

## Application of a Sankey Diagram to Migration Patterns of Construction and Engineering Workforce

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**ABSTRACT:** Sankey diagrams are a powerful data visualization tool used to map inflows and outflows at different stages of a process. These diagrams utilized “arrows” of differing proportional widths to represent movement between stages, offering an intuitive way to analyze complex system. Sankey diagram have been widely applied in various fields most iconic being the flow of troops during Napoleon’s invasion of Waterloo, their use in construction publications remains exceptionally limited. A preliminary Google Scholar for “Sankey” and “Construction” yielded no results. Thus, this paper explores the utility of Sankey diagram in three approaches: First, provides a use case of Sankey diagrams in other disciplines, Second, identify uses in construction research. Finally, provides a case study of implementing Sankey diagrams in construction research. The study explores the potential of Sankey diagramming to visualize workforce migration patterns between 2013 and 2023 in construction. In inflow rates represents workers hired, while outflow denotes separation. By illustrating hiring, employment, and separations, the diagram provides a proportional representation of movement highlighting industry transitivity. This is particularly relevant given the projected 1.9 million workers migration to other sectors in 2024. The turnover rate is generally higher in the construction industry when compared to others, which may be a limiting factor in meeting projected construction workforce demands. The tool has broader applications in construction and engineering, specifically optimizing flow processes and resource planning. The case study visualizes the movement of people, the diagram can drive visual improvement in a wide range of engineering and construction areas.

### 1. INTRODUCTION AND BACKGROUND

The construction industry plays a critical role in global economic development, yet it faces persistent workforce shortages that threaten project timelines, productivity, and overall industry growth (Ginige et al. 2007, Ayodele et al. 2020). Skilled labor shortages have become more pronounced in recent years due to several factors, including an aging workforce, high turnover rates, and declining interest among younger generations in pursuing construction careers (Greenberg et al. 2024). According to the Associated General Contractors of America (AGC), 88% of construction firms report difficulty in filling craft positions, indicating an urgent need for skilled labor (AGC, 2023). This labor gap not only delays project completion but also increases labor costs and reduces overall efficiency, particularly due to underrepresentation. Therefore, a need to investigate the causes of a a leaky employment pipeline.

The “leaky pipeline” metaphor has been used to describe the loss of Under-Represented Minorities (URM) in STEM for quite some time (Pell 1996), with research continuing to the present (Saraswathamma et al. 2010, Appelhans et al. 2019). The purpose of the “leaky pipeline” metaphor is to illustrate movement, the inputs and outputs of a system, whether it be an actual pipeline or aqueduct (Lehrman 2018) or students moving in and out of a major (Loder 2024). However, the “leaky pipeline” metaphor may be lost in graphs and tables (Witteveen and Attewell 2020) or perceived as extremely linear without acknowledging movement (Malla et al. 2024). Sankey diagrams are typically used for the same purpose as the “leaky pipeline” metaphor. One example would be the use of a Sankey diagram to visualize student flows into and out of psychology (Loder 2024). Another example is the use to describe migration into and out of engineering majors (EbrahimNejad et al. 2020).

While student migration has been studied (Appelhans et al. 2019, Loder 2024, Saraswathamma et al. 2010), another concern is the perceived shortage of engineers (Williams 2021, Archer 2025, RUSO 2025). Valle et al. (2024), perhaps describe it best, identifying the relationship between licensed workers and industry demand. Efforts to address these shortages must include an enhanced focus on construction education, apprenticeship programs, and industry-academic partnerships to attract, train, and retain skilled workforce. This study explores the impact of workforce migration in the construction industry and discusses potential interventions.

### 1.1 Case of Sankey Diagrams in Other Disciplines

Sankey diagrams have been used to illustrate inflows and outflows of a system for a very long time, with an example of Napoleon’s troop movements at Waterloo being one of the first (Minard 1869). While a brief literature search may receive many “hits” or “instances,” not all of these papers actually illustrate the diagram to which they refer in their abstracts (Rohde & Godwin 2019, Skurla & O’Neal 2021, Richardson & Knight 2024). Sankey diagrams have been used in a variety of industries, including healthcare (Mica et al. 2020), production and processes (Kampf & Hlatka 2019), and energy processes (Karaagaç et al. 2019).

