Actor-Network Theory & Punctualization in Boston's "Big Dig"

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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

The Central Artery/Tunnel (CA/T) Project in Boston, Massachusetts – also known as the "Big Dig" – has been described as "the largest, most challenging highway project in the history of the United States" (Commonwealth of Massachusetts, n.d.). The CA/T Project experienced several delays and severe cost overruns. In 1982, it was estimated to cost $2.6 billion and to be completed in 1998 (Transportation Research Board, 2003, p. 7). The project, however, was not completed until 2007 and cost $14.8 billion (Greiman, 2010). When adjusted for inflation, the initial $2.6 billion estimate in 1982 would be equal to $5.75 billion at the time of completion in 2007 (Bureau of Labor Statistics, 2020). The cause for this time and cost overrun may be attributed to mitigative efforts and the vast scope of the entire project. Existing scholarship does not attend to the full scope of the project, performing analyses on specific aspects for publication in topical periodicals. These analyses do not mention the existence of heterogeneous actors within these networks. By not considering the role of both human and non-human actors within the scope of a network, this limited understanding inhibits the ability of a network builder to stabilize one's network to meet budgetary and schedule constraints in a construction project, as seen in the CA/T Project.

I will be examining several scholarly works and local media sources pertaining to the CA/T Project to explore the factors contributing to the substantial time and cost overrun of the Project. In the case of the CA/T Project, I will show how the failure to consider all heterogeneous actors within a network may cause that network to destabilize and have critical consequences to the success of that network. This destabilization was experienced in the form of time and cost overruns. To explore my claim, I will analyze three contributing factors: quality of life, subsurface conditions, and rats. I will use actor-network theory (ANT) and the concept of punctualization to isolate these factors into micro-networks and analyze the destabilization that occurred within the scope of each of these factors.

Background

Before the construction of the CA/T Project, Boston's Central Artery (I-93) was considered "one of the most congested highways in the United States." Daily traffic jams reached 10-hour periods and models predicted the congestion to reach 16 hours per day (Commonwealth of Massachusetts, n.d.). The CA/T Project looked to replace the existing

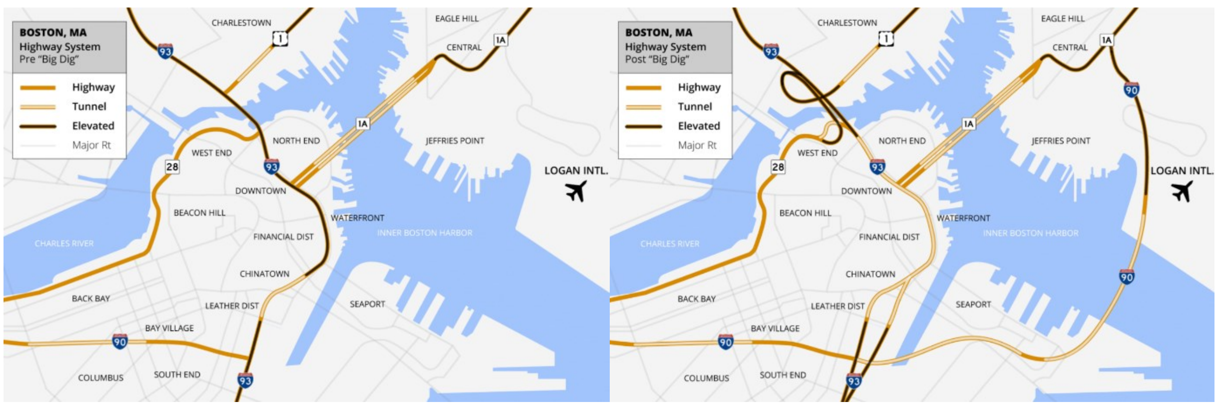

Figure 1 – Comparison of Pre- and Post- Construction

Boston's highway system before and after the Central Artery/Tunnel Project (Andrew, 2015)

elevated Central Artery with a more effective below-ground highway. The removal of the elevated highway created 27 acres of open space (Transportation Research Board, 2003). The Project replaced 7.8 miles of highway and required over 100 construction contracts and the services of nearly 200 construction-related companies (Beck, 1999). Figure 1 helps show the scale of the project and the changes that it brought to the Boston area.

