ECONOMIC AND POLITICAL UNCERTAINTY AND THE EFFECTS OF ORGANIZATIONAL INTEGRATION, VOLUME FLEXIBILITY, AND REDUNDANCY ON RELIABILITY AND DELIVERY FOR WATER UTILITIES

by

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Dedication

I dedicate this dissertation to the thousands of men and women across the United States and the world who labor tirelessly every day without recognition to ensure that we always have clean, fresh drinking water, who treat and return our wastewater to the environment so that it can be safely used again, and who provide constant stewardship of the earth's most critical resource, water, without which we could not live.

Acknowledgments

When I undertook this journey three years ago, I had envisioned that it would be a means for me to pursue my dream after retiring of teaching at the university level. I come from a family of educators and people dedicating their lives to different forms of public service, and even though I chose a different path, choosing a career in the private sector, I always felt the pull of education. I never dreamed that this journey would all come full circle and that I would have a chance not only to realize my dream to teach, but I would also be able to apply my life long love of the water industry to my dissertation. I want to thank my chair, Dr. Moutaz Khouja, who has been a great teacher and supporter throughout the dissertation process. I would also like to thank Dr. Zhao for all her help in structuring and interpreting the analysis, and for the critical guidance and feedback she provided me throughout the development of my dissertation. I thank Dr. Subramanian and Dr. Stanley for serving on my committee and for their support and valuable input. I could also not have done this without the help and support of my sister, Dr. Erin Fraher, who, despite being younger than me in years, has always been far ahead of me in wisdom and knowledge on so many of life’s lessons. Her reassurances and kind words of support enabled me to not only get through this dissertation; it helped me to appreciate it so much more. Finally, I couldn’t have done any of this without the love and support of my fantastic wife, Donna Fraher, who has endured countless nights of me working on my dissertation, who made sure that I always kept my energy levels up with late-night deliveries of water and cheese and crackers, and who has always been at my side supporting me in achieving all of my dreams. I am so very grateful to everyone for all that you have done for me; I could not have done this without you.

Abstract

Andrew P Fraher. Economic and Political Uncertainty and the Effects of Organizational Integration, Volume Flexibility, and Redundancy on Reliability and Delivery for Water Utilities. (Under the direction of **Dr. Moutaz Khouja**)

Every hour of everyday water utilities across the United States labor tirelessly to supply clean, safe, and affordable drinking water to residential and industrial consumers. Wastewater from these homes and businesses is captured and moved to treatment plants where it is then treated and returned to the environment so that it can be used again. Water utilities utilize vast networks of steel and iron pipes in their distribution and collection systems, as well as valves to control and direct the flow as needed to ensure uninterrupted service. Over time, as these pipes and valves age and wear, they will need to be maintained, and the costs of those repairs are part of the annual budgeting cycle. Water utility budgets are determined on a yearly basis, so any material cost increases must be accurately forecasted to avoid budget overruns. Economic and political uncertainty (EPU) in the form of new regulations, tariffs, taxes, etc. can materially impact a water utility's ability to reliably and consistently deliver water to their customers. While the current literature has shown the impact of EPU on for-profit companies across a range of industries, as well as the result of regulations on not for profit firms, little research has been conducted on the impact of EPU driven by new tariffs on non-profit utilities. This study will draw upon resource optimization theory to better understand and explain how water utilities respond to EPU. We will examine the relationships between internal and external integration, volume flexibility and redundancy, and reliability, and delivery. This quantitative study will utilize survey data from water utilities in NC, SC, and VA, and the results will be analyzed using structural equation modeling.

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Chapter 1 - Introduction and Research Questions

Water and wastewater conveyance and treatment is a critical element of the US infrastructure providing the nation's citizens and industries with access to water, a necessary resource for survival. Water can be considered an entitlement by many in that when they turn on their faucets and showers, they expect to receive clean, contaminant-free water that they can then use for drinking, cooking, bathing, and washing clothes. The waste products from these activities need to be conveyed away from these homes and businesses so that it can then be safely treated to standards as defined by the US Environmental Protection Agency (EPA). Once the wastewater is cleaned, it can then returned to bodies of water, such as lakes, streams, and rivers, so that the water can be used again (Metcalf & Eddy, 1972; USEPA, 2019b).

Drinking water can be obtained directly by residences and commercial operations from groundwater sources through the use of water wells and surface water sources such as lakes, rivers, and streams. Approximately 10% of the United States population rely on drinking water from wells (USEPA, 2019a). Wastewater from residences and businesses can be treated onsite through the use of septic fields for homes, and onsite wastewater treatment systems for commercial enterprises. Approximately 1 in 5 homes in the United States rely on onsite treatment or septic systems to treat their wastewater (USEPA, 2019c). In cases where residences and businesses do not have access to their own drinking water supply or wastewater treatment system, they can choose to obtain these services from a water utility.

Many consumers are willing to pay approximately $8.00 per gallon for bottled water, which is almost 4,000 times more expensive than drinking water supplied by a water utility (Livingston, 2019). And yet when water utilities try to raise rates to pay for infrastructure improvements, they must first get approval from regulators, which can then be met with strong opposition from ratepayers. Customers cite convenience, taste preferences, fashion, and perceived health advantages for bottled water, even though in numerous cases, utility water quality can be higher than that of bottled water (Grigg, 2003; Livingston, 2019). An illustration of the typical water cycle is shown below in Figure 1.

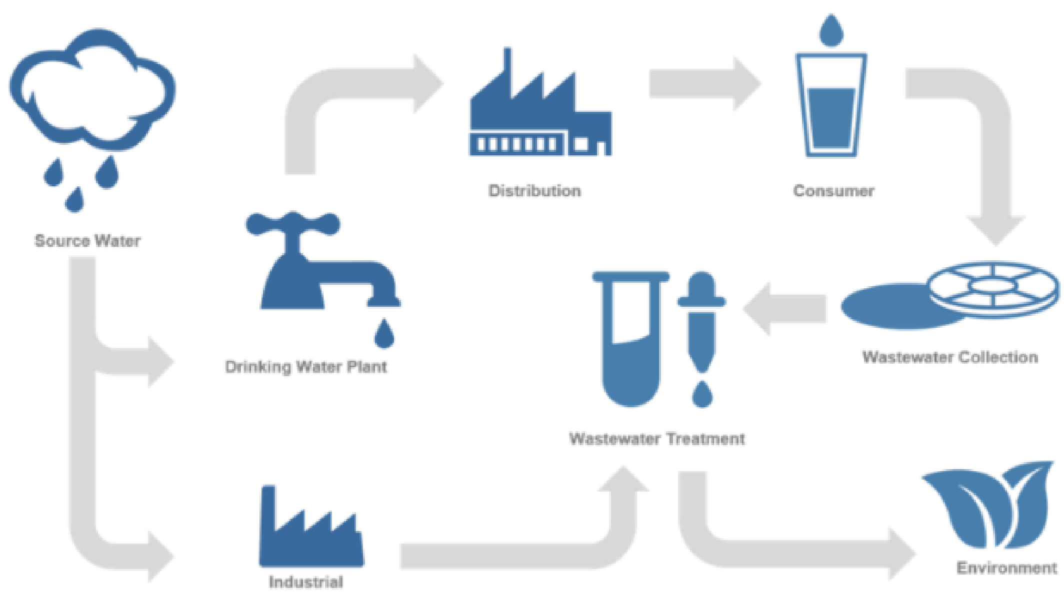

Figure 1 Water Distribution Cycle (Graphic courtesy of https://www.dhwater.com/)

The United States water and wastewater infrastructure have been in existence in some areas for more than 250 years when early settlers installed wooden pipes to carry sewage to the treatment plant (Metcalf & Eddy, 1972; Spellman, 2003). These systems aged and deteriorated over time, and when combined with a lack of drinking and wastewater standards, and heavy industrial waste discharge, the result was polluted waterways (Stradling & Stradling, 2008). The severity of this contamination in the waterways ultimately rose to a national level of awareness when the Cuyahoga River in Cleveland caught fire in 1969 as a result of pollution from an oil slick, as depicted in Figure 2 (Boissoneault, 2019).

Figure 2 Cuyahoga River fire - 1969 - Photo courtesy of smithsonianmag.com

This event caused many to rethink the current state of the US waterways, resulting in the creation of the modern environmental movement within the US and the passing of the Clean Water Act (CWA) of 1972. This goal of this legislation was to provide standards to which water must be treated before being delivered to the users, the levels that wastewater must be treated to before being discharged into the waterways, and ultimately to ensure the safety and reliability of the nation’s water supply ("FEDERAL WATER POLLUTION CONTROL ACT," 1972; Spellman, 2003).

These standards, once enacted, compelled utilities to upgrade their conveyance and treatment systems, including the distribution and collection pipes, to more modern materials and technologies. As the amount of money required to fund these activities was well beyond the capacity of many of these utilities, and the only legal option was to remediate aging systems, there was an immediate and significant need for a funding mechanism to facilitate these upgrades. The federal government implemented drinking water and clean water (wastewater) state revolving funds (SRF), which enabled utilities to borrow up to 80% of a project cost; these funds are repaid over a 20-30 year time frame at low-interest rates. Bond offerings, enterprise funds generated by the utility in its periodic customer billing through the imposition of surcharges, and other funding mechanisms cover the balance of the project costs ("Clean Water State Revolving Fund," 1987; "Drinking Water State Revolving Fund 1997," 1997; Grigg, 2003; Spellman, 2003).

As we are now 40 years beyond the implementation of the CWA, infrastructure installed during those early years is approaching the end of its life and needs to be replaced. This infrastructure need includes pipes, valves, and technologies initially installed in those plants and systems as a response to the Clean Water Act. The need for infrastructure funding is becoming more and more critical, as a study by the American Society of Civil Engineers (ASCE) gave the overall United States water and wastewater infrastructure a “D” rating. As a result of the deterioration of these systems, it is estimated that in the United States, there are more than 240,000 water main breaks per year, resulting in water losses and unrealized utility revenue ("Report card for America's infrastructure," 2017). The American Water Works Association (AWWA) estimates that it will cost $1 trillion to bring the US water and wastewater infrastructure up to current standards over the next 25 years (AWWA, 2018).

Each year Congress, as part of the omnibus budget, approves funds that replenish the respective state revolving funds and provides additional resources that municipalities can borrow for infrastructure projects. For 2018, the United States House of Representatives approved $2.9B as part of their annual Omnibus to fund state revolving funds. This funding level was a substantial shortfall from the estimated $1T needed to bring the infrastructure back to current standards ("2018 Consolidated Appropriations Act," 2018; AWWA, 2018; "Report card for America's infrastructure," 2017).

Studies have shown the benefit of infrastructure investment to be impactful, as every $100 of investment in infrastructure boosts private-sector output by $6-$8. $100B in investment is estimated to create ~ 1M full-time equivalent employees (Stupak, 2018). The argument, therefore, for infrastructure investment is both environmentally as well as economically justifiable. Based upon the corresponding increase in raw material costs resulting in a reduction of funds for investment, any material tariff on infrastructure inputs could not only reduce the available financing, but it could also reduce the corresponding positive private-sector benefit.

Water utilities are a variation of industrial manufacturing, in that they utilize various processes and technologies to produce and deliver freshwater, and collect and treat wastewater, similar to how a traditional manufacturing plant operates. Through the design of their plants, water utilities have some degree of process flexibility built-in through excess capacity that enables them to absorb demand fluctuations within the system throughout the day as well as to address seasonal demand (Santos Bernardes &

Hanna, 2009). Water utility distribution and collection systems are relatively fixed and not easily relocated without incurring substantial costs. The pipes and valves used in these systems are composed of different types of materials, such as High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), steel, ductile iron, concrete, and cast iron. These materials will vary based upon the required size and pressure ratings of the required components. Valves can be manufactured from plastic, steel, or cast iron, again depending on the necessary size and pressure ratings (Spellman, 2003).

Additionally, due to environmental conditions, piping systems can corrode and fail, resulting in the unwanted and unplanned discharge of water and wastewater. Preventing these incidents from occurring to ensure uninterrupted service and to protect public health requires water utilities to perform ongoing monitoring, maintenance, and replacement of pipes and valves, and when needed, procure replacement components to use in these activities (Grigg, 2003; Metcalf & Eddy, 1972; Spellman, 2003). Pipe expenditures represent more than 50% of the projected overall infrastructure investment between 2016 and 2025 ("Water Data and Tools," 2019).

As part of his election campaign, then-candidate Donald Trump stated that if he were to be elected president of the United States, he would enact material tariffs on imported steel and aluminum to protect the United States steel and aluminum industry. In April of 2017, the US Department of Commerce at the direction of the administration initiated an investigation into the effects of US steel and aluminum imports on national security under section 232 of the Trade Expansion Act of 1962. The provisions of the Trade Expansion Act "allows the president to take action to adjust imports of products the Department of Commerce finds to be *threatening to impair U.S. national security*"

(Williams, 2018, p.3). The President signed a memorandum prioritizing these investigations. Commerce completed the study and submitted its findings to the president in January of 2018 ("Escalating Tariffs: Timeline and Potential Impact (IN10943),"; Williams, 2018)

Fulfilling his campaign promise, President Trump enacted Presidential Executive Order 9705 on March 8, 2018, which imposed a 25% ad Valorem tariff on steel products and 10% on aluminum products coming from most countries. This action was taken to protect the nation's security, specifically as it relates to the ability of the United States to be self-sufficient in iron and steel production (Trump, 2018). After this order, certain countries were first temporarily and then later permanently excluded from these duties based upon quota arrangements, including Brazil, Argentina, Australia, South Korea, Canada, Mexico, and the European Union ("Escalating Tariffs: Timeline and Potential Impact (IN10943),").

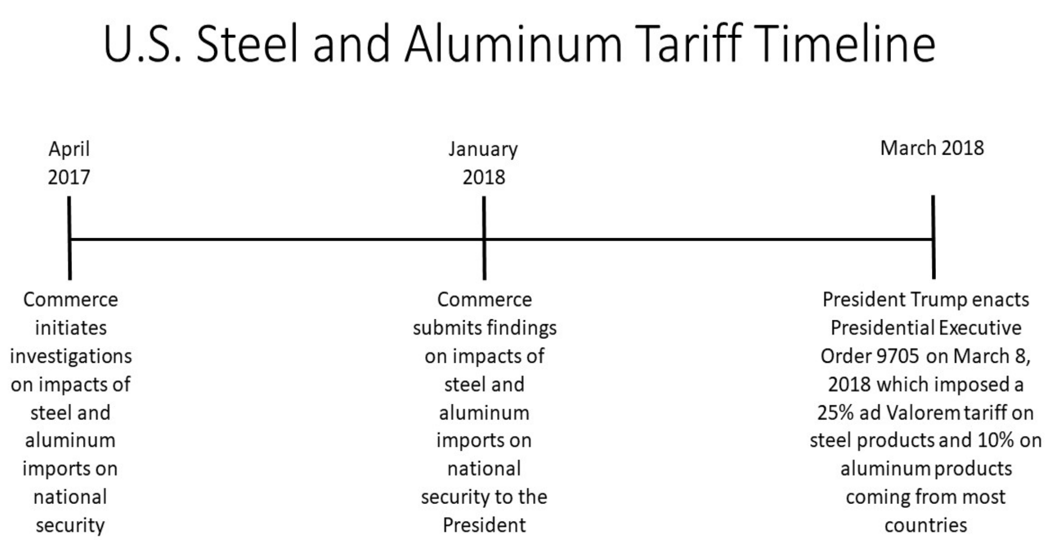

Figure 3 US Steel and Tariff Timeline – 2017-2018 - ("Escalating Tariffs: Timeline and Potential Impact)(IN10943)

Steel pipe is manufactured both domestically and internationally, including in South Korea and China, and these are amongst some of the manufacturing regions that have been a focus area for the current administration's material tariff focus (Yukins, 2017). The implementation of material tariffs combined with domestic procurement regulations such as Buy America could create significant sourcing hardships for the water industry. The strategies to address these emerging challenges could provide substantial opportunities for beneficial research, specifically by looking at how water utilities can use their organizational capability and leverage their infrastructure to improve their reliability and delivery and successfully address these regulations.

