Assessing the Efficacy of Virtual Reality Site Visits to Enhance Remote Learning Experiences for Civil and Construction Engineering Students

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Abstract –

Remote construction engineering education can provide immense benefits to students and colleges by removing time and cost hindrances that currently prevent enrolment. However, replicating the hands-on experiential learning provided by traditional in-person site visits poses significant challenges for remote students due to accessibility barriers. These barriers include limited access to physical construction sites and the inability to engage in peer-to-peer interactions common in in-person settings. This research aims to bridge this gap between remote and in-person students of construction engineering by studying the potential of virtual reality site visits on undergraduate education for civil and construction engineering students. Thus, the study developed and deployed a virtual site visit using the discrete event simulation software ConStrobe and game engine Unity, accessible through WebGL on smartphones. Participants experienced both in-person and virtual site visits and engaged with the simulation to complete classwork tasks such as calculating equipment productivity for the Heavy Civil Construction Management course. Data was collected using surveys and analysed to assess their understanding and engagement. Initial findings suggest that virtual simulations effectively complement traditional site visits by improving students' understanding of construction concepts, particularly productivity and equipment interaction. However, some students reported challenges such as feeling overwhelmed, emphasizing the need for enhanced user guidance. These insights provide guidance for construction instructors and curriculum designers aiming to integrate virtual simulations into the classes, offering an accessible and effective tool to support experiential learning for remote learners.

Keywords – Virtual Reality Site Visits, Remote Education, Experiential Learning, Construction Education

1 Introduction

The evolving demands of construction management education necessitate innovative approaches to deliver experiential learning, especially in remote and hybrid settings. The shift toward remote education, accelerated by the COVID-19 pandemic, further highlights the need to address issues of student engagement and experiential learning. Studies, such as those by (Neisler 2020), indicate that remote students often struggle with motivation due to a lack of hands-on experiences and peer interactions. In response, (Park et al. 2020) recommend the use of virtual spaces and tools to replicate the serendipitous interactions and moments of engagement that occur in in-person settings. On the other hand, traditional in-person site visits are invaluable for providing hands-on exposure but pose challenges related to accessibility for remote students.

Thus, the goal of this research is to explore the use of virtual reality to enhance remote learning by providing in-person student experiences of construction site visits and peer interaction through virtual reality platforms. This research will implement virtual reality site visits for students in the Heavy Civil Construction Management course and collect student feedback and data about its use to answer the following research questions: (1) Can virtual reality site visits improve student experience for remote students? (2) Can virtual reality site visits measurably improve student understanding compared to site visits?

By addressing these questions, the study assesses whether and to what extent virtual simulations can replicate in-person construction site visits and serve as a robust learning tool. The findings contribute to the development of scalable, sustainable, and inclusive learning tools in construction management education, aligning with broader goals of accessibility.

2 Literature Review

Remote learning technologies, such as virtual site visits, are increasingly used in construction education, providing accessible and cost-effective alternatives to traditional methods (Jaselskis *et al.* 2012). During the COVID-19 pandemic, remote teaching broadened accessibility but highlighted challenges in maintaining educational quality and hands-on skills acquisition (Martínez-Muñoz *et al.* 2021). These challenges underscore the need for innovative solutions like virtual simulations to bridge gaps in accessibility, engagement, and comprehension while addressing technological and pedagogical challenges. This section explores the use and approaches of virtual simulations in construction education.

2.1 Use of Virtual Simulations in Construction Education

Virtual simulations are transforming construction education by bridging theoretical knowledge and practical application. They have been effectively applied in safety training (Ismail *et al.* 2021), immersive learning for specific construction phases (Salman 2023), and onboarding programs (Belaroussi *et al.* 2023). Studies demonstrate their role in enhancing comprehension, engagement, and problem-solving skills across topics like highway engineering (Seifan *et al.* 2020), railway transportation (Eiris *et al.*, 2022), and steel structure assembly (Salman 2023).

Virtual scenarios also support construction management education by reinforcing principles such as project planning and safety compliance (Shojaei *et al.* 2023) and enabling hands-on practice in scheduling *(Ilbeigi et al*. 2024) and post-disaster assessment (Humayoun *et al.* 2024). Despite these advances, research on their application in customized heavy civil construction management topics remains limited, which this study aims to address.

