation. An average internal consistency of 0.67 for natural environment-oriented CSR (630) indicates that environmental perception is relatively consistent with the greater topic of corporate social responsibility. This consistency suggests that as corporate social responsibility continues to grow in importance for all stakeholders, the relevance and importance of environmental efforts will progress.

B. Student Perspective

As younger generations flood the workforce, organizations are placing higher importance on environmental objectives. To remain relevant and competitive, environmental education is being built into university curriculum. A unique challenge presents itself as “personal views on environmental sustainability can differ significantly wherein individuals may range from passionate environmental advocates to cynics who dismiss environmental objectives as trivial and even fictitious” (Swaim, Maloni, Napshin, & Henley (3). This challenge led a team of researchers to study the factors that influence student behavior and intention toward environmental sustainability. The information and data found provides great insight into the inhibitors that are promoting and restricting all sustainability initiatives. Three factors that control intention and behavior toward environmental responsibility are “*Attitude* toward environmental sustainability, *Subjective Norm* toward environmental sustainability, and *Perceived Behavioral Control* toward environmentally responsible behavior” (7). Results found that the most significant link between influence and intention of environmental sustainability was the path from attitude to intention (14). Student attitude is simply the students personal feeling toward environmental sustainability (7). The importance of the student’s general attitude played a significantly larger role in predicting student behavior than other factors. The best way to shift attitude through immersion. Though projects, debates, dialogs, and interviews can lead to shifts in attitudes, “immersion in actual situations and/or locations with current sustainability issues, whether physical or virtual, can further provoke student attitude evaluation” (21). In pursuit of

greater environmental education, immersion is recommended to build influence and behavior. Another factor that influenced relationship towards behavior was subjective norm, “willingness to conform to environmental sustainability beliefs of referent groups” (8). The largest example of this factor in education is the ability of a professor to encourage students to adapt their opinion. Educators must approach this method with great caution as “a professor should be unbiased impart sustainability facts and evidence” (22). Educators also risk alienating some students by attempting to encourage conformity as many will respond by becoming even more entrenched in their current beliefs. This implies a long-term negative impact toward sustainability initiatives, which should be avoided.

C. Transportation Application

With a better understanding of the intentions and perceptions of general environmental sustainability research, shifting statistics in current transportation methods can be analyzed. According to a 2012 MITSloan article “New research shows that young people from the U.S. and Canada to Germany and South Korea are driving less, biking more and using public transportation in significantly higher numbers” (Brokaw 1). As improved sustainable transportation intentions are difficult to track, analyzing a younger age demographic paints a clearer picture. Below are statistics reported by the U.S Public Interest Research Group (Brokaw 2),

- **Driving is down:** The number of vehicle miles traveled by 16 to 34-year-olds in the U.S. dropped 23% between 2001 and 2009. As well, the share of 14 to 34-year-olds without driver’s licenses grew between 2001 and 2010 from 21% to 26%.
- **Biking is up:** In 2009, 16 to 34-year-olds in the U.S. took 24% more bike trips than in 2001 - even with that age group shrinking in size by 2%.
- **Public Transportation is up:** Public transport use by that same group also rose in the same period – passenger miles traveled are up by a huge 40%.

These statistics are very much in line with much of the academic research regarding intentions of sustainability. The study notes that the reduced driving trend “has occurred among young people who are employed and/or are doing well financially” (Brokaw 3). This is important to note as

underemployed populations inherently have greater difficulty affording personal vehicles. Considering the trends still exist among financially well individuals, the underemployed counter argument is invalid. This trend is a strong indicator that infrastructure and transportation demands are shifting with an emerging generation. According a 2012 US. Public Interest Research Group Report *Transportation and the New Generation*:

“America’s transportation policies have long been predicated on the assumption that driving will continue to increase. The changing transportation preferences of young people – and Americans over – throw that assumption in doubt. Transportation decision-makers at all levels – federal, state, and local – need to understand the trends that are leading to the reduction in driving among young people and engage in a though reconsideration of America’s transportation policy-making to ensure that it serves both the needs of today’s and tomorrow’s young Americans and moves the nation toward a cleaner, more sustainable and economically vibrant future” (Davis, Dutzik & Baxandall 27).

