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Developing a Team-Based Regulatory Framework for Mobility Engineering Professionals

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Abstract

Transportation mobility has gained burgeoning attention in the past decades driven by the advancement of Connected and Autonomous Vehicles (CAVs) and ubiquitous Internet Communication Technologies (ICT). As the innovation of CAVs progresses towards an upper level of automation, safety concerns induced by advanced autonomous vehicle operation are becoming complex. To correctly manage uncertainties in protecting the public, it is critical to take long-term preventive measures by regulating mobility engineering practices in delivering autonomous driving solutions. To date, the lack of licensure for all mobility engineers remains one of the significant challenges. As we investigated NCEES exam products in the civil engineering domain, none of the exams are targeting the unique knowledge base and skills requirements for a mobility engineer profession. Without an effective mechanism to regulate this emerging occupation, ethical practice and quality assurance of engineering projects could be undermined. In this study, we investigated the current educational programs, job market, requirements, and engineering licensure mechanism in the United States. The analysis identified the gap between the requirements of the mobility engineers' profession and the current licensing mechanism. As a response, we recommend further study of regulatory alternatives, including a team-based regulatory model to ensure reliable industry practice in the mobility engineering industry.

Keywords

Mobility engineering, team-based model, regulatory model, public safety

Introduction

Mobility engineering is one of the era's most active areas in both research and practice. It integrates the knowledge of various fields to provide public mobility services, including autonomous vehicles, transportation infrastructure, supply chain, energy, IT, finance, public policy, sociology, etc. Even though there is a perceived prominent need for mobility engineers in various sectors, including industry, government, and university, the description of this emerging profession and its implication to public safety is less discussed in literature. The National Council of Examiners for Engineering and Surveying (NCEES) is a nonprofit organization, whose mission is to advance professional licensure for engineers and surveyors. In terms of protecting public safety, NCEES has implemented licensure solutions that regulate engineers who deliver the public facilities to demonstrate a level of competence through education, experience, and examination requirements [1]. From our investigation of NCEES engineering exam products, there is not an exam specifically for mobility engineers. Since examination is one of the pillars toward licensure, the gap reflects the lack of a complete roadmap toward the professional career of mobility engineers. It implies the effectiveness of education programs and quality of practice in this field could be undermined. For example, decision making generated from engineering judgment may lack the grounds of widely accepted norms. Besides, engineering practice could be less tracked, disciplined, or protected. Eventually, less regulated practice could lead to adverse impacts on public safety as well as the health of the engineering community.

One of the most important purposes of professional engineering licensure is to provide assurance to the public of a minimum level of competence [2]. In highly technical professions, the public itself does not have the specialized knowledge to evaluate the qualifications and performance of engineering products. Also, the public needs help to choose the ultimate provider of safety features in the infrastructure domain. Therefore, professional licensure plays a critical role in ensuring that the practitioners are adhering to a strict code of conduct, which requires them to put public safety as the top priority [3]. To implement engineering licensure, NCEES considers competent education, experience, and examination as the three pillars for the qualifications of engineering licensure, termed as “three Es” [2]. On top of “three Es”, most states require licensed engineers to retain their qualifications with continuing education requirements, which could be evidenced by professional development hours.

In the discipline of mobility engineering, how these three pillars could ensure public safety remains unclear at a detailed level. To understand the fitness and gaps between the engineering licensure model and the needs of mobility engineering practice, we set up the following research questions.

- RQ1: What are the qualifications for a mobility engineer professional?
- RQ2: What are the comparative differences between traditional professional engineers and mobility engineers? Does the traditional licensure mechanism fit the characteristics of mobility engineers?
- RQ3: To better protect public safety by providing effective licensure stewardship to mobility engineers, what could be the potential solutions?

To answer the research questions, we investigated the necessary qualifications of mobility engineers from sources of educational programs, job market, NCEES examinations, as well as the current engineering licensure model. We compared the characteristics of mobility engineers and Professional Engineering in traditional disciplines and identified both the transferable similarities and gaps of the current licensure model. In the end, we recommend exploring additional regulatory options, such as implementing a team-based regulatory framework, to ensure reliable engineering practice in this field.