Literature Review

Few scholarly sources have investigated the CA/T Project as a whole. Most analyses are published in topical periodicals, many of which are centered around a specific factor that contributed to either time or cost overrun. However, there exists some scholarship understanding how several stakeholders are involved within a project of this grand scale, some even discussing the network that exists between structural and social factors.

In *Transportation at the Millennium: In Search of a Megaproject*, Wendy Haynes provides a short list of some major stakeholders of the Project including, but not limited to, the Boston business community, federal and state transportation agencies, Boston's neighborhoods and its residents, and environmentalists. She acknowledges how "organizational relationships and the various project delivery mechanisms" are influenced by these diverse stakeholders (Haynes, 2002). Haynes also discusses the management and oversight structure of the Project, noting the project owner, Massachusetts Turnpike Authority, its hiring of Bechtel/Parsons Brinckerhoff (B/PB) to manage the Project, and the complexities of overseeing such a large project with its many contracts. She alludes to the idea that this management network "itself significantly contributed to cost overruns and schedule delays" (Haynes, 2002). Haynes fails to mention the presence of heterogeneous actors that exist within the network of the Project, drawing attention solely to the human-to-human interactions that exist within management. While Haynes provides a useful exploration into the various stakeholders of the Project and its management network, she does not take account of the full scope of the Project, rather focusing on a singular network and its responsibility for the Project's shortcomings.

In contrast to Haynes, Virginia Greiman and Elliott Sclar claim: "to judge megaprojects by the criterion of standalone efforts is akin to judging the forest by its individual trees and not the synergy of the larger ecosystem that they jointly comprise" (Greiman & Sclar, 2019). In *Mega infrastructure as a dynamic ecosystem: Lessons from America's interstate system and Boston's big dig*, Greiman and Sclar take account of the structural, social, and environmental aspects of the CA/T Project and how these aspects form a network created over the completion of the Project. Unlike Haynes, they acknowledge the presence of several non-human actors, such as the organizational and environmental factors that can contribute to the time and cost overrun of a project. Despite this, their focus is shifted to analyzing the benefits created by various actors within the whole network. They consider how these benefits should also be considered in judging project success or failure, not solely budget or schedule adherence. Their analysis fails to acknowledge how these networks and their interconnectedness contribute to the time and cost overrun of the Project, regardless of the judgment of the Project's success.

While there is value in understanding the management network and the benefit that the Project brought to the Boston area, it is important to understand the intricacies of a project of this magnitude and the large scope in which it encompasses. In this paper, I will utilize actor-network theory (ANT) to explore the vast scope of the CA/T Project and the factors that contributed to its severe time and cost overrun.

Conceptual Framework

My analysis of various factors contributing to budget and schedule deviation in the CA/T Project draws on the science, technology, and society (STS) framework of ANT, which allows me to sequester these factors into micro-networks for individual analysis. John Law (1987) defines ANT as a "combination of social and technical engineering in an environment filled with indifferent or overtly hostile physical and social actors" (p. 235). ANT studies the associations and interactions between human and non-human actors, called "heterogeneous actors" (Cressman, 2009, p. 4). These heterogeneous actors are assembled by a network builder to accomplish a certain goal. Law (1987) states that these actors may be indifferent or hostile. It is the role of the network builder to identify which actors are allies or adversaries of a network. These indifferent or hostile actors must be translated or converted to serve the interests of the network, hereto referenced as "rogue actors." Michel Callon (1987) states that "an actor network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of" (p. 93). Thus, the size of an actor network is variable; larger actor networks are composed of smaller actor networks, an idea conceptualized by punctualization.

Cressman (2009) defines punctualization as "the process by which complex actor-networks are black boxed and linked with other networks to create larger actor-networks" (p. 7). This concept may be visualized as a tree diagram representing the entire actor network, with the root node representing the network builder. This root node is linked to another node, which is linked to others, in a seemingly endless pattern. The concept of punctualization allows one to pick any node out of that tree and analyze it as its own actor network, supported by Callon's notion that an actor network is both an actor and a network. Law (1992) states that "punctualized resources offer a way of drawing quickly on the networks of the social without having to deal with endless complexity" (p. 385). For the purposes of this paper, I will black box the complex network that comprises the whole of the CA/T Project. This is due to the large number of contracts managed by B/PB and the improbability of analyzing each factor that may have contributed to the time and cost overrun of the Project. By using the concept of punctualization, I will explore three factors that contributed to the time and cost overrun of the CA/T Project and treat them as their own micro actor networks to give context into the vast scope that the Project encompasses.

