Optimization of Air Traffic Control Training at the Federal Aviation Administration Academy

Jessica A. Updegrove[1] and Shafagh Jafer[2]
Embry-Riddle Aeronautical University, Daytona Beach, Florida, 32114

This paper investigates current and future uses of simulation in FAA Academy ATC training to identify potential improvement areas to the current training program in the areas of simulation technologies and course content. Once identified, recommendations for changes to the current training program are made. A thorough literature review of current training techniques used at the FAA Academy and training centers was conducted. In addition, this study utilized interviews and surveys to collect data regarding a variety of ATC training interest areas, such as virtual reality, current maintenance schedules, and simulator features. Finally, a thorough cost-benefit analysis was conducted to determine the potential improvement areas with the highest feasibility for implementation and highest potential to reduce training costs and/or time. The primary findings of this research revealed three feasible improvement areas to the current training process and simulation technologies: (1) reducing the dependence on instructors during simulation training, (2) utilizing web-based training methods, and (3) updating current simulator systems to include new features, such as recording and playback features. These changes were recommended to be implemented first, with voice recognition and virtual reality improvement areas being recommended for future studies and/or implementation.

I. Introduction

WITH advancements in computer simulation and visual graphics capabilities, the use of advanced flight simulation training devices in general aviation has increased significantly. A variety of simulation training devices

[1] Graduate Research Assistant, Department of Electrical, Computer, Software, and Systems Engineering, Embry-Riddle Aeronautical University – Daytona Beach Campus, Lehman 343, 600 S Clyde Morris Blvd, Daytona Beach FL 32114-3900, updegroj@my.erau.edu .
[2] Assistant Professor, Department of Electrical, Computer, Software, and Systems Engineering, Embry-Riddle Aeronautical University – Daytona Beach Campus, Lehman 343, 600 S Clyde Morris Blvd, Daytona Beach FL 32114-3900, jafers@erau.edu .

and technologies are utilized in every phase of current pilot and air traffic control (ATC) training programs, ranging from low-fidelity desktop trainers to high-fidelity full-flight simulators. Simulation is one of the only methods currently available which gives trainees hands-on experience in learning such a high-skilled and detail-oriented occupation as ATC. However, as technology rapidly improves, current training devices can become outdated and less effective than when first implemented in a training program, leading to training inefficiencies and increased training times. In an effort to reduce the effects of outdated simulators, current simulation training practices must be evaluated and analyzed to identify inefficiencies, areas of improvement, and potential applications for new or updated simulation technologies.

As pilot and ATC training programs constitute a large area of research, improvements to the Federal Aviation Administration (FAA) Academy ATC training process is the primary focus of this study. In this paper, a brief background of the FAA ATC training process is presented in section II. In section III, a literature review introduces current simulation technologies available to the training community, as well as a presentation of current training techniques and areas of interest. Section IV provides the methods and materials used in conducting a research study for investigation of current training techniques and the resulting analysis, including an industry vendor survey and individual vendor interviews. Section V presents a detailed cost-benefit analysis of topics and areas of interest identified via the literature review, survey, and interviews. Section VI then suggests recommendations for improving the ATC training process and simulation at the FAA Academy. Finally, an overview of the paper contents and contributions to the field of ATC training is provided via a brief conclusion.

II. Background

In order to understand where simulation technologies can be applied or improved, the current FAA Academy training process and how it fits into the overall ATC training process must first be understood. These processes, explained in detail in a previous publication [1] by this research team, is presented in brevity here as a brief overview for the reader.

ATC training occurs over two main phases: FAA Academy training and on-site facility training. All official training starts at the FAA Academy, located in Oklahoma City, Oklahoma; however, all developmental ATCs are hired from one of three paths: previous controllers, Air Traffic-Collegiate Training Initiative (AT-CTI) developmentals, or the general public. Previous ATC training and knowledge varies in each of these three paths, resulting in a wide range of skill levels as students begin training at the FAA Academy. At the FAA Academy, ATC training consists of three main phases: air traffic academics, part-task training, and skills building. Individual courses in these phases are listed in the FAA Catalog of Training [2]. Some courses are considered job jeopardy, which are courses deemed essential to ATC and failure of these courses results in a permanent dismissal from the FAA Academy. All job jeopardy courses utilize cumulative scoring from multiple performance assessments and written tests, consisting of a total of 100 points with a passing score of 70 points, to evaluate if a student has successfully completed the job jeopardy course [1].