Literature review

The role of engineering licensure

Licensure is a tool to regulate engineering practice. Given the significant impact engineering projects can have on public safety, the primary objective of engineering licensure is to offer assurance to the public. To ensure public safety through licensure, engineers must meet the minimum competency level set by statutory regulations for their tasks. Furthermore, they must adhere to a professional code of conduct while carrying out responsibilities [2]. Failure of compliance with the stipulations may result in subsequent disciplinary processes.

Engineering licensure has a long history in the United States. States began to adopt engineering licensure statutes in the early 1900s, and it took approximately 40 years for all states to have engineering licensure laws in place [4]. Over time, a strong and well-established licensure system has been developed and proven effective. In the US, regulating professions is a state function. Each state maintains its own statutes and rules to regulate engineering professions. To enforce regulations, state PE boards adhere to formal procedures for implementing statutes and rules. The primary functions of these boards include reviewing licensure applications, addressing disciplinary complaints concerning professional engineers, and formulating state rules [2]. In the meantime, NCEES plays a vital role in offering guidance to each PE Board by upholding a model law and model rules [2]. Additionally, other missions of NCEES include providing nationally normed examinations for engineers and surveyors, enhancing professional ethics, and coordinating and promoting the mobility of licensure across states [5].

Licensure versus Certificate

In the engineering context, the technical term 'licensure' is different from 'certification'. Licensure is issued by an agency of government, which grants permission to the licensees to practice upon supporting evidence of the minimum competency attained to protect the public safety [6]. Basically, licensure prohibits non-engineers to offer any engineering services unless certain state exemption requirements are met [2]. In contrast, certification is defined as the process by which a governmental or nongovernmental agency grants the authority to use a specified title when a person or team has met predetermined qualifications [8]. The key difference is that certification standards do not prohibit the individual or team from engaging in certain practices.

Mobility engineers as a profession

To distinguish the common attributes of professional occupations from the non-professional ones, researchers have identified five key elements: 1) Systematic theory, 2) Authority, 3) Community sanction, 4) Ethical codes, and 5) A culture [7]. As a significant contributor to engineering practice, NCEES has implemented regulations covering 30 sub-specialties within traditional engineering fields. However, for the emerging mobility engineer profession, no distinct educational pathway or regulatory statutes have ever been established. Without any authoritative approval of qualifications, it could be hard to recognize mobility engineering as a formal profession. Also, mobility engineering practice without well-established regulatory statutes and rules could expose the public to danger. Moreover, it is essential for the state Board to provide additional clarification on engineering liabilities and community sanctions for violation. Therefore, the current role of NCEES and state Board in regulating the emerging mobility engineers reflects a lack of validation of systematic theory, authority, and communication sanction.

As an emerging profession, mobility engineering professions are subject to unique characteristics. First, the ethics of Connected and Autonomous Vehicles (CAVs) differ from those of traditional engineering. An illustrative debate is risk allocation when CAVs are driven by AI algorithms. A recent study conducted by European Commission has discussed the ethical considerations surrounding CAVs and proposed 20 recommendations in addressing aspects including road safety, privacy, fairness, explainability, and responsibility [8]. For mobility engineers tasked with delivering CAV products and safety features, clear guidance from ethical codes is indispensable for the implementation of ethical solutions in practice. Second, the products delivered by mobility engineers, such as CAVs and autonomous driving systems, possess a distinct geographical cross-border characteristic when compared to traditional infrastructure like roadways and buildings. Since existing licensure is administered by states, regulating products beyond state borders may pose a regulatory dilemma. Third, traditional engineering expertise has matured over many years, ensuring basic safety standards. However, the adoption of cutting-edge technology in the mobility engineering industry is on the rise, presenting a distinct characteristic where ethics in regulating rapidly evolving technology becomes crucial.

