An analysis of the true root cause behind the Texas City Refinery explosion using Actor-Network Theory

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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

Fires, explosions, and accidental chemical releases (referred to as *process safety incidents*) occur regularly at chemical process facilities despite ever-improving qualitative and quantitative methods for assessing the hazards of said chemical processes (CCPS, 2016, p. 2). For reference, the Center for Chemical Process Safety (CCPS) recorded 9 process safety incidents across the U.S. in December 2020 (CCPS, 2020). A particularly devastating process safety incident is the Texas City Refinery explosion of 2005. Process safety incidents can have catastrophic effects and can result in multiple fatalities, as well substantial environmental, property, and economic damage, therefore requiring serious prevention efforts from scholars, engineers, and safety experts (The Baker Panel, 2007). Much research has been devoted to determining both the direct and root causes of these incidents. Surprisingly, many incidents share common "root" causes despite adequate resources available to prevent the occurrence of these chemical disasters (Bhusari et al., 2020). The fact that the same incidents continue to occur suggests that these analyses are incomplete, preventing the adequate understanding and subsequent efforts needed to eliminate chemical disasters from the industry. In this paper, I will approach the analysis of the Texas City Refinery disaster using Actor-Network Theory to argue that the failure to adopt safety improvements due to the human tendency to reject change was the true reason that the incident occurred. I argue that cognitive inertia is the rogue actor in the Texas City refinery actor-network that destabilized the company's intention for the refinery. I will begin my argument by highlighting the shortcomings of other incident investigation reports and then laying out the evidence of rejection of change in the refinery. This will allow for a critical analysis of the actor-network before and after the introduction of the rogue "cognitive inertia" actor. Within the context of this network, I will ultimately show that cognitive inertia dominates the other actors with its power over human behavior. This analysis will reveal the impact that inherent human psychology had on the Texas City Refinery and how this led to a catastrophic disaster.

BACKGROUND

On March 23, 2005, the British Petroleum (BP) America Texas City Refinery experienced the most serious U.S. workplace disaster since 1990. Explosions and fires on site resulted in the death of 15 people and hurt 180 others, many of which were left with severe and disabling injuries. Damage to nearby houses was recorded up to three-fourths of a mile away from the refinery. In addition to the invaluable loss of life, BP suffered financial losses exceeding $1.5 billion.

On the fateful day of the disaster, operators began a routine startup of an isomerization (ISOM) unit by beginning the flow of gasoline to a 170 foot-tall distillation tower. The tower was only ever supposed to contain 6.5 feet of liquid during normal operation. Due to the failure of a liquid level alarm, the tower was steadily filled to a liquid level of 98 feet, more than 15 times the normal level. When vapor pressures reached extreme levels, the ISOM unit's antiquated blowdown drum relief system, which vents directly to the atmosphere, was activated. Fifty-two thousand gallons of boiling gasoline spewed out of the blowdown drum, immediately evaporating. This huge vapor cloud was ignited within seconds, causing a powerful explosion that destroyed the unit and ignited fires around the plant that lasted for hours. (CSB, 2007, p. 47-67)

LITERATURE REVIEW

The Texas City Refinery explosion commanded the attention of many civilians, industry workers, and federal safety organizations alike. The severity of the incident spawned many independent investigations, which have generated multiple analyses into the causes of the incident. Saleh et al. (2014) draw upon the findings of three different investigation panels to analyze the system's technical failures, and more importantly, the "accident pathogens" or lurking adverse conditions which compound over time before initiating an incident. The authors argue that the refinery's significantly weak safety culture allowed for repeated safety violations that culminated in the technical failures that occurred on that fateful day. The paper explains that the ISOM unit had experienced two hazardous startups before the startup that caused the explosion, although these near misses were not investigated and the opportunities to learn from these precursor events were missed. Although the analysis done by Saleh et al. (2014) thoroughly examines the impacts of the refinery's weak safety culture, they do not explain *why* the culture was so poor. Also, they neglect to relate this incident to the repetitive nature of other process safety incidents.

