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Electric Vehicle Weights and Infrastructure in Civil Engineering Courses

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Abstract

Electric vehicles are significantly heavier than their petroleum counterparts, some weighing an additional 3,000 pounds. In addition to the electric vehicles being drastically heavier than petroleum cars, petroleum cars have increased in size which directly correlates with the weight of the vehicle. The average car weighs approximately 650 pounds more today than they did 60 years ago. The additional weight places higher demands on our infrastructure.

As civil engineers, we are counted on to provide safe and secure infrastructure. This work studies the additional weights of current vehicles and their integration into civil engineering university courses. It works to contribute to greater awareness and knowledge of future civil and structural engineers around the additional weights of electric vehicles and infrastructure demands.

Faculty were surveyed at 3 institutions. Faculty were asked about their perceived importance of the topic of vehicle weights and infrastructure, if they had included this topic in their civil engineering courses, and their thoughts on applicable courses and teaching methods.

Results showed that 28% of faculty perceive this topic to be of high importance, 50% mid importance and 22% low importance. The course that was voted as most relevant was Transportation Systems, followed by Concrete Design and Computational Structural Analysis, then Mechanics of Materials. Suggestions for teaching methods include case studies, simulation projects material comparison, bridge design, impact studies, predictive modeling and cost-benefit analysis.

Introduction

It is important for skills gained in university courses to align with workforce needs [1]. A newer challenge for civil engineers is accounting for the heavier vehicle weights of electric vehicles (EV's) in their designs and calculations for new and existing infrastructure. This paper describes the additional weights of EV's and why it is important in civil engineering education. Faculty perspectives are shared and are accompanied by examples of potential coursework to help introduce this topic to students.

Electric vehicles have had an increasing trend over the past decade. In 2013, 97,000 electric vehicles were sold in the United States and in 2023, that number had increased to over 320,000 electric vehicles sold in the United States [2]. And the total number of electric vehicles registered globally hit approximately 14 million in 2023 [3]. With the relatively new type of car on the market, there has been some hype about EV's. EV's are mostly talked and written about in regard to their positive contribution toward reducing greenhouse gas emissions. While less popular, EV's are also written about in many other ways including about their increases in sales, weights, and how they impact infrastructure. Javier Colato and Lindsey Ice write about how EV car sales have increased drastically in recent years and are predicted to continue to increase [4]. Anmar Frangoul and James McDonald and company also agree that EV's are becoming more popular and that the EV trend will continue to grow in popularity [5] [6]. These authors also agree on the fact that EV's are much heavier than their petroleum counterparts resulting in the need for parking garages to be adjusted for the extra weight [5] [6]. McDonald et al elaborate by saying that the codes have yet to be updated, which increases the potential of failure of the infrastructure [6]. Scoblete supports Frangoul and McDonald by writing about the extra weight the EV's bring and the damage that can do to the roads and parking structures but argues a significant source of the damage is from transporting multiple EV's and not from single vehicles [7]. In addition to agreeing that vehicles run by electricity weigh significantly more than vehicles run by gas/diesel, Haye Kesteloo writes about how structural engineers need to focus on upgrading the infrastructure in order for there to be a safe transition to EV's [8]. While some has been said about electric vehicles and their increased weight, few have written about their impact on infrastructure, and we were not able to find any publications that mentioned educating the next generation of structural engineers on the problem. Even though structures are designed to withstand extra weight, and the codes are designed to be conservative, the additional weight of EV's could be putting some infrastructure at risk. So, we think that for greatest safety, the topic of the weight of electric vehicles should be included in universities' civil engineering programs.

As authors, we feel it is important to state that while EV's add weight to the current infrastructure, we still encourage the change, because EV's have many potential positives when it comes to reducing greenhouse gas emissions. Therefore, we do not believe electric vehicles should be removed from the market but rather believe that the infrastructure needs to be prepared for the coming change.

This paper will review facts on electric vehicles and the current codes. Then it will explore the implementation into education and faculty perspectives on the topic. And finally, it will conclude with suggestions and examples to incorporate the topic into civil engineering courses.