2.2 Variance of Simulation Approaches

The degree of immersion and type of simulation significantly impact virtual learning outcomes. Visualization methods range from 2D displays to immersive 3D environments (Shojaei *et al.* 2022), allowing educators to tailor experiences based on subject complexity and learner proficiency. Custom VR platforms, like those by Eiris et al. (Eiris *et al.* 2022) and Elgewely et al. (Elgewely *et al.* 2021), explore innovative teaching methods that enhance student engagement. However, immersive tools like head-mounted displays (HMDs) and CAVE systems (Wang *et al.* 2024) offer high levels of engagement while presenting challenges related to comfort, accessibility, and cost, particularly in large or remote learning settings (Lucas 2018). In contrast, web-based platforms such as Mozilla Hubs® (Eiris et al. 2022) offer greater accessibility for devices like smartphones and tablets. However, allowing diverse hardware use, ranging from phones to laptops and HMDs, can result in inconsistent user experiences and technical challenges, such as varying device capabilities and a lack of experimental control. Additionally, cybersickness with immersive systems can be another issue (Eiris et al. 2022), whereas WebGL-based platforms mitigate this problem and ensure consistent performance across devices.

This study adopts a simpler approach, avoiding immersive technologies like 360-degree images, which can sometimes overwhelm students. Instead, the simpler visualization was tailored to meet specific course learning outcomes. The implementation relied on a web-based simulation accessed primarily through smartphones, ensuring affordability and consistency across devices. This standardization minimized variability caused by diverse hardware setups and provided an equitable learning experience for all students. By prioritizing accessibility, simplicity, and alignment with educational objectives, this approach demonstrates the potential of virtual simulations to effectively enhance remote learning in construction education.

3 Research Methodology

This research examines differences in student perceptions of experience and understanding between real-world and virtual simulation environments. Key steps include 1. Development of Survey Questions 2. Real-World site visit, 3. Development of virtual site visit, 4. Data collection, and 5. Data analysis. Figure 1 shows research methodology workflow.

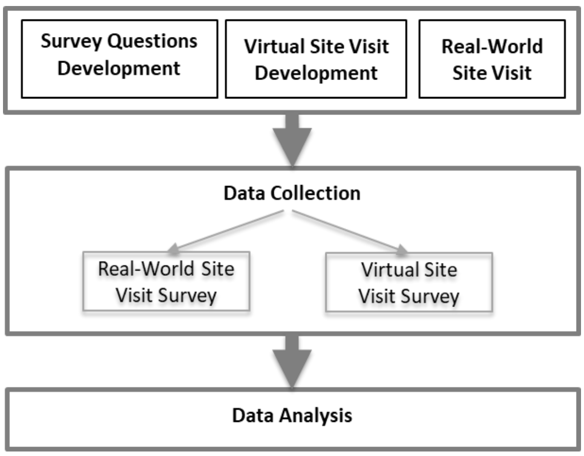

Figure 1. Research Methodology Workflow

3.1 Development of Survey Questions

The development of survey questions to evaluate the impact of virtual simulations is grounded in a diverse range of scholarly sources. For instance, (Yuan Sun et al. 2022), Kamińska et al. (2022), and (Wen et al. 2023) provide frameworks and insights that inform the design of assessment tools. These studies emphasize the importance of crafting questions that capture both qualitative and quantitative aspects of the learning experience, such as engagement, comprehension, and ease of use.

To ensure relevance, survey statements were derived from major topics covered in the CEM441/541 class, such as equipment productivity (both individual and collaborative performance), factors influencing productivity, cost implications of equipment usage and maintenance, and the importance of selecting appropriate machinery to optimize efficiency and minimize costs. The survey comprised two main parts: the first included statements derived from literature-based questions to evaluate students' learning experience. The second focused on CLO #6 (“Develop an estimate for a project using production and costs from a real-world project”) and CLO #7 (“Critically analyze a heavy civil operation and suggest alternatives”), assessing students' understanding of operational and productivity concepts. The post-virtual simulation survey also included five open-ended questions for deeper insights. Tables 1 and 2 categorize statements related to experience and understanding, respectively.