More comprehensively, Bhusari et. al (2020) explores the common contributing factors to severe and catastrophic process safety incidents across 14 different industries. In studying 81 different noteworthy historic incidents, including the Texas City Refinery explosions, it was found that weak safety culture, insufficient emergency preparedness, and poor mechanical integrity are common to disasters across all industries (Bhusari et al., 2020). These incidents span across the globe, from laboratory scale to billion-dollar industrial plant scale. Collective analyses of this sort reveal that while the technical details concerning various industrial disasters differ, the cultural causes for incidents are extraordinarily consistent. However, the analysis by Bhusari and colleagues does not go beyond the common institutional root causes of these incidents. They effectively evade the idea that there must be a reason why the same incidents continue to occur albeit with countless opportunities to learn from past tragedies. In this manner, the investigation falls short of identifying the true root cause of safety accidents, which span every industry across the world.

In this paper, I will reflect on the predictability of process safety incidents concerning how cognitive inertia influences industrial safety. I will utilize actor-network theory to provide a systematic analysis of the Texas City Refinery explosion and introduce the sociotechnical connection between process safety and the tendency to reject change.

ACTOR-NETWORK THEORY

Actor-Network Theory (ANT), as defined by French sociologist Michel Callon (1987), will serve as the framework to characterize the complex relationships that exist between the people, technology, and ideology involved in the Texas City Refinery explosion. ANT was chosen for this case study because it methodologically provides the tools to critically analyze human and nonhuman connections alike that result in science and technology. Fundamentally, ANT sets out to follow the primary actors within a given network to better understand how they shape and are shaped by one another (Law, 1991). ANT allows for the deconstruction and critical analysis of complex sociotechnical systems, which in effect simplifies the heterogeneous relationships present in these systems to a coherent network of actors (Callon, 1987). Actors within ANT are defined semiotically- that is to say that the identity of an actor is to be understood only through its interaction with the other actors in the network (Latour 1996). Understanding of the actors' positions within the network will be achieved through the means of Callon's concept of translation (Callon, 1997).

Translation is the process of actor-network formation by and around a primary actor. The four phases of translation are problematization, interessement, enrolment, and mobilization, in that order. In problematization, the network's primary actor identifies a problem that must be solved. The primary actor will define itself as the “obligatory passage point” (OPP) through which other actors must pass to participate in the network. In interessement, the primary actor will recruit other actors and align their interests with the problem statement. Next, in enrollment, the primary actor assigns roles to recruited actors, which they accept and perform. In mobilization, the primary actor secures their role of representing and speaking for the other actors. Importantly for this paper, Callon notes that an actor-network can fracture or fail if even one actor refuses its role. ANT will allow me to track the actor responsible for the destruction of the Texas City Refinery’s network.

ANALYSIS

Network Formation

Construction of the sociotechnical network behind the Texas City Refinery incident is necessary for the following critical analysis. I have identified the primary actors in the heterogeneous network by synthesizing the groups who were directly involved with the refinery on the day of the incident, as well as all groups who were issued recommendations following the CSB’s investigation in light of their indirect responsibility for the accident (CSB, 2007; The Baker Panel, 2007). In addition to these well-documented actors in the Texas City Refinery network, I will identify the ideological actor of cognitive inertia as a rogue actor in the network. The human actors are enumerated as follows: (i) *Operations workers* who directly controlled the equipment at the Texas City Refinery; (ii) *Management personnel* who wield the responsibility of operational oversight and plant safety; (iii) *BP Corporate* who provide funding and direction to refineries; (iv) *OSHA* who enforces federal safety guidelines; and finally, (v) *Engineers* who design refinery manufacturing equipment. The central non-human actors in the case are: (vi) *Outdated equipment* such as malfunctioning alarms and safeguards, and the 1950’s era blowdown drum; (vii) *Inherent risk of hydrocarbon processing*; and finally, (viii) *cognitive inertia* which ultimately controls our tendencies and behaviors.

As described above in the ANT summary, the actors in the network only have significance through their associations and relationships with the other actors in the network. To study the power within the Texas City Refinery network, it is necessary to identify the association between the 8 primary actors listed above. I will elaborate on the network's associations by tracking the network's formation through the phases of translation. The primary actor of which the network is formed by and around must first be identified to begin the translation process. BP's corporate will serve as the primary actor in this situation, as they took ownership of the refinery in 1999, subsequently hiring a workforce and creating the culture that was present at the refinery in 2005 when the incident occurred (Hamilton, 1998).