Background

The transportation sector is the biggest source of greenhouse gas emissions in the United States [9]. And EV's can have significant emissions benefits when compared to conventional vehicles [9]. Along with the benefits of EV's, there are a host of necessary support. The American Society of Civil Engineering has identified the following as support needed for the planning, design, investment and integration of EV's: establishing reliable funding sources to incorporate EV facilities into existing and future roadways; making recharging speeds comparable to petrol refueling facilities; equitable access to EV charging stations; and the planning, design, construction, integration, maintenance and operation of the transportation and energy networks that support EV's [10]. This paper will focus on the challenge of the increased vehicle weight of EV's on infrastructure.

Electric vehicles weigh more than their combustion counterparts. EV's typically weigh about 30% more than their petroleum partners [8]. The percent of total car sales in the US of EV's on the roads has increased with time from 0.2% in 2011 to 3.2-4.6% in 2021 to 7.5% in 2024 and is expected to have a "strong acceleration" within the next decade: "S&P Global Mobility forecasts electric vehicle sales in the United States could reach 40 percent of total passenger car sales by 2030" [4] [6]. EV's are not solely increasing in the US. EV's are also drastically increasing in China and Europe: "In China, the number of new electric car registrations reached 8.1 million in

2023, increasing by 35% relative to 2022 … [and] [i]n Europe, new electric car registrations reached nearly 3.2 million in 2023, increasing by almost 20% relative to 2022" [11] [12]. The US, China, and the European Union accounted for about 95% of all EV car sales in 2023 [11] [12]. Looking deeper into Europe's different countries; Germany's EV sales decreased while all the other countries increased [11] [12]. Norway leads Europe with 95% of their car sales being electric cars [11]. In India car sales are also increasing, but the challenge in other countries around the world seems to be affordability [11]. In some countries, personal cars are not the most common to travel [11]. Either way, EV's are seen in many countries around the world meaning any advantages or challenges resulting from EV's will be seen in all these countries. Electric vehicles are effectively advertised as a way to reduce emissions and as cheaper in the long run, resulting in sales increasing. The sales also continue to grow as electric vehicles become more regular and affordable to the average consumer. What started with very few options has now spread to various car companies of different luxury levels. The new rise of EV's on the road brings many complications.

With the increase in popularity of electric vehicles, the weight the infrastructure must support also increases drastically: "according to the institution, the average vehicle's weight has increased from 1.5 metric tons in 1974 to nearly 2 metric tons in 2023 ... [and] the reason behind the weight increase was 'due to electric and hybrid batteries and the size of cars increasing'" [5]. The transport of these vehicles across the country is another complication: "car haulers are reportedly lobbying to add an extra 8,000 pounds to [the cap of weight of commercial vehicles] to accommodate the influx of heavier EV's" [7]. The extra weight on the large trucks would greatly increase the amount of wear and tear on the current infrastructure. The consumers do not necessarily consider the extra weight when purchasing a vehicle, but as civil engineers we must account for it. Without the inclusion of the extra weight from electric vehicles parking garages can collapse: "there are many cases of parking structure failures, and the growing demand for EV's will only increase the probability of failure" [6]. One example of a failure in a parking structure was in April 2023 when a parking garage in New York collapsed and killed one person [7] [13]. Safety is a top priority when designing structures, so when a building collapses, the codes used to build the building should be reviewed.

Some important factors the engineers need to account for when designing buildings are horizontal loads and two kinds of vertical loads [14]. The horizontal loads are the forces in the xy plane, like "the forces due to wind and earthquakes" [14]. The vertical loads are in the z direction. The first vertical load is a dead load which is the weight of the building including the reinforced concrete structure, and the second vertical load is a live load which is "anything that could be removed by the occupants without requiring the aid of a construction team," including people and furniture [14]. The cars are considered part of the vertical live load on the parking structures. To ensure all buildings are built strong enough to be safe and are all built to the same standard, there are codes that structural engineers must design their buildings to adhere to. These codes are laid out in the 2024 International Building Codes. Table 1607.1 describes the minimum uniformly distributed live loads and minimum concentrated live loads for various structures [15]. For passenger vehicle garages, the table states it must have a minimum of 40 pounds per square foot (psf) of uniformly distributed live loads [15]. The psf limit for passenger vehicle garages has not changed from the 2021 International Building Codes [16]. The passenger vehicle parking garages laid out in the 2024 International Building Codes account for most cars, but not cars that exceed 10,000 pounds [15]. Vehicles above 10,000 pounds are considered “heavy vehicle loads” and must comply with a different set of codes [15]. For “heavy vehicle” parking garages, the vehicular live loads are “allowed to be determined using the actual vehicle weights for the vehicles allowed on the garage floors,” but they are to be “based on rational engineering principles and approved by the building official” and be greater than 50 psf [15]. The codes are there to keep the buildings safe and to be a standard for structural engineers. The codes cover most vehicles, but there are some EV’s that are an exception.

