Failure Upon Recruitment: An Actor-Network Theory Analysis of Florida International University's Role in the FIU Pedestrian Bridge Collapse

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

On March 15th, 2018, the Florida International University (FIU) Pedestrian Bridge, which spanned over an eight-lane highway in Miami, Florida, collapsed during construction, killing six individuals and injuring ten more (National Transportation Safety Board, 2019, p. xiv). Many writers and forensic structural engineers have researched the probable cause of the bridge collapse and often argue that it occurred due to technical design and construction errors, such as the underestimation of expected loads and the use of cold joints in the bridge structure, that were made by FIGG Bridge Engineers and Magnum Construction Management (MCM) (Cao et. al, 2020, p. 15). While these analyses provide important information regarding the technical, probable cause of the bridge collapse, they fail to consider the numerous conceptual, economic, and social factors that played a role in the disaster.

If we continue to attribute the FIU Pedestrian Bridge's collapse only to the technical errors that were made by FIGG and MCM prior to and during bridge construction, then we will fail to gain a more comprehensive understanding of the roles that certain non-technical actors, namely FIU, played in the failure of the bridge network. In what follows, I argue that FIU significantly contributed to the bridge collapse by imposing stringent design, budget, and schedule requirements on bidding design-build firms that resulted in a complex, rushed design-build process and left open opportunities for error.

By using the science, technology, and society (STS) framework of actor-network theory (ANT), which analyzes how network builders recruit certain human and non-human actors to join a sociotechnical system and achieve a certain goal, I will offer a more comprehensive overview of the role that FIU played in the ultimate collapse of the bridge structure (Cressman, 2009, p. 3). To perform this analysis, I will utilize evidence from the FIU UniversityCity

Prosperity Project Request for Proposals (RFP), the FIGG and MCM UniversityCity Prosperity Project Proposal, the Accelerated Bridge Construction University Transportation Center (ABC-UTC) 2014 Highlights Report, and the National Transportation and Safety Board's (NTSB) Incident Report on the bridge collapse.

Literature Review

An extensive amount of research has been conducted regarding the probable cause of the FIU Pedestrian Bridge collapse incident, both prior to and following the release of the official NTSB Incident Report. Many of these analyses utilize model simulations to highlight the technical causes of the bridge collapse and to identify the design and calculation errors that were made by FIGG. While these analyses provide valuable information regarding the specific design flaws that led to the bridge failure, they fail to recognize the conceptual, economic, and social factors that played an equally important role in the bridge's collapse.

In the "Investigation of Collapse of Florida International University (FIU) Pedestrian Bridge," Zhou et. al (2019) performed a detailed structural analysis and model simulation assessment to identify the reason for the bridge collapse (p. 1). Given that this was completed prior to the release of the official NTSB Incident Report, Zhou et. al (2019) analyzed only the photos, videos, design documents, and reports that were made publicly available just following the collapse (p. 1). The results of this detailed analysis indicated that FIGG "significantly underestimated the internal force of the structure" during a temporary stage of construction, which allowed for the "shear failure of the 11-12 deck joint" and the collapse of the bridge (Zhou et. al, 2019, p. 14). While the authors do provide substantial technical evidence as to the probable cause of the bridge collapse, they do not mention any non-technical factors that contributed to the incident.

Similar to the above investigation, Cao et. al (2020) completed a forensic analysis of the bridge collapse after the publication of the NTSB report to identify the “specific design flaws” and “sequence of mechanisms” that led to the bridge’s failure (p. 1). The purpose of this study was to identify the shortcomings of the NTSB Incident Report and to elaborate on the bridge’s specific failure mechanisms through model simulations (Cao et. al, 2020, p. 1). Building on the notion that FIGG underestimated the shear demand at the 11-12 deck joint, Cao et. al (2020) concluded that this calculation error, in conjunction with the decision to use a cold joint, where concrete members are cast separately from one another, between the truss members and the concrete deck caused the bridge collapse (p. 15). Although this analysis does mention several non-technical factors that played a role in the bridge collapse, such as the risk of utilizing Accelerated Bridge Construction (ABC) methods and limitations on the project budget and time frame, these factors are not considered as “significant” by the authors as the technical design flaws made by FIGG in the bridge’s collapse (Cao et. al, 2020, p. 16).