IV. The Role of The Private Sector

Though the often discussed as a political topic, sustainability initiatives often find themselves deeply engrained in the private sector. Whether it be solar panel technology, electric vehicles, or nuclear energy, the bright minds of the private sector have built and perfected these sustainable technologies in the competitive arena. Reaching truly sustainable transportation, specifically, is impossible without the dedication of the private sector. Significant monetary opportunities await businesses willing to invest in sustainable transportation technology whether it be, traffic control units, autonomous transport, or hydrogen vehicles. A look into the transportation sectors private sector will be split into four focus groups: electric vehicle outlook, alternative fuel development, light electric vehicle outlook, and the growth of shared micro mobility.

A. Electric Vehicle Outlook

Electric Vehicle transportation is rapidly growing in popularity. Thanks to improved practicality and affordability EV’s are becoming more commonplace. As of 2018, “the global electric car

fleet exceeded 5.1 million, up 2 million from the previous year” (Global EV Outlook 2019 4). Though that number makes up a small percentage of the previously estimated 1.4 billion vehicles on our roads today (Chesterton 1) there is reason to believe the future is in electrification. China makes up nearly half of the electric car sales, with 2.3 million units which were purchased in 2018 (13). Europe and the United States followed behind, each purchasing just over 1 million units each (13). Many other markets are seeing growth in electric vehicle sales, but not as significant as the three major markets mentioned.

It is important to notice, that though electric vehicles are becoming more commonplace, electrification does not inherently remove their carbon emissions. Of course, electric power is often derived from carbon emitting powerplants. This is a major criticism for many sustainable transportation critics. There is, however, solid data that provides a clearer understanding. The entire stock of electric vehicles around the world emitted an equivalent total of 38 million tons of carbon-dioxide (14). With the same size fleet of internal combustion engines, 78 million tons of carbon-dioxide would have been emitted (14). Though the carbon emission issue has clearly not been solved, this shows that the investments auto manufactures are making in producing and selling electric vehicles is having a net positive effect on the environment. With improved battery technology and greener power generation, electric cars offer the potential of a net zero environmental impact. Pure green power sources still require significant emissions during the construction and disposal process. In its infancy, the supply chain construction and disposal costs are believed to be higher than traditional vehicles. Further, the full life cycle emissions are likely to decrease as EV supply chains become more robust and competitive. Recyclability and disposal costs remain unestablished.

The automotive industry is at an interesting point in its history. Demand for vehicles in most markets has begun to plateau but electrification has re-ignited the industries excitement. Both century old auto manufactures and countless zealous EV startups are all racing to build the vehicle that consumers desire. A look into two polarizing auto manufactures that are both racing to enter the EV market will help develop a picture for the industries uncommon situation.

Established vs Startup EV Competitors

| | Volkswagen Group | Byton |
|------------------------------|-------------------------|------------------|
| Founded | 1937 | 2017 |
| Headquarters | Wolfsburg, Germany | Nanjing, China |
| Number of Employees | 656,000 | 1,600 |
| Planned EV Models | 75 models by 2029 | 2 models by 2022 |
| EV Funding | \$33 billion (by 2024) | Unknown |
| Vehicles sold in 2018 | 10.8 million | 0 |

(Szymokowski 1 & Bryton Wikipedia)