Analysis of Evidence

During work on the CA/T Project, the project manager, Bechtel/Parsons Brinckerhoff, was met with a litany of change orders. Change orders are changes to contract specifications that arise when unanticipated challenges appear during construction. B/PB claimed that "the changes in Boston… reflected a host of legitimate circumstances, including the discovery of unforeseen underground obstacles such as undocumented utilities and old wharves buried in landfill, state-mandated changes in the scope of project work and schedule adjustments caused by factors such as public requests for noise or traffic mitigation" (Scranton Gillette Communications, 2003). B/PB reported that project scope changes contributed $321 million to cost overrun, "unforeseeable schedule adjustments" contributed $152 million, and "differing site conditions" contributed $357 million (Scranton Gillette Communications, 2003). These unforeseen and unaccounted-for factors helped contribute to large sums of cost overrun and, while schedule data is not readily available, the completion time was similarly negatively impacted. As I will show in the following sections, the failure to account for all possible heterogeneous actors within a network of a construction project may have severe time and cost penalties. I will explore three individual actor networks that helped contribute to the time and cost overruns of the CA/T Project: quality of life, subsurface conditions, and rats. It must be noted that these factors are not deemed to be the most influential challenges but ones that have been featured in topical periodicals and local media during the Project. I also believe that these helps present diverse examples of actor networks that may appear during a construction project, especially one of this magnitude. Through ANT and punctualization, these varying challenges may be explored and respected as their own actor network. The following sections explore each of these challenges and their impact on the performance of the CA/T Project.

Quality of Life

To ensure quality of life, project managers needed to consider the Project's impact on the community. When considering this quality of life, one must look to the actors in the surrounding Boston area, namely its businesses and its residents. Peter Zuk, CA/T Project director from 1991 to 1998, said that minimizing disruption from the Project was akin to "performing open heart surgery on someone who continues to go to work and play tennis" (Beck, 1999). It was a massive undertaking to cause disruptions and traffic delays in such a bustling metropolis. Mitigative efforts needed to be taken to ensure the happiness of the people as well as the success of the Project, for community uproar would spell disaster. These mitigative efforts were not cheap; the initial $2.6 billion estimate for the Project did not include mitigative costs, which ended up accounting for one-third of the total cost (Beck, 1999; Gelinas, 2007).

To ensure businesses operated at full capacity and to satiate residential neighborhoods, more than $3 billion was spent on "signage, traffic rerouting, temporary roads, clean up, noise abatement and the like" (Beck, 1999). The Project's mitigative efforts were helped by the community, installing a watchdog to monitor the Project's impact on local businesses. The Artery Business Committee was a coalition of over 60 companies representing more than 100,000 employees in the downtown Boston area (Beck, 1999). This accountability between the Project's managers and the community helped ensure the stability of the network. One may argue that the consideration of local businesses is out of the scope of construction, in that the businesses would be as equally affected by the Project as the rest of the community. However, this view fails to consider the impact that such a coalition can have, as the Committee protected both downtown Boston from any harm that construction may pose, as well as "safeguarding the project from political and legal controversies that could threaten its completion" (A Better City, n.d.). Project management was able to consider some of the heterogeneous actors in this micro-network, including the various downtown businesses and their employees. They also considered the politics and legislation of the downtown Boston area, understanding the possible ramifications of not establishing a relationship with the various actors.

Within this micro-network, traffic presented itself as a rogue actor. Namely, the South Boston neighborhood was expected to get a third of all construction traffic. In response, a temporary 1.1-mile-long road, to function as a primary highway, was constructed to alleviate pressure on the neighborhood (Hodges, 1998). The South Boston Bypass Road still exists and is still in use today. Additionally, in terms of pedestrian traffic, temporary and shiftable pedestrian walkways were installed to meet construction needs and public safety requirements. Along these walkways, public information about the project was posted (Hodges, 1998). This posting of information helped promote public positivity about the Project and increase public morale, even as the Project exceeded its initial schedule. From these examples, there are several actors to consider, both human and non-human. Human actors include the residents of surrounding neighborhoods, associated pedestrians, and commuting and construction traffic. However, it is also important to consider the non-human actors that are apparent in these situations. Some of these actors include ambient noise from passing cars, the exhaust produced from congested traffic, and the morale of the community. If such factors were not considered by project managers, one may imagine how the CA/T Project would have been received by the community.