As mentioned earlier, the codes have not changed in the past three years but the sales of EV’s have increased by 2.9-4.3% since 2021, and thus the weight on the roads and structures has increased [4] [6]. Some EV’s break the standard set by the codes. As the number of EV’s on the roads increases, there could be scenarios where with several EV’s in one parking structure, or one part of a parking structure. In this scenario there would be the potential for the psf to be higher than the 40 set by the codes, thus increasing the chance of failure in the structure. For example, the 2025 Toyota Tacoma is very comparable to the 2025 Rivian R1T in size, but not in weight. The area of the Tacoma and the R1T are 113.75 feet squared and 123.63 feet squared respectively [17] [18]. There is approximately a 10 square foot difference in the areas but there is a 2,927-pound difference between the two vehicles (gross weight) [17] [19]. The Tacoma has a gross vehicle weight rating of 5,605 pounds which means it has about a 49.27 psf and the R1T has a gross weight of 8,532 pounds which means it has about a 69.01 psf [17] [18] [19]. The gross weight vehicle rating is used to determine psf because it includes the maximum weight of the car including people and cargo, which is important to consider when assuring a structure is strong enough [20]. Both trucks are above the 40 psf that is said in the building codes, but the R1T is 29.01 psf over the limit which can be dangerous. Even if the garage was made for “heavy vehicles” at the minimum uniformly distributed psf of 50, it would be risky as the R1T is still significantly higher [15].

Another car that exceeds weight limits for current infrastructure design, especially parking garages, is the GMC Hummer EV truck that has a gross vehicle weight rating of 10,559 pounds [6]. The battery alone in this vehicle “weighs nearly 3,000 pounds,” which is the “weight of an entire Honda Civic” [6]. Additionally, the Hummer EV truck is over 10,000 pounds which by the International Building Codes is considered a “heavy vehicle” and should park in specified garages. However, these are passenger vehicles and thus are often parked with other passenger cars [15]. This could increase risk in parking structures. The cumulative additional weight from electric vehicles increases the “crack numbers, widths, and depths” and this can result in a decrease of the parking structure’s lifespan [6]. Additionally, “EV charging stations are commonly grouped to make electrical distribution systems more cost-effective,” but this action results in a concentration of heavier vehicles and can intensify cracking [6]. The 1400 Wewatta/1401 Wynkoop Public Parking garage in Denver, Colorado has a group of four chargers on the second level of the garage. While this can be convenient for either building the parking garage or for the EV owner’s parking location, it can increase demand on the parking structure to have the concentration of heavier vehicles on floors above the ground floor.

Furthermore, the roads are also receiving damage due to the heavier EV’s: “the American Association of State Highway Officials (AASHO) Road Test in the 1950s resulted in the Law of the Fourth Power, which postulates that increased axle weight increase road damage by the ratio of the increased weight to the fourth power" [6] [7]. This could be applied to repair costs as well to say that a "30% increase in axle load" would most likely "increase repair costs by 185%", a significant increase [6]. Therefore, this issue is important for the next generation of engineers.

Current engineering students will play key roles in the development of electric vehicles and their surrounding infrastructure [21]. The additional weight of electric vehicles (EVs) presents a pressing challenge that should be included in civil engineering education in order to prepare future engineers for changing infrastructure needs. As EVs become further widespread, their heavier weights exert greater stress on roads, bridges, and parking structures, demonstrating the need for structural resilience.

In 2015, to gain understanding about educational needs around the rising hybrid electric vehicle industry, Stanton & Bradley interviewed individuals from state and federal regulatory agencies, federal and private research laboratories, equipment manufacturers, automotive suppliers, consultancies, and companies from the entrepreneurial automotive industry. They found that stakeholders responsible for hiring stated that they are more interested in awareness of the state-of-the-art and existing problems in the hybrid-electric vehicles and were not as interested in deep technical knowledge in engineers." [22]

These findings from Stanton & Bradley highlight that engineering graduates need awareness of current challenges to address real-world problems effectively [22]. Incorporating EV weight considerations into civil engineering courses gives students the opportunity to connect theoretical knowledge to current infrastructure demands. This positions them to design systems and infrastructure capable of accommodating the heavier vehicles.