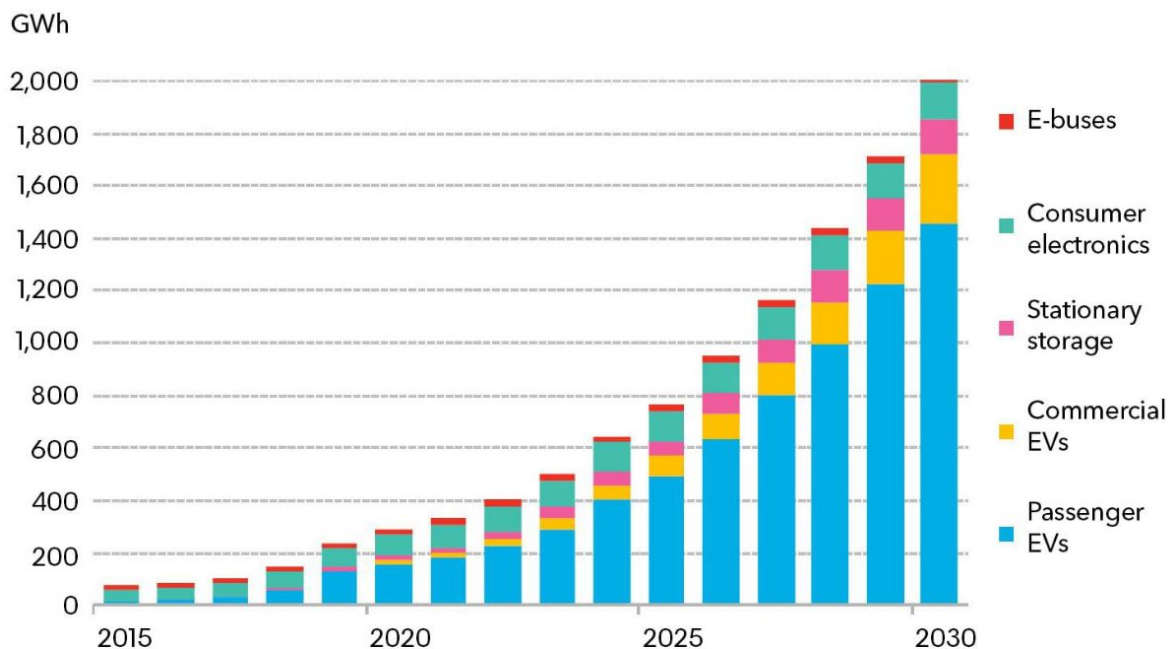
At first glance, it may seem as if an EV startup would have no chance against the massive Volkswagen company. Tesla is largely responsible for inventing this market segment and was able to reach success at an even more difficult time in the industry. The large multi-national automotive companies will be slower to respond and evolve which has unlocked a large opportunity for smaller auto manufactures to fill. Industry giants like Volkswagen, Fiat Chrysler Automobiles, and GM will be fighting off an entire army of EV startups which will pose a significant threat. The high level of competition in this developing industry shows no signs of slowing down. EV technology will continue to quickly evolve over the next decade. Companies who choose to innovate and respond to change quickly are likely to end up on top, a daunting task for more bureaucratic automotive giants.

B. Alternative Fuel Development

Advancements in battery technology are beginning lower costs and improve performance benefits for EVs. In recent years the cost of electric vehicles has dropped significantly, quickly headed towards the competitive pricing of traditional internal combustion vehicles. The battery is the single largest cost when developing and manufacturing electric vehicles. For example, “Buy a Tesla Model 3, for instance, and an estimated one-third of the \$35,000 price tag is from the battery” (Ma & Thomas 2). With the increasing demand and public interest in these vehicles, auto manufactures are putting pressure on their research teams and suppliers to make

improvements in performance and affordability of EV batteries. Below is a diagram of project annual lithium-ion battery demand by Bloomberg's energy research organization.