While insights gained from the current scholarship surrounding the FIU Pedestrian Bridge collapse provide a clear understanding of the accident’s technical, probable cause, it is important to consider that engineering disasters are rarely solely a function of technical factors. Instead, engineering failures are often influenced by both social and technical forces that can culminate into deadly disasters like that of the FIU Pedestrian Bridge. In this paper, I will use actor-network theory to perform a sociotechnical analysis of the key conceptual, economic, and social factors that contributed to the bridge collapse. This sociotechnical analysis will provide further insight to the lessons that can be learned from the FIU Pedestrian Bridge collapse and will increase the likelihood that we will be able to prevent a tragedy such as this from occurring in the future.

Conceptual Framework: Actor Network Theory

The science, technology, and society (STS) concept of actor-network theory (ANT) provides an effective framework for the sociotechnical analysis of the FIU Pedestrian Bridge collapse, as it allows for a more comprehensive examination of the heterogeneous factors that played a role in the failure of the bridge network. In essence, ANT can be used as a tool to better understand the construction of sociotechnical systems because it focuses on how network builders recruit certain human and non-human actors to join the system and achieve a certain goal (Cressman, 2009, p. 3). It is through this analysis that ANT aims to "trace" how certain "primary actors" can influence the "trajectory of scientific and technical innovation" (Cressman, 2009, p. 7).

To apply ANT to a sociotechnical case study analysis is to study the associations that exist between heterogeneous actors and to map how the network builder both defines and assigns the roles to be played by actors within the network (Law & Callon, 1988, p. 285). This process of network development and construction is best explained through Michel Callon's theory of translation, which outlines the process in which an actor-network is formed and maintained (Callon, 1984, p. 201). In his theory, Callon (1984) defines four main stages of translation: problematization, interessement, enrolment, and mobilization (p. 196).

In problematization, the network builder is tasked with identifying a compelling problem that must be addressed by the network and determining the relevant actors necessary to solve it. During this stage of translation, the primary actor must define the roles of other actors in the network and must determine the relative associations between these actors (Callon, 1984, p. 201). During interessement, the primary actor recruits all identified actors to abandon competing networks and looks to persuade them to adopt the problem definition and its solution (Callon, 1984, p. 203). In enrolment, those actors whose interests have been aligned are assigned roles within the network by the primary actor (Callon, 1984, p. 205). Finally, during mobilization, the primary actor secures their role as the main representative for the network and begins to mobilize all other actors towards achieving the goal (Callon, 1984, p. 209).

Drawing on Callon's concept of translation within ANT, I will analyze the extent to which FIU, the primary actor within the pedestrian bridge actor-network, influenced the network's conception and trajectory. Specifically, by analyzing the interessement stage of the translation process for the FIU Pedestrian Bridge actor-network, I will identify the key factors that caused the network to depart from its original definition and will determine how the actions and characteristics of certain actors ultimately led to the network's failure.

Analysis: Failure During Interessement

Stringent Design Requirements

Immediately upon the conception of the FIU Pedestrian Bridge Project, FIU imposed stringent design requirements on competing design-build firms, causing FIGG, the winning bridge design firm, to propose an unprecedented, complex superstructure design that was vulnerable to complete structural failure. FIU's Request for Proposals (RFP) for the pedestrian bridge project highlighted its desire to incorporate novel, innovative design techniques into the bridge. In the following excerpt, FIU makes it clear that competing firms should primarily consider these conceptual actors when creating their bridge design proposals:

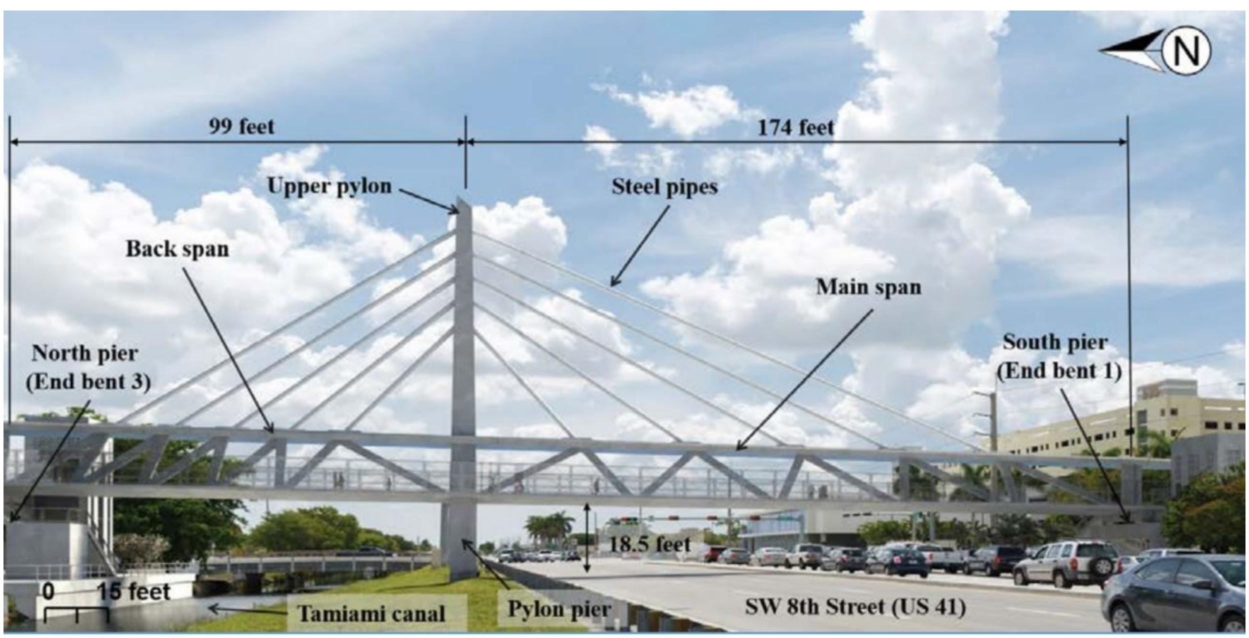
> The owner expects to engage a design-build team with the expertise to deliver an exceptional bridge, both in terms of aesthetic form and practical function. Our commitment to design excellence and design innovation is neither veneer nor luxury. It

is an integral feature of this project's culture. (Florida International University, 2014, p. 1).

By characterizing "design innovation" as an aspect that is "an integral feature" to the "culture" of the project, FIU highlights the importance of applying unprecedented design techniques to the pedestrian bridge. From the perspective of a competing design-build firm, FIU's notion that design innovation and "aesthetic form" will be integral to the project's success indicates that the University will likely place an emphasis on these aspects of the bridge design when evaluating project proposals. Thus, FIGG was prompted to propose a bridge superstructure design that had never existed before: a single-plane concrete truss bridge meant to resemble the aesthetic of a cable stayed bridge, shown in Figure 1 (National Transportation Safety Board, 2019, p. 2).

Figure 1.

FIGG Conceptual Design of FIU Pedestrian Bridge.