Integrating EV-related topics into civil engineering curricula aligns with McDonald's assertion that engineering students should and will play pivotal roles in shaping EVs and their supporting infrastructure [21]. This includes adapting design standards for roads, bridges, and urban environments to ensure longevity and safety in the face of increased vehicular weight. Educators have a duty to assist in bridging the gap between traditional principles and emerging EV technologies, as Pourorouz emphasizes, to equip students with skills that transcend conventional capabilities [23]. Students can engage with real-world demands and constraints by addressing how EV weights influence infrastructure design. They can also help develop innovative solutions to new challenges that help balance technological advancement with sustainable development.

The shift toward EVs requires adding to current engineering education in order to account for the relationships between transportation and infrastructure systems. As McDonald notes, education is the foundation for the industry's future, thus emphasizing the need for instructional strategies that connect classroom concepts to real challenges [21]. Beyond merely adopting smart grid technologies, civil engineers must reimagine infrastructure to withstand the demands of EV mass production and utilization. By embracing this important challenge, civil engineering courses can prepare students to navigate some of the complexities of EV use and integration. This can foster a workforce capable of designing resilient infrastructure for a sustainable future.

Research Questions

This work was done to answer the following research questions:

RQ1: What are instructors' perspectives on the topic of additional weights of EVs and its impact on infrastructure?
RQ2: Are faculty including impacts of EV weights into their Civil Engineering courses?
RQ3: How can EV weights and their impact on infrastructure be included in Civil Engineering courses in ways that are congruent with set civil engineering learning outcomes?

Methods

We evaluated the topic of infrastructure impacts due to the additional weights of electrical vehicles in civil engineering courses. In order to investigate this topic, we researched the topic, developed and implemented a survey, and correlated learning outcomes and course options. The research was reviewed by the University of Colorado Institutional Review Board (IRB) for human subjects Protocol #24-0700.

We first investigated the weight differences between electric vehicles (EVs) and internal combustion engine (ICE) vehicles. We related the additional loads to potential impacted infrastructure. Once we verified that we do indeed see this as an important topic, we developed a survey to investigate faculty insights related to the topic. The survey was developed to answer the first two research questions.

An objective of the survey was to identify basic information about the perceptions and experiences of faculty around incorporating concepts related to the added weights of electric vehicles into civil engineering courses. The survey design selected was cross-sectional and quantitative [24]. The survey was primarily multiple-select with one open-ended question (see Appendix A). We chose to include primarily multiple-select because of its ease for the survey recipient. It is shown that surveys with mostly multiple select or closed questions have higher response rates [25]. We also included an open-ended question in hopes to dig deeper. Open-ended questions provide the opportunity to find deeper insights [25].

The survey first asked, 'To what extent do you think it is important for civil engineers to be trained to design infrastructure for the increased vehicle weights of electric cars?' Respondents were given options from no importance to high importance. Faculty were then asked in what civil engineering courses, do they see this as a valid topic? Five options were given, with one additional fill in the blank option for courses not listed. The next question asked if the faculty has included this topic in any of the courses they teach and were offered the answers of yes or no. If the faculty answered 'yes' then the survey proceeded to gather more information about which courses and teaching methods utilized. The complete survey is included in Appendix A.

Via email we invited the civil engineering faculty from three universities to complete the short survey. The three universities included were Auburn University, University of Colorado Boulder, and Texas A&M University. According to Carnegie Classification of Institutions of Higher Education [26], all three of these institutions are classified as doctoral with very high research activity. All three are 4-year large public universities. The variation comes in the region. Auburn University is in the Southeast Region. The University of Colorado Boulder is in the Rocky Mountain Region and Texas A&M University is in the Southwest Region.

We used university websites to retrieve faculty email addresses. The civil engineering faculty at Auburn University, the University of Colorado Boulder and Texas A&M University were contacted via email with a survey invitation and a link to the online survey in Qualtrics; 175 invitations to instructors were successfully delivered. Survey responses were gathered in December 2024. The research study was introduced using the IRB-approved script, emphasizing that participation was fully voluntary. Those opting to participate completed the survey in about 5-10 minutes.