A search was performed using online library resources and the American Society of Civil Engineers publications which produced a small number of Sankey diagrams, indicating that their use in Civil Engineering is quite limited. There are examples of Sankey diagrams being used to describe inputs and outputs in civil engineering like water systems (Curmi et al. 2013, Lehrman 2018). An appropriate use of the Sankey diagram of a water system (Figure 1) clearly illustrates inflows and outflows, size, location or time.

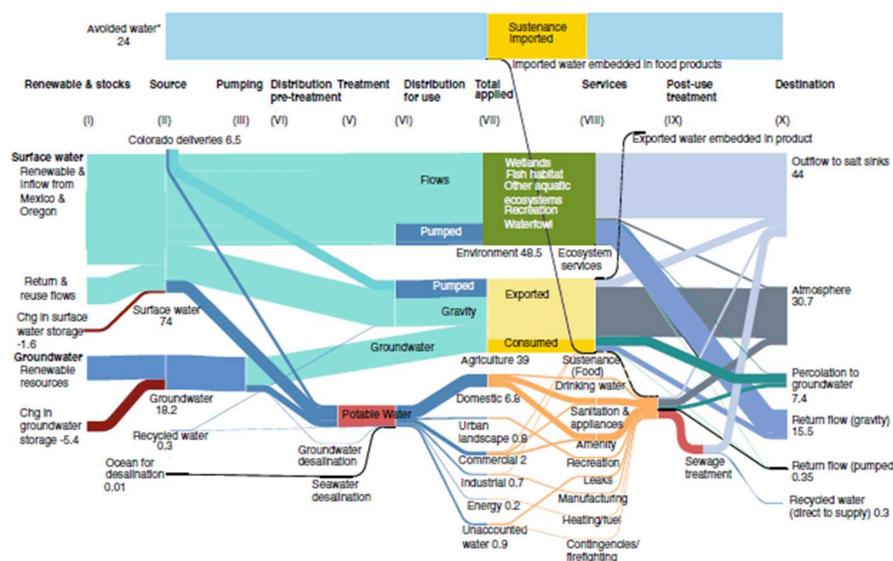


Figure 1: Example Sankey Diagram of a Water System (Curmi et al. 2013)

Other uses in civil engineering include building information technology (Figure 2) and sustainability (Andriyani et al. 2024), project planning and scheduling (Sheikhhoshkar et al. 2023), effects of working from home (Zubair et al. 2024), and information management (Malla et al. 2024).

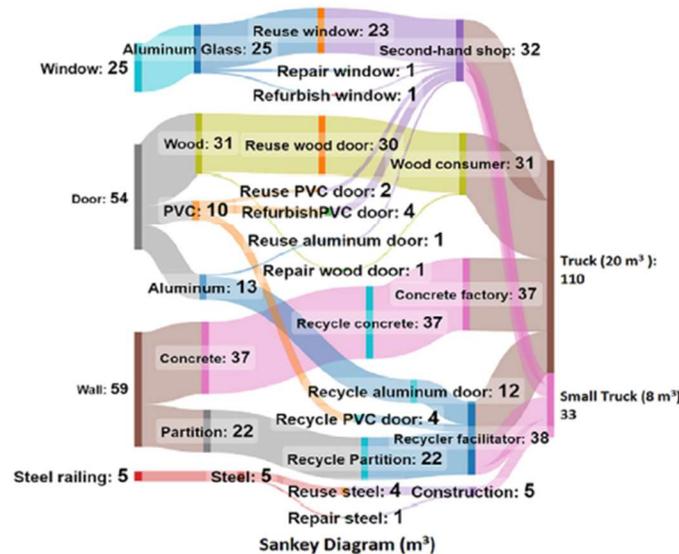


Figure 2: Example Sankey Diagram of a Building Information Modeling (Andriyani et al. 2024)

While Sankey diagrams are not new as graphical descriptors for visualizing flow, they are not always used correctly (Kampf & Hlatka 2019, Richardson & Knight 2024, Rohde & Godwin 2019, Skurla & O'Neal 2021). Sankey diagrams are best suited for multiple inputs and outputs, which is why they are so effective in describing the movement of students (Lykkegaard and Ulriksen 2019). While identifying the where, when, and why of students changing majors, the same understanding is needed for the engineering workforce. Where, when, and why are engineering graduates leaving the workforce? A determination of when engineers typically leave the workforce will provide a timeline for interventions.

