# Infrastructure Asset Management (IAM) Educational Needs and Workforce Competencies: Mapping Findings from a Survey and Expert Workshop to a Rail IAM Module

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## Abstract

As civil infrastructure systems face evolving threats, there is a critical need to equip students with technical and professional competencies that reflect real-world problems and needs. This study presents the findings of a process used to identify these necessary competencies and develop a rail-focused infrastructure asset management (IAM) module created to strengthen students' career readiness. Drawing on input from a survey and interactive workshop, the research captures practitioner and scholar perspectives on key IAM topics and competencies. Prioritized IAM topics included risk and uncertainty management; planning for lifecycle renewal, repair, and replacement of assets; and condition assessment and performance-based planning. Prioritized competencies included systems thinking, analytical thinking, communication, and continuous learning. Across all engagement efforts, experts highlighted the importance of combining qualitative and quantitative skill-building activities and assignments to effectively prepare future IAM professionals for practical realities. These insights informed the development of a rail IAM module, where assignments were designed to foster student competencies in the prioritized topic areas. Throughout the module, students had several opportunities to learn directly from rail and asset management professionals, exposing them to day-to-day challenges, emerging technologies, and management strategies shaping the field. By embedding expert engagement and practice-informed content, this study illustrates one approach for strengthening connections between academic learning and professional practice. This approach can be applied while developing educational materials across civil engineering curricula to continuously prepare students for evolving challenges and augment the practical relevance of learning activities.


## Introduction

Workforce shortages, advances in technology, shifting priorities, and external threats are elevating the importance of advanced asset management approaches across transportation modes. One National Cooperative Highway Research Program project description notes that transportation asset management professionals are expected to possess the technical and interpersonal skills necessary to adapt to emerging challenges, but there is a gap between the competencies needed to face these challenges and the available educational and professional development offerings [1]. This gap is exacerbated in the rail sector, where there are even fewer educational opportunities; one study highlighted that "rail-focused university programs are

relatively scarce", posing a threat to the sustainability of the rail workforce in the United States [2]. Researchers Zarembski, Palese, and Chalupa have explicitly called out the need for future researchers to examine the required qualifications – including training and skills – for the next generation of rail and transit workers [3].

This study intends to address this gap by combining asset management practitioner and scholar insights to inform the development of targeted educational resources. Acknowledging the relatively limited emphasis on rail systems within infrastructure asset management (IAM) and civil engineering educational programs in the United States, rail-specific asset management is the subject of the educational resources. This study defines rail systems as any network for moving people or goods comprising infrastructure and operational components; these systems include freight railroads like CSX, intercity passenger rail systems like Amtrak, commuter rail systems like Chicago's Metra, urban transit systems like the New York City MTA, and others. To better understand the needs for rail-specific asset management education and workforce development, this study explores the research questions: (1) *What are the topics and competencies necessary to prepare IAM professionals for evolving conditions, especially in the context of rail systems?*, and (2) *How can these findings be directly mapped to a new, rail-specific asset management module?*

To answer these questions, we first review guidance and literature on IAM workforce competency frameworks from major asset management and transportation institutions like the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Asset Management, and the National Academies of Sciences, Engineering, and Medicines (NASEM) Transportation Research Board. Then, we present the methodology used to collect data followed by the results and discussion from the survey and the workshop, highlighting key priorities and expert insights. We then describe the design of the rail-specific IAM module, detailing how the findings informed the module's structure and content. Finally, we conclude with implications for education, practice, and future research in these and related areas.

**Background**

The Institute of Asset Management Competences Framework highlights that asset management professionals need to be able to solve problems, communicate effectively, and work well with others to perform competently [4]. Similarly, according to the AASHTO Transportation Asset Management Guide [5], IAM requires a mix of competencies, defined as the "combination of observable and measurable knowledge, skills, abilities, and personal attributes that enable individuals or groups to successfully perform their roles and responsibilities" (p. 3-16). The key competencies highlighted in the guide include leadership, management, problem solving, relationship building, communication, and others related to planning, attitude, and analysis. To support the development of these skills within organizations, AASHTO encourages a combination of peer exchanges, training, and information sharing, but these events often require

registration to attend conferences or participation in existing transportation- or asset management-focused professional networks. Additionally, transportation asset management agencies often find it difficult to attract and retain talent, meaning there is a critical need to investigate effective approaches to inspire students to enter and remain in these fields [5].

Several national research reports further describe the competencies necessary for asset management and rail transportation professionals. For example, a report from the National Research Council stresses that collaboration, research, technical skills, and leadership are core competencies for federal facilities asset management [6]. A National Cooperative Rail Research Program report on building and retaining the railroad workforce highlights skills like communication and systems thinking as well as leadership capabilities [7]. Pulling from research from the National Research Council, the Institute of Asset Management, NASEM, AASHTO, and others, Table 1 summarizes the professional competencies needed for IAM.

**Table 1. IAM Competencies and Categories.**

| ***Competency Category*** | ***Professional Competencies*** |
|---|---|
| Problem Solving | Conceptual Thinking, Analytical Thinking, Systems Thinking, Researching, Applying Expertise |
| Strategic Leadership | Leading Teams, Helping Others Grow, Engaging Stakeholders, Collaborating Across Disciplines, Managing Risk and Uncertainty |
| Self-Management | Being Flexible and Adaptable, Having a Learning Orientation, Picking Up/Using New Technologies, Continuously Learning |
| Achievement and Action | Planning and Managing Projects, Taking Initiative |
| Communication | Having Strong Oral Communication Skills, Having Strong Written Communication Skills |
| Corporate and Social Responsibility | Adhering to Values and Principles |
| Influence and Persuasion | Networking/Relationship Building, Leveraging Impact and Influence |
| Emotional Awareness | Facilitating, Understanding, and Managing Emotions |
| Coping with Pressure | Balancing Work-Life Demands, Maintaining a Positive Outlook |

## Methodology

This study explores the necessary topics and competencies to support contemporary IAM practice by analyzing key literature and guidance, survey responses, and findings from an interactive workshop involving a broad group of IAM experts.