As noted in the National Transportation Safety Board (NTSB) Incident Report for the FIU Pedestrian Bridge Project, the design decision to utilize a concrete truss as the bridge's main structural system was both unprecedented and significantly contributed to its collapse:

> Concrete truss bridges are exceedingly rare. Research has revealed no other designs similar to the FIU bridge. Generally, truss bridges are constructed primarily of steel. (National Transportation Safety Board, 2019, p. ix)

> The uniqueness of designing a concrete truss bridge led to the circumstances that accounted for the collapse of the pedestrian bridge. The bridge design team made two errors that resulted in the under-design of the nodal area (11/12) that failed, resulting in the collapse. (National Transportation Safety Board, 2019, p. xv)

The "uniqueness" of FIGG's decision to design the FIU Pedestrian Bridge in a manner that "no other design" has done before relates directly to the University's call for extreme innovation in the bridge's design. Had the University not placed such an emphasis on the requirement for design innovation, and had it instead opted for a traditional truss bridge that was "constructed primarily of steel," it is likely that FIGG never would have designed a bridge that was so susceptible to collapse. While it is important to note that FIGG is still ultimately responsible for the design errors that "resulted in the under-design of the nodal area that failed," one must be careful not to overlook the role that FIU's desire for such an unprecedented bridge design played in the collapse of the structure.

Non-Negotiable Budget Requirements

Not only did FIU place stringent requirements on design innovation during the RFP process, but it also enforced a non-negotiable budget requirement in the RFP that severely limited the amount of money that could be allocated to the design process by FIGG, leaving the bridge design susceptible to error. Returning to the RFP issued by FIU during the recruitment stage of bridge network formation, FIU clearly stated that economic factors, namely the project budget, would be strictly enforced upon the review of proposals:

> For the purposes of bidding, all proposers should submit Base Bid Price Proposals that do not exceed the Maximum Bid Price of $9,388,076.00. For this Contract, the OWNER will reject as nonresponsive any Base Bid Price Proposal in excess of this Maximum Bid Price. (Florida International University, 2014, p. 2)

By enforcing a "Maximum Bid Price" requirement of "$9,388,076.00," FIU severely restrained the competing design-build firms' ability to apply cost-constrained engineering judgement in their project proposals. Given that design fees are often estimated as a percentage of total construction cost, the maximum bid price restriction imposed by FIU in the RFP consequentially reduced the amount of money that could be allocated to the bridge design (Turochy et al., 2001, p. 20). In addition, by indicating that the University will "reject as nonresponsive" any proposal that "exceeds" this maximum price, FIU applied immense pressure to all competing firms to remain within this budget upon the development of their proposals. These two factors highlight the notion that, through the budget requirements listed in its RFP, FIU immediately fostered an environment that restricted competing firms and would lead to a rushed design-build process that was vulnerable to error.

Although this stringent budget requirement was explicitly stated as non-negotiable in the project RFP, this did not prevent FIGG and MCM from voicing their concerns about design complexity and cost implications in their proposal response:

> The biggest challenge for this project has been to determine how to deliver FIU with an iconic signature bridge structure… as outlined in the RFP… within the Maximum Bid Price of $9,388,076. Our goal is to provide the essential elements as listed… within the RFP requirements and, in addition, provide FIU with other options unique to this signature design that are not required in the RFP, but can be added after award or in the future as funding becomes available. (MCM & FIGG, 2015, p. 7)

By describing FIU's maximum bid price requirement as the "biggest challenge for this project," FIGG and MCM subtly indicate that the University's desire for signature design innovation while maintaining a rigid project budget may be unrealistic. Although this statement seems to primarily refer to the cost of construction for the "signature bridge structure," by suggesting that "other options unique to this signature design… can be added after award… as funding becomes available," it is clear that FIGG had similar reservations about the amount of design customization that could occur with such a small design fee budget. Had FIGG and MCM been given more flexibility in the total project budget estimate for their proposal, it is likely that they would have been able to allocate more money towards the design and construction of the FIU Pedestrian Bridge, resulting in a more traditional, thorough design-build process that would have produced the "iconic bridge structure" that FIU was aiming to receive.