Table 1. Real Site Visit and Virtual Simulation Experience Statements

No.	**Experience Statements**
1	I have a clearer sense of the complexity of a worksite
2	Seeing the activity clarified concepts discussed in class
3	I learned something about site processes that was not discussed in class
4	Questions I had, or unclear concepts, were clarified.
5	The atmosphere/environment was overwhelming and made it difficult to learn
6	The experience was more engaging than I expected
7	The experience captured and held my attention
8	The experience was a valuable part of my learning process
9	I am more comfortable identifying interdependence of site activities
10	The experience provided me enough time to feel fully engaged with material presented
11	I felt like I could ask questions and receive satisfactory answers
12	I felt present and involved in the learning process
13	The experience aligned with my expectations
14	Peer interaction was an important component of the experience
15	I felt like my presence was disruptive to the work process

Table 2. Real Site Visit and Virtual Simulation Understanding Statements

No.	**Understanding**
10	Understanding factors that can improve equipment production (Improving
4	Identifying improvements to maximize equipment production
12	Ability to describe what swell and shrinkage factors are, how they apply to soil volume, and the effect of swell and shrinkage on site production
1	Estimating material to be excavated (either cut of fill)
11	Understanding of how soil is converted from a bank state to a loose state and the effect
14	What a fill factor is, and how it relates to the type of soil being moved or loaded, and its effect on production
3	Estimating cost of equipment
6	Estimating cost per unit of material moved
8	Optimizing equipment pathways for maximum productivity
9	Causes for delays, long lines, and long wait times
19	Understanding how cycle times relate to matching of equipment, and causes of delays, and bunching/queueing
13	Understanding of grade and rolling resistance, and their influence on production
7	Calculating ideal ratio of pieces of equipment (trucks: excavators or pushers: scrapers)
15	Understanding the importance of selecting the proper equipment
16	Describing different pieces of equipment and what they do
17	Understanding how efficiency relates to heavy equipment production
18	Describing how different factors affect efficiency (operator skill, visibility, blade adjustment factor, etc.)

3.2 Real Site Visit

The in-person site visit was a critical component of this study, providing students with firsthand exposure to real-world applications of concepts discussed in class. This visit allowed participants to observe an active construction site, engage with ongoing activities, and experience the complexities of heavy civil engineering projects in a controlled environment. Figure 2 illustrates multiple pieces of equipment working together to excavate and haul earth. Also, it highlights the impact of an unbalanced ratio of excavators to trucks, resulting in idle equipment.

Figure 2. Left Image: Excavator idle, and right image: Excavator and truck working in tandem

3.3 Virtual Site Visit

The virtual environment, developed using simulation tools and visualization techniques, enables students to observe and analyze critical concepts in heavy civil construction, including equipment productivity, operational delays, and system efficiency. The details of the simulation and visualization are explained in the following sections.

3.3.1 Simulation

The discrete event simulation (DES) was conducted using ConStrobe (Construction Operations Network Simulation for Time and Resource-Based Evaluation) (Louis 2025) to simulate real-world construction activities. The simulation focused on earthmoving operations, including activities such as loading, hauling, dumping, and returning. Fixed timings were used for loading and dumping activities, while uniform timings, representing variable durations, were applied to haul and return activities. The simulation involved one loader and four trucks per cycle. Figure 3 illustrates the simulation model, with various shapes representing activities like loading and hauling, along with their respective timings. Links within the model define system functions and the sequence of operations.

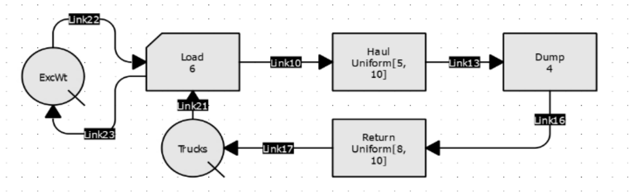

Figure 3. DES in ConStrobe Software

As seen in Figure 3, a model is created to represent earthmoving operations on a construction site. From this model, a text file is created which is exported from ConStrobe and used as input to create an animation in Unity, a game engine.

3.3.2 Visualization

To make the simulation more comprehensible for students, it was visualized using the Unity game engine. The simulation exported a trace file containing commands such as CREATE, TIME, MOVE, SETOBJCELL, and DYNUPDATECELL, which were used to generate animated visualizations.