Annual lithium-ion battery demand

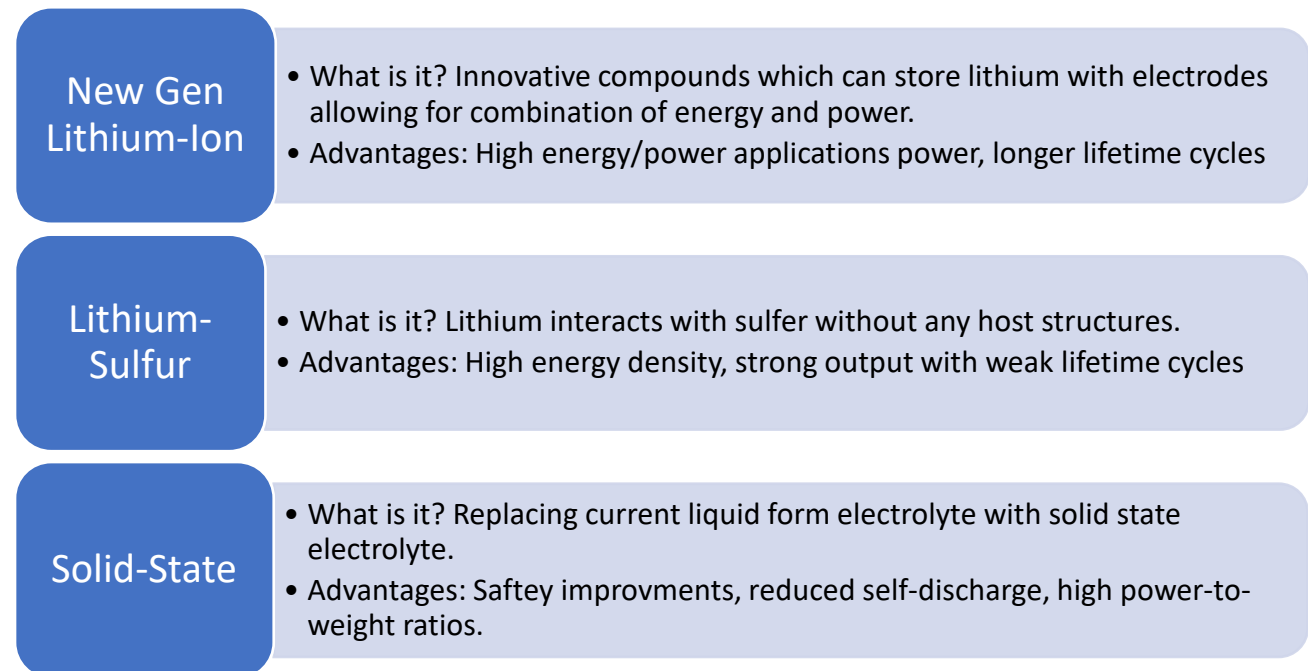


Source: BloombergNEF, Avicenne

Passenger electric vehicles are expected to drive the demand of lithium-ion batteries exponentially. Battery cost and performance have seen incredible development in recent years, however, are still the two largest factors holding back passenger EV growth. This bottleneck cost factor for electric vehicles has led to an international technology race, with one country leading the pack. Though many countries are researching and developing battery technology, China seems to largely control manufacturing. As of April 2019, “Of the four main components in a lithium battery, China manufactures 65.7 percent of the anodes, 64.3 percent of the electrolytes, 44.8 percent of the separators, and 39 percent of the cathodes. U.S. companies, however, barely register” (Ma & Thomas 4). China is largely controlling the lithium-ion manufacturing process and shows no sign of letting go. Whatever the country is doing from a business and policy perspective is leading a massive shift in powering their transportation. China recognizes this trend and is acting on it quickly, “Benchmark Mineral Intelligence is now tracking 70 lithium ion battery mega factories under construction across four continents, 46 of which are based in China with only five currently planned for the US” (Stutt 2). From a competitive business approach,

China seems to be far ahead of any other countries in this area. Quick response to a growing intentional market opportunity and fast-acting policy change plays into China's success around the EV industry. An in-depth look into the transportation policies and processes of their government at both a national and local appears later in this manuscript.

Lithium-ion may seem to be the clear future for battery technology; however, research is being conducted with reasonable success in other directions. Though an in-depth understanding of how a lithium-ion battery works is not relevant in this study, a basic understanding of the technology basis may be helpful. "In lithium-ion (Li-ion) batteries, energy storage and release is provided by the movement of lithium ions from the positive to the negative electrode back and forth via the electrolyte" (Bernard 1). As with any technology, there is only so much performance and efficiency that can be derived. It is likely that, "With actual materials and cell designs, Li-ion technology is expected to reach an energy limit in the next coming years" (Bernard 1). Considering the approaching energy limit, three possible options for new generation batteries are discussed below:



The future path of battery technology development is entirely uncertain, but innovation is guaranteed. Electrification within the transportation industry is showing signs exponential

growth in the near future. Competition in the private sector over innovation will drive sustainable transportation adoption through electrification.

C. Light Electric Vehicles

Adoption of Light Electric Vehicles as a mode of daily transportation is believed by many to solve many of the urban transportation challenges while remaining sustainable. These LEV's offer a viable alternative for the transportation methods currently used in urban settings especially. Vehicles that fall into this category are electric skateboards, bicycles, four-wheelers, Segaways, scooters, and more. Electric bicycles are already offered by many traditional bicycles manufactures and other e-bike startup companies. In recent years, consumers have proved their interest in electric bicycles with their purchasing power. Like most other areas of electrification, China is the largest current market for electric bicycles (Hyvonen, Repo, & Lammi 259). Many European countries are catching on to this trend also. According to Cycling Industries Europe CEO Kevin Mayne, "There has been an increase of 36% in Germany, with 980,000 e-bikes sold last year. We had predicted that it would take until 2024 before more e-bikes were sold in the Netherlands than [mechanical] bicycles, but that milestone was reached last year" (Reid 2). This purchasing trend indicates a shift in the desired transportation methods of many in Europe. It is worth noting that many of these electric bicycle purchases are for recreational purposes and should not all be viewed as sustainable transportation solutions.