## 1.2 Precarity and Transitive Nature of Construction Work

A lack of workers and local industry demand does not directly correlate to a workforce shortage, but that is how the lack of an easily accessible workforce is presented. Williams (2021), however, suggests that the workforce leaves over time due to both employer and employee rationales. Mader states that anticipated infrastructure construction means 138,000 Plumbing-Heating-Cooling technicians are needed (2017). Business NH Magazine (2018) also presents a workforce shortage in the construction industry, especially with craft workers. Both articles focus on the perception of the construction industry as a 'dirty job' (Mader, 2017 and Business NH Magazine, 2018). However, a workforce shortage may not be entirely due to the perception of construction as a dirty job. There is also precarity in the workforce, where precarity is defined as contract employment, day labor, or having a lack of security and benefits (Jankowski, 2024). The precarious nature of changing projects, locations, and economic climate may also play into the construction workforce shortage.

Voluntary employee turnover has previously been identified as a factor in the U.K. construction workforce, and can be partially explained by the "Unfolding Model of Voluntary Turnover" (UMVT) (Jones et al. 2010). While voluntary workforce reduction is based on the employee, their choice to leave may be due to a sudden change or "shock," incompatibility with the employer or "image violation," (Jones et al. 2010), or involuntary workforce reductions (lay-offs or strategic firings), which cause the former feelings of shock and image violation (Williams 2021). Similarly, a correlation has been found in construction workers between perceived organizational injustice and psychological strain, or a negative result (Chih et al. 2017). The author stated that organizational injustice has an inverse correlation to worker commitment to the organization.

## 2. METHODOLOGY

### 2.1 Method

To illustrate the inflows and outflows of employees in the construction sector, the official U.S Bureau of Labor Statistics (U.S. BLS) database was used. The segment of the datasets used provided monthly, quarterly, and annual data on the current construction workforce size (employment), hiring, and separations from 2013 to 2023 (U.S. BLS 2025). The Sankey diagram can likewise be used to illustrate times when a greater number of the workforce enter or leave. It should be expected that in May-June, high school, career tech, and college graduates create an influx into the industry. There is also common business practice to fire during December, before the end of the year. Identifying the “when” of employee migration will allow the industry to identify when interventions should be made.

The US. BLS provides data from a variety of surveys where information about employment, lay-offs, and hiring are collected. Due to the U.S. BLS (2025) survey data series being collected from multiple sources (i.e. Current Employment Statistics, Current Population Survey, Job Openings, and Labor Turnover Survey), the data presented on the website can be inconsistent. The U.S. BLS (2025) database was filtered for “Construction” then “Job Openings and Labor Turnover Survey,” “Rates of gross job gains and gross job losses,” and “Employment, Hours, and Earnings from the Current Employment Statistics Survey (National).”

The Sankey diagram creates a visualization of movement, to easily identify trends in employment migration. The data were transposed to create chronological columns of data. The data were then imported into Python and Jupyter to create the Sankey diagram. The visualization is created through the creation of a source or parent node and target node. For transitions, an arc flows from the parent node to the target node. The sizes of the node and arc (e.g. width, height, thickness) represent the number of members within the node/arc, which then illustrates the magnitude of flow in any direction (Glover et al. 2022, Otto et al. 2022).

## 3. RESULTS

Overall, the data show the workforce has increased over time. However, the industry is still concerned over the lack of workforce (Mader, 2017 and Business NH Magazine, 2018). When comparing the new hires to losses, the USBLS data show more new hires than losses (Table 1). However, based on identified need, it is evident that the new hires do not provide a replacement for the workforce leaving the construction sector.

Table 1: Transposed USBLS (2025) Datasets

Year	Hires	Employment*	Separations / Losses
2013	3933	5,932,000	3703
2014	3716	6,293,000	3410
2015	3982	6,630,000	3645
2016	4059	6,818,000	3922
2017	4597	7,091,000	4276
2018	4530	7,396,000	4217
2019	4986	7,527,000	4873
2020	4970	7,357,000	4988
2021	4361	7,601,000	4162
2022	4422	7,892,000	4133
2023	4459	8,099,000	4207

\*Employment data was initially presented in 1,000s, therefore rounding errors are inherent.