Reflect on the initiation of the mechanism of engineering licensure, triggered by publicized construction failures with fatalities in the late 1900's and early 1900's [2]. Similarly, casualties in traffic accidents involving autonomous vehicles call for urgent regulatory solutions in the mobility engineering industry. According to the National Highway Traffic Safety Administration (NHTSA), from July 2021 to May 2022, 392 crashes in the United States were involved with Level 2 Advanced Driver Assistance Systems (ADAS) equipped vehicles. Because the interplays between regulatory frameworks and technological progress often propels each other forward, establishing suitable regulatory mechanisms is crucial for the success of mobility engineers. At present, there exists no distinct license specifically developed for the mobility engineering profession. The compatibility of the traditional licensure model with the requirements of mobility engineering profession remains unevaluated.

Methodology

Effective licensure design stems from a comprehensive understanding of the knowledge base of the Mobility Engineering discipline. To answer RQ1, we visited the roles of education and experience indicated by the three Es within the context of mobility engineering. For education, data sources are from the best engineering schools listed in US News. We leveraged Google search engine and reviewed the Top 52 universities and compiled their education programs in relation to mobility engineering. For experience, we investigated the job needs and qualifications of mobility engineers from Indeed, which is one of the largest job search engines. To address RQ2, we analyzed the examinations provided by NCEES, which constitute the third dimension of the three Es. The objective is to identify the existing gap within the current regulatory system for mobility engineering professionals. For RQ3, we developed a team-based regulatory framework tailed for mobility engineering professionals with findings from RQ1 and RQ2.

Results

RQ1: Qualifications for a mobility engineering professional

Educational programs analysis

Motivated by the fast-changing industry development and penetration of autonomous vehicle technologies, universities and research institutes have been actively developing mobility engineering curriculum to nurture the competencies of engineering students and prepare them for the market and their career growth. To better understand these mobility engineering programs, and the body of knowledge embedded within the coursework, we reviewed the engineering programs from the US News Top 50 (52 counts in total) engineering programs in the United States. Our objective was to identify the existence of mobility engineering educational programs, including both degree programs and professional certificate programs, as well as the core courses provided.

In this analysis, the Google search engine was used for the purpose of data collection. Keywords were defined as a combination of mobility engineering degrees and the name of top engineering schools from US News. Acronyms of universities were also considered within the search scope. For example, to investigate mobility engineering educational programs at the University of Maryland, we searched the keywords "mobility engineering, the University of Maryland", or "mobility engineering degree, UMD". Once a suitable link was found, we further investigated the program information page at the researcher's discretion. As a result, 21 educational programs were found from 18 universities. The results are shown in Figure 1.