The *Infrastructure Asset Management Workforce and Education Needs Survey* was developed to assess current workforce competencies, perceived educational gaps, and priorities for future

training of IAM professionals. Survey questions were informed by a review of the Institute of Asset Management's Competencies Framework [4], the AASHTO Transportation Asset Management Guide [5], and national research reports on workforce development needs in the transportation or rail sectors [3], [6], [7]. The survey instrument included four primary sections: (1) respondent background and professional context, (2) competencies and skills using Likert-scale items, (3) prioritization of educational topics and training needs using ranking or rating questions, and (4) open-ended questions to capture emergent themes and contextual insights.

The survey was distributed electronically via email lists for IAM scholars and professionals, professional society channels, and direct email invitations to over 150 potential respondents. Participation was voluntary, and responses were anonymous. Data collection remained open for a three-month period. The responses were used to identify overall trends in IAM topics, competencies, educational needs, and instructional methods.

The survey findings were presented within a subsequent interactive expert workshop in the summer preceding the instruction of the module. Using an interactive virtual white board platform, the workshop participants ranked the topics and competencies necessary for success within IAM. Each participant was designated a set of topics and another set of competencies (on virtual sticky notes). Before any discussion occurred, participants were invited to move the sticky notes representing topics or competencies to one of three boxes: essential, important but not essential, or not essential. After the participants ranked the relative importance of the concepts, the research team led a full group discussion based on the disagreements until all participants reached consensus that a ranking was correct. The insights from the survey and expert workshop informed the development of a rail-specific IAM module involving practitioner guest lectures and practice-informed assignments.

**Survey: Results and Discussion**

*Respondent Characteristics*

Respondents represented a range of perspectives of IAM experts from several US states, including Tennessee, Texas, Illinois, Delaware, Colorado, Virgina, Georgia, Pennsylvania, and others. Figure 1.1 shows respondents by sector, with 57% of respondents being academic faculty and 26% of respondents working in private consulting. Figure 1.2 shows the areas in which the respondents have experience (respondents selected all that applied). Figure 1.3 shows years of experience, where most respondents have more than 20 years of experience. Figure 1.4 shows that respondents learned IAM skills through various means, with most respondents indicating that their skills were learned through graduate education (e.g., Ph.D. in Civil Engineering), on the job, and through self-study. These respondent characteristics reflect a strong combination of research, teaching, and practical experience that spans multiple decades of IAM experience.

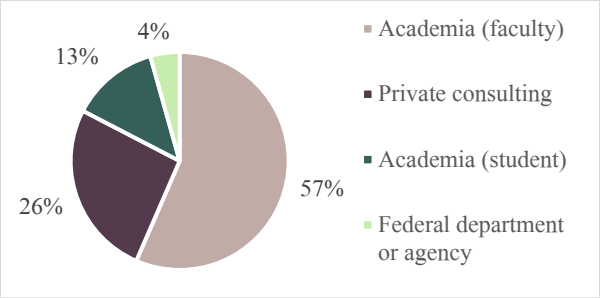


**Figure 1.1 Survey Respondents by Sector.**

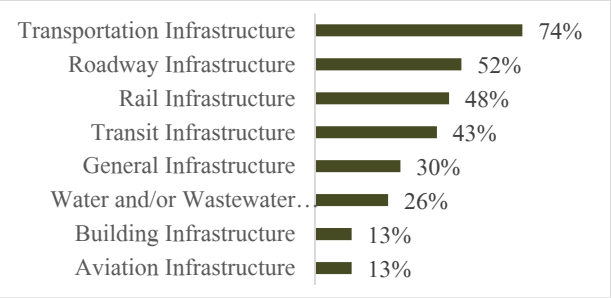


**Figure 1.2 Survey Respondent Area of Focus.**

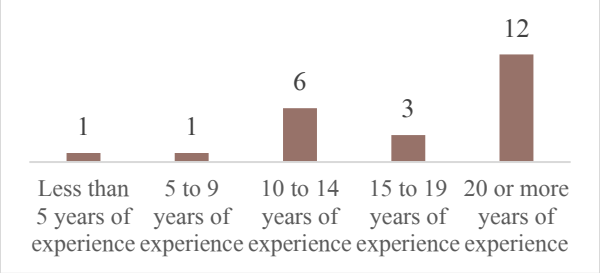


**Figure 1.3 Years of Experience.**

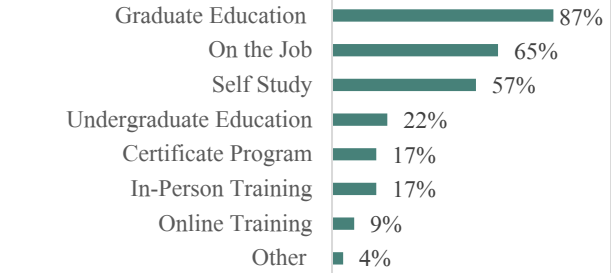


**Figure 1.4 Method(s) of Learning IAM Skills.**

*Necessary Technical Skills, Topics, and Competencies*

The survey asked respondents to identify the technical skills and tools that infrastructure asset managers need, shown in Figure 2.