In follow-up to the survey, consideration was given to the relevancy of this topic to civil engineering learning outcomes. We gathered course examples and correlated them to the American Society of Civil Engineering Body of Knowledge and to the Civil Engineering Fundamentals of Engineering Exam content.

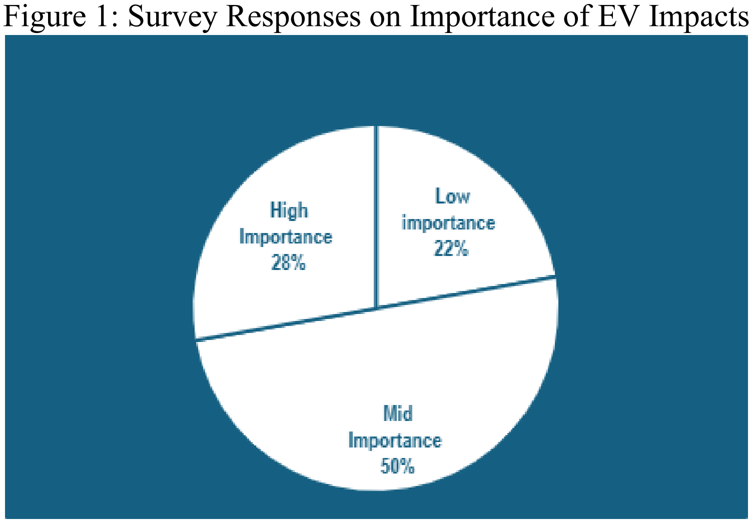
Limitations of our work include the limited geographic location of the three universities. All three universities are located in the United States. An additional limitation is the small n value of survey respondents. Expansion of the work could include surveying a larger group in more varied locations. Another expansion of the work could be to seek front-runners who have actively included this topic in their courses and to interview them in regards to their strategies and techniques, as well as successes and failures.

Results

Out of 175 survey invitations sent, there was an approximate 10% return rate with 18 respondents completing the survey. Of the 18 respondents, 10 were from Auburn University, 5 from the University of Colorado Boulder and 3 from Texas A&M University.

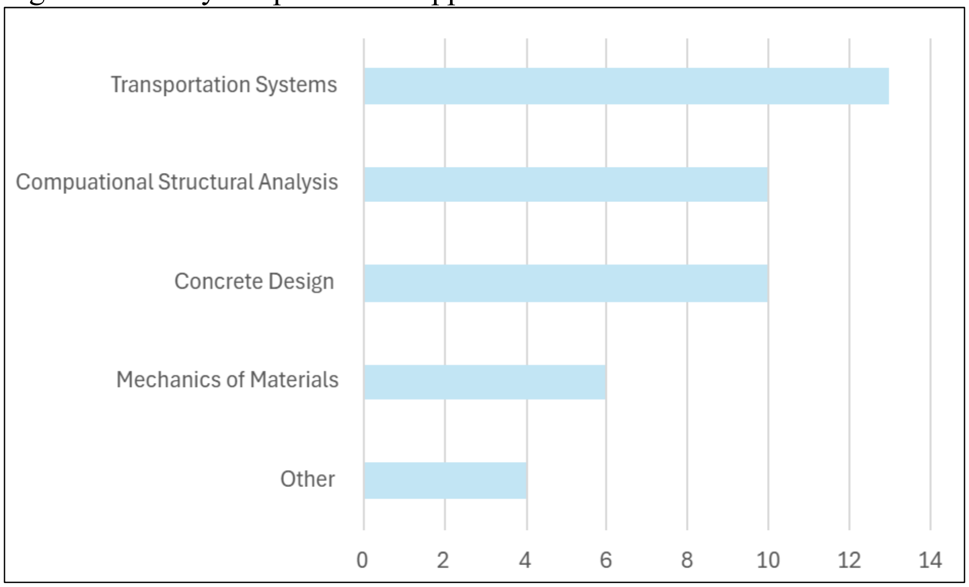
The first question we asked on the survey was: ‘To what extent do you think it is important for civil engineers to be trained to design infrastructure for the increased vehicle weights of electric cars?’ The responses are shown in Figure 1. It can be seen that about 78% of the professors who responded believe that there is mid-to-high importance in training engineers to evaluate the impact of EV’s on infrastructure.

