Analysis of Sociotechnical Failures that Lead to the Partial Collapse of Champlain Towers South

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By

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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

It is within any communities' best interests to have structures that are built to last, but throughout the United States, many areas are dealing with aging infrastructure that is crumbling and inadequate. According to the American Society of Civil Engineers (2021), the overall infrastructure of the country has an abysmal grade of "C-". One of the most tragic examples in recent years occurred in Surfside, Florida, located in the suburbs of Miami. At around 1:30 in the morning of June 24, 2021, the twelve-story oceanfront condominium Champlain Towers South partially collapsed, killing ninety-eight people, making it the third deadliest civil engineering structural failure in the United States (Vassolo, 2022). This prompted immediate questions about the safety of similar buildings in the area and sparked investigations into potential causes of the failure, creating a lasting impact on the broader engineering community.

Given the recent nature of the event, no conclusive evidence has been released yet on the exact origin. However, some researchers suggest that the collapse was most likely caused by structural failures during the design and construction of the building by simulating the collapse of Champlain Towers South itself (Pellechia et al., 2024) or through analyzing historical trends (Caredda et al., 2023). While structural issues played a significant role, it is important to consider other factors contributing to the collapse. Among these factors are the potential impacts of natural elements that may not have been adequately accounted for, or inadequate enforcement of building codes by inspectors during the building's lifespan. Focusing solely on structural failures overlooks the broader context leading up to the event, limiting our understanding of the collapse's underlying causes.

In examining the partial collapse of Champlain Towers South, I will use actor-network theory (ANT) to argue that it was the technical failures in conjunction with the engineers and architects, developers and owners, building inspectors, and natural elements that contributed to the building's ultimate failure. ANT offers a unique analytical framework that focuses on the interactions of heterogeneous networks comprising both human and non-human actors. Central to ANT is the theory of translation, which refers to the process by which a primary actor creates and maintains a stable network. By applying this theory, I aim to map out the network involved in the collapse, discussing the contributions of actors by analyzing testimonies, correspondence, and scholarly analyses. Through this analysis, I will then be able to identify the points during network formation where destabilization occurred due to hostile actors. By following these interactions and examining how they contributed to the collapse, I aim to provide a comprehensive understanding of the failure of the Champlain Towers South network.

Background

Champlain Towers South was designed in 1979 by the architecture firm William M. Friedman & Associates Architects, Inc., and Breiterman Jurado & Associates took on the engineering responsibilities (Swaine et al., 2021). Completed in 1981, the South Tower was the oldest and largest condominium of the three-building Champlain Towers complex, including Champlain Towers North and Champlain Towers. The apartment building was in operation for nearly forty years and attracted both full-time residents and seasonal tourists because of its prime location, facing the Atlantic Ocean and providing easy access to the beach. Champlain Towers South was not without its own controversy, even prior to its collapse. An inspection performed by the engineering firm Morabito Consultants in 2018 noted a severe flaw in the waterproofing of the pool deck, exposing the concrete below to water damage (Swaine et al., 2021). Two months prior to the collapse, the owners of the building acknowledged the damage had accelerated and proposed a $15 million repair of the building (Nottingham & Lemos, 2021). Despite the concerns, Champlain Towers South remained in use for its residents.

Literature Review

Given that the partial collapse of Champlain Towers South occurred in the middle of 2021, the literature analyzing the failures that could have led to this specific event happening is limited at the time of this paper. The National Institute of Standards and Technology (NIST) has been investigating the collapse since the beginning but is not expected to release its conclusive report until some point in 2025 at the earliest. While conclusive evidence is not yet available, some literature exists, speculating the probable causes with the information that is currently available. Additionally, previous research on similar cases has been conducted that can provide insights into common potential failures of partial collapses.

Pellecchia et al. performs a collapse analysis on the Champlain Towers South Condo by using the original structural drawings and examining multiple scenarios in which the apartment could have collapsed (Pellecchia et al., 2024). The method used for the analysis was the Applied Element Method (AEM), a versatile numerical technique that simulates the behavior of structures under various loading conditions. AEM allowed the researchers to effectively simulate the mechanisms of collapse by being able to account for larger deformations and nonlinear material behavior. The first scenario tested was the removal of key central or perimeter columns in the observed area of the collapse to determine the most probable cause of failure. The researchers discovered that "the building was able to…avoid progressive collapse, even when three inner columns were removed", while "removal of two perimeter columns was enough to initiate the progressive collapse", highlighting the critical nature of the outer columns. Another scenario was the progressive structural degradation of the pool deck slab as a potential initiator, where it was discovered that the one-story pool deck area underwent double the normal stress as the twelve-story building. While the results of the technical paper are only hypothetical, the simulations from Pellechia et al. demonstrate probable structural failure scenarios consistent with recorded videos of the collapse.