### 3.1 Sankey Diagram

The Sankey Diagram in Figure 1 shows the construction workers hired, employed, and separated each year between 2013 and 2023. The numbers represent thousands of people. So, for example, in 2023 there were 8,099,000 workers employed in the construction industry and 4,207,000 workers separated from their companies the same year representing 52% of the workforce. This Sankey Diagram easily showcases the significant amount of construction workers switching jobs each year. As the U.S. BLS data has been aggregated, it is not possible to determine if these workers who separated each year re-entered the workforce in construction. However, if the data was available, that information could be easily added to the Sankey Diagram to better understand the construction force employment flow.

It can be observed that each year shown in the Sankey Diagram there has been an increase in the workers hired, workers employed, and worker separated. In this case the Sankey diagram (Figure 3) illustrates the employment data in numbers of thousands, or for year 2013, the value is shown as 5,932 where the value is actually 5,932,000. Further, the totals are not accumulated in this diagram.

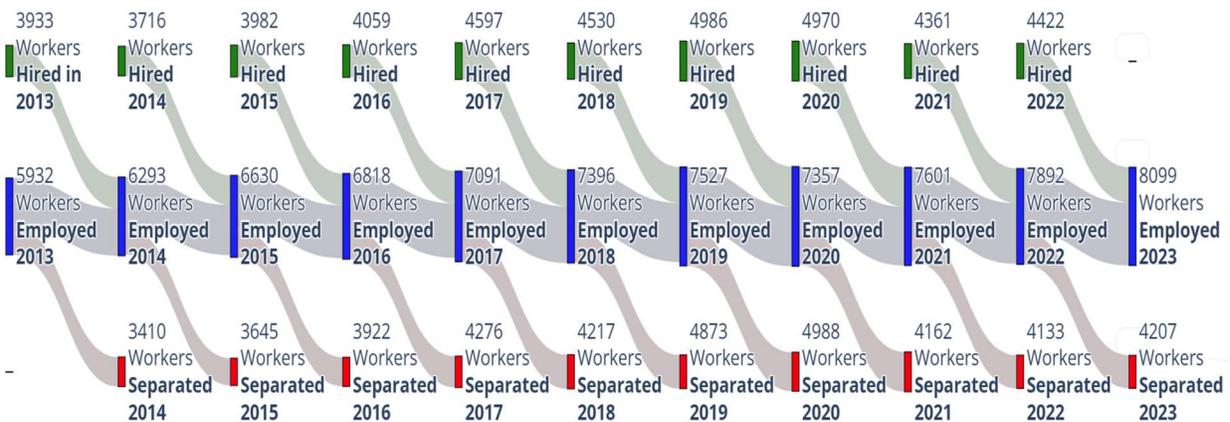


Figure 3: Sankey Diagram Construction Worker Migration 2013-2023

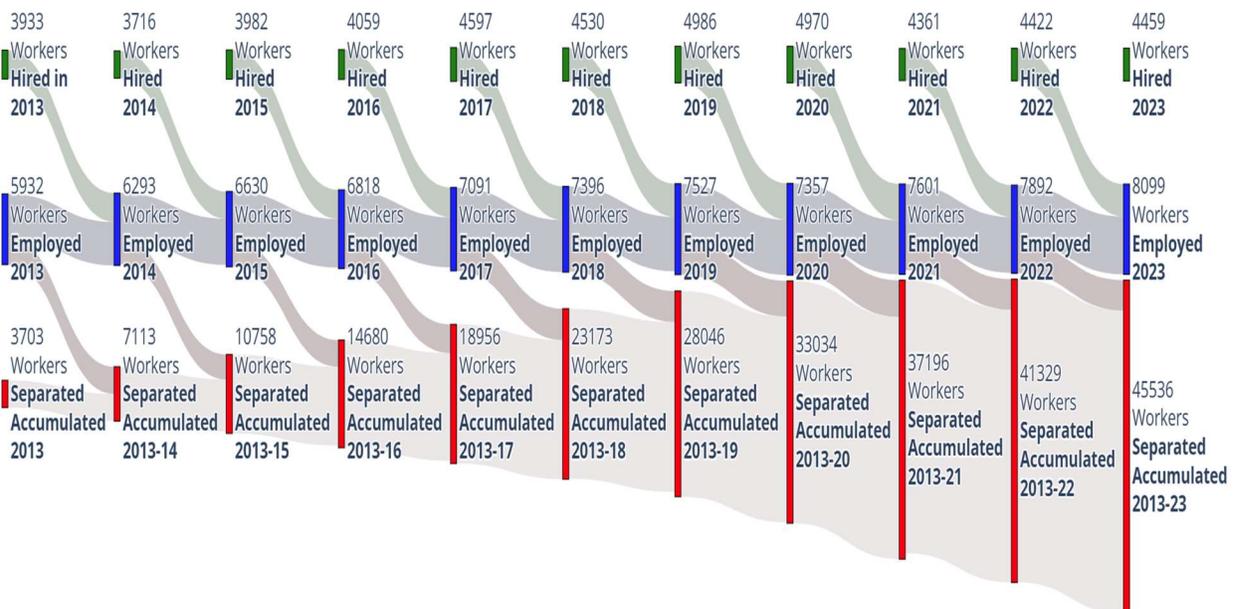


Figure 4: Sankey Diagram Construction Worker with Accumulation 2013-2023

Alternatively, the Sankey diagram can express the data in thousands, as it was presented in Table 1. In this case (Figure 4), the data was accumulated showing the change in workforce over time. What is most succinctly expressed is the change in the workforce over time. Although the total workforce has annual increases, the cumulative overall turnover indicates separations can be visualized at a substantial rate. The Sankey diagram illustrates the need to limit these separations. While the Sankey diagram illustrates the need to reduce separation, it is also worth noting that the construction industry experiences high voluntary turnover due to the nature of contract work with limited durations.(Jankowski 2024). Even so, interventions are likely worth exploring.

#### **4. DISCUSSION**

This study demonstrated a single instance where the utilization of Sankey Diagrams could be a useful visualization tool for assessing workforce migration patterns. However, the potential benefits of Sankey Diagrams in workforce migration patterns are numerous, and additional applications will be discussed in this section.