Unity's versatility allows for exporting simulations in various formats, including desktop applications (.exe), mobile apps, and WebGL. For this study, WebGL was chosen due to its compatibility, ease of use, and ability to run in any web browser without requiring additional software installations or powerful hardware, such as head-mounted displays (HMDs) or high-performance computers. Most students accessed the visualization on their smartphones, while a few opted to use laptops. For homework, students accessed the simulation via a QR code linked to the WebGL platform, where they calculated cycle times for trucks and loaders.

The animations illustrated key earthmoving activities, including loading, hauling, dumping, and returning. Students could identify trucks by their assigned colors and interact with the simulation using features such as pause/play controls for timing calculations, touch navigation for exploration, and a reset button to restart the simulation from the initial camera angle. The visualization provided an opportunity for students to observe various scenarios in earthmoving operations as the simulation's time clock progressed. These scenarios demonstrated essential course concepts, such as bunching and queuing, variable timing, idle loaders, and waiting trucks, offering a dynamic and engaging learning experience. Figures 4–7 showcase examples of the visualization environment encountered by students.

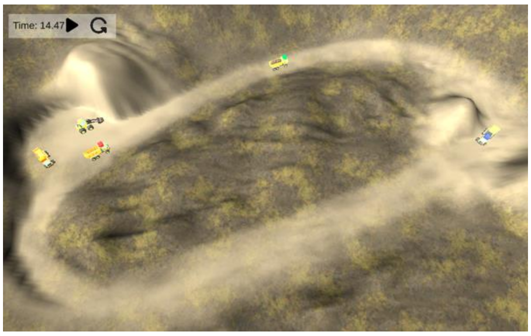

Figure 4. Scenario 1: Blue truck dumped, green hauling, red waiting to load, yellow is idle.

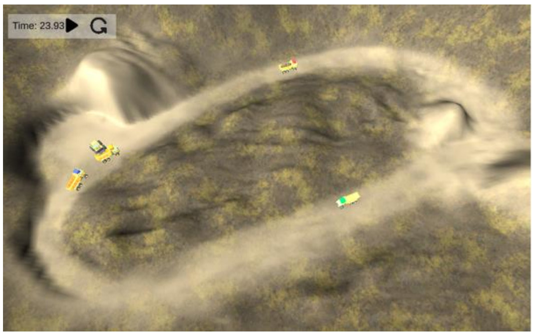

Figure 5. Scenario 2: Blue truck waiting, green returning, red hauling, yellow loading.

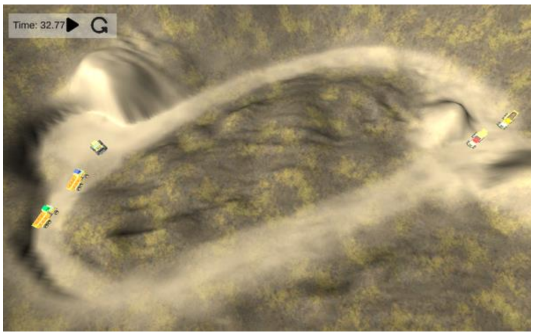

Figure 6. Scenario 3: Bunching in both loading and unloading areas.

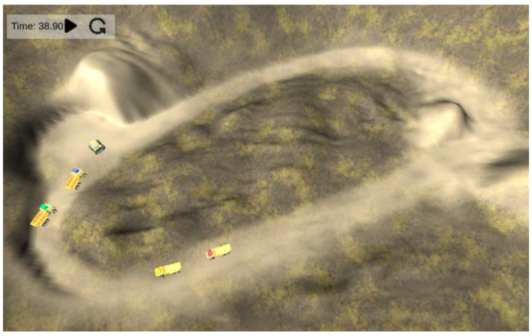

Figure 7. Scenario 4: Yellow truck overtaking red one, showing different timing.