Maintenance, Repair, and Operations (MRO) along with Capital Improvement Plan (CIP) budgets are intended to provide funding for ongoing system repairs and upgrades to treatment plants and distribution and collection systems to ensure uninterrupted delivery of drinking water and collection and treatment of wastewater. Maintenance budgets are established on an annual basis as part of the municipal funding cycle. CIP budgets are set using water utility intended use plans which identify and prioritize necessary capital improvements over a defined period. Some of the capital spending can occur in the current fiscal year, while other spending may occur over a three to five-year period or longer depending upon the complexity and scope of the necessary improvements. MRO budgets are focused on maintaining, repairing, and to a lesser extent upgrading infrastructure through the current fiscal cycle to ensure uninterrupted service (Grigg, 2003).

Research Questions

1. What types of organizational practices will help a water utility ensure their service quality?
2. How does internal integration impact a water utility's ability to provide quality service?
3. How does external integration impact a water utility's ability to provide quality service?
4. How does volume flexibility impact a water utility's ability to provide quality service?
5. How does redundancy impact a water utility's ability to provide quality service?
6. How does political and economic uncertainty in the form of material tariffs on repair component materials impact a water utility's ability to provide quality service?
7. Does manager experience have an impact on a water utility's response to the imposition of material tariffs?

Chapter 2 - Literature Review and Hypotheses Development

2.1 Environmental Uncertainty

The trend toward global manufacturing continues to be driven by customers' demands for the latest technologies and products at the lowest prices, resulting in the creation of complex supply chains located in both emerging countries as well as the developed markets (Ponomarov & Holcomb, 2009; Rice & Caniato, 2003). Companies such as Apple, Dell, GM, Suez, and Nike have all chosen to establish global networks to more efficiently and effectively meet their customers' expectations, including their manufacturing operations. (Gaonkar & Viswanadham, 2007). Firms expect suppliers to deliver the required products and subcomponents on time and at the specified quality levels, so these companies can then ensure they meet customer delivery commitments and provide a seamless and satisfying experience. Firms also expect their suppliers will address any risk or uncertainty that may arise in the global supply chain. (Christopher & Peck, 2004; Gligor, 2018; Sheffi & Rice, 2005).

Disruptions in global supply chains due to human-made or natural disasters have been observed over the last 20 years. Ericsson lost 400 million Euros due to a plant fire in 2000, and Apple lost customer orders when an earthquake hit their supplier plant in 1999. There were also significant adverse impacts from the tsunami that hit Japan in 2011 (Blome, Schoenherr, & Rexhausen, 2013; Christopher & Peck, 2004; Deane, Ragsdale, Rakes, & Rees, 2009; Reuters, 2016; Rice & Caniato, 2003; Sheffi & Rice, 2005; Tang, 2006). The creation of economic and political uncertainty (EPU) through the imposition of domestic procurement legislation manifesting as material tariffs, sanctions, import restrictions, and trade agreements can impose additional disruptions on global supply chains as firms assess their current and future sourcing (Charles, 2015; Parker, 1986; Yukins, 2010, 2017).

Environmental uncertainty is different than environmental risk. It is possible to calculate an overall project risk-based upon known and definable factors. Environmental risk is contrasted to environmental uncertainty, where environmental uncertainty possesses none of the clarity of definition as does environmental risk (Bourgeois, 1980; Downey, Hellriegel, & Slocum, 1975; Downey & Slocum, 1975; Henry, 1974; Huber, O'Connell, & Cummings, 1975; Jones & Ostroy, 1984; Swamidass & Newell, 1987; Tintner, 1941). Environmental complexity is defined as both the range of various activities or processes a firm undertakes as well as the degree to which those activities are similar or dissimilar to one another (Child, 1972; Downey et al., 1975; Downey & Slocum, 1975; Duncan, 1971, 1972). Additionally, the more complex the environment, the greater the volume of information the firm’s decision-makers will need to interpret. Environmental variability is characterized by the frequency of changes that are occurring in the environment, the degree of difference in each of these changes, and the degree of variability of these changes (Child, 1972). Environmental dynamism refers to the degree and speed at which the environment is perceived to be changing by the decision-makers (Downey et al., 1975; Wernerfelt & Karnani, 1987). The final factor that impacts environmental uncertainty is illiberality, which describes the potential uncertainty in the form of threats a firm may face when attempting to achieve its goals, including competitor’s actions as well as internal hostility or indifference (Child, 1972).

In response to environmental uncertainty, firms can focus on marketing to help promote their existing offering (Lawrence & Lorsch, 1967; Sethi & Sethi, 1990;

Venkatraman & Prescott, 1990), R&D to create new product and service offerings (Lawrence & Lorsch, 1967), and manufacturing flexibility to help them address changes in the external environment (Gerwin, 1993; Lawrence, 1967; Pagell & Krause, 1999; Sethi & Sethi, 1990; Swamidass & Newell, 1987; Venkatraman & Prescott, 1990; Voss, Tsikriktsis, & Frohlich, 2002).

Several studies have explored the impact of risk and uncertainty created by both natural as well as human-made disruptions on global supply chain performance within the supply chain context (Carvalho, Maleki, & Machado, 2012; Manuj & Mentzer, 2008a, 2008b; Ponomarov & Holcomb, 2009; Tang, 2006). These studies provide valuable insights into the impacts of uncertainty and risk for a broad range of unplanned events. However, they do share some significant limitations. Although supply chain disruptions can occur from a broad range of unforeseen occurrences (Blome et al., 2013; Carvalho, Maleki, et al., 2012; Christopher & Peck, 2004; Sheffi & Rice, 2005), the traditional focus of research in this area has been primarily on impacts of weather-related events such as tsunamis and earthquakes, supplier bankruptcies, and terrorist activity (e.g.,(Blome et al., 2013; Charles, 2015; Haimes, Crowther, & Horowitz, 2008; Urciuoli, Mohanty, Hintsa, & Gerine Boekesteijn, 2014). There is a noteworthy gap in the research as supply chain performance could also be negatively impacted by EPU created from the imposition of domestic procurement legislation such as trade agreements, material tariffs, sanctions, stimulus, and sourcing regulations (Alesina & Rodrik, 1994; Baker, Bloom, Canes-Wrone, Davis, & Rodden, 2014; Baker, Bloom, & Davis, 2016; Davarzani, Sander de Leeuw, Zanjirani Farahani, & Rahmandad, 2015; Drazen, 2000). Additionally, existing research in this area focuses more on private, for-profit global enterprises such as automotive and computer manufacturers, IT firms, and transportation companies (Carvalho, Azevedo, & Cruz-Machado, 2012; Charles, 2015; Haimes et al., 2008; Hertz, 2010; Parker, 1986). To my knowledge, this research is the first to look at the impacts of economic and political uncertainty (EPU) manifesting as material tariffs on publicly owned, not for profit, water utility supply chains, as well as the implications of this environmental uncertainty on utility supply chain reliability and delivery.

The concept of EPU and its impact on investment has long been of interest to supply chain researchers and has mostly been explored within the context of election cycles, trade policy including bilateral and multilateral trade agreements and government investment and stimulus programs (Baker et al., 2014; Baker et al., 2016; Christopher & Peck, 2004; Dinc, 2005; Drazen, 2000; Handley & Limao, 2012; Julio & Yook, 2012; Nekarda & Ramey, 2011; Santa-Clara & Valkanov, 2003; Sheffi & Rice, 2005). Tintner et al. (Tintner, 1941) were the first to extend the concept of subjective risk and uncertainty on choice, where he stated "subjective risk deals with the case in which there exists a probability distribution of anticipations which, however, is itself known with certainty (probability one). Subjective uncertainty assumes that there is an a priori probability of the probability distributions themselves, i.e., a distribution of probability distributions" (Tintner, 1941, p. 298). The critical distinction here is that in the case of risk, outcomes are generally known, but with uncertainty, they are not (Wernerfelt & Karnani, 1987). Pindyck et al. (R. Pindyck, 1982) extended this concept to look at the effects of future demand and cost uncertainty on investment, and how a firm best reacts to these future uncertainties based upon their adjustment costs as a reaction to the changes in the levels of their input factors. In this case, uncertainty would manifest itself as the imposition of domestic procurement legislation raising costs on water utilities' iron and steel material inputs, such as valves and pipes. This definition is consistent with the conceptualizations of Caballero (Caballero, 1991) who further refined the concept of adjustment costs and uncertainty in terms of competitive and non-competitive environments, which in the case of a monopolistic public utility would emulate more of a non-profit, non-competitive firm.

2.2 Supply Chain Resilience

Supply chain research has shown that firms can prepare for potential disruptions caused by environmental uncertainty through the use of supply chain resilience (SCR) strategies to partially or entirely mitigate the impact of unforeseen impacts from EPU (Barroso, Machado, Barros, & Machado, 2010; Davarzani et al., 2015; Tang, 2006; Wagner & Neshat, 2010; Wang, Gilland, & Tomlin, 2011). We utilize Tang's definition of supply chain management as "the management of material, information, and financial flows through a network of organizations (i.e., suppliers, manufacturers, logistics providers, wholesalers/distributors, retailers) that aims to produce and deliver products or services for the consumers. It includes the coordination and collaboration of processes and activities across different functions such as marketing, sales, production, product design, procurement, logistics, finance, and information technology within the network of organizations" (Tang, 2006, p. 453). Christopher and Peck describe resilience as "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed" (Christopher & Peck, 2004, p. 2). Falasca then defines supply chain resilience as "the ability of a supply chain system to reduce the probabilities of a disruption, to reduce the consequences of those disruptions once they occur, and to reduce the time to recover normal performance" (Falasca, Zobel, & Cook, 2008, p. 596). Through supply chain resilience (SCR), firms can, therefore, decide to implement systems and strategies focused on enhancing and ensuring the firm's competencies and capabilities to help reduce or eliminate the impact of unforeseen events. In doing so, they can then either recover and return to their previous state, or more optimally, evolve to a new and improved configuration. These systems are intrinsic to the firm and could include internal process and procedures focused on ensuring business continuity, building in volume flexibility and redundancy to overcome supply chain disruptions, enhancing interdepartmental and inter-functional efficiency through tighter integration, and implementing policies and procedures to improve communication and alignment with suppliers and customers. These constructs are shown in Table 1.

2.3 Constructs

2.3.1 Redundancy

One approach to improving a firm's supply chain resiliency is redundancy, which for a water utility is defined as the ability to maintain operations by ensuring they have sufficient safety stock (inventory), can operate at reduced capacity utilization rates, maintain multiple suppliers, and operate duplicate water production, water treatment, and distribution and collection systems. The latter of these can be achieved by ensuring that there is sufficient redundancy in the system design so that when there are component failures, the overall water delivery and collection system will continue uninterrupted function (Carvalho, Azevedo, et al., 2012; Carvalho, Maleki, et al., 2012; Haimes et al., 2008; Scholten, Sharkey Scott, & Fynes, 2014; Stupak, 2018). These strategies, when deployed in a firm's supply chain, can result in additional resilience, in turn, resulting in the potential to reduce the impact of supply chain disruptions (Chopra & Sodhi, 2004).

2.3.2 Volume Flexibility

Volume flexibility can be described as a firm's ability to operate efficiently and effectively at different levels of output (Khalaf & El Mokadem, 2019). It can be utilized as a strategy to respond to market uncertainty (Slack, 1987). Volume flexibility for a water utility, therefore, would be the ability to deliver various amounts of water efficiently and economically while meeting various levels of a customer's drinking water distribution and wastewater collection demand. Having high volume flexibility involves reviewing all the steps in a supply chain, including supplier inputs, production, and distribution of products and services, and ensuring that there is flexibility or multiple options for as many of these factors throughout the supply chain (Christopher & Peck, 2004; Sheffi & Rice, 2005; Tang, 2007; Zhang, Vonderembse, & Lim, 2003).

2.3.3 Internal Integration

Internal integration can be defined as the degree to which interdepartmental and inter-functional coordination and communication enhances a water utility's ability to respond to disruptions caused by uncertainty (Braunscheidel & Suresh, 2009). The extent to which a water utility's processes and people are internally integrated could be impactful to a water utility's service quality, which we will define shortly. In a water utility, these functions can include treatment operations, maintenance and repair, and business support tasks, such as customer service and billing, purchasing, technical support, marketing, and communications. A typical water utility organization can be observed in Figure 4.

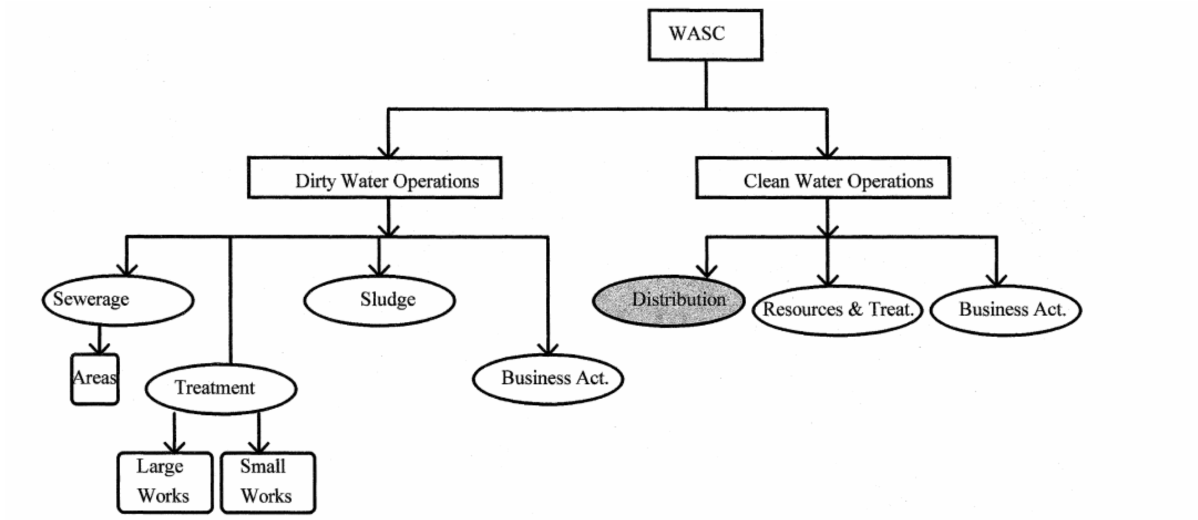

Figure 4 Grouping Water Company Functions – Thanassoulis, 2000

2.3.4 External Integration

External integration is defined as the degree to which a water utility is connected to and coordinated with its external customers and suppliers, to maximize customer satisfaction and supply chain efficiency and effectiveness in responding to disruptions caused by uncertainty (Braunscheidel & Suresh, 2009). Like internal integration, the extent to which a water utility is externally integrated with its supply chain could also be impactful to a water utility's service quality levels. External integration with suppliers can be comprised of several different factors, including information sharing, joint planning, and feedback on performance and quality (Zsidisin, Hartley, Bernardes, & Saunders, 2015).