While this case study utilized macro (national-level) data to demonstrate the utility of Sankey Diagrams in reporting workforce trends, the same tool could be utilized at an organizational or regional level to explore longitudinal workforce trends and to identify factors that may be correlated with high employment turnover. For example, at an organizational level, Sankey diagrams could be a valuable tool for visualizing various human resource-related factors, such as when employees leave the organization or if turnover rates vary by region, job role (superintendent, project manager, or foreman), or demographic factors (gender, age, parental status). By exploring and comparing employment retention trends across these factors, organizations can quickly identify disparate turnover outcomes in specific positions or groups. The Sankey diagram (Figure 4) clearly illustrates the revolving door of turnover in construction a trend often associated with low job satisfaction which is frequently correlated with money (Jones et al. 2010). In fields where employees are in great demand, a job offer is not needed for an employee to choose to leave their current employer (Jones et al. 2010).

By visualizing trends in turnover patterns, organizations can utilize this information to pinpoint potential underlying causes and explore interventions intended to reduce employee turnover, such as increased training, targeted compensation, or career progression opportunities. Furthermore, in addition to identifying the magnitude and timeframe in which employment turnover occurs, Sankey Diagrams can also be utilized to identify the effectiveness of targeted employment interventions after implementation. For example, if individuals leave an organization at a much higher normal in the years typically associated with childbirth, interventions focused on parental leave or reducing stigma related to “long-hour culture” could be implemented and evaluated as a means of supporting employee retention. Or, for example, if foremen begin to leave an organization at a disproportionately higher after the five-year mark, training programs designed to support career progression to new roles (e.g., superintendent) or expanded opportunities within their existing role could be explored and evaluated. As such, Sankey Diagrams can be a valuable visualization tool for understanding the effectiveness of pre and post-employment intervention.

In addition to the employed workforce, Sankey Diagrams could be beneficial in exploring the professional construction management pipeline beginning in higher education and continuing into industry. For example, if women who enroll in construction education programs leave the program at a disproportional rate than men during their first two years of enrollment, targeted interventions such as mentorship programs could be evaluated through Sankey Diagrams. By utilizing an intuitive visualization tool such as a Sankey Diagram to represent the professional construction pipeline, stakeholders from various backgrounds (HR, C-Suite, Educators, etc.) can jointly identify trends and patterns and where intentions may be merited (or effective) in supporting the construction workforce pipeline.