For consumers there are numerous options when considering a purchase of a Light Electric Vehicle. Factors such as commuting distance, typical terrain, budget, and ease of use will help guide a purchaser to a specific product. Bicycles, scooters, mopeds, and skateboards are all traditional modes of transportation which have been electrified in recent years. These are the four most basic categorization of LEV's. It is important to understand which LEV types consumers are purchasing to predict what the future of LEV use will be. Each general vehicle type has different strengths and weaknesses which intelligent consumers likely use to determine their purchase.

The electric bicycle industry is the largest LEV subsector with a market valued at "\$16.34 billion in 2017, and is expected to reach \$23.83 Billion by 2025" (Jadhav & Baul 3). This

statistic, however, does include some overlap from electric moped and electric scooter sales as some industry analysis have not yet differentiated sales data between the two. Considering the recent emergence of this industry, this article will still separate LEV's into the four basic categories defined above. Electric bicycles are typically pedal assist, which means there is no throttle go

generate power. As you pedal the bicycle, the electric motor will assist in propelling the vehicle forward. Electric bicycles can be purchased or built by outfitting electric battery, motor, and other accessories to an existing bicycle platform. Many manufactures also offer a folding bicycle version which is aimed at consumers in urban environments with limited storage space. Other benefits of electric bicycles are the general reliability and ease of use. The largest barrier to purchase is the relatively high cost. A median quality electric bicycle will cost a consumer upwards of \$2000.

Electric scooters are stand up battery-powered light electric vehicles. These scooters are often foldable and easy to store in an urban environment. Due to their smaller size, the range and top speed is typically lower than its bicycle competitor. The scooters are typically also priced lower than an electric bike which is attractive for many consumers. The scooters have smaller wheels and require the user to stand up which can result in a less comfortable ride. Unlike other LEV's, electric scooters have attracted ride sharing companies in recent years. Likely due to the vehicle's simplicity, relatively low cost, and



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limited maintenance. According to a Planet Forward article, “in highly congested urban areas, use of the scooters can relive some car traffic and emissions (Bernard 2). The adoption and expansion of these scooter sharing companies around the country seem to suggest a significant potential for this type of LEV in the future of urban transportation.

Electric Mopeds are larger, heavier, and more refined form of light electric vehicle transportation. These mopeds are more outfitted than an electric bicycle typically made up of fenders, plastic body lines, storage, and a larger seat. These mopeds are often a premium priced option but give the user more features and a more comfortable ride. It is likely that these vehicles will eventually require registration and possibly insurance as they are often capable of motorcycle like speeds and ranges. Traditionally, mopeds have been an alternative transportation method with small gasoline engines. With the introduction of electric motors into the mix, mopeds may become a viable option in LEV transportation in both urban, suburb, and rural regions.

Electric skateboards are a unique example of an LEV. These vehicles require slightly more skill to ride than the other options discussed. Most adults are comfortable riding a bicycle while most adults are not comfortable on a skateboard. The approachability and safety challenge are likely the greatest inhibitors to the greater adoption of these electric skateboards. Due to the infancy and small size of this industry sub-sector, there is limited information available. Some benefits of the electric skateboard are the relatively low cost and simplicity of the vehicles. The vehicles are also very compact for a mode of transportation and easily stored in an apartment or urban work setting.

D. Shared Micromobility

The rapid population growth in cities and urban areas continues to threaten current transportation systems, a mobility services has emerged in the private sector. The term Micromobility “constitutes forms of transportation that can occupy space alongside bicycles (Zarif, Pankratz & Kelman 2). Micromobility is a collective term that includes all the LEV types discussed previously, as well as their unelectrified counterparts. Compact, personal alternatives to urban transportation is not new. Very recently, businesses across the world have begun using