The general form of the actor-network is outlined in Figure 1, where all connections are simply presented as associations as intended by corporate in the translation process. The first phase of the translation process is problematization. During this phase, BP corporate decides that they are to acquire a refinery to manufacture materials and create a profit for their company. Corporate will need their refinery to comply with federal regulations while carrying out the problem statement. Corporate will not be present at the site of the refinery, therefore, other human actors must be recruited to allow for the execution of the problem statement daily. The recruitment process will

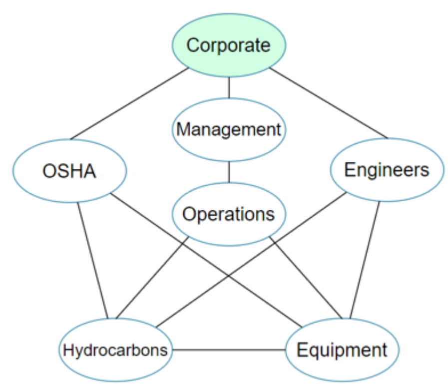

Figure 1: Actor-Network of the Texas City Refinery present during translation

begin by forming the necessary associations in the network to achieve the most basic goals of corporate as described above.

Interessement occurs as the network builder (corporate) recruits actors to align with their goals. Based on this problem definition, corporate identifies that engineers are needed to develop the technology and chemistry for the refinement of hydrocarbons to usable gasoline products (BP, n.d.). Corporate then recruits OSHA into the network under federal requirements for refinery safety regulations. Finally, corporate hires the refinery managers who will carry out the daily tasks associated with achieving the goals of corporate at the refinery (Chron, 2020). As illustrated in Figure 1, corporate lays the foundations for the network by connecting three primary human actors by acting as the OPP into the network. Corporate must align the interests of these actors with the problem definition. Engineers will readily join the effort of corporate to design and develop the technical aspects of the refinery as the advancement of technology is their career and passion. OSHA's mission statement is to "ensure safe and healthful working conditions for men and women by setting and enforcing standards" (OSHA, 2021). Corporate accepts their mission statement as an alignment with the problem statement since the productivity of the refinery is directly related to the safety and health of the employees. Managers can be assumed to align with the problem statement upon hire, as corporate has conducted interviews and selected the candidates that hold the company's values to the highest concern.

In this theoretical enrollment scenario, engineers, OSHA, and managers will accept their allotted roles and assume their position in the network as illustrated in Figure 1. Assuming this scenario to be true, the recruited actors will then proceed to recruit more actors into the network. Engineers recruit the non-human actor of hydrocarbons, as the chemistry and technology needed to process this chemical are central to a refinery. OSHA also forms a direct relationship with the hydrocarbons, as this chemical is inherently dangerous and introduces many risks to the process, of which OSHA is concerned (OSHA, n.d.). The engineers also recruit equipment into the process as the main technology that allows the refinery to carry out the problem statement of manufacturing products and making a profit. OSHA then forms a relationship with the equipment, as its federal duty is to regulate the equipment and ensure its safe functioning. Management recruits operations personnel by hiring them as workers in the plant (OSHA, n.d.). Operations personnel are recruited to carry out the problem statement as specified by management, which, in theory, is the same problem statement as specified by corporate. These four actors pass through the OPP indirectly, as corporate's main function is to instill its problem statement with the human actors, which then instill the problem statement into the actors that are recruited subsequently. The operations actor forms direct relationships with the equipment and hydrocarbons, as the operations personnel will be the actor in the most direct contact with these two actors daily. The operators directly control the equipment and hydrocarbon actors in the refinery, under the supervision of management. Under this configuration, the concept of safety is primarily the responsibility of OSHA, which monitors the hydrocarbons and equipment, relaying messages to corporate. Corporate should have a strong relationship with OSHA, taking recommendations seriously and passing the recommendations to management. Management should regard the goals of corporate as their own, enforcing safety recommendations within the refinery and ensuring operations personnel hold these same safety standards. This configuration should not allow for process safety incidents.

Cognitive Inertia

Before I deconstruct the preceding actor-network, it is necessary to introduce the rogue actor of *cognitive inertia* to the network. Cognitive inertia is a term coined by psychologist W. J. McGuire to explain his finding that people were resistant to change in their beliefs and behaviors, even after receiving information that conflicted with their original beliefs (McGuire, 1969). Resistance to change is commonly used as an explanation for why efforts to introduce changes in technology, work routines, and management practices often fall short of expectations or fail altogether (Laumer, 2011). I believe that the common shortcomings in safety performance at chemical manufacturing plants may also be attributed to the human tendency of resistance to change. Resistance to change was extremely prominent in the Texas City Refinery; I will argue that cognitive inertia ultimately led to the explosion. Evidence for this claim is explained as follows.