These rogue actors forced the hand of project managers, leading to the construction of the South Boston Bypass Road, for example. In the case of mitigation, there is a significant rogue actor that caused the network to adapt and transform: construction noise.

With any construction project, it is inevitable that a substantial amount of noise will be produced, ranging from communications between workers to sounds produced from heavy-duty machinery. As parts of the approximately 7.8-mile-long highway project passed through residential and "noise sensitive" areas, such as around hotels and hospitals, this produced noise that needed to be controlled. With the presence of this rogue actor, the network was forced to adapt to ensure its stability and success. In response, the project managers developed the CA/T Construction Noise Control Specification 721.560, "the most comprehensive and stringent construction noise control specification of any public works project in the country" (Thalheimer, 2000, p. 159). The specification considered the project's location, the time of day, and even what tools were being used. Every piece of equipment used on-site had to be approved and failure to adhere to criteria could have led to fines or the shutdown of the site until noise mitigation could be ensured. In certain cases, noise barriers had to be constructed in residential areas or windows had to be treated to reduce noise for those not protected by the barriers. Estimates for this noise control program approached $17 million, which accounted for 0.13% of the total cost of the project (Thalheimer, 2000). By enacting these policies, the project managers were able to transform the network to counteract the harm that was posed by the presence of noise. This is an example in which the project managers were able to adequately assess human and non-human actors present in the network. They considered workers on the site and the community in surrounding areas as well as each tool and its "acoustic usage factor," the ambient noise created by the tool (Thalheimer, 2000). The program was considered "an essential element to facilitate ongoing construction that could otherwise be hindered by distressed community groups and/or city officials" (Thalheimer, 2000, p. 158). Without the created specifications, the community may have interrupted the Project until the noise generated from construction sites could be abated. This highlights the relationship that the Project has with the community, one that is stable if the Project's execution respects the needs of the community.

Subsurface Conditions

The CA/T Project included construction work both above and below ground, requiring project managers to account for heterogeneous actors at multiple levels. During the digging of the various tunnels, construction teams encountered various problems. The first rogue actor was encountered while excavating and preparing for tunnel construction. Located 20 feet below a layer of landfill, was a "layer of soft organic matter with lenses of sand, and beneath that are strata of the marine material peculiar to the area known as Boston blue clay" (Rogers & Taylor, 2003, p. 44). This Boston blue clay was a rogue actor in that it had threatened both the stability of the network and the stability of the tunnel itself. The clay would not have been able to support the base of the excavations and was likely to collapse. The team responded by using a method called jet grouting to improve the base and prevent movement of the surrounding walls (Rogers & Taylor, 2003, p. 48). The presence of this rogue actor was somewhat unexpected, delaying the progress of tunnel construction, as the design team had to develop the method of jet grouting. In rectifying this problem, the design team had to consider all non-human actors present in the network, including the surrounding slurry walls, settlement of the ground above the tunnel, the direction of the tunnel, and more (Rogers & Taylor, 2003). By considering the scope of this tunnel network, the design team was able to stabilize the network even in the presence of the

Boston blue clay rogue actor. The CA/T Project also had tunnels that ran under existing railways, which produced another instability in the network.

The construction team encountered another rogue actor in the form of weak soil underneath railroad tracks. In attempting to construct the tunnel underneath nine active railroad tracks, the construction team wanted to use a method called tunnel jacking, in which the tunnel would be constructed first and then pushed into place using hydraulic jacks. If work were carried out with the presence of the poor soil, the railways would settle, disrupting train service, including commuter tracks that transported 150,000 people in and out of Boston daily (Wood, 2001). To stabilize the soil and consequently the network, the construction team elected to freeze the soil to prevent groundwater flow. Steel pipes were inserted into the ground and chilled calcium chloride brine was circulated to freeze the ground. This could only be done at night, however, to prevent affecting rail operations (Rogers & Taylor, 2003). The team considered the importance of rail operations to the city of Boston and was able to construct the tunnel underneath the set of tracks without disturbing the operations. By considering the heterogeneous actors present in this network, the team was able to stabilize the network by adapting and presenting a new solution to the problem.