Looking at 31 cases of progressive collapses from 1968 to 2022, Caredda et al. aims to analyze components that lead to failures of buildings and the patterns of collapse propagation (Caredda et al., 2023). Creating a database of these events, the researchers were able to see historical trends in the initiating events, hazards, and structural types. In parsing through the data, some of the trends help to back up the hypotheses of collapse Pellechia et al. proposes, while others seem to provide refuting information. Design and construction errors were found in 48% and 39% of the cases respectively, seeming more in line with the potential deficiencies in the original plans. Initial column failure was the leading cause in 52% of the cases, of which 64% were multiple columns rather than single. However, the researchers deviate in where the horizontal and vertical locations of the failures occur, happening in outer columns (74%) and localized towards the roof and upper levels of the buildings (59%) rather than the ground floor (22%). From the research, Caredda et al. suggests that design and construction errors escalate into larger failures involving multiple structural elements, arguing that building codes and regulations are most vital in ensuring the structural integrity of buildings.

While many of these analyses tend to focus more on the structural components that lead to the failure, they often overlook the broader contexts of the events. It is important to recognize that the partial collapse was likely the result of a combination of interconnected networks and parts, rather than a singular factor. Building upon ideas presented by previous literature, I will examine the sociotechnical failures between relevant actors and network builders, explaining how actors beyond the commonly blamed structural components could have led to the partial collapse of Champlain Towers South.

Conceptual Framework

To analyze the partial collapse of Champlain Towers South, I will utilize the science, technology, and society (STS) framework of (ANT). Developed by Bruno Latour, Michael Callon, and John Law, ANT serves as a comprehensive lens for analyzing STS aspects of human interactions and their way of shaping society, emphasizing the importance of non-human actors in playing a critical role in whether technological projects succeed or fail. This analytical framework examines the interactions of heterogeneous networks, comprised of both non-human and human actors, with special attention given to network builders that actively construct these networks. These actors are not passive objects or neutral tools but instead have agency, meaning they can act and influence the actions of other actors within a network. ANT provides valuable insights into how these networks evolve, offering a more nuanced understanding of their development (Cressman, 2009).

Translation, developed by Michael Callon, is a key concept within ANT, referring to the process by which a primary actor creates and maintains a stable network (Callon, 1984). The process of translation is further separated into four subsections: problematization, interessement, enrollment, and mobilization. Problematization is the first step of translation, where a primary actor establishes itself as the “obligatory passage point” (OPP) through which all other actors recruited into the network established by the primary actor must go through. As the OPP, the primary actor identifies other actors that are needed to accomplish the goal, defining the roles that will lead to the overall stability of the network. During the interessement phase, the primary actor then actively recruits the other human and non-human actors, bringing them into its own network. After successful interessement, enrollment begins when actors are assigned their specific roles by the primary actor that were laid out in defining the goal. Once accepting their roles, the actors begin to carry out and perform their roles as intended. Finally, the last stage of translation is mobilization, where the primary actor acts as a speaker for the network and represents the other actors. (Callon, 1986). Only at the successful conclusion of these four steps can a black box be formed, where the actors all work together to form a stable and cohesive network. However, Callon warns of a fifth stage, dissidence, in which hostile actors can challenge the stabilization of the network. This can occur during any part of the translation process, creating instability and potentially causing the failure of the network.

It is with this information that I intend to use ANT to analyze the partial collapse of the Champlain Towers South network. To do so, I will identify and examine the various agencies of each actor involved in the building's lifecycle, seeing the interactions and influence on one another. From this, I will be able to effectively map out the interconnected network that has been laid out by the primary actor. In using the theory of translation, I will be able to show the points during network formation where destabilization occurred through network builders overlooking hostile actors, whether intentionally or not, leading to the failure of the network and partial collapse of the building.