micromobility as a service in urban areas. These companies typically offer shared electric scooters, electric bicycles, and traditional bikes. The vehicles are typically unlocked and paid for using a smart phone and can either be stored on any sidewalk or, sometimes, at specific docking stations. According to the National Association of City Transportation Officials, “In 2018, people took 36.5 million trips on station-based bike share systems and 38.5 million trips on shared e-scooters. (Zarif, Pankratz & Kelman 4)”. Just one year prior, these shared scooters did not even exist. In a matter of one year, the electric scooter usage matched that of shared bicycles which has existed for over a decade. As one new mode of alternative transportation was introduced, consumers adopted quickly, “More than twice as many trips – 84 million – were taken on shared micromobility in the U.S. as compared to the year before (Zarif, Pankratz & Kelman 2).” The success of shared electric scooters services in 2018 is interesting as exhibited pent up demand of shared urban transportation. This should give sustainable transportation firms confidence in their consumer demand moving forward. Even more interesting, data for NACTO, suggest that people are not only using these shared micromobility methods for just transportation. These services are also modes of social interaction, recreation, exercise, and connection to transit. Given usage data for this new technology only exists for 2018, future analysis will determine the utility and longevity of shared micromobility as a sustainable transportation method.

E. Dangers

The popularity growth of alternative electric scooter and bicycle use has been widespread. The rate of its expansion has grown as quickly as its backlash. Questions over electric scooter safety have been raised nationwide in urban communities. Regarding craniofacial injuries, “According to a new Rutgers University study, the number of incidents climbed from 2,325 in 2008 to 6,957 in 2018. A staggering 66% of those treated were not wearing helmets” (Abrahamson 2). This factor has generated a lot of attention in cities where shared scooters have become popular. Considering the 38.5 million trips taken last year, a 0.018% chance of a craniofacial injury is likely a risk many are willing to take. For application, that is less than 2 incidences per every 10,000 uses. Many communities are pushing for regulations in varying degrees. Some communities suggesting everything from helmet laws to outright bans. In response to a 2019

Article shining light on these safety risks, one of the largest micromobility players, Lime stated “We appreciate the attention on this very important issue, and we look forward to continue working with the industry, medical community and regulators to create a meaningful ecosystem for this new evolving technology” (Abrahamson 4). Though this form of alternative urban transportation is not without its flaws, after accident analysis the activity seems relatively safe. The high society costs attributed to cranio-facial injuries are significant and should not be overlooked. The additional suffering, medical care, insurance costs, and uninsured costs to society can be minimized by helmet laws. It is highly unlikely that shared electric scooters will be going anywhere over safety concerns, any time soon. It is possible that helmet laws are a cost-effective solution in minimizing the injuries attributed to this transportation option.

V. The Role of The Public Sector

The Public Sector will play an equally important role in the large-scale adoption of alternative transportation. As the private sector meets consumer demands the public sector should act quickly to maximize the benefits of new transportation options. We do know that as urban populations grow and resources dwindle, sustainable transport improvements and alternative transportation methods will be imperative. Public perception of alternative transportation and sustainable transport is shifting and growing in popularity. As the private market has begun to shift and react, the public sector of the economy will eventually follow suit. In the context of transportation, the public sector is responsible for infrastructure and regulation. In the context of infrastructure, the public sector funds, maintains, improves, and operates the roadways, waterways, railways, and airways within its nation.

In the United States the Department of Transportation is responsible for all the national transportation needs. Established in 1966, the DOT is made up of 11 operating administrations which all specialize in different modes or support roles in the sector (U.S. DOT 2019). As stated on their website “the mission of the U.S. Department of Transportation is to ensure our Nation has the safest, most efficient and modern transportation system in the world, which improves the quality of life for all American people and communities, from rural to urban, and increases the productivity and competitiveness of American workers and businesses (U.S. DOT 2019).” With no direct mention of sustainability in the mission statement, a mention of the

previously discussed link to efficiency and sustainable should be recognized. If the two are synonymous, then continuous efforts in the public sector towards sustainable transportation are intended. The U.S. DOT sustainability statement was last updated in November of 2014 and does not mention any systematic goals of sustainable transportation. The statement does, however, state “DOT employees at all levels must be responsible and accountable for integrating sustainability stewardship into day-to-day activities” (U.S. DOT 2014). The United States public sector cannot be considered a core proponent of sustainable transportation.

In clear contrast, the Mobility and Transport department of The European Commission is responsible for transportation policy in the European Union. The commission is full of sustainability statements, initiatives, and goals. The sustainable transport page states:

“Our aim is to reduce the adverse effects connected to mobility. This means, above all, promoting co-mobility, i.e. optimally combining various modes of transport within the same transport chain, which looking forward, is the solution in the case of freight.

Technical innovations and a shift towards the least polluting and most efficient modes of transport – especially in the case of long distance and urban travel – will also contribute to more sustainable mobility.” (EU Mobility and Transport 2020).