Figure 1: Survey Responses on Importance of EV Impacts in Civil Engineering Courses



Next respondents were asked to specify which courses for which they see this as a valid topic. We chose four courses as select options and the possibility to specify an alternate course was offered as well. Results from question two are shown in Figure 2.

Figure 2: Survey Responses on Applicable Courses



Gathering information from Figure 2, it can be seen that the topic of EV's and their impact on infrastructure can be implemented in multiple classes: transportation systems, computational analysis, concrete design, mechanics of materials, and others. Transportation Systems received the most votes. Professors also had the option to input another class for which this would be a relevant topic. Two professors suggested Pavement Design, one suggested Bridge Design, and one suggested Environmental and Water. This information can be utilized as a starting place of courses for universities to include EV's and their impacts on infrastructure.

Question three asked: 'Have you included this topic in any of the courses you teach?' Of the 18 respondents, 4 responded 'yes' and 14 responded 'no.'

Applications of Results

Only 22% of the professors said they already incorporated this topic into their classes, yet 78% said they believe the topic has mid to high importance. In this disparity there is opportunity to increase the number of classes that teach about EV's. If it is desired to start incorporating the topic of EV's impact on infrastructure in civil engineering courses, below are a few suggestions for ideas of ways to include this topic. As applicable, they are related to an American Society of Civil Engineering (ASCE) Body of Knowledge (BoK) Learning Outcome [27] and to the Fundamentals of Engineering (FE) Civil Exam Specifications [28].

> Parking Structure Evaluation – Students can evaluate an actual parking structure. In this evaluation, students can start with finding the codes the structure was built to meet, estimate the loads it has endured in various years since its inception, and consider predicted future loads. Students can determine if its design is sufficient to meet future needs. A possible deliverable could involve the calculations and written

recommendations. This project relates to ASCE BoK learning outcome: 'Apply concepts and principles of solid and/or fluid mechanics to solve civil engineering problems'. For high level students, a possible expansion on this project could be to design additive support measures to meet the predicted loads, with a deliverable of the design with supporting calculations of the new design's carrying capacity. The expansion relates to ASCE BoK learning outcome: 'Select appropriate concepts and principles of solid and/or fluid mechanics to solve civil engineering problems'. And this project aligns with FE Civil Exam topic: 'Structural Engineering' and specifically 'Design of reinforced concrete components (e.g., codes and design philosophies, beams, columns)'.

Basic Simulation Projects - Pavement Wear Simulation: Students could run a simple simulation using pre-built models in software used by the department (e.g., MATLAB, AutoCAD or Python). They can input EV weights, compare them to ICE vehicles, and witness how the stress distribution changes. Data could be evaluated with distributions, regressions and curve fitting. Students could provide a brief simulation report with an analysis of the difference in road wear between EV's and traditional vehicles. This project fits with FE Civil Exam topic: 'Statistics'.

Focus on Materials - Material Comparison: Students can focus on evaluating two to three materials that could be used in road construction to accommodate heavier EV's. They can look at basic properties like cost, strength, and environmental impact. Students could then provide a comparison matrix and a written summary of findings, recommending one or two materials for future infrastructure projects. This project relates to ASCE BoK learning outcome: 'Apply concepts and principles of materials science to solve civil engineering problems'. This project can associate with the FE Exam topic: 'Materials' and specifically the 'Mix design of concrete and asphalt' and 'Test methods and specifications of metals, concrete, aggregates, asphalt, and wood'.

Simplified Bridge Design - Load-Bearing Analysis: Students could use basic bridge formulas to compare the load-bearing capacity of a small bridge under normal vehicle weight versus a fleet of EV's. The task would involve calculating maximum allowable loads using standard load distribution methods taught in class. A possible deliverable is a set of basic calculations with a diagram illustrating how the bridge would handle increased weights. This project relates to ASCE BoK learning outcome: 'Apply concepts and principles of solid and/or fluid mechanics to solve civil engineering problems'. An example of basic calculations on this topic is included in Appendix C.

Basic Predictive Modeling - Modeling EV Adoption and Road Wear: Students could develop a basic mathematical model using provided EV adoption data and its correlation to road maintenance schedules. The model could be run in MATLAB or another software. The task would focus on learning to input variables and calculate expected wear based on vehicle weights. Students could provide a simple predictive model with graphs showing the predicted increase in road wear over time as EV adoption grows. Dependent on the mathematical model developed, this project has the potential to relate to ASCE BoK learning outcome: 'Apply concepts and principles of mathematics, including differential equations and numerical methods, to solve civil engineering problems'.