There are three major flight control divisions in ATC and ATC training: Tower, Terminal Radar Approach Control (TRACON), and En Route. Each division has a unique training track, with each track specifically designed to teach the required materials for only one division; however, all three tracks follow the aforementioned training phases. The Tower track focuses on air traffic management activities within a radius of a few miles of the airport and utilizes simulators to replicate real ATC towers and airport views. TRACON training occurs via the Terminal Basic Radar Training Course (RTF), which is the job jeopardy course for developmentals continuing on to a standalone radar facility. The RTF course incorporates classroom and simulation training focused on managing traffic outside the radius managed by Towers, generally extending only a 40-mile radius from the primary airport. En Route courses are the most detailed courses as the FAA Academy and focus on managing air traffic along defined routes. This track consists of classroom instruction, medium-fidelity skills practices utilizing interactive computer-based instructional systems, and high-fidelity En Route Automation Modernization (ERAM) simulation in an En Route lab [1].

III. Literature Review

In January 2013, the FAA conducted a review and evaluation of air traffic controller training at the FAA Academy and reported their findings, detailed in [3]. The Air Traffic Division (AMA-500) was identified as delivering initial, advanced, and specialized air traffic training at the FAA Academy. Although divided into three primary areas of research: roles and responsibilities, communication of roles and responsibilities, and accommodation of developmental ATCs, only the accommodation of developmental ATCs proved particularly relevant to this research. This area focused on the ability of the FAA Academy to meet developmental ATC demands in the form of facility size, available instructors, available training equipment, and a variety of other factors. It was found that the FAA Academy historically had no issues accommodating developmental ATC demands as instructors could be contracted as needed and limited simulator space could be mitigated via a rotating class schedules. However, it was noted that the number of available simulators can eventually affect the total number of developmental ATCs that the FAA Academy can accommodate. High-fidelity simulation creates a very limited amount of learning positions, effectively creating a bottleneck for developmentals as they approach the end of their training. In addition, lack of funding and financial support was found to make course maintenance and simulation updates more challenging to complete in a timely manner. As a result, it was recommended that new technologies be utilized in the development, maintenance, and delivery of training materials, as well as for training developmental ATCs more effectively. More courses which utilize web-based material and online training solutions were suggested. In addition, an analysis of ways to stabilize and improve the FAA Academy funding was recommended [3].

In a 2006 study, Brudnicki, Chastain, & Ethier [4] provided an in-depth overview of training technologies utilized in the FAA Academy and on-site facility training, as well as recommendations for future applications of technologies. High fidelity, intelligent training systems technologies such as voice recognition and synthesis, intelligent tutoring, and instructor support capabilities were identified as potential areas of improvement in the FAA Academy training process. In addition, web-based instruction and location-independent, site-specific training was recommended. Although deemed too immature for complex scenarios, voice recognition and synthesis has the potential to automate pseudo pilot and ghost controller capabilities in beginner-level scenarios, which can improve the overall practice environment for skill development, support self-paced and independent learning, enforce the teaching and use of standard ATC phraseology, and reduce faculty costs. An Intelligent Tutoring System (ITS) is a set of automated capabilities combined with human performance models that provide for an objective assessment of learned skill levels, infer strengths and weaknesses of a student, and enable tailored instruction. Proven effective in several similar domains, this technology could reduce training times and increase instructional quality via accurate and objective feedback. Instructor support includes updated simulator features, such as recording and playback of scenarios. These support features could reduce instructor workloads and thereby potentially improve teacher feedback to real-time student progress. Web-based instruction could replace or supplement standard lecture-based training courses, leading to a reduction of FAA Academy resources and on-site staff, support self-paced learning in geographically separate locations, and test the aptitude of trainees before entry into the FAA Academy or a field facility. Finally, networking and video teleconferencing technologies could enable location-independent training in a variety of courses. This can greatly reduce training times and costs while improving quality [4].