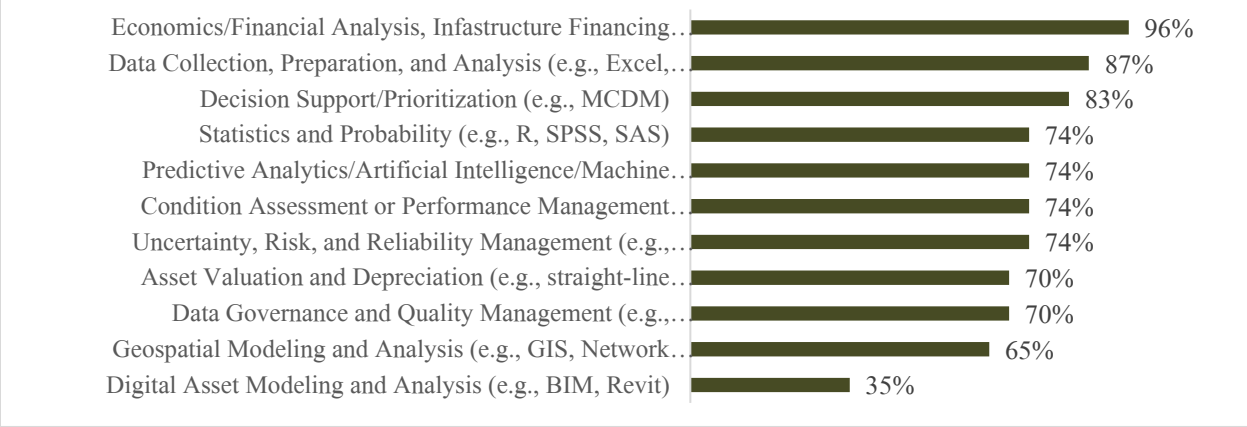


**Figure 2. Technical Skills and Tools for IAM Professionals.**

Figure 2 shows that respondents commonly selected *economics/financial analysis and infrastructure financing (e.g., Benefit-Cost Analysis)* and *data collection, preparation, and analysis (e.g., Excel, R, Python)* as the necessary technical skills and tools for IAM professionals. In addition, *decision support and prioritization* approaches (like multi-criteria decision-making analysis) were recognized by almost 90% of respondents. Besides *digital asset modeling and analysis (e.g., BIM, Revit)*, most participants indicated that all other technical skills are needed for IAM. Still, not all technical skills or tools are needed at every stage of a career in IAM; one

respondent noted, “I think all the topics listed above are important and relevant to [asset management]. The challenge, in my opinion, is how much knowledge you need in these areas. And I think this depends on the specific role and job description. A young professional working as an analyst will need a different set of skills than a high-level executive.” This indicates that there may be benefit in exposing students to many of these skills and providing them with a channel of continued learning as opposed to focusing a module or course on one or two technical skills.

Beyond technical skills, the survey asked respondents to select the topics that should be included within IAM educational programs or courses, shown in Figure 3.

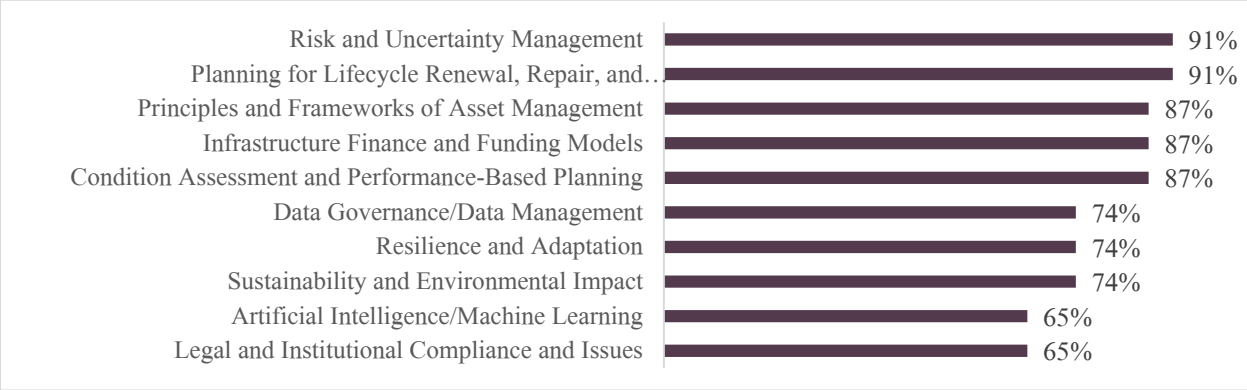


**Figure 3. Topics for Inclusion in IAM Educational Programs or Courses.**

Interestingly, *Risk and Uncertainty Management* and *Planning for Lifecycle Renewal, Repair, and Replacement of Assets* were highlighted most commonly as topics that should be included within IAM educational programs or courses. These topics are followed closely by *Principles and Frameworks of Asset Management*, *Infrastructure Finance and Funding Models*, and *Condition Assessment and Performance-Based Planning*. The topics selected by fewer than 70% of respondents were *Artificial Intelligence/Machine Learning* and *Legal and Institutional Compliance and Issues*; as a result, these topics were not included within the workshop ranking activities. Across questions, respondents emphasized analytical capabilities as well as lifecycle planning, infrastructure financing and funding mechanisms, risk and uncertainty management, and understanding of asset management principles and frameworks.

Respondents then reported the level of importance of 24 professional competencies (Table 1). The results, shown in Figure 4, indicate that systems thinking, analytical thinking, collaborating across disciplines, and continuous learning are considered extremely important by more than 40% of surveyed IAM experts. Other emphasized competencies by respondents include engaging stakeholders, managing risk and uncertainty, conceptual thinking, networking/relationship building, applying expertise, and being flexible and adaptable. The bottom five competencies, which were mostly related to influence and persuasion, emotional awareness, and coping with pressure, were not included in the workshop prioritization activity.