3.4 Data Collection and Analysis

This study compared the educational impact of in-person construction site visits and virtual simulations on students' experience and understanding. Surveys were administered digitally via Qualtrics to all participants. A baseline survey was collected after the in-person site visit, followed by a post-virtual simulation survey. For post-virtual survey, participants engaged with the virtual simulation via a QR code through a WebGL platform on smartphones or laptops, completing tasks such as analysing equipment productivity and calculating cycle times(Figure 8). The surveys were identical except for 5 open-ended questions included at the end of the post-virtual simulation survey. Response options for questions evaluating experience were scored on a 5-point Likert-type scale: 1 = Strongly disagree, 2 = Somewhat disagree, 3 = Neither agree nor disagree, 4 = Somewhat agree, 5 = Strongly agree. For questions assessing understanding, the scale ranged from 1 = Not knowledgeable at all, 2 = Slightly knowledgeable, 3 = Moderately knowledgeable, 4 = Very knowledgeable, to 5 = Extremely knowledgeable. Responses were automatically recorded to the Qualtrics web portal. A total of 46 responses were collected, providing valuable insights into the educational effectiveness of virtual site visits. It is important to note that the analysis is based on a single course with 46 responses, which limits the generalizability of the findings.

Initial feedback indicates that virtual simulations improved students' understanding of key construction concepts, including equipment productivity, optimal ratios, and delay management. The simulation effectively enhanced comprehension of dynamic and complex topics compared to in-person visits. However, students' experiences showed mixed results, with some finding the virtual environment overwhelming or misaligned with expectations, emphasizing the need for improved user guidance and interface design.

Future work will involve detailed statistical analysis to compare paired ordinal responses and further evaluate the educational impact of the two methods.

Figure 8. Students working on homework using visualization

4 Findings and Discussion

This study successfully developed and deployed a virtual site visit using Unity and WebGL to enhance students' understanding and experience of heavy civil construction concepts. The visualization allowed students to explore key topics, including equipment productivity, cycle times, queuing, and delays, in a structured and accessible environment. Students accessed the simulation via a QR code, enabling them to interact with the visualization and apply course concepts through homework tasks, such as calculating cycle times and equipment productivity by observing earthmoving operations. Initial feedback from surveys indicates that the virtual simulation provided valuable insights into construction operations and effectively complemented traditional in-person site visits. While most students found the simulation engaging and informative, some reported challenges, such as feeling overwhelmed or unsure of what to expect, highlighting areas for improvement in interface design and user guidance. Future work will analyze the survey data in detail to assess the educational impact of the virtual simulation compared to in-person site visits and to identify further opportunities to enhance the virtual learning experience. Additionally, future research will incorporate objective performance metrics, such as pre- and post-simulation assessments, to provide a more concrete measure of learning effectiveness.

5 Conclusion

This study demonstrates the potential of virtual simulations as an effective and accessible alternative to traditional in-person site visits in construction management education. Virtual simulations enhanced students' understanding of key concepts such as equipment productivity, optimal ratios, causes of delays, and overall production efficiency. Compared to traditional in-person site visits, virtual simulations provide a controlled, tailored learning environment that simplifies dynamic, abstract processes and allows for deeper conceptual comprehension.

These advantages make virtual simulations particularly valuable for remote learners who may lack access to physical construction sites, bridging gaps in hands-on learning opportunities. While virtual simulations successfully replicated and, in some areas, surpassed the learning outcomes of in-person visits, areas for improvement remain. Students reported challenges, such as feeling overwhelmed, or uncertain about what to expect, emphasizing the importance of pre-simulation preparation, such as tutorials or demonstrations, to improve alignment between expectations and experiences. Furthermore, virtual simulations proved particularly beneficial in teaching concepts reliant on dynamic visualizations, such as cycle times and delay analysis, highlighting their potential as a complementary tool to traditional methods.

As remote and hybrid education continues to grow, virtual simulations offer a promising pathway to enhance accessibility and inclusivity while maintaining the quality of experiential learning. Future research should focus on tailoring simulations to specific educational objectives and optimizing learning environments for better accessibility and usability. With thoughtful implementation and continued refinement, virtual simulations hold the potential to transform construction management education, ensuring an optimized balance between virtual and in-person learning experiences. Despite these promising results, the study's scope was limited by its single-course design and sample size. Future research should validate these findings across multiple courses and larger, more diverse student populations, explore the scalability and practical implications of virtual simulations.

References

[1] J. Neisler, B. Means. *Suddenly online: A national survey of undergraduates during the COVID-19 pandemic*. Digital Promise, 2020.

[2] J. J. Park, M. Park, K. Jackson, G. Vanhoy. Remote Engineering Education under COVID-19 Pandemic Environment. *International Journal of Multidisciplinary Perspectives in Higher Education*, *5*(1), 160-166, 2020.