2.3.5 Reliability

Reliability is defined as a water utility's ability to dependably, accurately, and consistently meet customer demand over time (Zeithaml, 1990). Customers expect that when they turn on their faucet, they will always receive clean water. The higher the probability that the utility has adequate production and delivery capacity, the greater the water utility's reliability (Berериche & Kadi, 2015; Eddy, Burton, Tchobanoglous, & Tsuchihashi, 2013).

2.3.6 Delivery

Delivery is defined as the extent to which a water utility is capable of providing the volume of water required by the customer on time (Gunasekaran, Patel, & McGaughey, 2004; Li, Rao, Ragu-Nathan, & Ragu-Nathan, 2005). Utilities work to build treatment, distribution, and collection capacity to ensure they can meet their customer's demands (Grigg, 2003).

2.3.7 Service Quality

Water utility customers expect to receive the quality and quantity of drinking water they need for their various tasks, including personal consumption, washing, and cooking food. Service quality is therefore defined as how well a water utility's delivered products of clean drinking water and treated wastewater meet conform to their customer's expectations. Service quality can be impacted by changes to either reliability or delivery (Grönroos, 1984; Zeithaml, 1990).

2.4 Theoretical Model and Hypotheses Development

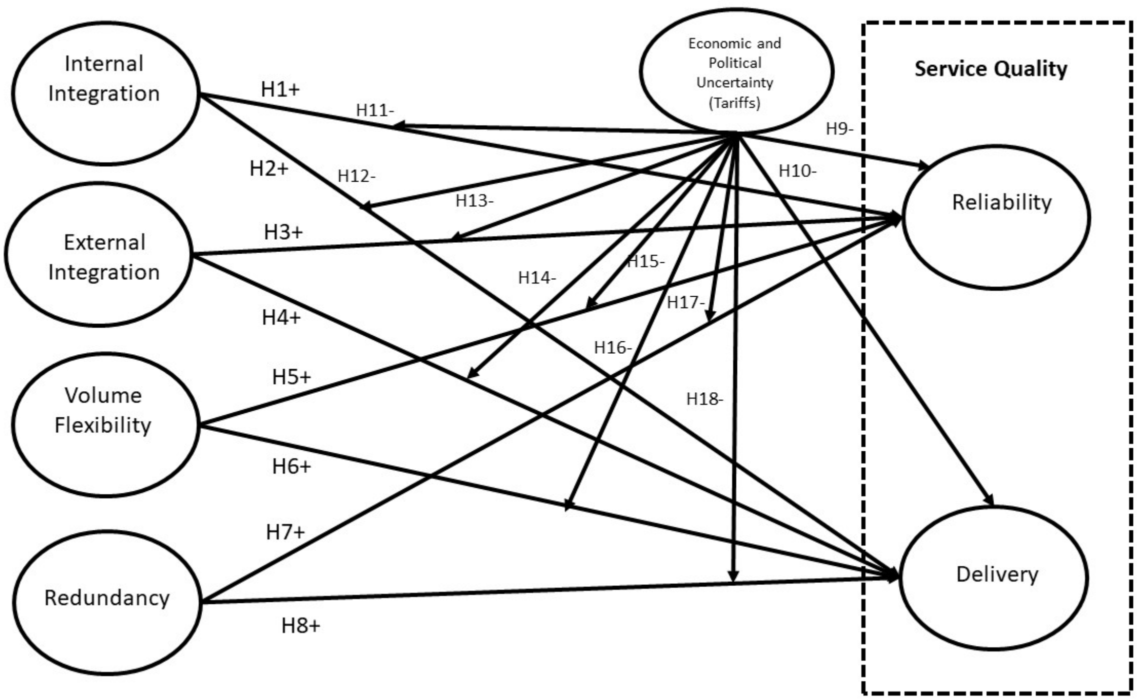

Figure 5 Theoretical Model

2.4.1 Resource Orchestration Theory

Resource Orchestration Theory – We will use the Hitt et. al definition of ROT, namely that "ROT describes and examines the roles of managerial actions in the process of structuring a firm's resource portfolio, bundling the resources to build relevant capabilities, and leveraging these capabilities to eventually realize a competitive advantage" (Hitt, Ireland, Sirmon, & Trahms, 2011, p. 64). ROT is an extension of the Resource Based View (RBV) theory, where RBV states that a firm's resources (assets, capabilities, processes, information, knowledge, etc.) must be valuable, rare, inimitable, and organizationally capable for it to sustain a competitive advantage (Barney, 1991). Water utilities are typically non-profit, governmental entities operating in a regulated, monopolistic environment and whose services are paid for by ratepayers and taxpayers. ROT, with its focus on managerial actions and the prioritization of resources, is more appropriate to this research than RBV, as this research focuses on water utility manager responses to the imposition of material tariffs. This assertion is supported by the fact that water utility managers must ensure continuous delivery of drinking water, and collection of wastewater in a resource-constrained environment where municipal budgets are usually fixed on a yearly fiscal cycle and, for the most part, are inflexible (White, 1960).

Studies have suggested a negative link between policy uncertainty and investment, and with firms that rely on government spending, this link can be even stronger (Gulen & Ion, 2015). However, the literature also suggests that this may not always be the case depending on the degree of irreversibility of the investment (Bernanke, 1983; Gulen & Ion, 2015; Henry, 1974; R Pindyck, 1991). Considering the adjustment costs associated with these decisions (R. Pindyck, 1982), it is feasible that utilities could experience diminishing responsiveness as adjustment costs increase. Interestingly, many articles focus on the impacts of investment under uncertainty in competitive environments. (Bernanke, 1983; Downey & Slocum, 1975; Lucas & Prescott, 1971; R. Pindyck, 1982; Wernerfelt & Karnani, 1987) The ROT perspective could help in examining the impacts of uncertainty on a water utility and its effects on service quality. This theory focuses on both internal and external integration, as well as the synchronization of actions to address uncertainty within the firm (Peuscher, 2016). It is possible to magnify a firm's uncertainty as more decision-makers are involved when considering an investment in a given project. This uncertainty, in turn, may result in a higher degree of conservatism in terms of estimation of adjustment costs, and could potentially lower the firm's responsiveness. Studies have also shown that the rate of investment can also be impacted during the project life cycle as additional information becomes available, further increasing or reducing responsiveness (Majd & Pindyck, 1987).

Considering the above arguments, it is reasonable then to expect that as EPU increases, there could be a corresponding impact on service quality level for a water utility. A water utility's budget is established as part of the annual municipal budget cycle, and the water utility's budget typically includes funds for both new projects as well as ongoing system maintenance. For new projects, the utility usually defines what projects it intends to complete that year, and then acquires funds for these projects either through federally funded, state revolving funds, additional charges on the ratepayer's utility bill, and municipal bonding ("Clean Water State Revolving Fund," 1987; "Drinking Water State Revolving Fund," 1997; White, 1960). Water and wastewater treatment plants and distribution and collection systems are typically designed with some volume flexibility to be able to address unforeseen weather events. These events can include significant increases in stormwater as well as overall system expansion needs driven by population growth and housing starts (Metcalf & Eddy, 1972; Tchobanoglous & Burton, 1991). And although a water utility does not operate in a competitive environment, its delivery is expected to be continuous and uninterrupted; the inability to provide clean water or treat sewage could lead quickly to a breakdown of the municipality and result in a public health crisis. (Haimes, 2006; Homsy, 2018) Any project input cost increases driven by EPU should result in a reduction in a water utility's ability to deliver its services, as well as a corresponding decrease in reliability, assuming they are unable to obtain additional capital through rate or surcharge increases.

There are reasons to believe that through robust management of a firm's supply chain resiliency, the firm can mitigate or possibly eliminate the impacts to its supply chain based upon unforeseen and uncertain political and economic events (Blome et al., 2013; Borges, 2015; Davarzani et al., 2015; Ivanov, Sokolov, & Dolgui, 2013; Mandal, 2012; Sheffi & Rice, 2005; Tang, 2007; Wang et al., 2011). Mitigation strategies could consist of postponing activities in one area and diverting resources to another more urgent need, implementing strategic stock and incorporating supplier flexibility, performing activities organically when possible, and incenting suppliers and customers as appropriate to ensure a seamless delivery of their product and services (Tang, 2006). Resource Orchestration Theory supports this assertion in that it suggests that firms that better understand how to organize themselves and their operations to address EPU, and that possess a clear understanding of how to execute this plan at all levels of the water utility through internal and external integration will likely perform better in terms of service quality levels (Peuscher, 2016).

2.4.2 Study Approaches

Given the discrete timelines of the tariff investigation, announcement and implementation, an event study could be considered as a means for analyzing the impacts of tariffs on the relationships between water utility volume flexibility and redundancy, and reliability and delivery. Event studies have been widely used in finance to analyze the impact of corporate actions on stock prices, and further extended into marketing and management. Some critical assumptions of using an event study are satisfied for this model, in that 1) markets are efficient, 2) raw material costs incorporate all available information on the status of material tariff implementation, 3) the material tariff investigation, institution, and implementation were all announced in the press, 4) there were no confounding events from other events that may have adversely impacted material costs, and 5) the length of the material tariff event window was relatively short, taking place over less than a year as illustrated in Figure 2 (Corrado, 2011; Giaccotto & Sfiridis, 1996; Henderson, 1990; Johnston, 2007; McWilliams & Siegel, 1997; P. Peterson, 1989). An event study could not be used for this analysis as municipal water utilities are not publicly traded, and financially reported data such as stock price and other required financial is not easily accessible.

Numerous studies have been undertaken to examine the comparative efficiencies of water utilities, focusing on overall water utility efficiency, costs, energy efficiency, wastewater treatment efficiency, regulations and reform (Abbott & Cohen, 2009; Anwandter & Ozuna, 2002; Cabrera, Estruch-Juan, & Molinos-Senante, 2018; Longo, Hospido, Lema, & Mauricio-Iglesias, 2018; Romano & Guerrini, 2011; Tabucchi, Davidson, & Brink, 2010; Thanassoulis, 2000; Walding, 2005; Walski, 1988). Studies have also been published examining the relationship between water utility volume flexibility and redundancy on performance (Falco & Webb, 2015; Haimes, 2006; Haimes, Matalas, Lambert, Jackson, & Fellows, 1998; Matthews, 2016; Matthews, Piratla, & Matthews, 2014; Rees, 1998; Yazdani & Jeffrey, 2012). None of these papers have investigated the impacts of political uncertainty as manifested by material tariffs on water utility reliability and delivery.

As a water utility's maintenance budget is determined and fixed on an annual fiscal cycle, this research will focus on MRO activities. We have defined MRO activities as the ongoing repair and upkeep of a water utility's drinking water treatment and distribution and wastewater treatment and collection systems (Eddy et al., 2013; Grigg, 2003; Metcalf & Eddy, 1972). MRO activities typically occur during a single yearly budget cycle versus capital spending activities, which can develop over multiple years, resulting in a more complicated analysis. As discussed previously, water utilities recognize the need to continue to invest in and maintain their infrastructure to ensure ongoing reliability and continued uninterrupted delivery of their services (Grigg, 2003).

2.4.3 Hypotheses Development

The extent to which a firm is internally integrated between its various internal functions and externally integrated with its suppliers could have an impact on the firms' productivity as well as its ability to respond to uncertainty in the form of material tariffs (Blome et al., 2013; Bode, Wagner, Petersen, & Ellram, 2011; Borges, 2015; Braunscheidel & Suresh, 2009; Graham, 2018; Riley, Klein, Miller, & Sridharan, 2016; Teece, 1994). Internal integration was previously defined as cross-functional and departmental alignment within an organization as it relates to achieving that organization's objectives and goals and managing the flow of goods, materials, and information into and out of the firm. Typical cross-functional teams could consist of members from strategy, marketing, finance, sales, supply chain, and government relations (Bhaduria, 2018). The extent to which each of these functions is coordinating activities with each other, as we have defined as internal integration, could be impactful to the water utility's service quality level. For example, if the maintenance and repair function does not correctly communicate the timing and quantities they need for specific components to maintain the water delivery system properly, purchasing may be unable to obtain the necessary materials in a timely fashion. In turn, this could lead to a system outage resulting in customers unable to get the water they require for bathing or drinking, or in the case of commercial customers, manufacturing products. Information management can play a critical role in a firm's reliability and delivery, in that historical ordering patterns derived from information technology (IT) systems combined with reliable maintenance component forecasts could enable a water utility to manage their distribution and collection systems more effectively, as well as water production and wastewater treatment (Bhaduria, 2018). The greater the degree to which a water utility is internally integrated, the higher the service quality level it can deliver to its customers. It is therefore hypothesized that:

H1 – Water utility reliability increases as water utility internal integration increases

H2 – Water utility delivery increases as water utility internal integration increases

The degree to which a water utility is coordinating activities with its supply chain, i.e., external integration, could also impact a water utility's service quality levels. External integration describes the degree to which organizations are aligned with their suppliers and customers to maximize supply chain efficiency and minimize supply chain risk. The higher the degree to which an organization is aligned externally, the greater its ability to respond to disruptions in the supply chain impacting the flow of goods or services and enabling the water utility to maintain it's level of service quality (Ambulkar, Blackhurst, & Grawe, 2015; Braunscheidel & Suresh, 2009; Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007). Alignment with suppliers can consist of regularly scheduled meetings between water utility and supplier discussing forecasted needs, risk-sharing in terms of the type of inventory as well as inventory levels required, and information sharing through technology collaboration. In the case of customers, water utilities can align in terms of increased demand due to new residential construction or new manufacturing customers' demand, or varying demand based upon special circumstances such as conventions, sporting events, or concerts. The higher the degree to which water utilities are aligned with their suppliers and customers, the greater their ability to meet their customer's delivery demands and to do so reliably. It is therefore hypothesized that:

H3 – Water utility reliability increases as water utility external integration increases

H4 – Water utility delivery increases as water utility external integration increases