Desire for Accelerated Bridge Construction Methods

FIU's advocation for the use of Accelerated Bridge Construction (ABC) methods through its newly established ABC University Transportation Center (ABC-UTC) ultimately produced social pressures to utilize ABC for the pedestrian bridge project, which introduced unnecessary complexities for the bridge design and construction process and significantly contributed to the collapse. The establishment of the ABC-UTC at FIU in early 2011 emphasizes the University's role as a large proponent for the use of the ABC method, as the goal of the center was to advance knowledge in the ABC field and to advocate for its use in bridge construction projects (Accelerated Bridge Construction University Transportation Center, 2015). Immediately prior to the issuance of the RFP for the bridge project, FIU released its 2014 ABC-UTC Highlights Report, where it reiterated its mission statement:

> The mission of ABC-UTC is to reduce the societal costs of bridge construction by reducing the duration of work zones, focusing special attention on preservation, service life, construction costs, education of the profession, and development of a next-generation workforce fully equipped with ABC knowledge. (Accelerated Bridge Construction University Transportation Center, 2015, p. 3)

By advocating for the reduction in "the duration of work zones" and the development of a workforce that is "fully equipped with ABC knowledge," FIU clearly emphasized its desire to utilize ABC methods for the FIU Pedestrian Bridge Project upon its recruitment of bidding design-build firms. FIU's goal of reducing the "societal costs of bridge construction" indicates that it viewed the project as an opportunity to showcase the societal benefits of ABC construction. Thus, similar to the role that design innovation played in FIGG's decision to propose a single-plane concrete truss bridge, FIU's advocation for the use of ABC methods signified that it would place an additional emphasis on construction schedule and methodology when evaluating project proposals, leading MCM to propose such construction methods for the bridge project.

Through an analysis of the FIGG and MCM proposal for the FIU Bridge Project, it is evident that the decision to utilize ABC methods introduced design and construction complexities that contributed to the bridge collapse. FIGG and MCM's step-by-step plan for the accelerated construction of the bridge is shown in Figure 2 below (MCM & FIGG, 2015, p. 11):

Figure 2.

MCM Step-by-Step for Accelerated Bridge Construction.