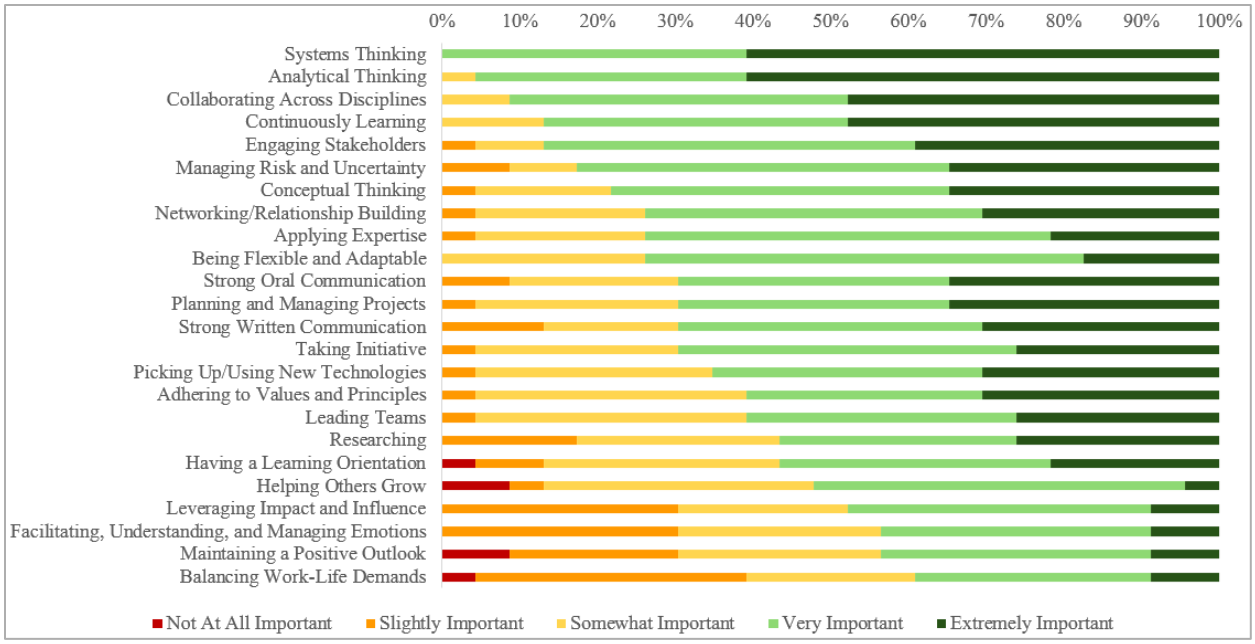


**Figure 4. Professional Competencies for IAM.**

*Effective Pedagogy and Assessment Types*

The survey asked about effective methods and practices for teaching IAM topics; responses to a question on effective pedagogy are shown in Figure 5. Based on the 20 respondents who elected to answer the teaching-focused questions, the most effective methods were *problem-based learning*, *project-based learning* (group or individual projects used to teach content), and *scenario-based learning* (simulated situations to apply knowledge/make decisions). Few participants indicated that *blended learning* (e.g., flipped classrooms) or *lecture-based learning* were effective approaches for teaching these topics.

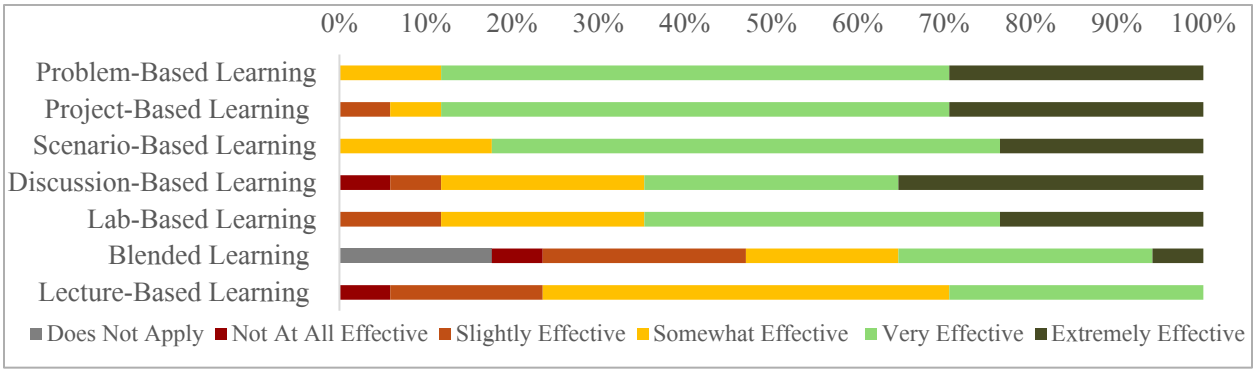


**Figure 5. Effective Pedagogy for IAM.**

Figure 5 shows that most participants agreed that *problem-* and *project-based learning* were very or extremely effective, which is consistent with studies on effective pedagogical approaches in civil engineering education [8]. In terms of *blended learning*, survey respondents had very mixed opinions, with approximately 30% indicating that the approach was not at all or slightly effective

and nearly 40% indicating that the approach is very or extremely effective. This aligns with broader findings on the effectiveness of blended learning approaches; multiple studies have concluded that students in blended learning environments have higher average scores than those in non-blended learning environments [9], [10], while others have found that there is a positive effect on final grades for students taking *non*-blended courses [11]. These discrepancies could arise in part because blended learning may be most effective for students with high self-regulation abilities [12].