Analysis

Network Formation

Constructing the actor-network for Champlain Towers South begins with the acknowledgment that the formation of the network is based upon probable and hypothetical actors, as no conclusive report has been released yet that clearly states the causes of the collapse. However, with the information available and a general understanding of civil engineering practices, as well as societal and environmental factors, the first step is to define the heterogeneous actors that are part of the network formation. The human actors include: (i) *developers and owners* who are responsible for the initial construction and maintenance of the building, and the primary actor for which all other relevant heterogeneous actors are dependent upon for the network formation during translation, (ii) *engineers and architects* responsible for the design and structural integrity of the building, as well as the duration of the construction process, and (iii) *building inspectors* that were responsible for ensuring the building complied with all legal codes and standards throughout its lifespan (Swaine et al., 2021). As with ANT, non-human actors also play a role in creating networks and are as follows: (iv) probable *technical failures* of the degraded pool deck slab and weakened outer columns (Pellechia et al., 2024), (v) *natural elements* that were not accounted for due to climate change such as subsidence and sea level rise (Wdowinski et al., 2016), and (vi) *monetary obligations* to the upkeep of the building which had begun to balloon (Nottingham & Lemos, 2021). To depict the relationships between the actors in the Champlain Towers South network, a conceptual model is presented in Figure 1 below. In this representation,

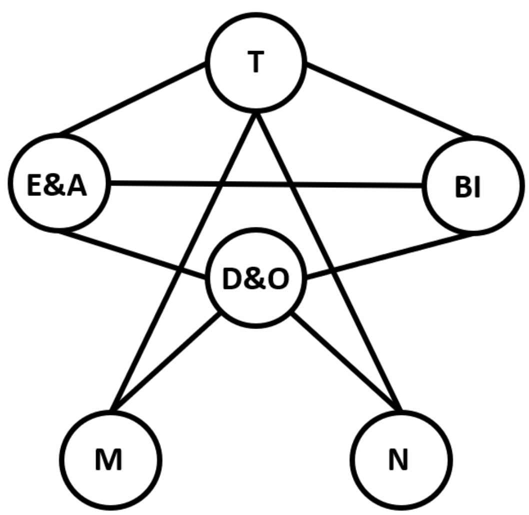

Figure 1. Actor-Network for Champlain Towers South. D&O is developers and owners. T is technical failures, E&A is engineers and architects, BI is building inspectors, M is Monetary Obligations, and N is natural elements

connecting lines symbolize the relationships between actors and are bidirectional. The chosen structure in Figure 1 highlights the significant influence the developers and owners have, as the central part of this network, over all the other actors, except in the technical realm. Each individual actor interacts with these technical failures and communicates concerns to the center but often neglects to collaborate with members in the periphery. These technical failures exert a hostile influence on those same actors, mirroring the reach of the developers and owners. A key implication of this network configuration is that in a stable system, competent developers and owners would be able to exercise effective control, thereby preventing technical failures from escalating beyond manageable levels.

Applying the Theory of Translation

Before I start to analyze the Champlain Towers South network fully, I will use translation to show how the network was formed and stabilized before subsequently failing. During the first stage of translation, known as problematization, a need for new residential buildings was identified in the suburbs of Miami by a group of developers and owners. This group then determines relevant actors necessary to the goal of creating residential buildings that will be built to last. By setting themselves up as the OPP, the developers and owners begin to construct the network by defining roles and responsibilities of the actors. This leads into the next stage of interessment, where the developers and owners can formally recruit human and non-human actors into the network. The initial recruitment of natural elements occurs during the site selection process, setting the foundation for the building's relationship with its environment. Next, they recruit money through securing funding to obtain the necessary resources for construction and ongoing maintenance of the building afterwards. Once the financing is secured, they recruit engineering and architectural firms to ensure structural integrity and functionality by bringing professional expertise to a building that meets safety and quality standards. In the final stage, building inspectors are recruited to identify and address potential issues that could compromise the building's integrity or safety during its lifecycle. The following stages of enrollment and mobilization are more hypothetical, blending together as the actors just recruited "accept" their defined roles and begin to perform them as the developer and owners intended. The developers and owners then solidify the connections between the architects and engineers, building inspectors, monetary obligations, and natural elements before forming a black box, or stable system, in which the building safely lasts for its intended lifecycle for its residents.

I did not mention the technical failures as part of translation because it is an actor that the developers and owners unknowingly recruited as a hostile actor that threatened the safety of Champlain Towers South from the day the project was conceived until the untimely collapse. The technical failures act as an opposite force on the same actors that the developers and owners do, but they never act directly with one another. Challenging the stability of the network, the technical failures slowly begin to recruit the actors to become hostile to the system until they essentially switch over.