[3] E.J. Jaselskis, C.T. Jahren, P.G. Jewell, E. Floyd, T.C. Becker. Virtual Construction Project Field Trips Using Remote Classroom Technology. pp. 236–245, 2012.

[4] D. Martínez-Muñoz, J.V. Martí, V. Yepes. Remote Teaching in Construction Engineering Management During Covid-19. Proceedings, pp. 879-887, 2021.

[5] R. Belaroussi, H. Dai, E. González, J. González. Designing a Large-Scale Immersive Visit in Architecture, Engineering, and Construction. *Applied Sciences*, 13(5), p. 3044, 2023.

[6] R. Eiris, Y. Sun, M. Gheisari, B. Marsh, P. Lautala. VR-OnSite—Online Site Visits Using Web-Based Virtual Environments. pp. 100–109, 2022.

[7] M.H. Elgewely, W. Nadim, A. ElKassed, M. Yehiah, M. Talaat, S. Abdennadher. Immersive construction detailing education: building information modeling (BIM)–based virtual reality (VR). *Open House International*, 46(3), pp. 359–375, 2021.

[8] S.R. Humayoun, J. Wong, Kh. Nguyen, P. Zinjarde, P. Ramesh. VREE: A 3D Environment to Train

Engineers about Post-Earthquake Damages in Building Structure. *IEEE*, pp. 931–932. 2024.

[9] M. Ilbeigi, D. Bairaktarova, R. Ehsani. Gamified Method for Construction Engineering Education: Learning through Guided Active Exploration. *Journal of Civil Engineering Education*, 150(2), p. 05023011, 2024.

[10] H.B. Ismail, A. Ismail, A.A. Abu Bakar, A.R. Abu Tali, N.A. Mohd Noor. The Effectiveness of Site Visit Approach in Teaching and Learning of Construction Site Safety: A Case Study in Civil Engineering Faculty, Universiti Teknologi MARA, Johor Branch, Pasir Gudang Campus. *Asian Journal of University Education*, 17(4), pp. 212–221, 2021.

[11] D. Kamińska, G. Zwoliński, A. Laska-Leśniewicz. Usability Testing of Virtual Reality Applications—The Pilot Study. *Sensors*, 22(4), p. 1342, 2022.

[12] J. Lucas. Student Perceptions and Initial Response to using Virtual Reality for Construction Education, 2018.

[13] A. Salman. Field Trips and Their Effect on Student Learning: A Comparison of Knowledge Assessment for Physical versus Virtual Field Trips in a Construction Management Course. *Virtual Worlds*, 2(3), pp. 290–302, 2023.

[14] M. Seifan, O.D. Dada, A. Berenjian. The Effect of Real and Virtual Construction Field Trips on Students’ Perception and Career Aspiration’, *Sustainability*, 12(3), p. 1200, 2020.

[15] A. Shojaei, A. Mahdavian, S. Rokooei, A. Al-Bayati. Use of Virtual Site Visits in Construction Management Distance Education. pp. 182–191, 2022.

[16] A. Shojaei, R. Ly, S. Rokooei, A. Mahdavian, A. Al-Bayati. Virtual Site Visits in Construction Management Education: A Practical Alternative to Physical Site Visits. *Journal of Information Technology in Construction (ITcon)*, 28(36), pp. 692–710, 2023.

[17] X. Wang, M. Chou, X. Lai, J. Tang, J. Chen. Examining the Effects of an Immersive Learning Environment in Tertiary AEC Education: CAVE-VR System for Students’ Perception and Technology Acceptance. *Journal of Civil Engineering Education*, 150(2), p. 05023012, 2024.

[18] J. Wen, M. Gheisari, J. Jain, Y. Zhang, R.E. Minchin. *iVisit-Communicate* for AEC Education: Using Virtual Humans to Practice Communication Skills in 360-Degree Virtual Field Trips. *Journal of Computing in Civil Engineering*, 37(3), p. 04023008, 2023.

[19] S. Yuan, G. Albeaino, M. Gheisari, R. Eiris. Online site visits using virtual collaborative spaces: A plan-reading activity on a digital building site. *Advanced Engineering Informatics*, 53, p. 101667, 2022.

[20] J. Louis. ConStrobe;Construction Operations Simulation for Time and Resource Based Evaluations. On-line: https://josephlouis.org/ConStrobe/, Accessed: 1/09/2025.