The survey also asked respondents to rate the most effective assignment types for assessing IAM learning outcomes; responses are shown in Figure 6. Most participants indicated presentations, group projects, participation and engagement, problem sets, individual projects, and quizzes and/or exams were effective or extremely effective assessment types for this subject. On the other hand, most participants indicated that lab reports are less effective in the context of IAM education. One participant further commented, "Given that IAM requires a blend of analytical, policy and communication tools, the course must be designed with many of these elements together."

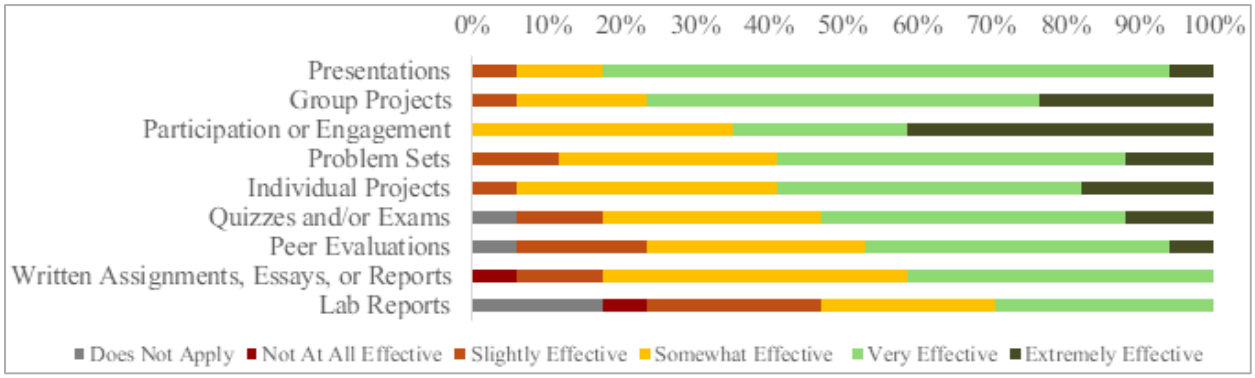


**Figure 6. Assessment Types for IAM Educational Material.**

These findings indicate that IAM educators find presentations and projects – assignment that require a mix of technical and interpersonal skills – are most effective for assessing IAM-related learning outcomes, reiterating an overall emphasis on project and problem-based learning.

**Expert Workshop: Results and Discussion**

Following the survey, a workshop was conducted with 10 participants with experience in IAM ranging from 6 years to 36 years working as consultant, public infrastructure managers, or scholars. All participants had expertise in asset management, and about half of the participants had expertise in rail-specific asset management. The goal of the workshop was to reach consensus on essential topics and competencies for IAM practice.

When ranking topics, all participants considered the following four topics ‘essential’ before any discussion: 1) *Principles and Frameworks of Asset Management*, 2) *Condition Assessment and Performance-Based Planning*, 3) *Planning for Renewal, Repair, and Replacement of Assets*, and 4) *Risk and Uncertainty Management*. Additionally, the topics *Infrastructure, Finance, and Funding Models*, *Data Governance and Management*, *Resilience and Climate Adaptation*, and *Sustainability and Environmental Impact* were considered ‘important but not essential’ by most participants. The workshop participant ranking of topics, presented in Figure 7 and 8, align with the survey results presented in Figure 3. The sticky notes along the left sides of the white box indicate the rankings agreed upon by all participants following the discussion.