Water utilities need to meet customer volume demand changes during the day as a result of consumption patterns defined by the diurnal curve (Eddy et al., 2013; Metcalf & Eddy, 1972), over more extended periods as populations move from one area to another, and increases resulting from population growth (Eddy et al., 2013; Metcalf & Eddy, 1972; Spellman, 2003). As a result, water utilities must have sufficient volume flexibility to serve these changing demands. We have defined volume flexibility as the ability of a water utility to deliver various amounts of water efficiently and economically while meeting multiple levels of customer demand. The greater a utility's volume flexibility, the greater the ability to meet these changing demands, increasing the water utility's service levels to its customers. Water treatment plants are typically designed for peak demand requirements, which can range from 1.2 to 4 times average daily flow (Eddy et al., 2013; Spellman, 2003; Tchobanoglous & Burton, 1991). Depending on local and state regulations, especially in areas that could be subject to protracted water shortages from drought or other environmental issues, there could be additional reserve design capacity built into the plant that may never be utilized (Edzwald, 2011). As a result, many of these systems have excess capacity that could be considered as a contributor to volume flexibility. It is therefore hypothesized that:

H5 - Water utility reliability increases as water utility volume flexibility increases

H6 - Water utility delivery increases as water utility volume flexibility increases

Water utilities can employ redundancy strategies to help ensure consistent levels of service quality and to ensure the safety of the water supply and public health when elements of the water supply and wastewater collection systems fail (Matthews, 2016). Redundancy is defined as the ability to maintain operations by ensuring the water utility has sufficient safety stock (inventory), they can operate at reduced capacity utilization rates, they keep multiple suppliers, and they operate duplicate water production and distribution, and wastewater collection and treatment systems. The latter of these can be achieved by ensuring that there is sufficient redundancy in the system design so that when there are component failures, the overall water delivery and collection system will continue uninterrupted function (Carvalho, Azevedo, et al., 2012; Carvalho, Maleki, et al., 2012; Haimes et al., 2008; Scholten et al., 2014; Stupak, 2018). For a water supply system, for example, redundancy may take the form of multiple valves and gates, spare piping capacity, duplicate control systems, and to the extent possible the standardization of water system components. There is also the possibility to connect with neighboring water systems (Haimes et al., 2008). The greater the ability of a water utility to build redundancy, the greater the resulting level of water utility service quality. It is therefore hypothesized that

H7 – Water utility reliability increases as water utility redundancy increases

H8 - Water utility delivery increases as water utility redundancy increases

EPU, in the form of material tariffs, could interfere with the processes and interchange of information required to operate a water utility efficiently and effectively. EPU could require a higher degree of vigilance and a greater degree of internal integration of water utility functions to mitigate the negative impacts of material tariffs. Water utilities deploy a significant amount of iron and steel in the form of pipes and valves in their systems. Pipes and valves will degrade over time through environmental and mechanical wear. As such, it becomes necessary for water utilities to replace those components to ensure the system continues to function effectively. The water utility, through planned replacement, can reduce the probability of failure of those components and ensure their water supply and wastewater collection systems are reliable, and that it delivers the volume of water demanded by its customers. It is therefore hypothesized that:

H9 - Water utility reliability decreases as water utility economic and political uncertainty manifesting as material tariffs increases

H10 – Water utility delivery decreases as water utility economic and political uncertainty manifesting as material tariffs increases

H11 – Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility internal integration and water utility reliability

H12 – Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility internal integration and water utility delivery

If the water utility's purchasing ability is reduced through increased material costs driven by increased uncertainty manifesting as material tariffs, it may result in a decrease in ongoing maintenance. For example, water utilities utilize pipes and valves in their operations. The announcement of material tariffs could lead to the introduction of uncertainties in the supply chain, resulting in speculative cost increases, pre-ordering to avoid anticipated cost increases, inventory holding costs, increases in material shortages in the market, and increases in lead times. These factors could lead to delays in a water utility's planned maintenance programs, which in turn could lead to increased aging of piping systems and equipment. These maintenance delays, in turn, could result in pipe and valve failures in the system, reducing the water utility's service quality levels and increasing the number of customers with unmet water demand. With a high level of external integration between the water utility, it's supply chain, and it's customers, they could avoid this decline of service quality. Continuous communication between the water utility and it's suppliers can help the water utility better understand and anticipate cost fluctuations of repair components; in turn, the water utility can optimize it's procurement needs while minimizing the impact of cost increases (Bhaduria, 2018). It is, therefore hypothesized:

H13 – Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility external integration and water utility reliability

H14 – Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility external integration and water utility delivery

Water utility maintenance budgets are determined yearly, and therefore cannot be easily changed once these budgets have been approved by municipal legislatures. The creation of political and economic uncertainty driven by the imposition of material tariffs could result in increased material costs, in turn, resulting in reduced water utility productivity and procurement capability, given the higher prices for iron and steel components. In turn, this could result in a reduction of the water utility's ability to create additional volume flexibility in their system required to meet varying levels of customer demand, given the decreased availability of necessary components due to increased costs. It is therefore hypothesized that:

H15 - Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility volume flexibility and water utility reliability

H16 - Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility volume flexibility and water utility delivery

Redundancy was previously defined as the water utility’s ability to maintain operations by ensuring they have sufficient safety stock (inventory), can operate at reduced capacity utilization rates, can maintain multiple suppliers, and operate duplicate water production and distribution, and wastewater collection and treatment systems. The latter of these can be achieved by ensuring that there is sufficient redundancy in the system design so that when there are component failures, the overall water delivery and collection system will continue uninterrupted function (Carvalho, Azevedo, et al., 2012; Carvalho, Maleki, et al., 2012; Haimes et al., 2008; Scholten et al., 2014; Stupak, 2018). Economic and political uncertainty could negatively impact a water utility's ability to implement redundancy strategies as the increased costs resulting from material tariffs could potentially reduce the available capital to invest in any or all of these strategies. In anticipation of material tariffs, research has shown that firms choose to "buy ahead" to avoid any anticipated price increases resulting from material tariffs. For example, in the case of the sugar industry, import prices and volume rose 200% in the two months leading up to material tariffs. They then fell dramatically in the months following the increases (Bowen, 2015). Given the increased costs from material tariffs and the inelasticity of a water utility's yearly maintenance budget, it is reasonable to believe that the water utility could experience a reduction in their purchasing power. With a protracted implementation of material tariffs, a water utility may be unable to maintain the same level of pre-tariff inventory unless resources were to be diverted from elsewhere in the maintenance budget, resulting in a reduction in efficiency and reliability elsewhere in their system.

Additionally, after the initial build-up of inventory during the early phases of the material tariff implementation, the reduction in repair component inventory could result in a corresponding reduction in the water utility's ability to maintain their system correctly. This reduction in maintenance, in turn, could lead to a higher number of failures in the system, water losses and sewage overflows, and reduced system reliability as well as resulting water delivery impacts and create the potential for a public health crisis.

Another supply chain redundancy strategy is to increase the number of available suppliers to ensure a greater degree of purchasing options. Material tariffs imposed on imported iron and steel materials are intended to compel manufacturers to produce these same products by utilizing domestic materials. As such, there may be a resulting inadequate supply of products manufactured with domestic raw materials, as well as a reduction in available suppliers who have access to quantities of these products made with domestic materials.

Operating duplicate water production and conveyance systems could encompass buying water from neighboring utilities (a type of outsourcing) or building in additional network capacity through parallel piping schemes. As explained previously, the introduction of tariffs and the potential increased costs could place additional financial stresses on water utilities that otherwise could sell water to neighboring water utilities, thereby reducing this as an available redundancy option.

Additional capacity expansion might also need to be deferred, given the increased costs of components needed to construct these systems with the imposition of material tariffs. Finally, although water utilities typically have reserve capacity as a result of designing for peak demand conditions, this excess production capacity could potentially deteriorate over time, especially in the case of a protracted material tariff implementation. Increased costs from material tariffs on components and the resulting decrease in water utility purchasing power could lead to a reduction in new projects to increase capacity. As this study is focused on MRO, the impact of this aspect of redundancy would be expected to be minimal.

It is therefore hypothesized that:

H17 - Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility redundancy and water utility volume reliability

H18 - Economic and political uncertainty manifesting as material tariffs negatively moderates the relationship between water utility redundancy and water utility volume delivery

Chapter 3 - Research Design and Methodology

3.1 Overview of Methods

This study employs surveys, descriptive analyses, and partial least squares regression analysis to establish the validity of the proposed hypotheses. Additional sensitivity analysis was conducted through examining the control variable work experience to understand the impact on the latent variable relationships. The model integrates the four exogenous constructs of internal integration, external integration, volume flexibility and redundancy with the moderating effect of economic and political uncertainty on the first order endogenous constructs of reliability and delivery, which we define collectively as service quality. All of the measures except for volume flexibility are reflective, the volume flexibility construct is formative and is comprised of two reflective measures, water volume flexibility, and wastewater volume flexibility.

3.2 Study Design

This research study proposes to survey publicly owned community water systems (utilities) in North Carolina (NC), South Carolina (SC), and Virginia (VA). These are neighboring states in the southeastern United States and, as such, were believed to be similar in terms of economics as well as demographics. The United States Environmental Protection Agency (USEPA) classifies a community water system (CWS) as “a public water system that supplies water to the same population year-round,” and a non-Transient Non-Community Water System (NTNCWS) as “a public water system that regularly supplies water to at least 25 of the same people at least six months per year. Some examples [of NTNCWS] are schools, factories, office buildings, and hospitals which have their own water systems", and Transient Non-Community Water System (TNCWS) as "a public water system that provides water in a place such as a gas station or campground where people do not remain for long periods of time."(USEPA, 2019, paragraph 4). There is a total of 13,186 water systems in these three states that are classified as community, non-transient, and non-transient non-community. This research study focuses on 1691 publicly-owned community drinking water and wastewater treatment systems, 530 of which are in VA, 881 in NC, and 280 in SC, where publicly owned is defined as owned by a public entity such as the United States government, or state, or local government, or a mix of public and private ownership.

3.3 Data Sources

Contact and demographic information for these entities to be surveyed were obtained directly from personnel working for the North Carolina Department of Natural Resources and the South Carolina Department of Health and Environmental Control, and the Virginia Department of Health website.

3.4 Description of Survey Variables and Measurement

The survey questions used to gather data from the above utilities were adapted from constructs in previous research studies for both the independent variables of Internal Integration, External Integration, Volume Flexibility, and Redundancy, the Moderator Economic and Political Uncertainty, and the dependent variables Reliability and Delivery as shown in Table 1. 5-point Likert scales were used for all of the indicators that, in turn, defined the constructs. Control variables were adapted from water industry literature, primarily the *AWWA 2019 State of the Water Industry* (AWWA, 2019).

Construct definitions and supporting literature are shown in Table 1

Table 1 Construct Definition and Supporting Literature

Construct	Definition	Literature
Internal Integration	The degree to which interdepartmental and interfunctional connectiveness enhances a water utility's ability to respond to disruptions caused by uncertainty	Braunscheidel & Suresh (2009)
External Integration	The degree to which a water utility is connected to and coordinates with its external customers and suppliers with the goal to maximize customer satisfaction and supply chain efficiency and effectiveness in responding to disruptions caused by uncertainty	Braunscheidel & Suresh (2009)
Volume Flexibility	The ability of a water utility to deliver various amounts of water efficiently and economically while meeting various levels of customer demand	Zhang (2003)
Redundancy	The ability to maintain operations by ensuring the water utility has sufficient safety stock (inventory), they can operate at reduced capacity utilization rates, they maintain multiple suppliers, and they operate duplicate water production and conveyance systems. The latter of these can be achieved by ensuring that there is sufficient redundancy in the system design so that when there are component failures, the overall water delivery and collection system will continue uninterrupted function	Carvalho, Azevedo, et al., (2012), Carvalho, Maleki, et al., (2012), Haimes et al., (2008), Scholten et al., (2014), Stupak, (2018)
Economic and Political Uncertainty	The extent to which a water utility's supply chain is impacted by disruptions resulting from uncertainty on who will make economic and political decisions, what political and economic decisions will be made, when they will make them and what the anticipated economic impact is of those decisions	Baker et al., (2016), Bode et al., (2011)
Reliability	The ability of a water utility to dependably, accurately, and consistently meet customer expectations over time	Thomas (2002), Zeithaml (1990)
Delivery	The extent to which a water utility is capable of providing the volume of water required by the customer on time	Li et al., (2005)

Table 2 Control and Demographic Questions, Scales and Responses

	Questions	Scale	Response
Control Questions	Q1 - What is your gender?	Nominal	M/F/N
	Q2 - What age range do you fall in?	Interval	<25, 25-34, 35-44, 45-54, >54
	Q3 - How many years of water utility experience do you have?	Interval	<1 year, 1-3 years, > 3 years to 5 years, > 5 years to 10 years, >10 years to 15 years , > 15 years to 25 years, >25 years
	Q4 - What type of water utility do you work for?	Nominal	Community, Non-Public, Non Transient Non-Community, Transient Non-Community
	Q5 - How many customers does your utility serve?	Interval	<1000, >1000 to 10000, >10000 to 50000, >50000 to 100000, >100000 to 250000, > 250000
	Q6 - What percentage is residential customers ____ and business customers _____	Ratio	Open text
	Q7 - What is the average age of your piping system (your best guess?)	Interval	0- 10 years, >10 years to 25 years, >25-50 years, >50 years
Demographic Questions	Q1 - We produce our own drinking water	Nominal	Y/N
	Q2 - We buy drinking water from other utilities	Nominal	Y/N
	Q3 - We are responsible for collecting wastewater	Nominal	Y/N
	Q4 - We treat our wastewater	Nominal	Y/N
	Q5 - We maintain our own network for delivering drinking water	Nominal	Y/N
	Q6 - We own other water utilities	Nominal	Y/N
	Q7 - Budgeting decisions are made locally/elsewhere	Nominal	Locally/Centrally
	Q8 - Maintenance, Repair and Operation decisions are made locally/elsewhere	Nominal	Locally/Centrally
	Q9 - Pipe and valve purchasing decisions are made locally/elsewhere	Nominal	Locally/Centrally