#### **5. CONCLUSIONS**

The Sankey diagram is not a novel approach to illustrating movements of people. However, it has not previously been used to illustrate the movement of the workforce, making this a novel use. The ability to visualize the movement of employees into and out of the workforce using the Sankey diagram is a novel solution to an existing problem. Over the last 10 years, the construction work force has increased, however,

the construction industry continues to have concerns over the lack of workforce (Mader, 2017, Business NH Magazine 2018). The increase in workforce is related to population growth and construction dollars during the same time. If the workforce has increased over time, then is there a real workforce shortage? The workforce shortage may be more about how we treat our employees and workforce satisfaction as compared to available workforce (Chih et al. 2017, Jones et al. 2010). While identifying intervention times may not be evident in this diagram, more specific data may elucidate optimal time periods for interventions.

This Sankey diagram is an effective tool to demonstrate workforce separations, additions and total workforce over time making the Sankey an effective way to evaluate and visually represent longitudinal data. While the U.S. BLS (2025) was used as a basis for the Sankey diagram, the diagram cannot provide a direct correlation, due to the USBLS collection methodologies. Further, the Sankey diagram highlights data that otherwise would be masked. The purpose of this case study was to provide a demonstration of how the Sankey diagram could be used to describe the leaky pipeline, and as a visualization method which allows identification of the accumulated turnover rate. By identifying areas of concern, interventions can be tailored to specific problems. While the focus has frequently been on attracting more employees to construction, it is also important to determine if voluntary employee separations remain in the industry or whether there is a long-term loss of workforce participants to other industries.

This methodology can be applied in Higher Education or Workforce Development concerns such as employee turnover and migration, which is otherwise not easily identifiable in a table or traditional reporting formats. The Sankey diagram also allows reader to easily identify the trends described.

## 5.1 Practical Applications

The leaky pipeline has long been used as a metaphor for migration in STEM education. The Sankey diagram is also used to illustrate actual leaky pipelines like the California water system (Curmi et al. 2013, Lehrman 2018). However, the Sankey has not yet been used to describe the migration of workforce. This is one more application which is appropriate to civil engineering, the construction workforce, and any workforce facing precarity. The tool presented and the diagrams highlight employee turnover rates as a potential cause of the workforce problems in construction.

## 5.2 Next Steps

While identifying intervention times may not be evident in the Sankey diagram provided, additional and more specific data is required to predict interventions. Additional data like gender, age, minority classification to compare with the overall data would help understand which populations leave and when. Additionally, a comparison of construction dollars, more specifically the cyclical nature of economic turndowns like recessions would be appropriate. It is important to determine where the construction workforce goes in times of economic downturn and if they return.

## REFERENCES

- AGC. (2023). "New Survey Shows Significant Flaws In Nation's Approach To Preparing Workers For Construction Careers And How That Hurts The Economy | Associated General Contractors of America." Retrieved February 23, 2025, from <https://www.agc.org/news/2023/09/06/new-survey-shows-significant-flaws-nations-approach-preparing-workers-construction-careers-and-how-0>
- Appelhans, S., De Pree, T., Thompson, J., Aviles, J. A., Cheville, A., Riley, D. M., Karlin, J., Fatehiboroujeni, S., & Akera, A. (2019). "From "Leaky Pipelines" to "Diversity of Thought": What Does "Diversity" Mean in Engineering Education?" Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida. 10.18260/1-2—32861
- Andriyani, N., Suprobo, P., Adi, T.J.W., Aspar, W.A.N., Jatmiko, A.D., and Santoso, A.D. (2024). "Integrating urban building information modeling and circular economy framework for green sustainability." *Global Journal of Environmental Science and Management*, 10(3), 1313–1332. <https://doi.org/10.22034/gjesm.2024.03.22>