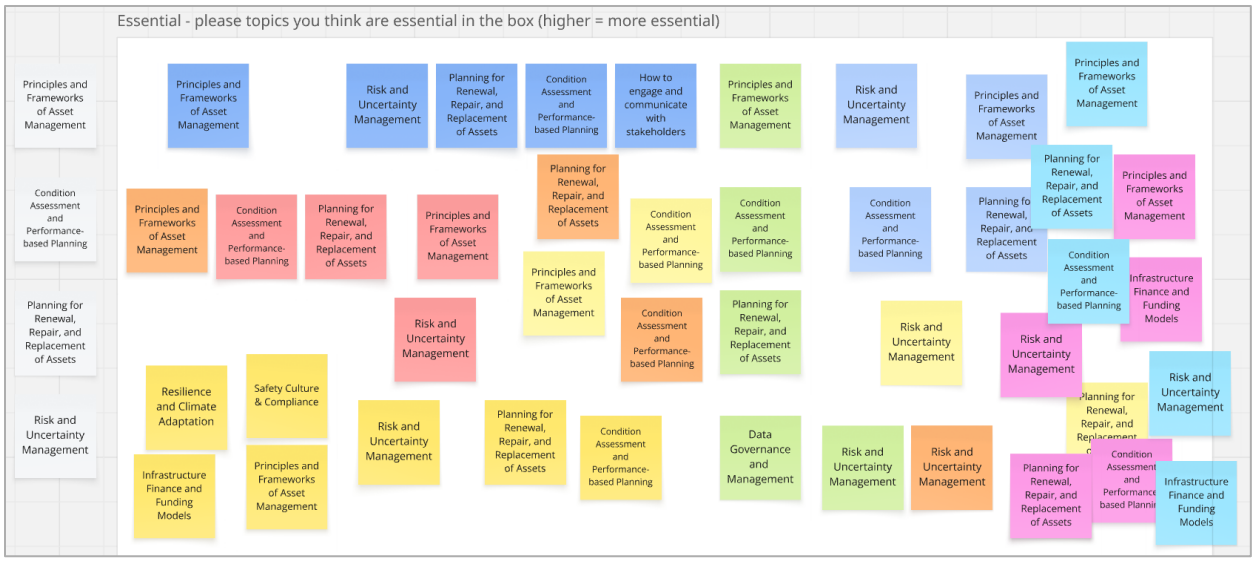


**Figure 7. Topics Ranked as 'Essential' in Expert Workshop.**

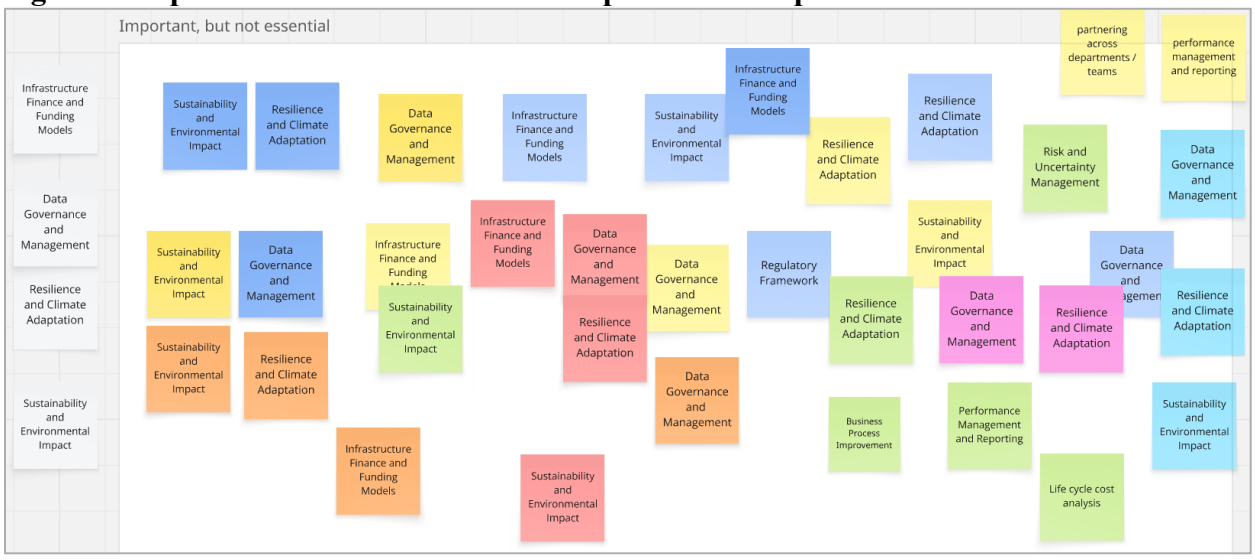


**Figure 8. Topics Ranked as 'Important but not Essential' in Expert Workshop.**

Beyond the predetermined topics, participants were invited to add new topics to the virtual white boards. One participant added *how to engage and communicate with stakeholders* and another

added *partnering across departments and teams* to the 'essential' box, referring to the importance interpersonal and communication-based skills (some of which are reflected in the subsequent ranking of competencies ranking). Other participants added *safety culture and compliance* and *regulatory framework[s]*, referencing how infrastructure asset managers must consider regulations in decision making (although this was one of the least selected topics by survey respondents, as shown in Figure 3). To the 'important but not essential' box, participants added *life cycle cost analysis*, *performance management and reporting*, and *business process improvements*. These concepts reinforce some of the broader topics included in Figures 7 and 8; for instance, *life cycle cost analysis* can be considered an example of a type of economic analysis and *performance management and reporting* can be included within condition assessment and performance-based planning. Participants agreed that none of the topics should be ranked as 'not essential'.

Participants were further asked to rank the key competencies (indicated by survey responses Figure 4) by the competency categories defined in Table 1. Participant responses varied more in the rankings of competencies than in the ranking of topics. Most participants considered three competencies to be 'essential' before any discussion: 1) *problem solving*, 2) *self-management,* and 3) *communication*. The sticky note rankings of the competency categories, with the 'consensus' sticky notes shown outside the white box, are shown in Figures 9 and 10.