A variety of other ATC publications were reviewed and analyzed when formulating future recommendations and improvements for future ATC training processes and practices. Discussed in more detail in [1], only the key aspects will be discussed here. A 2016 study by Knecht, Muehlethaler, & Ethier [5] analyzed training development, noting that training ATC nontechnical skills is an important aspect of ATC training that is better suited in practice-based environments. As a result, it was recommended that practice-based training be utilized over traditional frontal teaching methods when teaching nontechnical skills. Similarly, a study by Kang & Landry [6] explored using scanpaths as a learning method for air traffic conflict detection and showed significant performance increases and confidence boosts in students. A 2015 case study by Airservices Australia, detailed in [7], demonstrated the benefits of updated simulation systems with new features such as recording, pausing, and replaying training sessions with both video and audio. Finally, Arminen, Koskela, and Palukka [8] analyzed the stimulus and response pairs of ATC training to identify activities and stimuli in the training process, leading to the observation that ATC trainees respond either to the scenario itself or to an instructor prompt.

Along with studies conducted in the field of ATC, related studies have also shown training benefits through the incorporation of new technology. Risukhin et al. [9] investigated the benefits of utilizing more affordable software and hardware low-fidelity simulators (LFS) for improving the development of pilots' cognitive and behavioral skills, as well as acquire research results from simulator use. Although LFS are not as realistic in portraying what a student can expect to see in the workplace, use of LFS can be effective for training in normal flight operations if a high-quality training program supplements it. Therefore, LFS training can be best utilized in the early stages of the training process. Results from the study included optimistic outcomes in aviation college student pilots' flight proficiency progress, along with training cost reductions. In addition, peer mentoring was found to be a beneficial training technique. Of particular interest to the field of ATC, the study also included an investigation into the communication breakdowns between pilot and ATC leading to fatal accidents and other safety hazards. The software used could simulate pilot-ATC communication, which was then used to better understand language factors that influence pilots' radio communication with English as a second language controllers. The ability to use technology to study and improve safety between pilots and controllers can provide valuable benefits to the training community, such as better awareness of the consequences of unclear phraseology or speech on training performance [5].

IV. Methods and Materials

After the literature review was completed, it was determined that a formal investigation into the current state of simulation and training for the FAA Academy ATC training process needed to be conducted before recommendations for improvements regarding the training process and use of simulators could be made. To better understand the current state of simulation and training in ATC, the research team contacted a variety of industry professionals and vendors of ATC simulation technology to the FAA and other training establishments. These vendors and professionals were contacted via two methods: (1) phone interviews, and (2) surveys. These contact methods allowed the research team to better understand the current successes and barriers in the current ATC training process, and, in combination with the knowledge gained from the literature review, allowed for recommendations to be made that are more applicable to the current state of the field.

A. Setup

While the literature review provided an overview regarding the history of the ATC training process, the current state of the field was still unknown. Recommendations made in previous studies needed to be investigated by the research team to determine if these changes were in fact implemented as suggested. The feedback gained from the industry professionals and vendors allows the research team to cross-compare recommendations given by those contacted with the recommendations and observations found in the literature review. In addition, new ideas and recommendations can be formulated from the feedback of those vendors and professionals currently experiencing the drawbacks and limitations of current technology.

B. Approach

As the research topic continues to span a vast area of knowledge, only a select few topics were included in the survey and interviews. The two primary research areas the team focused on investigating were: 1) the current types of simulation technologies being used for ATC training and the maintenance and upkeep of these technologies, and 2) how simulation technologies affect the training process, both positively and negatively. As a result, two major topic areas can be seen in the selected questions for the survey and interviews: 1) current simulation technologies, their maintenance, and potential future simulation technologies, and 2) how simulation affects the training process. These topics were selected to validate and confirm which technologies are currently being used in FAA training against the literature review, understand the current limitations of simulator technology features, and determine an average update and/or replacement time for outdated simulator technologies. In addition, questions targeting how simulation is currently being used in the training progress focus on improving how simulation is incorporated into a training program.

C. Methodology

The survey and interviews were formulated with a time restriction in mind. It was assumed that a shorter survey would encourage more responses from an already limited number of participants. Interviews were conducted prior to the survey primarily as a means of determining which topic areas the survey should focus on. Interviewees were initially selected from a list of industry vendors and professionals potentially interested in the research area, many of whom are industry partners with the Center of Excellence for Technical Training and Human Performance sponsored by the FAA. The survey focused on collecting objective responses to some questions or topic areas discussed during the interview stage. In addition, open-ended questions allowed industry vendors and professionals to provide additional comments and ideas for future recommendations.