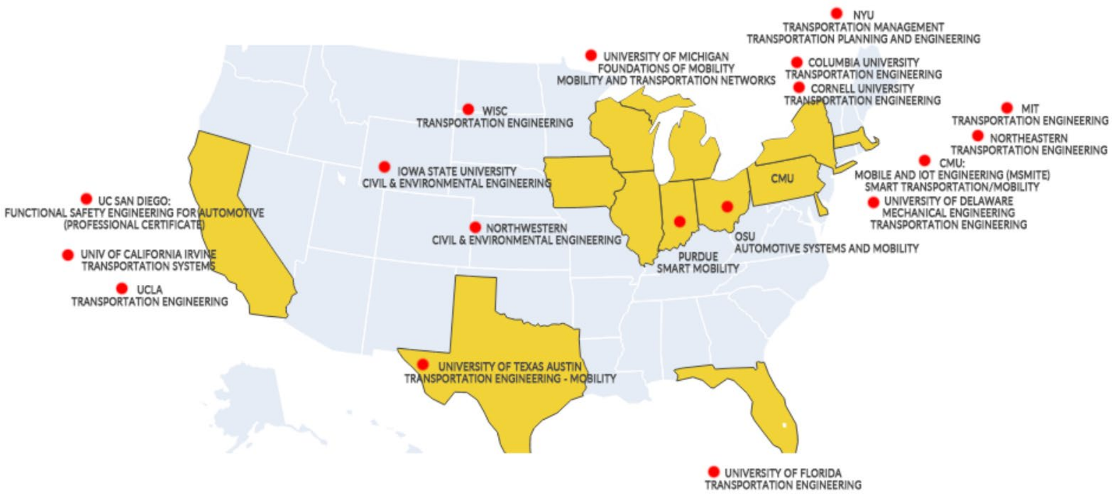

Figure 1: Mobility Engineering Education Programs in the U.S.

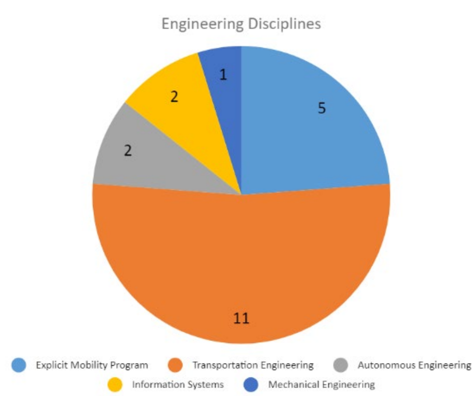

Figure 2: Disciplines Affiliations of Mobility Engineering Education Programs

The search result reflects that 18 out of 52 top engineering schools (34.6%) have already incorporated mobility engineering programs into their education landscape. A few universities have more than one educational program that has mobility engineering components in their curricula. Overall, a total of 21 engineering programs are identified with mobility engineering elements, among which 2 are professional certificate programs, and 19 are graduate-level degree programs. Among the 21 engineering programs identified, 5 are classified as independent mobility engineering programs because they explicitly specify mobility in their program titles. The rest of these programs are classified as non-independent mobility engineering programs. Even though they have mobility knowledge covered, they are rooted in traditional engineering programs, such as transportation engineering (11), autonomous engineering (2), information system engineering (2), and mechanical engineering (1).

To get a deeper understanding of the subjects covered, detailed coursework and topics in the identified mobility engineering educational programs were also reviewed. A total of 72 core courses were collected, as well as several elective courses due to their strong relationship with mobility engineering. Some example courses are Mobility Foundations and Methods, Mobility Behavior and Technology, and so on. A word cloud analysis was applied to the titles of the collected courses. The result is demonstrated in Figure 3. We identified that the top words in mobility engineering education are data science, control, intelligent transportation systems, automated (autonomous) vehicles, dynamic systems, resilient networks, etc.

Figure 3. Word Cloud of Mobility Engineering Curricula

To conclude, educational programs analysis reveals that 1) educational programs focusing on the discipline of mobility engineering exist. 21 pieces of evidence are identified from the top engineering universities. 2) The educational programs are provided in a mixed format including degree programs and professional certificates. 3) Independent mobility engineering programs are rare (only 5 in this study). Most of the programs are rooted in traditional engineering departments ranging from civil engineering, mechanical engineering, industrial and system engineering, etc. 4) The knowledge base reflected in the curriculum covers multidisciplinary domains. The main ideas are around data, systems, and networks.

Job market analysis

The job market directly reflects the qualifications and experience needed for a mobility engineer. Analysis of the job market could provide strong evidence of the knowledge base and requirements for mobility engineering practices. For this purpose, Indeed data was collected in July 2022 with predefined keywords. Indeed is a job search engine characterized by high traffic volume that aggregates job listings from thousands of websites. In July 2022, more than 15,800 job positions were returned for mobility engineers in Indeed. The job positions cover mobility planning, data analysis, automotive safety, traffic optimization, machine learning, etc. Figure 3 shows the distribution of mobility engineer jobs.