When considering the historical relevance of a city such as Boston, it was expected that the mass excavation of landfill would reveal numerous archeological discoveries. Such discoveries included colonial wharves, old industrial installations, and Native American and Revolution-era artifacts (Rogers & Taylor, 2003; Lewis, 2001). Archeologists were hired as a part of the Project and used maps from the 17th, 18th, and 19th centuries and cross-referenced them with current maps to identify possible areas that would harbor ancient discoveries (Lewis, 2001). While expected, these artifacts may be considered rogue actors, for they present uncertainty in their antiquity and their number. As tunnel excavations proceeded, these archeologists had to be on-site to uncover, preserve, and collect these artifacts. While the stability of this micro-network was minorly affected, the importance of this anticipation in terms of the full scope of the CA/T Project must not go unnoticed. By considering the non-human actor in the form of the historical relevance of the area, and the possible presence of historical artifacts, the project managers were able to prevent the entire network of the Project from becoming unstable, which would have taken even more time and money to perform remediations in retrospect.

Rats

As work began on the CA/T Project, it was predicted that Boston would experience a "rat plague of biblical proportions" (Mccown, 2002). Akin to the biblical plagues of Egypt, it was expected that a large swath of rats would invade Boston because of construction. As tunnel excavations proceeded, rat nests located in underground sewer systems would be disturbed, forcing the rodents out of their homes and into the streets of Boston. In this network, the rats are rogue actors. They threaten the success of the Project, for the presence of rats in the community because of construction would not be well received by its people. However, there are more rogue actors in this network than just the rats. William B. Jackson, an expert on rat control, was hired to assess the problem. He identified a problem in extermination efforts, an unreachable "subterranean labyrinth of unknown dimensions" (Allis, 1989). Some underground utilities were uncharted or undocumented, in which rats may have built nests. As digging and construction commenced, the disturbance of these unknown and hidden habitats would cause the rats to surface and enter the city proper. In response, project management established a rodent control team, consisting of biologists, inspectors, and code enforcement officers. An organizational network was created by considering multiple human actors that existed in the micro-network of rodent control, which is depicted in Figure 2. Through these efforts, the city's rodent population,

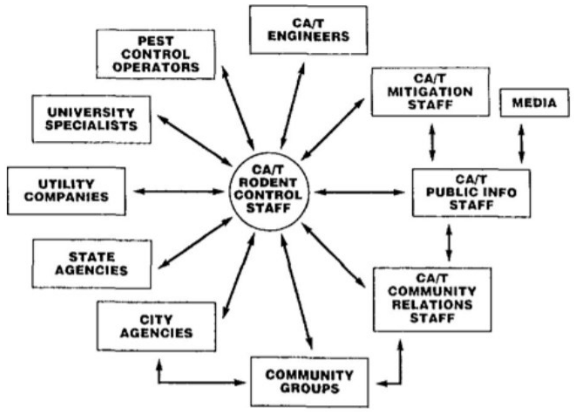

Figure 2 – Organizational Chart of Rodent Control Program

An organization chart showing central coordination of personnel and organizations participating in the CA/T rodent control program (Colvin et al, 1990)

estimated to be 80,000, was reduced by 90 percent (Associated Press, 2002). To prevent the re-emergence of these rats, sanitation rules were enforced on job sites, namely the disposal of food waste left by construction crews (Mccown, 2002). By identifying the rogue actors that existed in this network - the rats, uncharted sewer systems, and trash – project managers were able to transform and stabilize the network through its installation of the rodent control team and sanitation measures. Through these efforts, they were able to prevent a plague of rats from descending upon the city of Boston.

Conclusion

From examining a handful of factors that contributed to the time and cost overrun of the CA/T Project – quality of life, subsurface conditions, and rats - all the representative micro-networks experienced instability due to the presence of a rogue actor. These micro-networks created by the network builder are also constructed by the interactions between the heterogeneous actors that exist in its respective scope. It is imperative that, as an engineer, one is sure to identify all these heterogeneous actors, for failure to do so may cause critical instabilities.

Taking a step back, one must imagine being in the position of a project manager. While focusing not only on the macro network, the hiring of subcontractors, effective schedule management, etc., a project manager must also focus on the minutiae of the micro-networks that exist within the overarching network. When things such as a worker's lunch can threaten the stability of the network, it shows how complex of a problem it is to adequately account for all heterogeneous actors in that network. Through ANT and punctualization, a project manager must treat each micro-network as its own complex actor network. By ensuring the stability of these micro-networks, one may also ensure the stability of the actor network at-large.

Word Count: 3892

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