After the survey was distributed and responses were being collected, some responders opted to hold an informal interview in lieu of submitting a survey. This was primarily because some vendors did not have enough experience in all survey topic areas to complete the survey as intended, but had vast knowledge regarding a specific topic area that would benefit the research team.

D. Data Gathering

Interviews were conducted over the phone and typically lasted 30-45 minutes. During review, potential research areas were determined and listed for further investigation. In addition, survey topic areas and questions were formulated via the knowledge gained from the literature review and prior interviews.

The surveys were designed to be completed within 20 minutes and were distributed via email to industry vendors and professionals whom were already in contact with the research team. In addition to the survey, a consent form was provided. Surveys were then completed and returned via email. Survey completion is considered anonymous and no vendor or professional will be specifically linked to a response without prior permission from the responder.

After all surveys were collected, questions were consolidated and analyzed for patterns in responses, potential recommendations, and new research areas.

E. Results

A total of thirteen industry vendors were contacted to participate in a survey, an interview, or in some cases both. Nine vendors and professionals were contacted for an interview initially, with five focusing in a similar topic area to the research team. From the initial round of interviews, the following topic areas were identified as relevant to the current research: virtual reality (VR), adaptive training technologies, web-based training solutions, and voice recognition and synthesis (VR&S).

Of the thirteen industry vendors and professionals contacted to complete a survey, nine provided survey responses and one opted for a phone interview in lieu of completing a survey. Of the nine returned surveys, one was removed from analysis due to incomplete information, with only three of the seventeen questions having been answered. However, any information provided via this survey, when applicable to the selected topic areas, was still considered when deliberating on potential recommendations. Survey questions were comprised of the following topic areas: (1) current simulation technologies being used in ATC training and their features, (2) simulation technology potential for reducing training time, costs, and/or increasing transfer of learning, (3) average simulator update and maintenance schedules, and (4) the effect of simulation on the training process.

Results from the survey analysis supported many of the discoveries made during the literature review and interviews. When asked if simulation technologies enhance the ATC training process, respondents unanimously agreed that simulation is a great benefit in the training process, noting that training devices allow students to bridge the gap between training and reality and that training devices are cheaper, more available, and safer. In addition, simulation allows for learning from mistakes, creating obscure training situations, and builds student confidence. When asked which simulation technologies are currently used the most for ATC training, desktop simulators and high-fidelity simulators topped the list at 4 responses each, with VR, web-based trainers, and voice recognition falling behind, as shown in Fig. 1. However, these technologies then tied with currently used technologies as technologies with the most potential for reducing training costs and time, as these technologies allow for home training, self-paced learning, easy accessibility, and lower cost to prepare and maintain that the previously-used high-fidelity simulators that are popular today, shown in Fig. 2. Note that for these questions, respondents selected multiple answers, creating a total greater than eight responses. When asked if current ATC simulators provide personalized feedback depending on each student's need, only three responders could confirm their simulator technologies do. This supports an area of potential for improving simulator effectiveness and reducing training times through personalized and effective feedback.

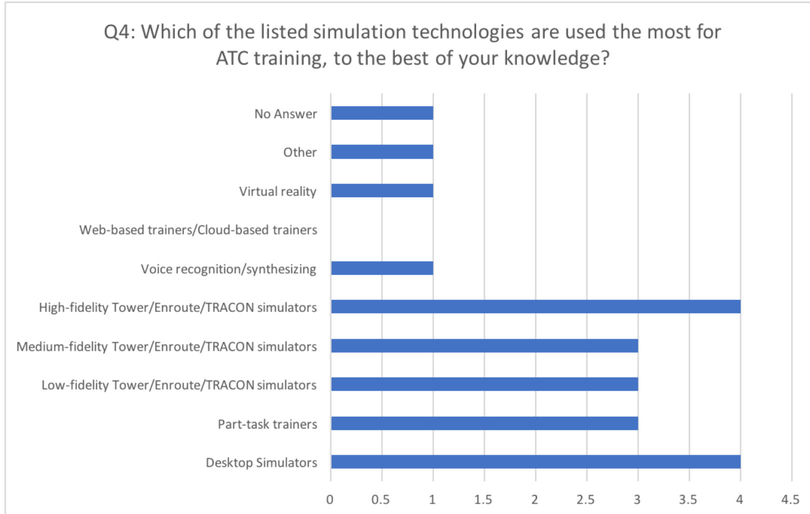

Fig. 1 Response distribution for current technology usage.