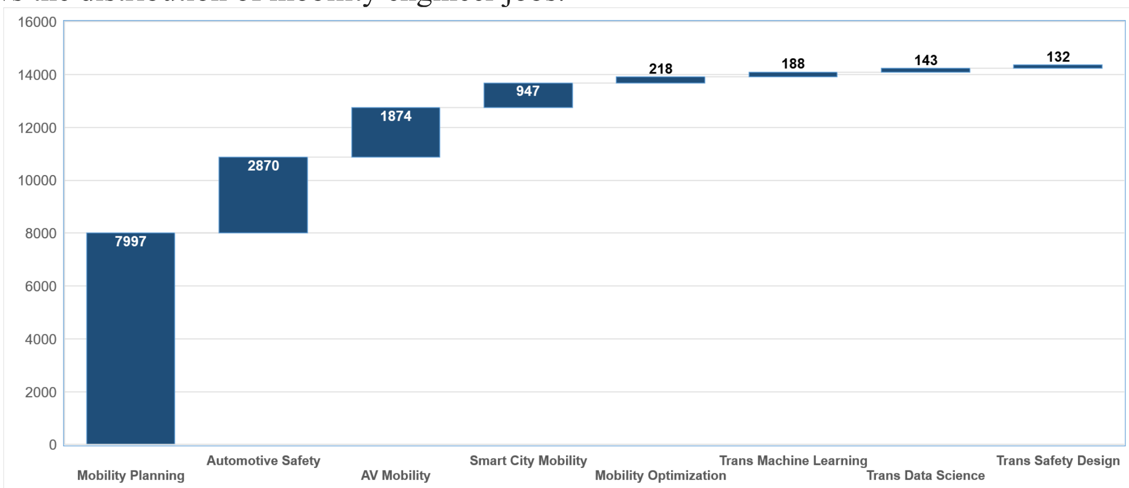

Figure 4: Mobility Engineering Job Positions

Given a large number of job positions, a selected sample of job descriptions was examined in detail to understand the job responsibilities and the required knowledge base or skill set. A content analysis was conducted to group the job responsibilities and skill sets into 5 categories namely testing, traffic, software/system, electrical, and safety (Table 1).

Table 1: Mobility Engineering Job Requirements and Qualifications

Job Position	**Job Requirements**	**Knowledge/Skillset**
Test Engineer	• perform vehicle tests, • draw electrical and electronic diagrams, • program scripts, • conduct test analysis, etc.	• electrical engineering (vehicle) domain knowledge, • mechanical engineering domain knowledge, • programming skills, • data analytics
Traffic Engineer	• simulate traffic flow and operation, • perform safety and capacity analysis, • design traffic mesoscopic modeling, etc.	• transportation domain knowledge, • programming skills (Python), • data analytics
Software/System Engineer	• design, implement, tune, and test novel algorithms, • design control system software; build and deploy system architecture, • generate CAV software documentation packages, etc.	• artificial intelligence (machine learning, machine vision), • robotics, • programming, • information system engineering domain knowledge
Electrical Engineer	• develop ADS platform, including power distribution, electrical architecture integration, etc. • Integrate ADS features into CAV vehicles, • perform the design and development of embedded electronic control modules; etc.	• electrical engineering (vehicle) domain knowledge, • mechanical engineering domain knowledge, • information system engineering domain knowledge
Safety Engineer	• Provide technical expertise to CAV research/development team, • mentor engineers about safety system industry standards, • Apply safety principles to support product investigation, analysis, planning, design, development, testing, evaluation, etc.	• project management knowledge, • safety engineering domain knowledge, • information system engineering domain knowledge, • knowledge of the CAV safety regulation (certificates, standards, principles)

The results show that mobility engineer-related positions require domain knowledge from multiple traditional engineering disciplines, including transportation engineering, electrical engineering, mechanical engineering, information system engineering, artificial intelligence, etc. This is consistent with our observations from the analysis of the educational programs. It is worth noting that data analytics skills are commonly required among all job descriptions as well as certain levels of programming skills. The need for cross-domain engineering knowledge, data analytics skills, and programming skills aligns with the findings from the educational programs analysis in the previous section. From the job market analysis, the knowledge base of mobility engineering centers on the following three fields:

- Vehicle-centric engineering knowledge: vehicle design, system design, electrical engineering, etc.
- Infrastructure-centric engineering knowledge: transportation infrastructure, civil infrastructure, safety, environmental engineering, etc.
- IT and data analytics skills: information system engineering, software engineering, machine learning, artificial intelligence, data analytics, etc.