In 1992, OSHA issued a citation to the Texas City plant (then owned by Amoco which merged with BP in 1999 [Hamilton, 1998]) regarding the unsafe designs of blowdown drum pressure relief systems at the plant. However, Amoco rejected this citation and successfully persuaded OSHA to drop the charges by relying on the less stringent safety requirements of the American Petroleum Institute (API). The blowdown drum atmospheric relief system was proposed to be eliminated multiple times by Amoco and BP in the future, following numerous safety concerns and citations, but the plans were never funded nor carried out. In 1995, a Pennzoil refinery suffered a tragic disaster when an explosion engulfed a nearby trailer full of worker's offices. After this incident, it was recommended (but not required) across industries that trailers should not be placed close to dangerous refining equipment (CSB, 2007). BP ignored these warnings, and multiple trailers full of workers were placed directly next to the ISOM unit and its blowdown drums. See Figure 2 (below) for detail on the layout of the ISOM unit, noting the trailer area (CSB, 2007).

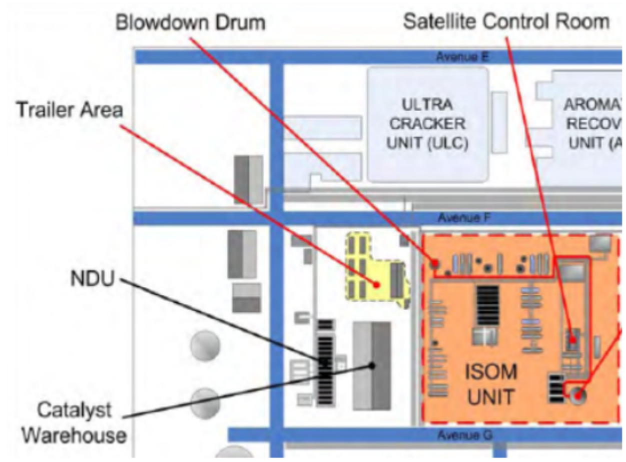

Figure 2: Depiction of the TX City Refinery ISOM Unit

Horrifically, the Texas City refinery had 23 deaths in the 30 years before the explosion (CSB, 2007). The site had over 80 accidental hydrocarbon releases in the 2000-2001 period (BP South Houston, 2002). Safety audits from numerous organizations in the 5 years leading up to the disaster of 2005 showed that there was serious concern about the potential for a major site incident. Unfortunately, these safety problems were not adequately corrected, and many played a role in the catastrophic consequences of the 2005 explosion (CSB, 2007). The blatant disregard toward the safety hazards identified at the Texas City Refinery before the 2005 incident is troubling, begging the question as to why a company would act in this manner. All human actors involved with the refinery's operation fell victim to cognitive inertia, which led to change aversion within the refinery. The human actors of the network became comfortable with their hazardous workplace and accepted outdated safety systems and a weak company safety culture. Again utilizing the framework of actor-network theory, I will now deconstruct the network, introducing cognitive inertia, which causes us to behave in a way that rejects the adoption of change. This rogue actor will be shown to destabilize the network, ultimately causing the Texas City 2005 disaster.

Network Destabilization and Disaster

The actor-network previously constructed was described as intended by corporate, when in reality, the actor-network contains cognitive inertia, which causes the relationships of the actors to falter, strengthen, or disintegrate. The introduction of cognitive inertia to the actor-network and its destabilizing implications can be seen in Figure 3. The red arrows represent the negative impact that cognitive inertia has had on the other actors. The dashed lines represent weak associations.