Although many responses supported prior discoveries, some seemed to waver from previous assertions made. One example of this is the responses regarding the updating and maintenance of simulation

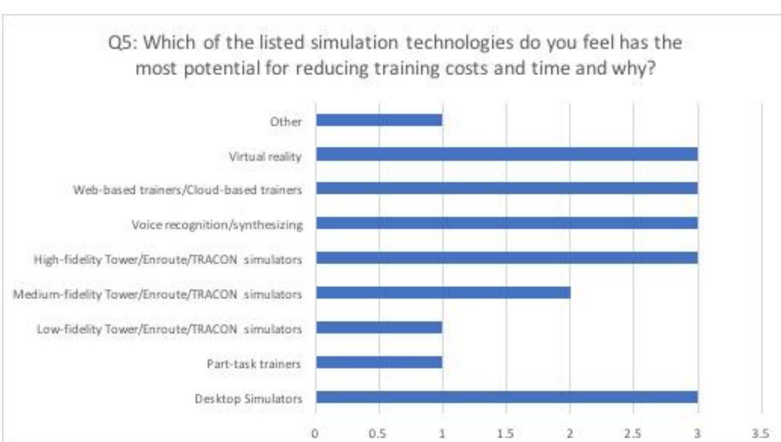

Fig. 2 Technologies with most potential for reducing training times and costs.

technologies. When asked if training simulators are current and up-to-date with present technologies available in the field, only two responders answered positively. However, later responses to more specific questions regarding the updates and maintenance of these same simulation technologies appear to claim the opposite. Although responses did vary, update and maintenance schedules average around updating at least once a year and up to four times a year. In addition, creating these updates in technology trended below three months. Finally, installing these updates was found to take less than thirty minutes, on average. These findings seem to somewhat counter the previous assumption that most simulator software is out of date. However, a note must be made that these questions did not include potential hardware updates, which could still be lagging behind industry improvements.

One of the most controversial topic areas was, unsurprisingly, the use of VR. Although supported in the literature review as a potential area of improvement for ATC training, the initial round of interviews refuted this idea. However, the survey again refuted the interviews with 88% of respondents answering positively when asked if incorporating VR components will improve simulator transfer of learning. However, while responses were positive, they were also skeptical. Many responses included recommendations and warnings, such as only being useful for experienced students and/or controllers needing refreshers on complicated scenarios, using augmented reality instead of VR, and that, while potentially useful, VR has not yet been proven as an effective training method. However, many positives were also identified, such as being a great means for 4-D learning, adding additional immersion and training realism, allowing students to experience a realistic training location and environment before arriving at a facility, and a good way to incorporate additional kinds of stress found on the job, such as facility noise and coordination.

V. Cost-Benefit Analysis

After careful analysis of the literature review suggestions, interview responses, and survey responses and recommendations, five potential improvement areas were selected for further analysis: (1) the replacement of live pseudo-pilots with simulated pseudo-pilots, (2) the use of VR, (3) updating current simulation systems' features, (4) reducing the dependence on instructors during training, and (5) utilizing web-based training solutions. These improvement areas were chosen after considering a variety of factors; however, many were selected due to popularity among responses, feasibility of implementation, and potential for improving the current training process.

To better compare these five improvement areas, a cost-benefit analysis was conducted. Each area was examined and potential benefits and costs/disadvantages were identified from the literature review, interview responses, and survey responses. Each benefit was given a benefit value between 1 and 10, with 1 indicating the benefit is of low value to improving the training process and 10 indicating the benefit is of high value to improving the training process. These values were subjectively chosen and were given based off all previously-gained knowledge and in consideration to the other listed benefits. Each cost was given a cost value between 1 and 10, with 1 indicating the cost is of low value to improving the training process and 10 indicating the cost is of high value to improving the training process. These values were also subjectively chosen. In addition to the cost value, costs were also given a time cost, or cost-to-implement, value between 0 and 10. This value takes into consideration how long it would take to implement an identified cost and/or how expensive the cost could be to the organization implementing the change. A time cost of 0 is given when a cost does not require a change to be implemented, such as when a cost is a disadvantage of the improvement area and not a change in technology. A time cost of 10 is given when an identified cost would require substantial changes to the current training process or training technologies. After all benefits and costs were assigned their corresponding values, an overall estimated value/feasibility value was determined by dividing the sum of all benefit values by the sum of all cost values added to the sum of all time cost values. The overall estimated value creates a comparable value by which all five improvement areas can be ordered by feasibility, while also accounting for all costs and benefits. Finally, all five improvement areas were given an overall recommendation rank based off the overall estimated value.