Cost-Benefit Analysis (Basic Version) - Simplified Cost Analysis: Students can perform a simplified cost-benefit analysis by estimating the maintenance costs of roads used by heavier EVs versus traditional vehicles. Using standard cost data for road repair and maintenance, they can estimate amounts costs would rise with specified percentages of the heavier EV's alongside traditional vehicles. A potential deliverable is a cost comparison table with a short summary explaining any variation in costs of maintaining roads for specified amounts of heavier vehicles. This project relates to the learning outcome to the ASCE BoK 'Apply concepts and principles of engineering economics in the practice of civil engineering'. And this example aligns with FE Civil Exam topic: 'Engineering Economics'.

Simplified Structural Engineering and Pavement Design - Mini Case Study: Students can analyze a specific road segment or bridge that would be impacted by heavier EV's. The task could involve using provided traffic load data to perform simplified calculations on pavement thickness or bridge stress, applying basic formulas provided in coursework. A possible deliverable is a short assignment with calculations, conclusions, and a recommendation for future infrastructure design adjustments. An example of a basic mathematical problem in this area is included in Appendix B. This project aligns with the FE Civil Exam topic of 'Transportation Engineering' and more specifically 'Pavement System Design'.

Current Events Article Review - Students can explore the topic of how the added weight of electric vehicles impacts infrastructure by reviewing selected articles. After reviewing the articles, students will analyze the challenges heavier EVs pose to roads and bridges, including increased wear, potential for structural damage, and implications for long-term infrastructure planning. A deliverable including a summary of the articles and their findings could be given in written or presentation formats.

These are a few ideas to get started in incorporating added EV weights into the preparation of structural engineers. The course doesn't have to be focused on the topic. Small exposures interwoven into traditional courses can increase awareness and create engineers more skilled for the current infrastructure needs.

Conclusion

Awareness of increased vehicle weights due to EV's and the impact on infrastructure is important for upcoming civil and structural engineers. The future generation of engineers will build to and continue to modify the existing codes. Competence in this topic can be of benefit for building and maintaining safe infrastructure, as they can then include it in their designs and calculations. When designing, evaluating, or re-designing infrastructure, EV's can become a regular factor of consideration for future civil engineers, as are environmental factors.

In general, EV's are increasing in popularity and are predicted to continue to grow in numbers in the years to come. EV's can be an important piece of the puzzle in the fight to reduce greenhouse gas emissions. However, the EV's weigh significantly more than their petroleum counter parts. And thus, infrastructure impacts from the additional weight from these EV's is an important topic for civil engineers. With the additional weight, many of the larger EV's exceed the codes set for parking structures. This can cause concern regarding the safety and strength of parking garages. Therefore, it is considered of importance for the up and coming generation of civil engineers to be educated on this topic while in their university courses. This is to give them proper preparation for the predicted increase of weight on the roads and parking garages.

Professors from three universities in the United States shared their perspectives on implementing this topic into classes. In summary, 56% more of the professors surveyed believe this topic is of mid to high importance than have included the topic in their civil engineering courses, thus demonstrating a gap to be filled. Transportation Systems followed by Concrete Design and Computational Structural Analysis were identified as the classes with the most votes as well-aligned courses to incorporate this topic.

EV's present new infrastructure challenges for civil engineers. Thus, making it an important topic to include in university level civil engineering courses.

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Appendix A - Survey for faculty

1. To what extent do you think it is important for civil engineers to be trained to design infrastructure for the increased vehicle weights of electric cars?

No importance (1) – Low importance (2) – Mid importance (3) – High importance (4)

2. In what civil engineering courses, do you see this as a valid topic?

Options: Mechanics of Materials, Transportation Systems, Computational Structural Analysis, Reinforced Concrete Design, Other: _________________

3. Have you included this topic in any of the courses you teach? Yes or No

If yes:

3a) What courses?

3b) What teaching methods did you use to include this topic?

Options: Case studies, mathematical calculations, design projects, article review, other:___________

3c) If willing, please provide a brief description of the incorporation.