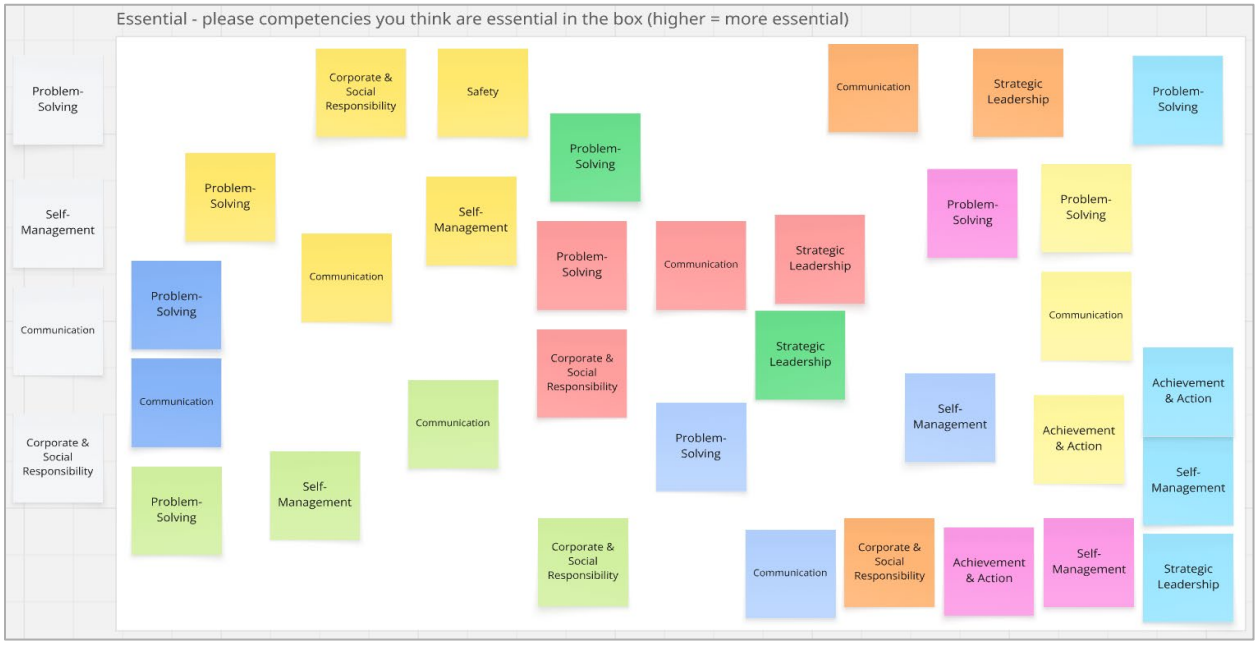


**Figure 9. Competency Categories Ranked as 'Essential' in Expert Workshop.**

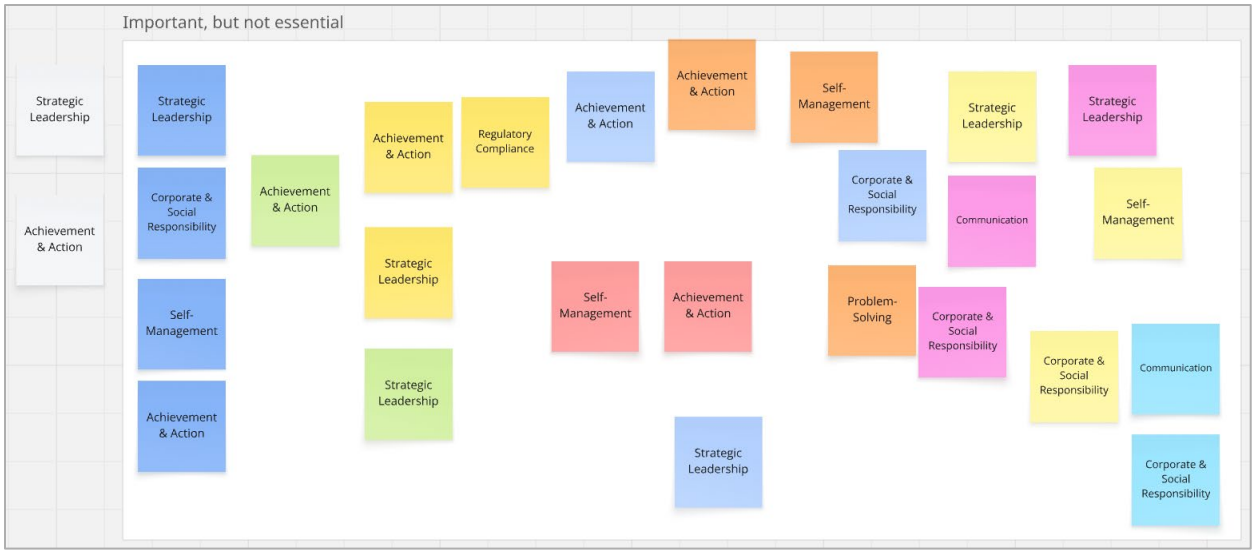


**Figure 10. Competency Categories Ranked as 'Important but not Essential' in Expert Workshop.**

One participant commented during the discussion that *problem solving* is the "core competency" of the field and may be considered more important than some soft skills like *communication*, but many other participants highlighted the importance of being a strong communicator. Another participant noted that communication in the rail industry can be critical for safety while another stressed that they had seen "ideas cast aside because the presenter doesn't have the skills to communicate" to stakeholders. The participants all agreed that communication skills can be taught within classroom environments and that these skills support successful careers across industry, government, and academia. The ranking of these competencies largely supported the survey results.

There was a lot of debate about whether *corporate and social reponsibility* was a competency that could be taught in the classroom or at all, as individuals range in the responsibility they take for the consequences of their actions. One participant commented that *corporate and social reponsibility* "is very important, but teaching it is a challenge. Some of this goes back to an individual's morals." Another participant agreed, saying that when emphasizing work quality and responsibility within educational activities, "some students take it to heart and others don't care as much." One participant indicated that case studies of failures and the consequences of employee errors could be a good way to expose students early on to the importance of *corporate and social reponsibility*, and the discussion concluded with participants agreeing that the competency should be considered 'essential'.

The participants debated about how to rank *strategic leadership* (including the skills to engage stakeholders, collaborate across disciplines, and manage risk and uncertainty) and *achievement and action* (related to taking initiative and planning and managing projects). Most participants

agreed that the skills associated with *strategic leadership* are important for certain individuals in IAM agencies – namely, executives or managers. Another participant remarked that, in the case that the entry-level employee is in a supervisory role (which occurs on the railways), being self-directed and managing risk are integral skills. Still, participants decided to rank these competency categories as 'important but not essential'. These findings diverged from the survey results, which indicated that collaborating across disciplines, managing risk and uncertainty, and engaging stakeholders are some of the most important IAM competencies. As was the case with the topics ranking activity, participants agreed that none of the categories should be ranked as 'not essential'.

Overall, the findings of the survey and workshop demonstrate that IAM experts consistently emphasize problem-solving, interpersonal skills like strong communication, and continuous learning as key competencies. Additionally, the survey respondents highlighted the effectiveness of problem- and project-based learning in IAM courses, indicating that educators can leverage these assessment types to help students cultivate these competencies. This section demonstrated how combining a survey (to capture breadth of expert perspectives) with a workshop (to provide additional depth on potential trade-offs) offers a practice-informed approach for developing or refining course content for civil engineering subjects. The following section describes how insights from the expert engagement activities informed the design of a new module for a graduate-level IAM course.