Table 1 Cost-benefit analysis overview

Potential Improvement Area	Overall Estimated Value/Feasibility	Overall Recommendation Rank
Simulated pseudo-pilots	-6	4
Virtual reality	-16	5

Updated simulation systems	-4	3
Reducing instructor dependence during training	22	1
Web-based training solutions	16	2

In the interest of length, only the overall estimated value and overall recommendation rank are shown here, as shown in Table 1. An overall estimated value less than 0 indicates a potential improvement area evaluated with more costs than benefits. As a result, these improvement areas would not be as easy, cost-effective, or feasible to implement. An overall estimated value greater than 0 indicates a potential improvement area evaluated with more benefits than costs and would therefore be a better investment of time and/or resources. Simulated pseudo-pilots and VR each had eight identified benefits and five identified costs. Updated simulation systems had five identified benefits and four identified costs. Reducing instructor dependence during training had five identified benefits and two identified costs. Finally, web-based training solutions had ten identified benefits and three identified costs. As shown in Table 1, reducing instructor dependence during training was identified as the most feasible improvement area. This was due primarily to a multitude of potential benefits with very low implementation costs. This improvement area would focus primarily on improving the capabilities of simulation systems (with separate costs and benefits identified under updated simulation systems) and improving the teaching process in ATC training programs.

VI. Recommendations

After considering the cost-benefit analysis results, it is recommended that the top three potential improvement areas be implemented. First, a focus should be made to reduce the dependence on instructors during training. A reduction on instructor dependence allows for larger class sizes and would require fewer instructors overall. In addition, instructors would have more opportunity to increase the quality and frequency of feedback during a training session as the number of tasks an instructor must manage could be significantly reduced with the aid of technologies such as voice recognition and personalized student feedback. However, one downside of reducing instructor dependence would be the need to update current simulator features to support this change, leading to implementation and/or replacement costs. Second, web-based training technologies should be utilized more heavily during the training process. These technologies can reduce the reliance on long, in-person lectures, allow students to learn at their own pace, allow materials to be more easily accessible, and can allow students to prepare for in-person training on their own time. However, some disadvantages include the need to create and manage new web-based courses and potential security issues as training materials would be hosted online. Third, current simulation systems should be updated to include additional features deemed beneficial to ATC training. These features include the ability to pause, rewind, record, share, and replay scenario sessions, the ability to provide personalized training feedback for each student, and the ability to display simulated trainer prompts that can notify trainees when an action that must occur was done incorrectly or missed completely. Some disadvantages include the potentially large cost to implement these new features and higher maintenance costs.

While the remaining two improvement areas are still being considered potential improvement areas, they are not being recommended at this time due to high implementation costs. In addition, these technologies must first mature before they can be deemed feasible for use in ATC training. However, it is recommended that these potential improvement areas be considered again in future studies.

VII. Conclusion

To reduce the effects of outdated simulators, current simulation training practices must be evaluated and analyzed to identify inefficiencies, areas of improvement, and potential applications for new or updated simulation technologies. To accomplish this task, current literature following the current ATC training process at the FAA Academy was identified and analyzed for potential improvement areas in both the training process and training simulation technologies. In addition to a literature, this study conducted phone interviews and distributed a survey to industry professionals and vendors to obtain insight into the current state of simulation technology and training processes in ATC. From the literature review, interviews, and survey results, five potential improvement areas were identified: (1) the replacement of live pseudo-pilots with simulated pseudo-pilots, (2) the use of VR, (3) updating current simulation systems’ features, (4) reducing the dependence on instructors during training, and (5) utilizing web-based training solutions. Of these improvement areas, reducing the dependence on instructors during training was found to have the most benefits with the fewest costs and was recommended as the first area of improvement to be implemented in future training processes. In addition, utilizing web-based training solutions and updating current simulation systems’ features followed as the second and third recommendations, respectively. The remaining two improvement areas were deemed not currently feasible; however, they are still being recommended for further analysis in future studies.

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