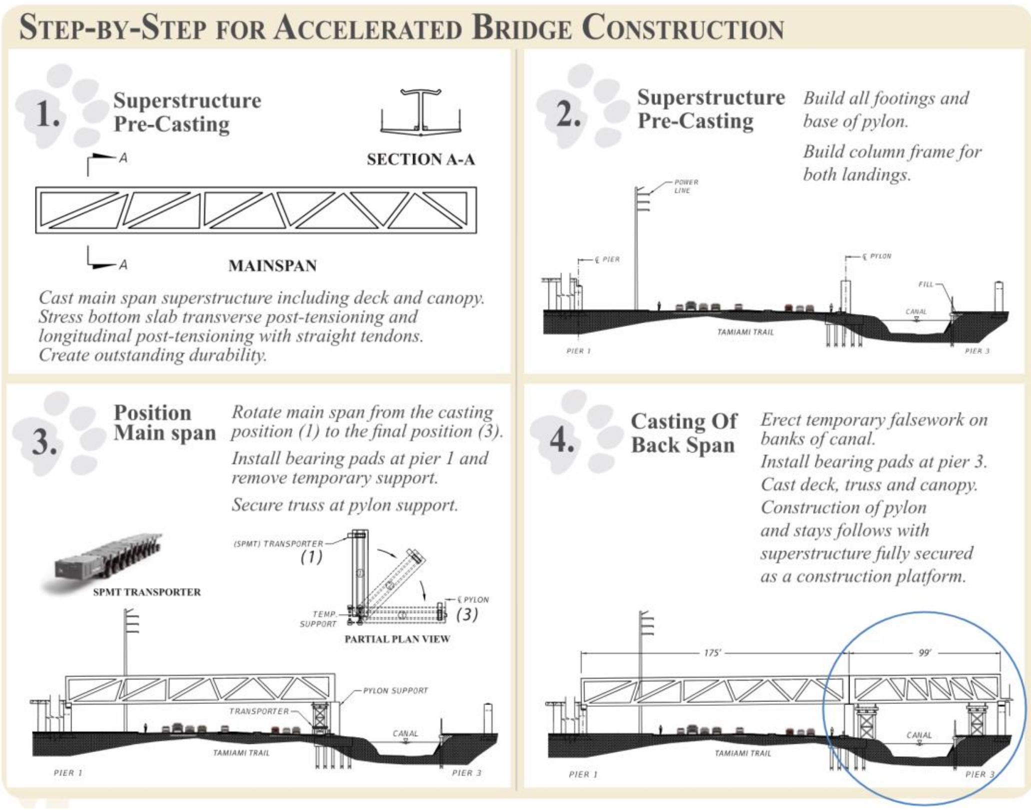


Figure 2 depicts the steps necessary to construct a bridge utilizing the ABC method, in which the bridge superstructure is pre-cast off-site and is subsequently transported "from the casting position to the final position." However, due to the innovative nature of the concrete truss bridge design, the utilization of ABC techniques for the FIU Pedestrian Bridge introduced significant design and construction complexities. In particular, given that the precast bridge superstructure was transported to its final position via a Self-Propelled Modular Transporter (SPMT, shown above), the two ends of the bridge superstructure had to be cantilevered off of the transporter, producing significant tensile loads in the bottom portion of the bridge.

Due to concrete's weakness in tension, FIGG determined that it would be necessary to introduce "transverse" and "longitudinal post-tensioning" of the bridge's "bottom slab" to direct the tensile loads towards steel "tendons" that were more fit for carrying this load type. Notably, the bridge collapsed during a re-tightening procedure of these post-tensioning rods following the transport of the bridge superstructure into its final position (Doing, 2020, p. 16). However, this procedure never would have been necessary if FIU had not applied social pressure to utilize ABC methods for the bridge project prior to and during the RFP process.

As I have argued, FIU's role as a large proponent in the advancement of ABC methodology research and usage influenced FIGG and MCM's decision to propose this construction method for the project. In turn, this decision resulted in significant design and construction process complexities, such as the requirement to provide post-tensioning in the bottom slab of the bridge structure, which subsequently contributed to the bridge collapse. Some might argue that FIU did not explicitly mention the requirement for the use of ABC methods in the project RFP, and therefore, FIGG and MCM imposed these unnecessary design and construction complexities on themselves.

While it is true that there was no explicit requirement for the use of the ABC method in the bridge project, it is important to note that FIU did reference the following evaluation criteria when considering the bridge construction schedule in its RFP:

> Develop and present a proposed Critical Path schedule for development of the project. Explain the advantages of your proposed schedule and how the schedule meets the university's goals and objectives. (Florida International University, 2014, p. 50)

Given FIU's role as a leader in the ABC-UTC and its desire to promote ABC education and usage, one could reason that FIU's call for competing firms to "meet the university's goals and objectives" when considering the project schedule directly influenced FIGG and MCM's decision to use the ABC method for the project. Thus, the social pressure imposed by FIU to implement ABC methods for future bridge projects did implicitly impact FIGG and MCM's decision-making process and contributed to the bridge collapse.

Conclusion

Through an actor-network theory analysis of the Florida International University Pedestrian Bridge collapse, I have argued that FIU, as the network builder for the pedestrian bridge network, significantly contributed to the bridge collapse by enforcing stringent design, budget, and schedule requirements immediately upon the release of the RFP for the project. These project constraints and the corresponding conceptual, economic, and social pressures applied by FIU influenced the bridge design and construction and resulted in a complex, rushed design-build process that was vulnerable to error.

The ANT analysis of the pedestrian bridge collapse provides a more comprehensive explanation of the non-technical factors that contributed to the incident. In addition, this analysis provides further insight to the lessons that can be learned, both as a project owner and design-builder, from a tragedy such as this and will increase the likelihood that we will be able to prevent a similar disaster from occurring in the future.

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