RQ2: The gap of engineering licensure

In the United States, engineering licensure is regulated at the state level. There are three major requirements to get official licensure, referred to as 'three Es'. The candidate is required to graduate from an Accreditation Board for Engineering and Technology (ABET) – accredited four-year college program with an engineering degree. Second, the candidate has to pass the Fundamentals of Engineering (FE) examination, which covers basic engineering principles. Third, the candidate needs to possess the desired amount of engineering experience. It varies by state, but four years are common. Last, the candidate has to pass the Principles and Practice in Engineering (PE) exam, which is aiming to test the candidate's knowledge of a specialized engineering discipline and ethics [3]. In addition to individual-based licensure, some states require registered engineering firms to obtain authorization by meeting certain qualifications.

From the analysis of the education and experience requirements of mobility engineers, we conclude that educational programs in mobility engineering are driven by market needs. They started from traditional engineering disciplines and are growing towards a mature and independent discipline. This implication is evidenced by the 5 well-established education programs and the link between the core courses and the job market. However, compared to traditional engineering disciplines, there is no licensure option provided for mobility engineering. This reflects the gap in public protection from the licensure perspective in the mobility engineering field.

As we observed from the educational programs and the job market, the knowledge base of mobility engineering is widely and deeply rooted in multiple traditional engineering disciplines. If a new PE licensure is to be established for mobility engineering, the available licensing resources from the state boards and NCEES need to be fully leveraged. Our reasons are listed below:

- Given the fact that educational programs are not fully provided across all universities, building up independent ABET-accredited degree programs needs great time and investment. Market forces for mobility engineers will demand fast action.
- Existing education resources, which offer broad engineering knowledge, could be easily transformed into the mobility engineering discipline to meet the knowledge requirements of the FE exam.
- NCEES has well-established PE exams in 5 traditional disciplines. Even though none of them are specifically targeting mobility engineering, each covers a portion of the mobility engineering disciplines.

To fit the needs of regulating mobility engineering practice by leveraging existing licensing resources, we consider knowledge from multiple specialties should be integrated and tailored rather than replicating the traditional engineering licensure mechanism.

RQ3: An overarching team-based regulatory model

Because of the multi-disciplinary nature of mobility engineering and the uniqueness of the occupation, we believe that a team-based regulatory model should be considered. Our objective is to explore a potential transformation of the engineering licensure model from the traditional engineering disciplines into the emerging area of mobility engineering. The proposed framework consists of four pillars: knowledge base, team composition, certificate process, and continuous education.