Network Destabilization

One of the reasons why the network destabilized was the losing battle Miami had with its natural elements over the duration of the building's lifecycle from its conception in 1979 to the collapse in 2021. Miami and its suburbs are located next to the Atlantic Ocean at around six feet above sea level in most neighborhoods, especially in the case of Champlain Towers South being directly situated next to the beach (Johnson, 2016). The increasing rate of sea level rise (SLR) since the late 1800's has become a problem for coastal communities, putting them in harms way of flood risks from storm surge with hurricanes and higher tide conditions. From 1998 to 2006, SLR in Southeast Florida was at 3 mm/year, which was tracking consistently with global SLR during that same period. However, from 2006 to 2013, the SLR significantly increased to 9 mm/year, and a 400% increase was observed in weather events associated with tidal waves (Wdowinski et al., 2016). While rapidly accelerating SLR in Southeast Florida is more well known to the broader population, another environmental factor paired with it further adds to the growing risk of flooding. Subsidence is a geological process that refers to the gradual sinking of the ground's surface. Therefore, subsidence contributes to increased flooding risks by lowering the elevation of coastal areas relative to sea level. By using elevation data from the 1990s, a localized area of subsidence at a rate of 2 mm/year was discovered around Champlain Towers South in 2020, one year before its collapse (Tejedor, 2022).

The issue of coastal flooding posed from SLR and subsidence becomes clearer when understanding the role of water damage on potential structural instability. Champlain Towers South was built of reinforced concrete, a composite material where steel rods are embedded into concrete to improve the strength of the material against compressive and tensile stresses (Swaine et al., 2021). However, over forty years, the water from coastal flooding can seep into concrete structures, causing them to crack and spall. This can weaken the concrete and reduce its ability to support loads. Furthermore, the cracking of the concrete allows water a pathway to the steel, corroding it over time. The developers and owners failed to consider this as an issue, and the technical failures as a hostile actor began to recruit the natural elements to work against the black box of the building, creating instability within the structure.

Another prominent factor causing the destabilization of the Champlain Towers South network was the role of building inspectors, who failed to properly do their jobs of ensuring that the building complied with all legal codes and standards. In 2018, the chief building official for

Surfside reassured residents that the building was in good shape, despite a structural report warning of damage to concrete and steel that may have threatened the structural stability of the building. When pressed later about conducting further inspections by residents, the official declined to do anything about it, restating that there were no issues with the building (Robles, 2021). This messaging completely ignored third-party consultants' findings from Morabito consultants, which had found evidence of abundant damage to columns, beams, and walls of the building (Swaine et al. 2021). Additionally, the third-party inspection was never followed up by the chief building official, nor was it ever communicated to other prominent officials in Surfside.

An alternative perspective that challenges the idea that the developers and owners of the building were the network builders is that it was instead the engineers and architects that created the network, bearing the primary responsibility for the collapse of Champlain Towers South. This may make sense at first given the structural failures that were the responsibilities of the engineers and architects during the design and construction phases. However, this argument fails to take into account the duration of the building, which lasted almost forty years. When structural deficiencies did emerge towards the end of the building's lifespan, they were due to a combination of factors that were a resultant of environmental changes and insufficient maintenance. Despite recommendations from a 2018 structural report, developers and owners chose to defer repairs, a decision that ultimately contributed to the collapse. Just days before, they were on the verge of approving a $15 million repair project, but it was not completed in time (Tolan, 2021). While the engineers and architects were pivotal in the initial stages of development, the ongoing maintenance and management of the building involved the broader network constructed by the developers and owners.

Conclusion

In this paper, I have used the STS framework of ANT to construct the actor-network for Champlain Towers South. ANT allowed me to develop a detailed network and analyze the connections and relationships among the various actors involved. In my analysis, I showed how the developers and owners lost control of the network, in which actors initially recruited by the developers and owners ended up working against them after the introduction of the hostile actor of technical failure. The technical failure did not occur on its own and is not the sole reason for blame; rather, multiple actors in conjunction with one another played roles throughout the duration of the lifecycle of Champlain Towers South in the destabilization process. The developers and owners failed to consider the ongoing role that they played in ensuring the safety of the building.

It is with this analysis that I hope professionals in the civil engineering field will take a further look at all actors when determining causes of a systematic failure. Without proper analysis of all actors involved, there is a risk of oversimplification and misattribution of blame, which could hinder efforts to prevent similar failures in the future. This approach can help professionals in the field identify potential risks and vulnerabilities early on, leading to more proactive and effective risk management strategies.

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