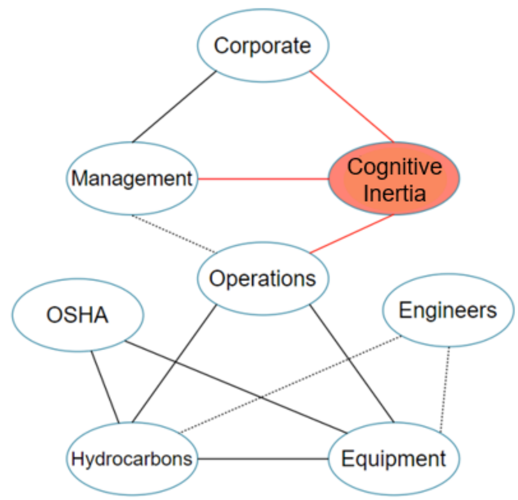

Figure 3: Actor-Network containing Human Nature

Some important discrepancies exist between the networks depicted in Figure 1 and Figure 3. With the introduction of cognitive inertia, corporate has lost its associations with OSHA and the engineers. The relationship between corporate BP and OSHA was weakened through the neglect to take safety regulations and recommendations seriously over the years leading up to the 2005 incident (CSB, 2007). Corporate BP lost its relationship with engineers as the company neglected to update outdated equipment, and neglected to utilize the engineering expertise of chemical hazards associated with hydrocarbon processing. Although the engineers still maintain their passion and careers in the advancement of refinery technology, the engineers' relationships with the hydrocarbons and equipment are now weakened, due to a lack of funding from the company to execute their designs. The relationship between management and corporate has also been weakened within the presence of cognitive inertia. As management systems try to incorporate policies into the work habits of operations personnel, these changes are rejected due to cognitive inertia. Since corporate and OSHA have cut ties, corporate no longer instills safety values in management personnel. In this disturbed network that existed in the reality of the Texas City Refinery, safety is no longer of importance to the human actors.

The effects of cognitive inertia on the actor-network can be summarized as follows. Corporate does not feel obligated to execute the changes imposed by OSHA's regulations, due to cognitive inertia. Without the guidance of OSHA, corporate and management lose sight of their obligation to keep employees safe. Operations personnel lose the important relationship with management, also due to cognitive inertia. Corporate is not willing to implement new engineering knowledge or designs into their plant, therefore continuing the usage of old antiquated equipment, although this equipment is responsible for the handling of the inherently risky hydrocarbon components of gasoline. All human actors in the network become complacent with the warning signs and signals in the many years leading up to the incident, as described in the *Cognitive Inertia* section of this paper. Ultimately, the rejection of change in the BP Texas City Refinery proved to be a fatal mistake on the afternoon of March 23, 2005.

Counterpoint Acknowledgement

As I have argued above, there is a natural human instinct to be change adverse which I believe is the reason that chemical tragedies occur. Considering human psychology in this case allows for a deeper and more comprehensive analysis into the true root cause of the incident, and may be extended to other process safety incidents. However, a great deal of chemical engineering and safety research has been devoted to developing quantitative risk assessment (QRA) models in the ongoing effort to create safer industrial workplaces. In fact, the Texas City Refinery explosion and its technical causes have been modeled numerous times in academia, such as the UNISIM dynamic process simulation by Manca & Brambilla (2012), the Bayesian failure updating mechanism with consequence assessment analysis by Kalantarnia et al. (2010), and the explosion QRA tools used by Khan & Amyotte (2007). Each paper makes the argument that the disaster could have been modeled using their program. They concluded that their model can be used in the future to predict incidents before they occur. Although these models are useful to predict process failures, they are no more than a technological fix that does not encompass the complex influence of society on technology. It is tremendously important that human factors are not neglected in root cause analysis of process safety incidents. MacKenzie et al. (2007) found, after an extensive investigation, that there were several pre-existing latent deficiencies in BP's safety culture that affected the worker's decisions and actions on the day of the incident, effectively causing the accident. It would be disastrous to the chemical industry if we were to rely solely on process modeling to predict disasters when research shows that incident causation is strongly dependent on human factors.

CONCLUSION

In this paper, I have used the socio-technical concept of ANT to create and deconstruct the actor-network behind the Texas City Refinery and its order of conduct specifically leading to the disaster that killed 15 and injured 180 more. The usage of ANT revealed the stark disparity between the corporate intended translation of the network and the actual functioning of the network, as cognitive inertia appeared as a rogue and unexpected actor. The analysis of the destabilization of the network by cognitive inertia reveals that safety became an ignored option to the refinery, as the human actors neglected to adopt the changes necessary to make the refinery a safe work environment. With this analysis, readers will be conscious of the invisible yet powerful force that cognitive inertia imposes on our behavior, and the grave consequences this may have on those around us, especially in the case of inherently risky processes such as hydrocarbon refining and chemical manufacturing. Engineers and corporations may use this insight to be assured to consider human psychological tendencies when creating process safety management plans.

Word Count: 3753

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