Table 3 Construct Items and Supporting Literature

Construct	Questions	Literature
Internal Integration	II1 - All departments within our water utility are connected by a single central information system [(e.g., enterprise resource planning) II2 - We use cross-functional teams to solve problems II3 - Communications from one department to another are expected to be routed through ‘‘proper channels’’ II4 - Internal management communicates frequently about goals and priorities II5 - Our water utility does not encourage openness and teamwork II6 - When problems occur in our water utility, finding someone to blame is more important than finding a solution II7 - Formal meetings are routinely scheduled among various departments II8 - When problems or opportunities arise, informal, face-to-face meetings never occur	Braunscheidel & Suresh (2009)
External Integration	EI1 - Our customers give us feedback on quality and delivery performance EI2 - Customers frequently share their water volume needs with our water utility EI3 - Our water production plans are shared with our customers EI4 - Joint planning with suppliers is important to us EI5 - We give our suppliers feedback on quality and delivery performance EI6 - We strive to establish long term relationships with our suppliers EI7 - Information integration with suppliers in the supply chain is important. EI8 - Our supply chain employs rapid response initiatives (e.g., continuous replenishment (CR) or vendor managed inventory (VMI) EI9 - It would be difficult for us to replace our suppliers	Braunscheidel & Suresh (2009)
Volume Flexibility	VO1: We can operate efficiently at different levels of water production VO2: We can quickly change the quantity of water produced VO3: We can vary water output as required (daily, monthly, seasonally) VO4: We always make sure we have some additional water production capacity beyond our peak demand VO5: We can operate efficiently at different levels of wastewater treatment VO6: We can quickly change the quantity of wastewater treated VO7: We can vary wastewater treatment capacity as required (daily, monthly, seasonally) VO8: We always make sure we have some additional wastewater treatment capacity beyond our peak demand	Zhang (2003), Braunscheidel & Suresh (2009)
Redundancy	RE1 - We can quickly change over our distribution or collection lines if a line is out of service RE2 - We think of building redundancy at the design stage RE3 - We have sufficient alternate force main/gravity line capacity if we lose a force main/gravity line RE4 - We have the inventory needed to change a pipe or valve in our system RE5 - We can easily increase our pipe and valve inventory levels if needed RE6 - We maintain sufficient safety stock of pipe and valve inventory	Matthews, Piratla, & Matthews (2014), Hoshiya & Yamamoto (2002), Todini (2002), Tabucchi, Davidson, & Brink (2010), Haimes, Matalas, Lambert, Jackson, & Fellows (1998), Scholten, Sharkey Scott, & Fynes (2014)
Economic and Political Uncertainty	EPU1 - The iron, steel and aluminum tariffs implemented on March 8, 2018 have caused a major disruption to our supply chain EPU2 - The full effect of the iron, steel and aluminum tariffs implemented on March 8, 2018 has occurred EPU3 - We have fully addressed the impacts of the iron, steel and aluminum tariffs implemented on March 8, 2018 EPU4 - We feel the need to be alert at all times for possible supply chain disruptions caused by material tariffs EPU5 - Material tariffs are creating a fast-changing environment EPU6 - Our material cost and expenses are reasonably predictable EPU7 - The possibility of future material tariffs is a major source of uncertainty	Bode, Wagner, Petersen, & Ellram,(2011)
Reliability	RL1 - We solve our water supply problems quickly RL2 - We solve our water supply problems right the first time (correctly and completely) RL3 - We solve our water supply problems in the time promised to our customers RL4 - We consistently keep our maintenance records up to date RL5 - Our maintenance records are accurate	Lai, Ngai, & Cheng (2002)
Delivery	DE1 - We provide our customers with the volume of water they require DE2 - Our customers receive water when they need it DE3 - We rarely have to ration or restrict water usage DE4 - We treat all of our customers wastewater DE5 - We can collect all of our customer's wastewater	Fawcett (1997), Ward & Duray (2000), Carvalho, Azevedo, & Cruz-Machado (2012)

All questions use a 5 point Likert Scale - 1. Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree

The survey was created, submitted, modified, and approved by the University of North Carolina Charlotte Institutional Review Board, Study #19-0425. The survey was then converted to an electronic format and sent out through a university supplied surveying system, Qualtrics. The full survey can be found in the appendix, section 6.1. Reminders were sent out at two and three-week intervals, and thank you emails were sent out to respondents. Email addresses were updated for bounced surveys and resent, as some individuals were no longer in the role due to employment change, voting results, legal suits, or email address changes. As some of the individuals identified in the supplied contact information were listed more than once as they were responsible for multiple utilities, these individuals only received one survey to complete. As a result, after duplicate emails were removed, and net of failed and undeliverable emails, a total of 1,234 surveys were successfully sent.

3.5 Description of Sampling Technique

One hundred sixty (160) responses were received, resulting in a 13% response rate. Of the 160 total responses, four were from survey reviewers, 34 did not finish, four declined to accept the consent form, and two more exited the survey without going beyond the consent question. Five of the 34 respondents completed 90% or more of the survey and based on guidance from Hair et al. (Hair, Black, Babin, & Anderson, 2010) these surveys were accepted for analysis. Based on this determination, 121 survey responses were determined to be valid. Control questions were used to identify the different functions that utilities performed, such as producing water, treating wastewater, and maintaining their networks. Not all utilities surveyed performed all of these functions, and as a result, survey respondents chose to either leave these questions blank or answer “not applicable.” Both blank and not applicable were considered missing indicators for the sake of analysis in Smart PLS, which will be discussed in more detail later. Using this definition of missing responses, construct indicators contained missing responses ranging from 0% to 38%, and for the demographic data, missing responses ranged from 0 to 8.3%. Indicators and their associated survey questions can be seen in Table 3.

3.6 Data Analysis and Measures

An initial analysis was performed in SPSS to obtain basic statistical measures, including descriptive statistics, skewness, kurtosis, intercorrelations, variances, and covariance for the construct indicators. Measures were then analyzed for non-response bias and common method bias to ensure the suitability and consistency of the data. (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Once this was confirmed, a Confirmatory Factor analysis was conducted to verify the theoretical grouping of the observed measures (Hair, Hult, Ringle, & Sarstedt, 2016).

3.6.a Demographics/control variables/descriptive statistics

Detailed descriptive and frequency demographic statistics can be observed in Table 5.

Table 4 Pearson Correlation/Covariance Matrix - Demographic Data

	Gender	Age	Experience	Customers	ResCust	BusCust	PipeAge	Produce Water	Buy Water	Collect WW	Treat WW	Maintain Network	Own Other Utilities	Budget Decisions	MRO Decisions	Pipe/Valve Decisions
Gender	1	-0.053	-0.069	-0.054	0.005	0.224	-0.048	0.007	-0.007	0.015	0	0.015	0.016	0.007	0.006	-0.001
Age	-.186*	1	0.333	-0.2	0.125	0.472	-0.126	0.033	0.005	0.017	0.036	-0.008	0	0.008	0.008	0.008
Experience	-0.129	.245**	1	0.46	-2.932	2.272	0.119	-0.069	0.072	-0.123	0.037	-0.023	-0.033	0.003	0.002	0.014
Customers	-0.158	-.230*	.285**	1	-2.981	1.853	0.091	-0.103	0.047	-0.043	-0.07	-0.013	-0.091	-0.005	-0.005	0.006
ResCust	0.001	0.011	-0.133	-.222*	1	-107.66	-0.965	-0.495	0.058	0.218	0.604	0.106	-0.155	-0.541	-0.535	-0.472
BusCust	0.051	0.044	0.109	0.149	-.717**	1	1.926	-0.278	0.143	-0.864	-0.89	-0.074	0.089	0.573	0.566	0.487
PipeAge	-0.175	-0.177	0.091	0.109	-0.084	0.178	1	-0.062	0.067	-0.061	-0.007	-0.014	0.008	0.012	0.012	0.002
ProduceWater	0.048	0.086	-0.099	-.226*	-0.078	-0.047	-0.166	1	-0.149	0	0.044	0.013	0	0.004	0.004	-0.002
Buy Water	-0.041	0.013	0.092	0.093	0.008	0.026	0.159	-.654**	1	0	-0.066	-0.009	-0.015	-0.01	-0.009	-0.005
CollectWW	0.12	0.054	-.209*	-0.114	0.042	-0.176	-.199*	0	-0.001	1	0.065	-0.001	-0.004	0.006	0.006	-0.001
TreatWW	0	0.09	0.051	-0.144	0.099	-0.139	-0.019	.209*	-.275**	.440**	1	-0.003	-0.009	-0.003	-0.003	-0.003
Maintain Network	.344**	-0.074	-0.117	-0.102	0.057	-0.042	-0.131	.215*	-0.14	-0.04	-0.066	1	0.001	0	0	0
OwnUtilities	0.144	0	-0.065	-.265**	-0.036	0.022	0.029	0.003	-0.088	-0.033	-0.054	0.035	1	0.001	0.001	0
BudgetDecisions	0.163	0.075	0.013	-0.038	-.290**	.326**	0.113	0.07	-0.144	0.12	-0.066	-0.017	0.036	1	0.017	0.008
MRODecisions	0.147	0.076	0.012	-0.038	-.290**	.326**	0.111	0.068	-0.14	0.121	-0.066	-0.017	0.036	1.000**	1	0.008
PipeValveDecisions	-0.035	0.107	0.095	0.064	-.360**	.395**	0.022	-0.056	-0.099	-0.041	-0.066	-0.012	.c	.704**	.704**	1

Covariances above the diagonal, correlations below the diagonal

** Correlation is significant at the 0.05 level (2-tailed).*

*** Correlation is significant at the 0.01 level (2-tailed).*

Gender – Respondents were predominantly male, of the 121 responses, 103 (85.1%) responded male, 15 (12.4%) responded female, and 3 (2.5%) preferred not to answer.

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Prefer Not To Answer	3	2.5	2.5	2.5
	Male	103	85.1	85.1	87.6
	Female	15	12.4	12.4	100.0
	Total	121	100.0	100.0	

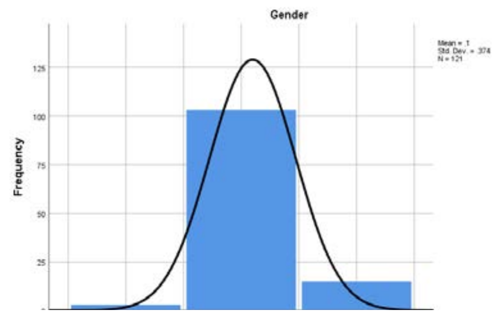

Figure 6 Gender Frequencies and Distribution

Age - Respondents varied widely in age, with five respondents identifying in the 25-34-year-old category (4.1%), 29 in the 35-44-year-old category (24.0%), 48 in the 45-55-year-old category (39.7%), and 39 in the > 55-year-old category (32.2%).

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	25 - 34 years	5	4.1	4.1	4.1
	35 - 44 years	29	24.0	24.0	28.1
	45 - 55 years	48	39.7	39.7	67.8
	> 55 years	39	32.2	32.2	100.0
	Total	121	100.0	100.0	

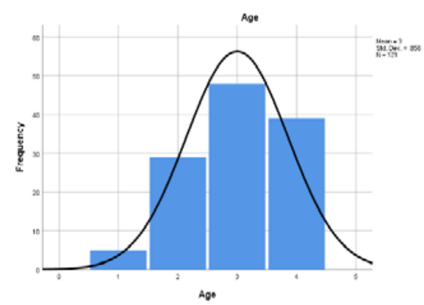

Figure 7 Age Frequencies and Distribution

Work Experience - Work experience was skewed to more experience, as only one respondent had < 1 year of experience (0.8%), nine respondents had 1-3 years of experience (7.4%), eight respondents had > 3 to 5 years of experience (6.6%), 15 respondents had > 5 to 10 years of experience (15%), 18 respondents had > 10 to 15 years of experience (14.9%), 35 respondents had >15 to 25 years of experience (28.9%), and 35 respondents had > 25 years of experience (28.9%).

Experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 1 year	1	.8	.8	.8
	1 to 3 years	9	7.4	7.4	8.3
	> 3 to 5 years	8	6.6	6.6	14.9
	> 5 to 10 years	15	12.4	12.4	27.3
	> 10 to 15 years	18	14.9	14.9	42.1
	> 15 to 25 years	35	28.9	28.9	71.1
	> 25 years	35	28.9	28.9	100.0
	Total	121	100.0	100.0	

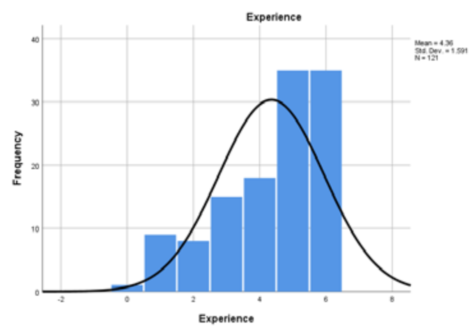

Figure 8 Work Experience Frequencies and Distribution

Customer Size – Approximately 67% of the respondents work for utilities serving 10,000 customers or less, with 25 respondents with < 1,000 customers (20.7%), 52 respondents with 1,000 – 10,000 customers (43.0%), 33 respondents with > 10,000 to 50,000 customers (27.3%), 6 customers with > 50,000 to 100,000 customers, (5%), 4 customers with > 100,000 to 250,000 customers (3.3%), and 1 respondent with > 250,000 customers (0.8%).

Customers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 1,000	25	20.7	20.7	20.7
	1,000 - 10,000	52	43.0	43.0	63.6
	> 10,000 - 50,000	33	27.3	27.3	90.9
	> 50,000 - 100,000	6	5.0	5.0	95.9
	> 100,000 - 250,000	4	3.3	3.3	99.2
	> 250,000	1	.8	.8	100.0
	Total	121	100.0	100.0	

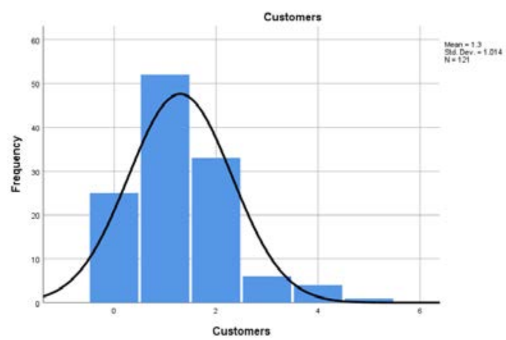

Figure 9 Customer Size Frequencies and Distribution

Customer Type – Of the 111 responses, the majority serviced residential customers, with 97 respondents (87.4%) indicating they serve 75% or more residential customers.

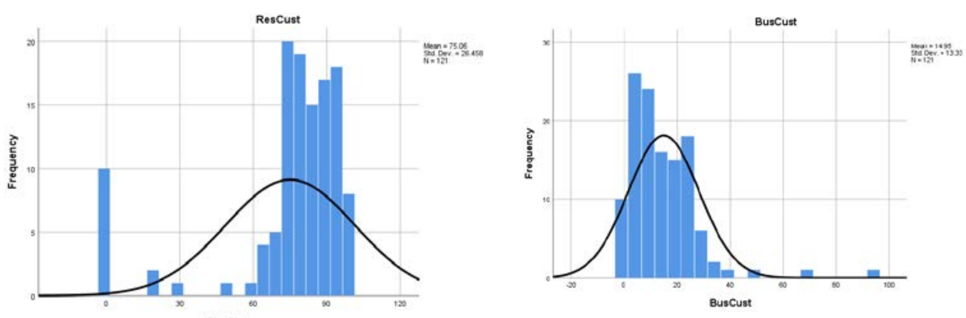

Figure 10 Customer Type Frequencies and Distribution

Pipe Age – Pipe Ages were skewed toward the higher values, as nine respondents answered 0 – 10 years (7.4%), 28 respondents indicated pipe ages of > 10 to 25 years (23.1%), 61 respondents or nearly half answered > 25 to 50 years for pipe age (50.4%), and 22 respondents indicated pipe ages of > 50 years (18.2%). One person did not respond to this question.

PipeAge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Response	1	.8	.8	.8
	0 - 10 years	9	7.4	7.4	8.3
	> 10 to 25 years	28	23.1	23.1	31.4
	> 25 - 50 years	61	50.4	50.4	81.8
	> 50 years	22	18.2	18.2	100.0
	Total	121	100.0	100.0	

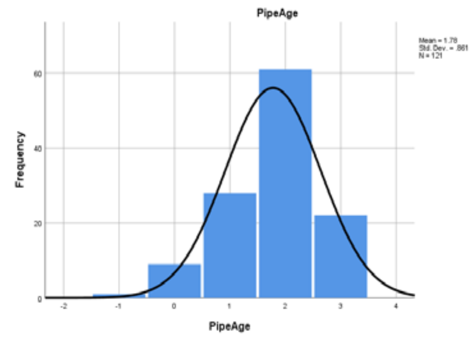

Figure 11 Pipe Age Frequencies and Distribution

Produce Water – The majority of respondents (86 – 71.1%) replied that they produce water, with 32 answering no (26.4%) and three more not responding.