- Archer, N. (2025). "Bridging the Gap: Addressing the Engineer Shortage." The Reserves Network. <https://www.trnstaffing.com/insights/bridging-the-gap-addressing-the-engineer-shortage/> Retrieved February 12, 2025.
- Ayodele, O. A., Chang-Richards, A., & González, V. (2020). Factors affecting workforce turnover in the construction sector: A systematic review. *Journal of construction engineering and management*, 146(2), 03119010.
- Business NH Magazine. (2018). "New President of ABC NH/Vermont Chapter Focuses on Workforce Shortage." 35(2), 9.
- Chih, Y.Y., Kiazad, K., Cheng, D., Capezio, A., & Restubog, S. L. D. (2017). "Does Organizational Justice Matter? Implications for Construction Workers' Organizational Commitment." *Journal of Management in Engineering*, 33(2), 1–10. [https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0000490](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000490)
- Curmi, E., Fenner, R., Richards, K., Allwood, J. M., Bajželj, B., & Kopec, G. M. (2013). "Visualising a Stochastic Model of Californian Water Resources Using Sankey Diagrams." *Water Resources Management: An International Journal - Published for the European Water Resources Association (EWRA)*, 27(8), 3035–3050. <https://doi.org/10.1007/s11269-013-0331-2>
- EbrahimNejad, H., Ricco, G. D., & Ohland, M. W. (2020). "Switching into and out of Engineering: Trends and Patterns (Work-In-Progress)." Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual On line. DOI: 10.18260/1-2--35262
- Ginige, K. N., Amaratunga, R. D. G., & Haigh, R. (2007). Improving construction industry image to enhance women representation in the industry workforce. *Management*, 377, 385.
- Glover, R. E., Al-Haboubi, M., Petticrew, M. P., Eastmure, E., Peacock, S. J., & Mays, N. (2022). "Sankey diagrams can clarify 'evidence attrition': A systematic review and meta-analysis of the effectiveness of rapid diagnostic tests for antimicrobial resistance." *Journal of Clinical Epidemiology*, 144, 173–184. <https://doi.org/10.1016/j.jclinepi.2021.11.032>
- Greenberg, E., Weddle, B., and Scheafer, E. (2024). "The critical demand for trade skills in the US | McKinsey." Retrieved February 23, 2025, from <https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/tradespeople-wanted-the-need-for-critical-trade-skills-in-the-us>
- Jankowski, K. Z. (2024). "Positioning precarity: The contingent nature of precarious work in structure and practice." *British Journal of Sociology*, 75(5), 715–730. <https://doi.org/10.1111/1468-4446.13125>
- Jones, S. M., Ross, A., & Sertyesilisik, B. (2010). "Testing the unfolding model of voluntary turnover on construction professionals." *Construction Management and Economics*, 28(3), 271-285–285. <https://doi.org/10.1080/01446191003587737>
- Kampf, R. & Hlatká, M. (2019). "Modelling a production process using a Sankey diagram and Computerized Relative Allocation of Facilities Technique (CRAFT)." *Open Engineering*, 9(1), 444–449. <https://doi.org/10.1515/eng-2019-0043>
- Karaağaç M.O., Kabul, A, Oğul, H. (2019). "First- and second-law thermodynamic analyses of a combined natural gas cycle power plant: Sankey and Grossman diagrams." *Turkish Journal of Physics*. 43(1):93-108. doi:10.3906/fiz-1809-9
- Lehrman, B. (2018). "Visualizing water infrastructure with Sankey maps: a case study of mapping the Los Angeles Aqueduct, California." *Journal of Maps*, 14(1), 52–64. <https://doi.org/10.1080/17445647.2018.1473815>
- Loder, A. K. F. (2024). "Student Flow Visualization." *European Journal of Education*, 59(2). <https://doi.org/10.1111/ejed.12619>
- Lykkegaard, E., & Ulriksen, L. (2019). "In and out of the STEM pipeline – a longitudinal study of a misleading metaphor." *International Journal of Science Education*, 41(12), 1600-1625. <https://doi.org/10.1080/09500693.2019.1622054>
- Mader, R. P. (2017). Workforce crisis is fueled by perceptions, says PHCC's Crigler. *Contractor Magazine*, 64(9), 4–6.
- Malla, V., Tummalapudi, M., & Delhi, V. S. K. (2024). Perceptions of Built-Environment Professionals on Using ISO 19650 Standards for Information Management. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 16(1). <https://doi.org/10.1061/JLADAH.LADR-1076>
- Mica, L., Niggli, C., Bak, P., Yaeli, A., McClain, M., Lawrie, C. M., & Pape, H.-C. (2020). "Development of a Visual Analytics Tool for Polytrauma Patients: Proof of Concept for a New Assessment Tool Using a Multiple Layer Sankey Diagram in a Single-Center Database." *World Journal of Surgery: Official Journal*