Mission and policy statements do not guarantee results or any form of positive change. Rather, statements of sustainable values indicate intention. Plan, desire, and intention are preliminary factors of any form of action and should be stated clearly. A closer look into transportation infrastructure around the world will provide a sustainability acumen.

A. Infrastructure for Sustainable Transport

Transportation Infrastructure is fundamental to a nations well-being by connecting employees to employers, consumers to businesses, families, and friends. The private sector is generally responsible for most of a countries infrastructure with a general exception of rural privately owned roads. One of the most unique urban infrastructures’ is the Denmark cycling system. In Denmark all urban planning is conducted to intentionally remove automotive and trucks. This allows for a denser city design, resulting in more efficient travel by foot or bicycle (Gesslein 2015). Bicycles are viewed as transportation vehicles instead of recreational vehicles

and are sold with more safety and utility features; weatherproof internal gearing, reliable roller brakes, safety lights, and traffic signals. A hindrance to the adoption of bicycle transportation is weather, while Denmark the highest rates per capita of bicyclist and is often rainy. A few infrastructure differences which promote alternative transportation are described below:

Bike paths in Denmark are often raised a few inches, like a pedestrian sidewalk, to provide a physical separation from automobiles and cyclists. This physical lane discourages crossover from both parties involved, keeping cyclist out automobile's way and cars out of the cyclist's way. Investment in this form of urban infrastructure would encourage alternative transportation in the cities around the world.



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Another key aspect of alternative urban infrastructure is specialized storage space. In many cities, bicycles can be found on the streets locked to any street pole, sign, or fence. This is counter productive to urban transportation as it packs the streets and takes up unnecessary room for pedestrians.

Specialized storage also includes allocated space on trains, taxis, and buses to encourage co-mobility as recommended by the EU Mobility and Transport department. Provided is an



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image of a robust and efficient bicycle storage system that can encourage alternative sustainable transportation.

Some claim that the public sector is not capable of effectively improving the shortcomings of the United States aging transportation infrastructure. A 2014 paper written by microeconomist; Clifford Winston lays out three potential ways firms in the private sector could help improve infrastructure performance. After analyzing pricing, investments, inefficiencies, policies, privatization, and modes, Winston concludes that “history appears to be repeating as transportation modes are exhibiting technological advances that will user in a new era of highway and air transportation. As noted, innovations with modal advances spurring infrastructure to improve (Winston 182).” Though the author favors private sector improvements, the concluding statements suggest that technology advancements will demand infrastructure innovations, regardless.

VI. Key Findings and Conclusion

The large-scale advancement of the motor vehicle, over a century ago advanced the strength and capability of economies around the world. Transportation continued to improve and refine itself into the system we have today. The ability to move products and people has allowed an international economy to thrive and led to modern-day globalism. The 21st century may see yet another drastic shift. The perceptions and intentions of today’s emerging population value an improved system of transportation. A system that focuses on efficiency and productivity is a system that maximizes long-term sustainability. There is clearly a gap between the demands of a modern transportation system and the infrastructure that currently exists.

Governments and economies are beginning to address this problem with academic research and technological advancement in the private sector. Energy firms throughout China quickly enhancing power generation with battery advancements. The country is also producing unprecedented research regarding efficiency maximization through regulation, simulations, and incentives. American automotive manufacturers are simultaneously exploring alternatives to the internal combustion engine to compete for the emerging EV market. Small startups, around the

world, are bringing alternative transportation methods such as LEVs and micro mobility options to market. European countries have implemented and have proven the sustainability and effectiveness of alternative transportation infrastructure. With a global view, the future of transportation has arrived. As the advantages begin to become evident, public and private sectors around the world can continue to strengthen their weakest links.

In conclusion, the transportation system has not yet experienced large-scale change. While no country or economy has all the answers, many countries have made significant advancements in different areas of sustainable transportation. Collaboration and adoption of successful alternative transport methods between competing economies will lead to decreased energy dependence, a reduction in emissions, and systematic efficiency gains. The demand for an evolved transport system shows no signs of slowing. The strengths and weaknesses outlined in this paper can direct private and public sectors to innovate and adapt to meet the growing demand. As economies and governments compete for strategic advantage in both the transportation and energy industries, a lack of collective information restricts large scale progress. The cumulative information gathered in this manuscript provides a wide-angle view of the current opportunities and challenges of wide-scale sustainable transportation change.

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