ProduceWater

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	3	2.5	2.5	2.5
	Yes	86	71.1	71.1	73.6
	No	32	26.4	26.4	100.0
	Total	121	100.0	100.0	

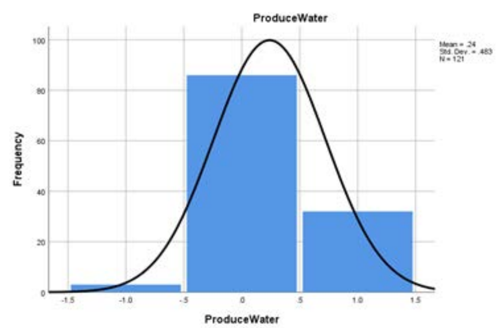

Figure 12 Utilities Produce Water

Buy Water – This category was relatively evenly split, with 44.6% or 54 respondents indicating they buy water, 59 or 48.8% responding they did not buy water, and eight respondents choosing not to respond.

Buy Water

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	8	6.6	6.6	6.6
	Yes	54	44.6	44.6	51.2
	No	59	48.8	48.8	100.0
	Total	121	100.0	100.0	

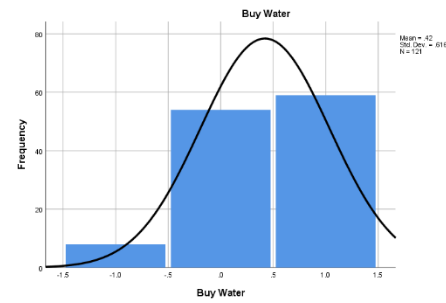

Figure 13 Utilities Buy Water Frequencies and Distribution

Collect Wastewater – The majority of respondents indicated that they collect wastewater, with 98 or 81% replied yes, 19 or 15.7% answering no, and four non-responses.

CollectWW

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	4	3.3	3.3	3.3
	Yes	98	81.0	81.0	84.3
	No	19	15.7	15.7	100.0
	Total	121	100.0	100.0	

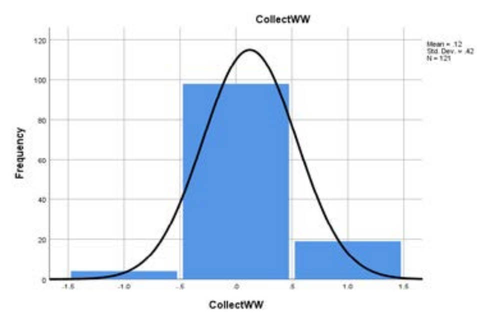

Figure 14 Utilities Collect Wastewater Frequencies and Distribution

Treat Wastewater – 75 respondents (62%) answered that they treat their wastewater, 36 (29.8%) indicated they did not treat their wastewater, and there were ten non-respondents.

TreatWW

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	10	8.3	8.3	8.3
	Yes	75	62.0	62.0	70.2
	No	36	29.8	29.8	100.0
	Total	121	100.0	100.0	

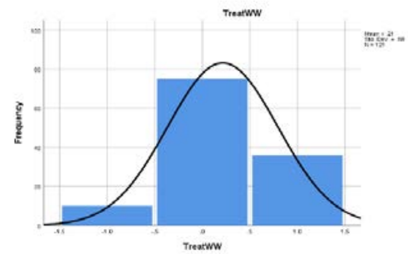

Figure 15 Utilities Treat Wastewater Frequencies and Distribution

Maintain Network – Nearly all of the respondents (117 – 96.7%) indicated they maintain their own networks, while two respondents (1.7%) replied they do not, and two respondents (1.7%) chose not to respond.

Maintain Network

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	2	1.7	1.7	1.7
	Yes	117	96.7	96.7	98.3
	No	2	1.7	1.7	100.0
	Total	121	100.0	100.0	

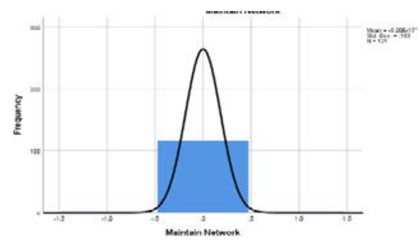

Figure 16 Utilities Maintain Their Own Network Frequencies and Distribution

Own Other Utilities – 102 respondents (84.3%) indicated they do not own other utilities, 15 (12.4%) replied they do own other utilities, and 4 (3.3%) chose not to answer.

OwnUtilities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	4	3.3	3.3	3.3
	Yes	15	12.4	12.4	15.7
	No	102	84.3	84.3	100.0
	Total	121	100.0	100.0	

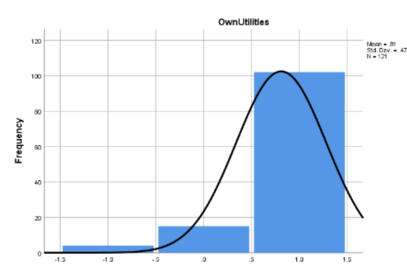

Figure 17 Utilities Own Other Utilities Frequencies and Distribution

Budget Decisions - Nearly all of the respondents (117 – 96.7%) indicated budgeting is done locally, two respondents (1.7%) replied budgeting is done centrally elsewhere, and two respondents (1.7%) chose not to reply.

BudgetDecisions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1	2	1.7	1.7	1.7
	Local	117	96.7	96.7	98.3
	Centrally Elsewhere	2	1.7	1.7	100.0
	Total	121	100.0	100.0	

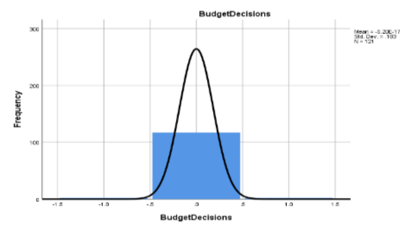

Figure 18 Utility Budget Decision Location Frequencies and Distribution

MRO Decisions – Similar to budget decisions, nearly all of the respondents (119 – 98.3%) indicated MRO decisions are made locally, and two respondents (1.7%) replied MRO decisions are made centrally elsewhere.

MRODecisions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Local	119	98.3	98.3	98.3
	Centrally Elsewhere	2	1.7	1.7	100.0
	Total	121	100.0	100.0	

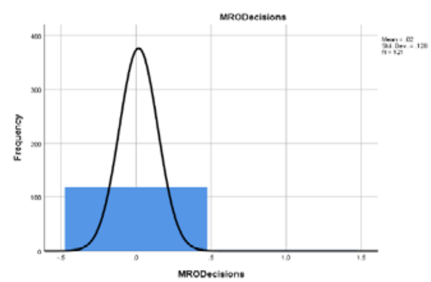

Figure 19 Utility MRO Decision Location Frequencies and Distribution

Pipe and Valve Purchasing Decisions – Similar to budget and MRO decisions, nearly all of the respondents (120 – 99.2%) indicated pipe and valve purchasing decisions are made locally, while only one respondent (0.8%) replied decisions are made centrally elsewhere.

PipeValveDecisions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Local	120	99.2	99.2	99.2
	Centrally Elsewhere	1	.8	.8	100.0
	Total	121	100.0	100.0	

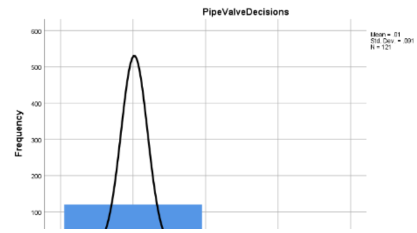

Figure 20 Utility Pipe and Valve Location Decision Frequencies and Distribution

3.6.b Common Method and Non-Response Bias

The data set was analyzed for common method and non-response bias. Common method bias testing was conducted in SPSS using Harmon's single factor method. The results of this analysis revealed that only 18% of the variance was explained by this single factor, which is well below the 50% threshold (Podsakoff et al., 2003).

A non-response bias test was conducted by segmenting the data into two groups, early and late respondents, and then running independent sample t-tests in SPSS to compare the latent variable scores (Lindner, Murphy, & Briers, 2001). After running this analysis, it was confirmed that there was no significant non-response bias at $p < 0.05$.

3.7 Test of the Base Model

3.7.a Exploratory Factor Analysis

Exploratory factor analysis was run in SPSS to confirm the items were loading on to the expected factors. The initial analysis was run with a fixed value of seven factors, as shown in the initial theoretical model using a principal components method and varimax rotation. As not all cases had complete responses, it was decided to exclude cases pairwise to preserve case data.

Using this approach, it was determined that a seven-factor loading resulted in 55% of the variance being explained by the model, the Kaiser-Meyer-Olkin (KMO) test was above 0.6 and Bartlett's test was significant, indicating a valid sampling set.

However, in reviewing the results, it could be observed that the Volume Flexibility items VO1-VO4 were loading onto a different factor than were the VO5-VO7 items. The Volume Flexibility items consisted of questions on both water and wastewater, with VO1-VO4 focused on the utility's water capabilities, and VO5-VO7 addressing the utility's wastewater capabilities. This result suggests that Volume Flexibility is a second-order formative construct, consisting of a Water Volume Flexibility Construct and a Wastewater Volume Flexibility Construct. The test was rerun with eight constructs and the Water and Wastewater Volume Flexibility items loaded on different factors. Therefore, Volume Flexibility was treated as a second-order formative construct consisting of Water Volume Flexibility and Wastewater Volume Flexibility.

3.7.b Partial Least Squares Analysis

Given the complexity of the theoretical model in that it does not lend itself to simple regressions, Partial Least Squares Structural Equation Modeling (PLS-SEM) was used for this analysis. PLS-SEM is defined by Hair et al. as "a causal modeling approach aimed at maximizing the explained variance of the dependent latent constructs (Hair, Ringle & Sarstedt, 2011, p. 139)" PLS-SEM was chosen to test the model, in this case, to develop a theory and to explain the variance of key target constructs as well as its suitability for small sample sizes and non-normal distributions (Hair et al., 2016; Hair, Ringle, & Sarstedt, 2011; Hair, Sarstedt, Pieper, & Ringle, 2012).

The two-step approach to analyzing the data was first to establish the final results and quality criteria of the base model without the moderators and establishing the p values (significance) for the indicator loadings and path coefficients. The analysis was then repeated with the moderators in the model.

3.7.c Structural Equation Modeling Without Moderators

The first PLS algorithm was run in SmartPLS 3 (Ringle, 2018) using a path weighting scheme on the model shown in Figure 21 with 300 iterations and a stop criterion of $10^{\wedge 7}$ to obtain path coefficients, direct, indirect and total effects, and outer weights and loadings for the constructs. Additionally, since volume flexibility was determined to be a second-order formative construct, the first-order constructs of water volume flexibility and wastewater volume flexibility were added to the model.

As the model is theoretical, an iterative process was used to ensure the average of the outer loadings for each latent variable was > 0.70, and that the indicators were significant. The model analysis showed that four of the indicator loadings (II5, II6, II8, and EPU6) were negative, these indicators were reverse coded, and the model was rerun (Hair Jr, Black, Babin, & Anderson, 2010). Indicators showing outer loadings less than 0.70 were eliminated in a stepwise fashion from the model by first excluding those indicators with the lowest loading values. Each time the model was rerun to ensure that the remaining indicators in the same construct were not adversely affected, that is that their values did not decrease below the desired threshold of 0.70, while also maintaining a minimum of three indicators per construct and an average of the loadings greater than 0.65. The resultant latent variable indicators and their descriptive statistics are shown in Table 5 and Table 6 below.

Table 5 Final Items Used in Partial Least Squares Analysis

Construct	
Internal Integration	II5 - Our water utility does not encourage openness and teamwork II6 - When problems occur in our water utility, finding someone to blame is more important than finding a solution II8 - When problems or opportunities arise, informal, face-to-face meetings never occur
External Integration	EI4 - Joint planning with suppliers is important to us EI5 - We give our suppliers feedback on quality and delivery performance EI6 - We strive to establish long term relationships with our suppliers EI7 - Information integration with suppliers in the supply chain is important.
Water Volume Flexibility	VO1: We can operate efficiently at different levels of water production VO2: We can quickly change the quantity of water produced VO3: We can vary water output as required (daily, monthly, seasonally)
Wastewater Volume Flexibility	VO5: We can operate efficiently at different levels of wastewater treatment VO6: We can quickly change the quantity of wastewater treated VO7: We can vary wastewater treatment capacity as required (daily, monthly, seasonally) VO8: We always make sure we have some additional wastewater treatment capacity beyond our peak demand
Redundancy	RE4 - We have the inventory needed to change a pipe or valve in our system RE5 - We can easily increase our pipe and valve inventory levels if needed RE6 - We maintain sufficient safety stock of pipe and valve inventory
Economic and Political Uncertainty	EPU1 - The iron, steel and aluminum tariffs implemented on March 8, 2018 have caused a major disruption to our supply chain EPU5 - Material tariffs are creating a fast-changing environment EPU6 - Our material cost and expenses are reasonably predictable EPU7 - The possibility of future material tariffs is a major source of uncertainty
Reliability	RL1 - We solve our water supply problems quickly RL2 - We solve our water supply problems right the first time (correctly and completely) RL3 - We solve our water supply problems in the time promised to our customers
Delivery	DE2 - Our customers receive water when they need it DE3 - We rarely have to ration or restrict water usage DE4 - We treat all of our customers wastewater DE5 - We can collect all of our customer's wastewater

Table 6 Descriptive Statistics - No Moderators

	N	Range	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
RL1	119	3	4.28	0.051	0.551	0.304	-0.276	0.222	1.337	0.44
RL2	119	2	4.35	0.047	0.514	0.264	0.239	0.222	-1.092	0.44
RL3	117	3	4.44	0.065	0.7	0.49	-1.484	0.224	2.935	0.444
II5	120	3	4.24	0.065	0.71	0.504	-0.816	0.221	0.909	0.438
II6	119	3	4.53	0.062	0.674	0.455	-1.627	0.222	3.219	0.44
II8	119	3	4.17	0.064	0.693	0.48	-0.703	0.222	0.968	0.44
VO1	104	3	3.88	0.073	0.741	0.55	-1.123	0.237	1.683	0.469
VO2	102	4	3.72	0.086	0.872	0.76	-0.963	0.239	0.606	0.474
VO3	106	4	3.99	0.065	0.669	0.448	-1.351	0.235	4.636	0.465
DE2	119	3	3.72	0.073	0.791	0.626	-0.401	0.222	-0.103	0.44
DE3	119	3	3.93	0.056	0.607	0.368	-0.432	0.222	1.116	0.44
DE4	121	4	3.81	0.083	0.916	0.839	-0.869	0.22	0.65	0.437
DE5	119	4	3.86	0.076	0.826	0.683	-1.285	0.222	2.679	0.44
EI4	104	4	3.71	0.091	0.931	0.867	-0.566	0.237	0.185	0.469
EI5	108	4	3.86	0.075	0.779	0.607	-0.96	0.233	1.666	0.461
EI6	110	4	4.13	0.07	0.731	0.534	-1.064	0.23	2.792	0.457
EI7	111	4	3.85	0.074	0.777	0.604	-0.792	0.229	1.318	0.455
EPU1	114	3	2.49	0.081	0.865	0.748	-0.056	0.226	-0.628	0.449
EPU5	119	4	3.1	0.076	0.827	0.685	-0.465	0.222	0.22	0.44
EPU6	119	4	2.59	0.08	0.877	0.77	0.836	0.222	-0.322	0.44
EPU7	120	4	3.28	0.089	0.972	0.944	-0.487	0.221	-0.16	0.438
RE4	121	4	3.88	0.083	0.909	0.826	-1.375	0.22	2.255	0.437
RE5	119	4	3.68	0.085	0.929	0.863	-0.994	0.222	0.706	0.44
RE6	118	4	3.7	0.083	0.899	0.809	-0.81	0.223	0.193	0.442
VO5	79	4	3.71	0.099	0.879	0.773	-1.246	0.271	1.532	0.535
VO6	76	4	3.37	0.117	1.018	1.036	-0.567	0.276	-0.489	0.545
VO7	76	4	3.61	0.113	0.981	0.962	-0.869	0.276	0.124	0.545
VO8	75	4	3.73	0.105	0.905	0.82	-1.348	0.277	2.083	0.548

3.7.c.1 Indicator Descriptives Dispersion Analysis

The indicator descriptives varied widely in several categories. Internal Integration and Reliability showed the lowest ranges and variances, Water Volume Flexibility, Delivery, and External Integration were generally in the middle of the ranges and variances, and EPU, Wastewater Volume Flexibility and Redundancy demonstrated the highest levels of variances and ranges. Distributions were generally negatively skewed, ranging from a -1.627 for II6 to 0.836 for EPU6. Kurtosis ranged from a -1.092 for RL2 to 4.636 for VO3. EPU kurtoses were generally lower than the others, indicating a lack of outliers in the distribution, although the ranges and variations for EPU were at the high end of the range, as shown in Table 6.