- of the International Society of Surgery/Société Internationale de Chirurgie, 44(3), 764–772. <https://doi.org/10.1007/s00268-019-05267-6>
- Minard, C. (1869). "Charles Minard's Flow Map of Napoleon's Invasion." Public domain. Retrieved August 7, 2024. <https://ageofrevolution.org/200-object/flow-map-of-napoleons-invasion-of-russia/>
- Otto, E., Culakova, E., Meng, S., Zhang, Z., Xu, H., Mohile, S., & Flannery, M. A. (2022). "Overview of Sankey flow diagrams: Focusing on symptom trajectories in older adults with advanced cancer." *Journal of Geriatric Oncology* (Vol. 13, Issue 5, pp. 742–746). <https://doi.org/10.1016/j.jgo.2021.12.017>
- Pell, A. N. (1996). Fixing the leaky pipeline: women scientists in academia. *Journal of Animal Science*, 74(11), 2843–2848. <https://doi.org/10.2527/1996.74112843x>
- Regional University System of Oklahoma (RUSO). (2024). "Oklahoma's Engineer Shortage Has a Solution." Retrieved February 12, 2015. <<https://www.ruso.edu/single-post/oklahoma-s-engineer-shortage-has-a-solution#:~:text=According%20to%20the%20Bureau%20of,keep%20up%20with%20workforce%20demands.>>
- Richardson, A. J., & Knight, D. B. (2024). "Credit Loss for Engineering Transfer Students: Visualizations Across Students and Structures." Paper presented at 2024 Collaborative Network for Engineering & Computing Diversity (CoNECD), Arlington, Virginia. DOI: 10.18260/1-2--45440
- Rohde, J., & Godwin, A. (2019). "Work in Progress: Survey Development of Factors Related to Engineering Graduates' Career Pathways." Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. DOI: 10.18260/1-2--33652
- Saraswathamma, M., Enger, K., Bilen-Green, C., Bazebaruah, A., & Schumacher, B. (2010). "Designing Model Based Solutions to Leaky Female Engineering Pipeline: A Qualitative Study Of Female Engineer Narratives." Paper presented at 2010 ASEE Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2—16412
- Sheikhkhoshkar, M., Bril El-Haouzi, H., Aubry, A., and Hamzeh, F. (2023). Functionality as a Key Concept for Integrated Project Planning and Scheduling Methods. *Journal of Construction Engineering & Management*, 149(7), 1–18. <https://doi.org/10.1061/JCEMD4.COENG-13427>
- Skurla, C., & O'Neal, D. L. (2021). "A Novel Tool to Visualize Student Flow Through the Curriculum." Paper presented at 2021 First-Year Engineering Experience, Virtual Conference. DOI: 10.18260/1-2--38363
- U.S. Bureau of Labor Statistics (USBLS). (2025). "Industries at a Glance: Construction: NAICS 23." Retrieved January 28, 2025. < <https://www.bls.gov/iag/tgs/iag23.htm> >
- Valle, J., Stepback, L., Parkinson, P., Groves, F., Minichiello, A., and Ohland, M. W. (2024). "*Pathways from Engineering Programs to Labor Unions.*" Paper presented at 2024 ASEE Annual Conference & Exposition, Portland, Oregon. 10.18260/1-2--47831
- Williams, C.L. (2021). "Gas-Lighted: How the Oil Industry Shortchanges Women Scientists." University of California Press, Oakland, CA. Pp. 213.
- Witteveen, D., & Attewell, P. (2020). "The STEM grading penalty: An alternative to the "leaky pipeline" hypothesis." *Science Education*. 104(4), 714–735. <https://doi.org/10.1002/sce.21580>
- Zubair, H., Susilawati, S., and Talei, A. (2024). Scientometric literature review: Effects of Work from Home (WFH) on transportation system. *Multimodal Transportation*, 3(3). <https://doi.org/10.1016/j.multra.2024.100152>