4. Would you like to receive notification of publication of this work? Yes or no

If yes: Please provide your email address: _______________

Appendix B – Example Mathematical Calculation 1

Simplified Structural Engineering and Pavement Design Mini Case Study

Scenario:

A road segment in a suburban area currently accommodates regular passenger vehicles with an average weight of 2,500 lbs per vehicle. With the increasing popularity of electric vehicles (EVs), which average 4,500 lbs per vehicle, engineers must assess the impact of this heavier load on the pavement thickness.

You are tasked with determining whether the pavement thickness needs to be increased to handle the additional load, using a simplified pavement design equation.

Provided Data:

- Current vehicle weight: W1 = 2,500 lbs
- EV weight: W2 = 4,500 lbs
- Current pavement thickness: t1 = 8 inches
- The recommended pavement thickness increases by 1 inch for every additional unit of LEF beyond 1.
- Load equivalency factor is: $LEF = (\frac{W}{W1})^{1.2}$ where W is the vehicle weight.

Task for Students:

1. Calculate the load equivalency factor (LEF) for the EV weight (W2).
2. Determine if the pavement thickness (t1) needs to be increased and, if so, by how much.
3. Provide a short recommendation based on your findings.

Equations:

1. $LEF = \left(\frac{W}{W1}\right)^{1.2}$
2. $t2 = t1 + (Additional\ Inches\ Based\ on\ LEF)$

Question for Students:

1. Calculate the LEF for the new EV weight.
2. Determine the necessary pavement thickness t2 for the road segment.
3. Write a short report explaining your calculations and recommendation for infrastructure adjustments.

Solution:

1. Calculate LEF: $LEF = (\frac{W}{W1})^{1.2}$ $LEF = \left(\frac{4500}{2500}\right)^{1.2}$ $LEF = 2.02$

2. Determine Additional Pavement Thickness

   Additional Thickness = $LEF - 1 = 1.02 \quad (round\ to\ nearest\ inch)$

$$t2 = t1 + 1 = 8 + 1 = 9\ inches$$

3. Recommendation: Based on the calculations, the pavement thickness needs to increase from 8 to 9 inches to handle the increased load from EVs. Future infrastructure designs should consider this increased load to ensure road durability and safety.

Appendix C Example Mathematical Calculation 2

Case Study: Evaluating Bridge Load Capacity with Increasing EV Traffic

Background:
A small bridge is designed to support a distributed load of q=4,000 lbs/ft under normal vehicle traffic. Anticipating variations in traffic, engineers initially designed the bridge to handle a maximum allowable load of P_{max}=220,000 lbs, incorporating a safety margin above typical traffic loads. However, with the increasing adoption of electric vehicles (EVs), which are generally heavier than gas-powered vehicles, the bridge's ability to safely support the increased load must be reassessed.

Problem Statement:
You will calculate the total load on the bridge under normal vehicle traffic and compare it to the load under an EV-dominant traffic scenario. Then, you will determine if the bridge's maximum allowable load remains sufficient.

Provided Data:

- Bridge length: L = 50 feet
- Original design load per unit length: q = 4,000 lbs/ft
- Maximum allowable load: P_{max} = 220,000 lbs
- Adjusted distributed load under EV traffic: q_{EV} = 4,200 lbs/ft

Task for Students:

1. Calculate the total load P_{normal} under normal vehicle traffic.
2. Calculate the total load P_{EV} under EV traffic.
3. Compare P_{EV} to P_{max} and determine if the bridge can safely handle the increased load.
4. Illustrate the load distribution on the bridge with a simple diagram.
5. Discuss potential engineering solutions if the new load is close to or exceeds the allowable limit.

Equations:

1. Total load: $P = q * L$
2. Compare:
   - If $PEV \leq Pmax$, the bridge is within safe limits.
   - If $PEV \geq Pmax$, the bridge may require reinforcement or traffic adjustments.

Solution:

1. **Calculate P_{normal}:**
   $P_{normal} = q \cdot L = 4,000 \times 50 = 200,000$ lbs
2. **Calculate P_{EV}:**
   $P_{EV} = q_{EV} \cdot L = 4,200 \times 50 = 210,000$ lbs
3. **Compare P_{EV} to P_{max}:**
   - Since $P_{EV} = 210,000$ lbs and $P_{max} = 220,000$ lbs, the bridge is still within its safe load capacity but with a reduced safety margin.
4. **Conclusion:**
   - The bridge can still support EV traffic, but engineers should monitor wear and consider reinforcement for long-term safety.