The structural equation model with no moderators is shown below in Figure 20.

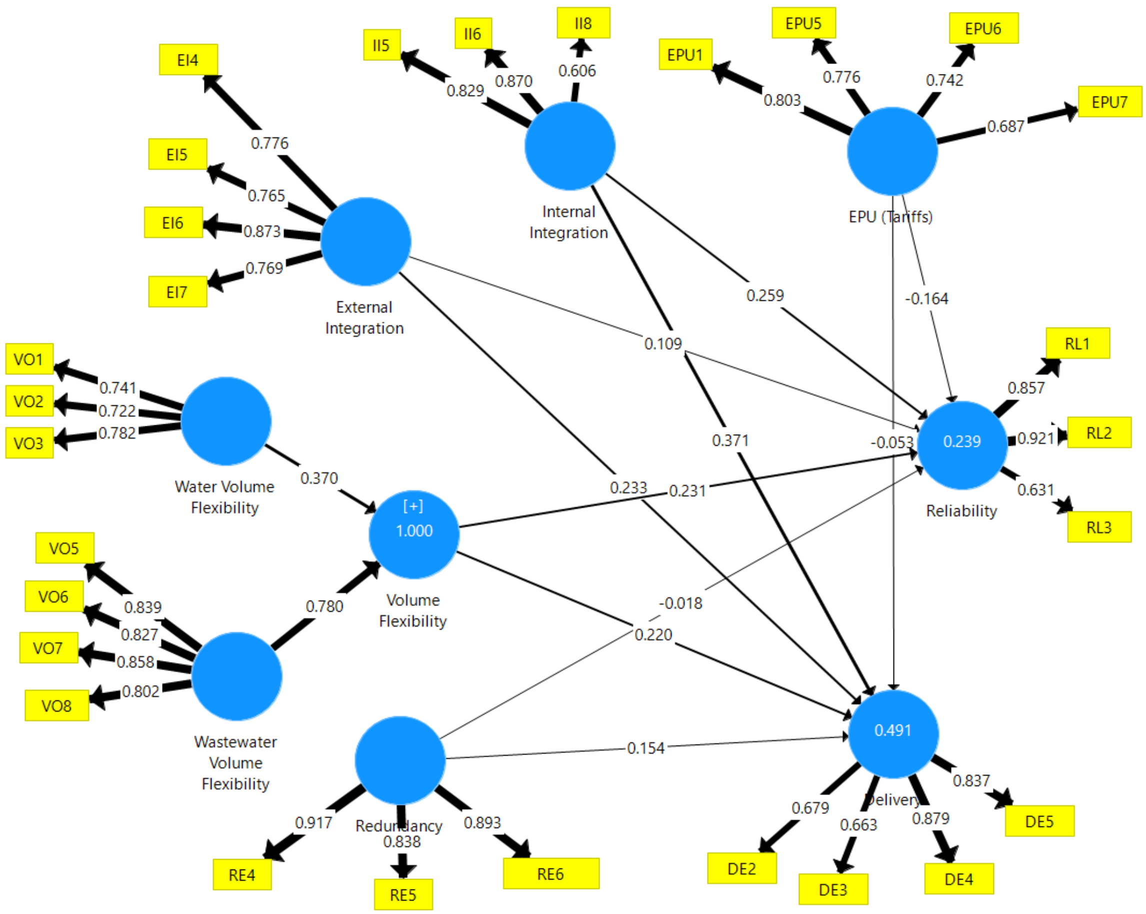

Figure 21 Structural Equation Modeling Analysis – No Moderators

Additional quality criteria, including path coefficients, latent variable correlation/covariances, construct reliability and validity, discriminant validity, and collinearity statistics, were also calculated.

Table 7 Latent Variable Correlations – No Moderators

	Delivery	EPU (Tariffs)	External Integration	Internal Integration	Redundancy	Reliability	Volume Flexibility
Delivery	1						
EPU (Tariffs)	-0.136	1					
External Integration	0.439	-0.023	1				
Internal Integration	0.604	-0.068	0.426	1			
Redundancy	0.404	-0.171	0.199	0.322	1		
Reliability	0.486	-0.208	0.237	0.395	0.195	1	
Volume Flexibility	0.432	-0.114	0.076	0.364	0.343	0.346	1

EPU, as expected, was negatively correlated with the other latent variables. However, it also demonstrated some of the lowest correlations with the constructs, as opposed to Internal Integration, which exhibited some of the highest correlations with the other constructs.

Table 8 Construct Reliability and Validity - No Moderators

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Delivery	0.766	0.792	0.852	0.594
EPU (Tariffs)	0.77	0.771	0.839	0.567
External Integration	0.812	0.83	0.874	0.635
Internal Integration	0.665	0.718	0.817	0.604
Redundancy	0.86	0.887	0.914	0.78
Reliability	0.73	0.767	0.851	0.661
Volume Flexibility	0.805	0.829	0.858	0.473

Cronbach's Alphas ranged from a low of 0.665 for Internal Integration to a high of 0.812 for External Integration. As the goal was to try and maintain a minimum average of 0.65 across the loadings for each of the constructs, and a minimum of three items per construct, the lower loading value contributed by item II8 could be the reason for the lower Cronbach's alpha score. Composite reliabilities were all greater than 0.7, and the average variance extracted is above 0.5 for all constructs except volume flexibility. Given the low number of cases (< 200), we will use composite reliability for structural equation models to determine construct reliability and validity for the constructs (R. A. Peterson & Kim, 2013).

Table 9 Discriminant Validity - Fornell Larcker - No Moderators

	Delivery	EPU (Tariffs)	External Integration	Internal Integration	Redundancy	Reliability	Volume Flexibility
Delivery	0.77						
EPU (Tariffs)	-0.136	0.753					
External Integration	0.439	-0.023	0.797				
Internal Integration	0.604	-0.068	0.426	0.777			
Redundancy	0.404	-0.171	0.199	0.322	0.883		
Reliability	0.486	-0.208	0.237	0.395	0.195	0.813	
Volume Flexibility	0.432	-0.114	0.076	0.364	0.343	0.346	0.688

Table 10 Discriminant Validity Cross Loadings - No Moderators

	Delivery	EPU (Tariffs)	External Integration	Internal Integration	Redundancy	Reliability	Volume Flexibility
DE2	0.679	-0.118	0.408	0.463	0.267	0.323	0.236
DE3	0.663	-0.02	0.206	0.368	0.212	0.362	0.369
DE4	0.879	-0.12	0.375	0.576	0.407	0.415	0.4
DE5	0.837	-0.145	0.342	0.423	0.328	0.399	0.327
EI4	0.211	-0.105	0.776	0.276	0.268	0.075	-0.034
EI5	0.374	0.056	0.765	0.38	0.121	0.142	0.175
EI6	0.387	-0.05	0.873	0.36	0.119	0.269	0.128
EI7	0.367	-0.01	0.769	0.318	0.184	0.208	-0.072
EPU1	-0.156	0.803	0.04	-0.085	-0.176	-0.164	-0.146
EPU5	0.001	0.776	0.035	0.04	-0.11	-0.168	-0.089
EPU6	-0.128	0.742	-0.124	-0.11	-0.115	-0.183	-0.047
EPU7	-0.065	0.687	0.046	0.071	-0.071	-0.025	-0.013
II5	0.484	-0.076	0.359	0.829	0.3	0.296	0.227
II6	0.572	-0.112	0.363	0.87	0.267	0.353	0.405
II8	0.312	0.072	0.261	0.606	0.172	0.267	0.18
RE4	0.396	-0.175	0.197	0.29	0.917	0.199	0.312
RE5	0.269	-0.071	0.136	0.317	0.838	0.145	0.292
RE6	0.386	-0.187	0.185	0.259	0.893	0.165	0.305
RL1	0.492	-0.145	0.244	0.335	0.121	0.857	0.28
RL2	0.431	-0.165	0.254	0.38	0.151	0.921	0.297
RL3	0.237	-0.209	0.05	0.231	0.219	0.631	0.271
VO1	0.261	-0.097	0.075	0.333	0.321	0.208	0.576
VO1	0.261	-0.097	0.075	0.333	0.321	0.208	0.576
VO2	0.126	-0.177	-0.01	0.158	0.167	0.195	0.447
VO2	0.126	-0.177	-0.01	0.158	0.167	0.195	0.447
VO3	0.285	-0.159	-0.024	0.279	0.066	0.33	0.565
VO3	0.285	-0.159	-0.024	0.279	0.066	0.33	0.565
VO5	0.419	-0.009	0.121	0.277	0.302	0.227	0.806
VO5	0.419	-0.009	0.121	0.277	0.302	0.227	0.806
VO6	0.214	-0.092	-0.07	0.125	0.201	0.164	0.791
VO6	0.214	-0.092	-0.07	0.125	0.201	0.164	0.791
VO7	0.302	-0.009	0.117	0.254	0.288	0.234	0.779
VO7	0.302	-0.009	0.117	0.254	0.288	0.234	0.779
VO8	0.403	-0.081	0.113	0.327	0.276	0.319	0.759
VO8	0.403	-0.081	0.113	0.327	0.276	0.319	0.759

The cross-loadings table demonstrates similar results as the discriminant validity table, as the indicators are properly loading on their respective constructs.

Multicollinearity statistics were all less than 4, with only two of the 25 indicators, DE4 and DE5 greater than 3. Discriminant validity results were evaluated based upon recommended guidelines (Hair et al., 2016). Fornell-Larcker criterion shows that all of the square roots of the AVEs for the five constructs were higher than the interconstruct correlations, as shown in Table 10. Discriminant validity and reliability were therefore demonstrated for all constructs, as shown in Table 9. Construct composite reliabilities range from 0.817 for Internal Integration to 0.914 for Redundancy. As discussed by Hair et al., composite reliabilities > 0.90 are generally not desirable as they might show that the indicators are measuring the same phenomena; for Redundancy, this may be the result of the way the questions were asked for the indicators that comprise the construct (Hair et al., 2016). The analysis shows coefficients of determination (R^2) for the delivery construct is 0.491, and 0.239 for the reliability construct.

As this model contains a second-order formative construct, it is necessary to conduct a second calculation for the model using the latent variable scores from the first step as the indicators for each of the latent variables in the model. The calculation method uses a two-stage approach by first employing the scores of the latent variables for the exogenous and moderator variables and then calculating the interaction between these two latent variables. The revised model is shown in Figure 22.

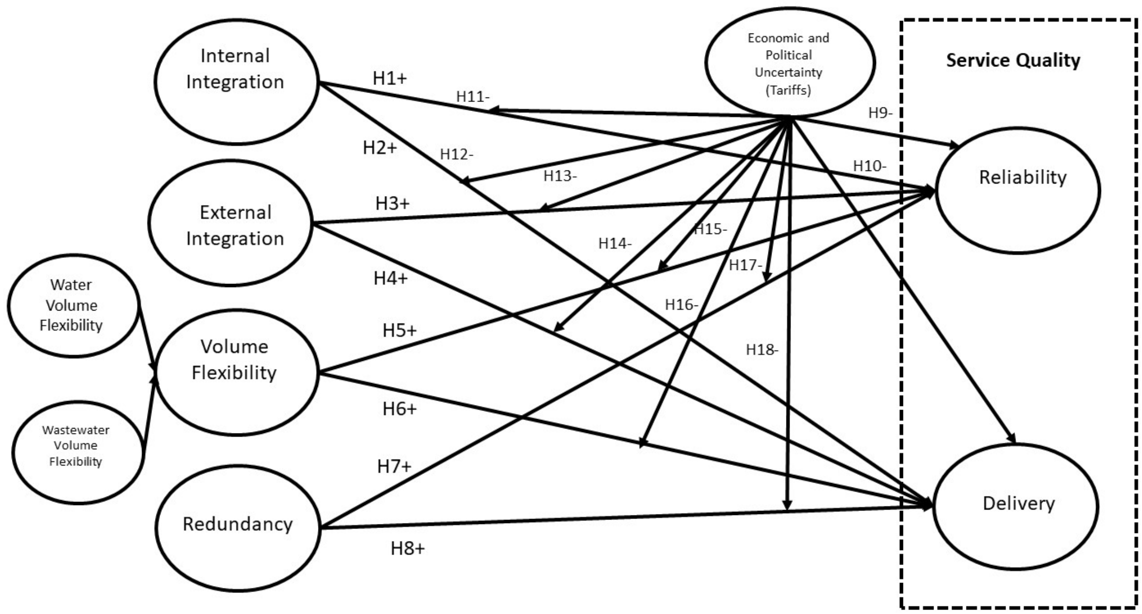

Figure 22 Revised Theoretical Model with Volume Flexibility as Second-Order Construct

Once the model was confirmed with a minimum of three indicators per construct with an average loading per construct > 0.70, bootstrapping was then run using 500 subsamples and parallel processing and a two-tailed significance level of 0.05. The revised theoretical model results, including path coefficients and p values, are shown in Figure 23.