**Module Design**

Considering the combined results from the survey and workshop, prioritized topics and competencies were mapped to related assignment and activity types, as represented in Figure 11. This figure does not show all course elements but rather provides a sense of how the findings were translated into educational content.

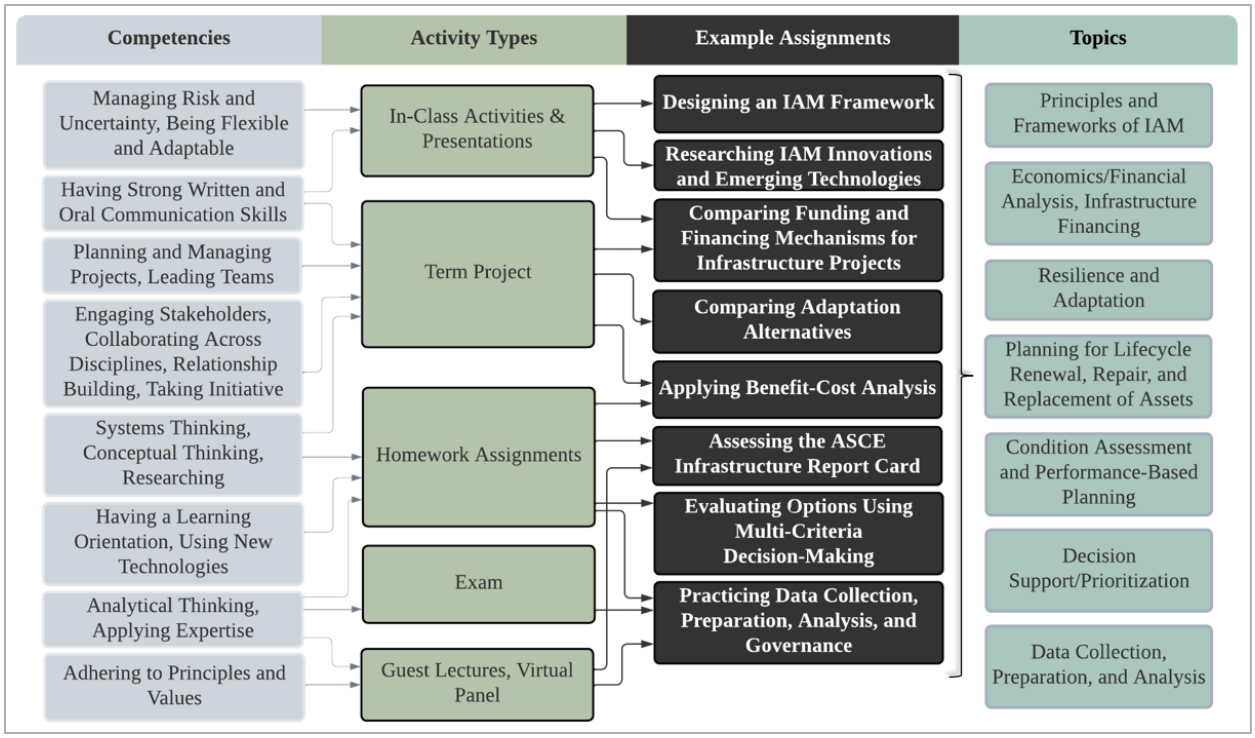


**Figure 11. Mapping Course Activities and Assignments to Prioritized Competencies and Topics.**

The module was piloted in an IAM graduate course in fall 2025 in which the primary author served as instructor of record. Throughout the module, students had several opportunities to learn directly from professionals within the rail and asset management sectors, exposing them to day-to-day challenges, emerging technologies, and management strategies currently shaping the field. These guest lectures included railway safety investigators from the Spanish Ministry of Transport and the United States Federal Rail Administration, a planner from a metropolitan planning organization working on rail station planning, consultants focusing on rail and transit funding and financing, and a practitioner panel representing Amtrak, Brightline West, and the High Desert Corridor Joint Powers Agency. This exposure enabled students to connect principles introduced through in-class activities to practical needs and challenges.

To help students build the IAM competencies highlighted in the survey and workshop, the course employed a range of assignment types. For example, students participated in a debate on the implementation of a controversial local rail project. This debate allowed students to develop evidence-based arguments, communicate technical ideas clearly, and think critically about how engineering decisions influence public outcomes - skills that are directly transferable to professional practice. Another example of an assignment modeled to help build key competencies while teaching prioritized topics was the term project. The project, co-developed with practitioners, mimicked a competitive grant application process modeled after the US Department of Transportation's Promoting Resilient Operations for Transformative, Efficient,

and Cost-Saving Transportation (PROTECT) discretionary grant program. Working in small teams, students proposed rail infrastructure adaptation projects that included decision-support frameworks such as benefit-cost analysis and other concepts introduced in class and guest lectures. Through these assignments and others, the rail-specific module gave students the opportunity to develop highly emphasized technical skills like economic analysis and data collection and analysis alongside critical professional competencies like collaboration, written and oral communication, and uncertainty and risk management.

## Conclusion

This study contributes to the growing body of knowledge on IAM education by identifying critical competencies and topics and then translating those insights into an educational module, illustrating an approach for strengthening connections between academic learning and professional practice while enhancing the practical relevance of learning activities. Future work will evaluate the effectiveness of the practice-informed module through a pre- and post-assessment of student-perceived confidence in IAM topics and professional competencies as well as stated interest in related careers, providing empirical evidence to guide module refinement. The approach presented in this study, combining expert insights from survey and workshop engagement with professional experience through in-class guest lectures and other activities, can be applied to course design across civil engineering curricula to prepare students for real-world situations and challenges. As conditions and workforce needs continue evolving, this approach can ensure that graduating civil engineering students remain equipped to design and manage complex infrastructure systems.

## Acknowledgements

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