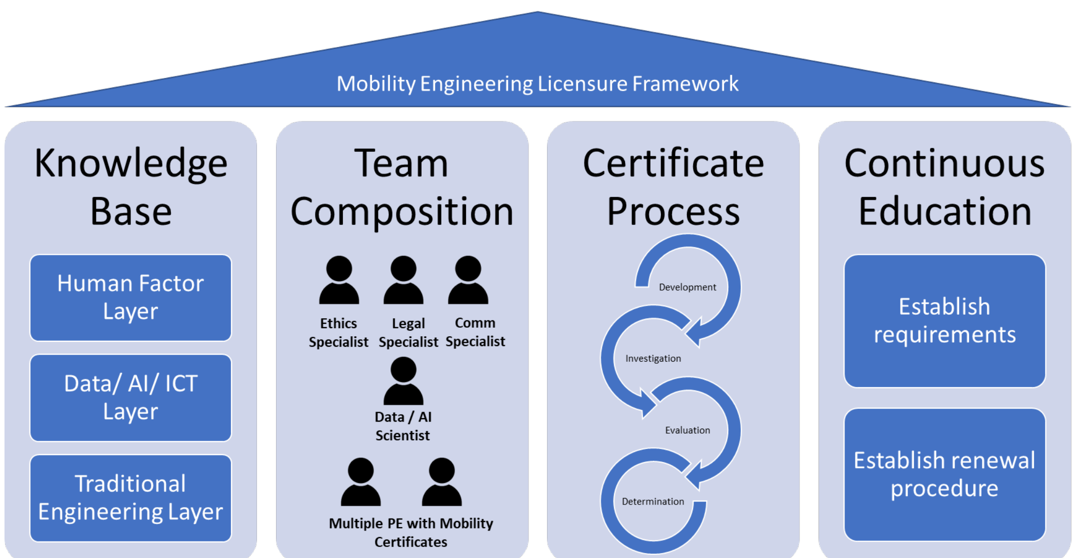

Figure 5: A Team-based Regulatory Framework for Mobility Engineer

Knowledge base

There are three layers included in knowledge base pillar.

- First layer: The first layer is the traditional engineering layer. From our study, the knowledge base of traditional engineering disciplines establishes the foundations of mobility engineering. It is necessary to have the competence of those disciplines in a ME team, which covers both the CAV and ITS knowledge. Considering the rigorousness and direct correlation between traditional engineering and public safety, we recommend team members have an individual PE license in their appropriate discipline.

- Second layer: The second layer reflects the knowledge requirements of data analytics, artificial intelligence, and internet communication technologies. This layer is the emerging knowledge required by a mobility engineering team.
- Third layer: The third layer is the human factor layer, which includes the competence of ethics, law, public communication, etc. This layer is taking responsibility to guide and evaluate the design of AI features, collect and interpret regulatory requirements, communicate and educate the public, and integrate the work of all team members into the final product.

Team composition

For the team composition pillar, the roles correspond to the three layers in the knowledge base pillar. For the traditional engineering layer, project engineers from the traditional engineering disciplines with additional knowledge of mobility engineering are the backbones to design, develop, test, and implement the safety products. In the second layer, professionals with a concentration on data, artificial intelligence, and ICT technologies are proposed. In the third layer, which is the human factor layer, various functional specialists on ethics, legal, and communications are proposed. The team members in each layer would support and deliver values to other layers internally, as well as collaborate with the external stakeholders to deliver a safe product.

Certificate Process

At this stage, we recommend consideration of a team-based certificate process to ensure the delivery of safe products. The certificate process could consist of four phases, which are development, investigation, evaluation, and determination. Before the certificate process is initiated, codes and standards of compliance should be developed by a regulatory entity. This entity could be an established organization such as NCEES or a new organization. In the development phase, the team seeking certification is obligated to present their approach and prove compliance with codes and standards. The investigation and evaluation phases are expected to be executed by the regulatory entity, with an objective to inspect and ensure safe operation of the developed process. After investigation and evaluation, the regulatory entity could determine a decision regarding the certification.

Continuous Education

From our review, traditional PE licensure requires continuous education to equip the licensed engineers with updated knowledge of their discipline. Considering the rapid innovation of the mobility engineering industry, it is necessary to adopt a continuous education mechanism. In this framework, we recommended adapting the continuous education mechanism from the traditional PE licensure model with newly designed standards that are customized to mobility engineering as a guidance. There are two major steps needed in this pillar, to establish requirements, and to define the renewal procedure.

Conclusion

In this study, we identified the qualification requirements for the emerging profession of mobility engineers from the perspective of ‘three Es’ defined by NCEES. Educational programs and the job market in the targeting domain are investigated. Followed by the identification of gaps between the current engineering licensure mechanism and the characteristics of mobility engineers. Since the mobility engineering industry is a highly multidisciplinary field subject to fast technology change and ethical AI for decision making, we recommended further exploration of a team-based certification framework as a potential regulatory mechanism for the emerging field of mobility engineering.

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