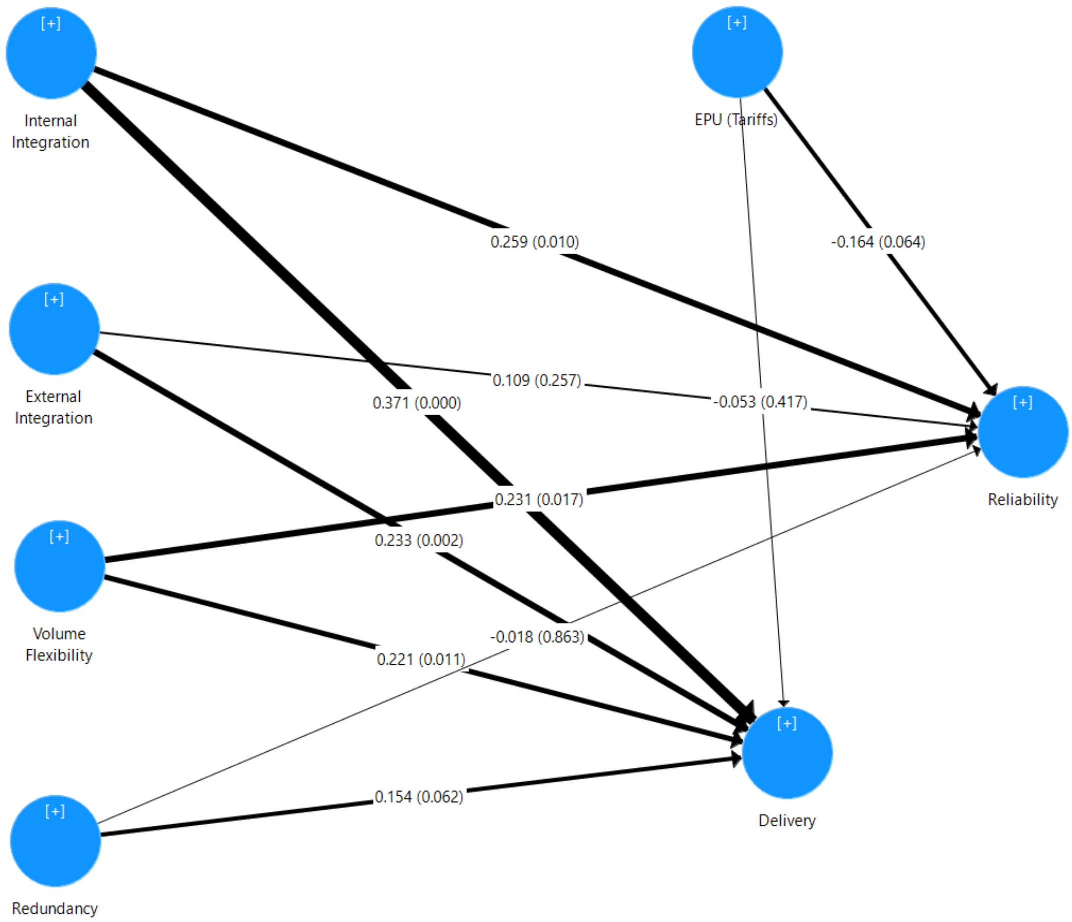

Figure 23 Structural Equation Modeling Analysis – Revised Model - No Moderators

Using a significance level of 0.10, it was determined that 7 of the ten paths, H1 - Internal Integration to Reliability, H2 - Internal Integration to Delivery, H4 - External Integration to Delivery, H5 - Volume Flexibility to Reliability, H6 - Volume Flexibility to Delivery, H8 - Redundancy to Delivery, and H9 - EPU (Tariffs) to Reliability were all significant, as shown in Table 11.

Table 11 Structural Equation Model - No Moderators - Path Coefficients and p Values

	Path Coefficients	
	Reliability	**Delivery**
Independent Variables		
Internal Integration	0.259**	0.371***
External Integration	0.109	0.233***
Volume Flexibility	0.231**	0.22***
Redundancy	-0.018	0.154**
EPU (Tariffs)	-0.164**	-0.053
Adjusted R^2	0.239	0.491
Notes *n=121, effects are significant at: *p < 0.10, **p < 0.05, *** p < 0.01*		

3.7.d Structural Equation Modeling with Moderators

EPU (Tariffs) was then introduced as a moderator in the Structural Equation Model on the H1 - Internal Integration-Reliability, H2 - Internal Integration-Delivery, H3 - External Integration-Reliability, H4 - External Integration-Delivery, H5 - Volume Flexibility-Reliability, H6 - Volume Flexibility-Delivery, H7 - Redundancy-Reliability, and H8 - Redundancy-Delivery relationships. A PLS algorithm followed by bootstrapping was run, similar to the approach used in the base model analysis, to determine pathway coefficients and their significance. The model results are shown below in Figure 24.

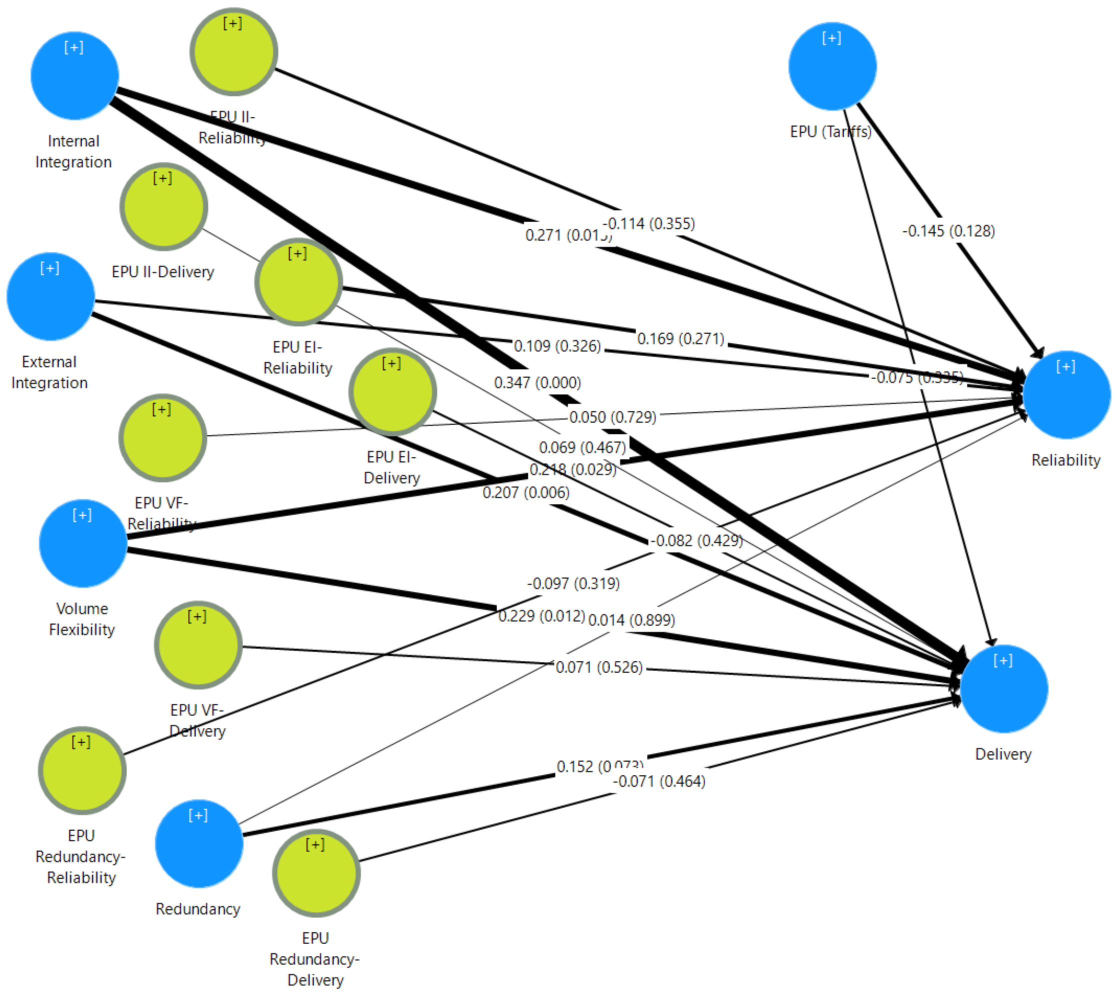

Figure 24 Structural Equation Modeling Analysis – With EPU as Moderator

Table 12 Moderated Structural Equation Model - Path Coefficients and p Values

	Path Coefficients	
	Reliability	**Delivery**
Independent Variables		
Internal Integration	0.271**	0.347***
External Integration	0.109	0.207***
Volume Flexibility	0.218**	0.229**
Redundancy	0.014	0.152*
EPU (Tariffs)	-0.145	-0.075
EPU (Tariffs) X Internal Integration	-0.114	0.069
EPU (Tariffs) X External Integration	0.169	-0.082
EPU (Tariffs) X Volume Flexibility	0.05	0.071
EPU (Tariffs) X Redundancy	-0.097	-0.071
Adjusted R^2	0.239	0.491
Notes *n=121, effects are significant at: *p < 0.10, **p < 0.05, *** p < 0.01*		

Table 12 shows the results of the analysis when when EPU as a moderator was introduced. H1 - Internal Integration-Reliability (0.271, $p < 0.05$), H2 - Internal Integration-Delivery (0.347, $p < 0.001$), H4 - External Integration-Delivery (0.207, $p < 0.01$), H5 - Volume Flexibility-Reliability (0.218, $p < 0.05$), H6 - Volume Flexibility-Delivery (0.229, $p < 0.05$), and H8 - Redundancy-Delivery (0.152, $p < 0.10$), were all supported. All of the relationships moderated by EPU (H11 – H18) as well as H3 - External Integration-Reliability, H7 - Redundancy-Reliability , H9 - EPU (Tariffs) – Reliability, and H10 – EPU (Tariffs) – Delivery were not supported at $p < 0.10$.

3.7.e. Sensitivity Analysis - Control Variables - Work Experience

Given that not all of the hypotheses were supported, a review of the control variables was conducted to identify bimodal distributions that could also be supported by prior research that, in turn could be used in a sensitivity analysis. The one control variable that met this criterion was work experience.

The extent to which individuals react to uncertainty has been shown to be influenced by their experiences with previous supply chain disruptions (Bode et al., 2011; Engau & Hoffmann, 2011). Material tariffs had been previously implemented during the Bush administration in 2002 (Ho, 2003), so individuals that were working during that period may have been able to rely on their previous experience to address the uncertainty arising from the most recent tariffs. Individuals, therefore with 15 or more years of experience, were placed in the high experience category, and those with less than 15 years were placed in the low experience category. A sensitivity analysis with high and low levels of work experience was performed, and the resulting models with path correlations and significance levels are shown in Figure 25.

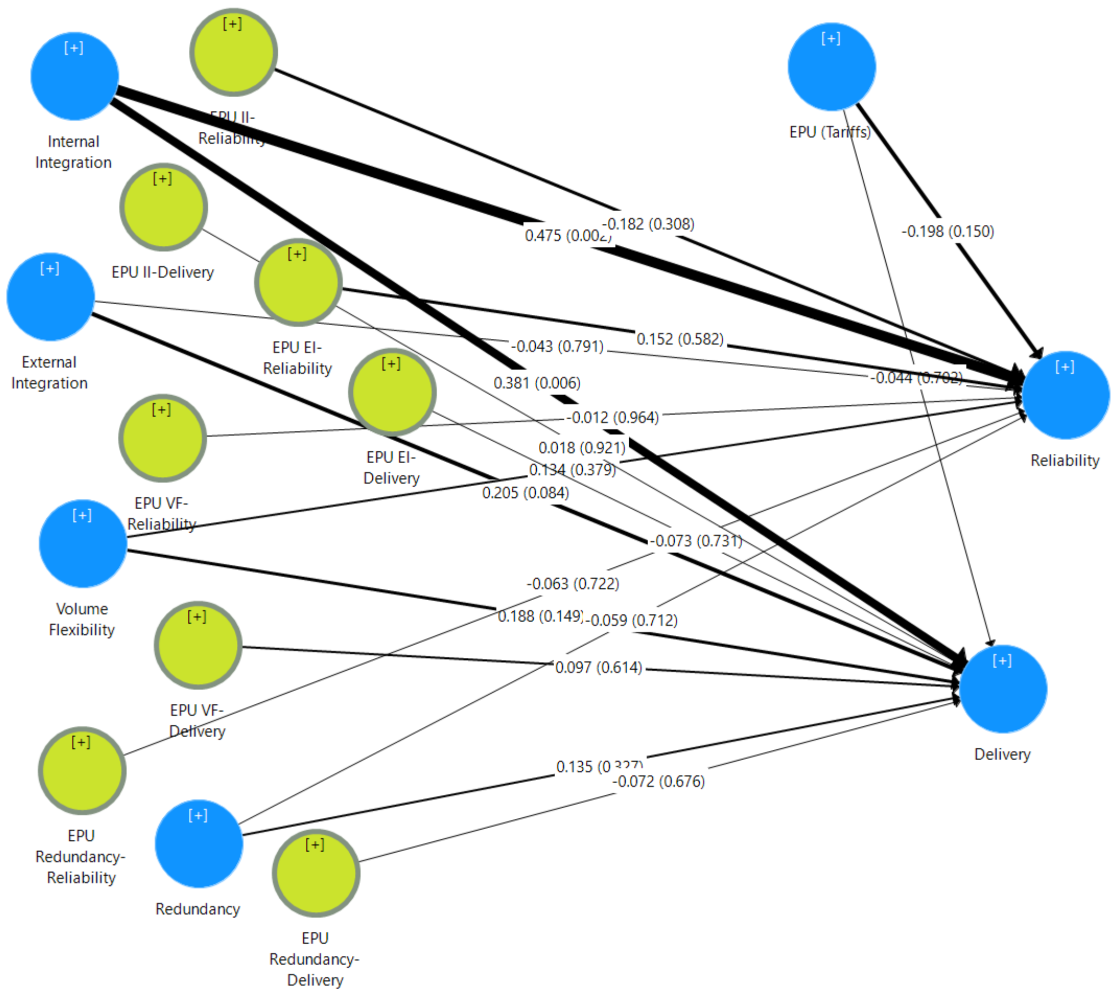

Figure 25 Structural Equation Modeling Analysis – With EPU as Moderator and Experience High

Table 13 Moderated Structural Equation Model - Path Correlations and p Values – Experience High

	Path Coefficients	
	Reliability	**Delivery**
Independent Variables		
Internal Integration	0.475***	0.381***
External Integration	-0.043	0.205*
Volume Flexibility	0.134	0.188
Redundancy	-0.059	0.135
EPU (Tariffs)	-0.198	-0.044
EPU (Tariffs) X Internal Integration	-0.182	0.018
EPU (Tariffs) X External Integration	0.152	-0.073
EPU (Tariffs) X Volume Flexibility	-0.012	0.097
EPU (Tariffs) X Redundancy	-0.063	-0.072
Adjusted R^2	0.299	0.524
Notes *n=70, effects are significant at: *p < 0.10, **p < 0.05, *** p < 0.01*		

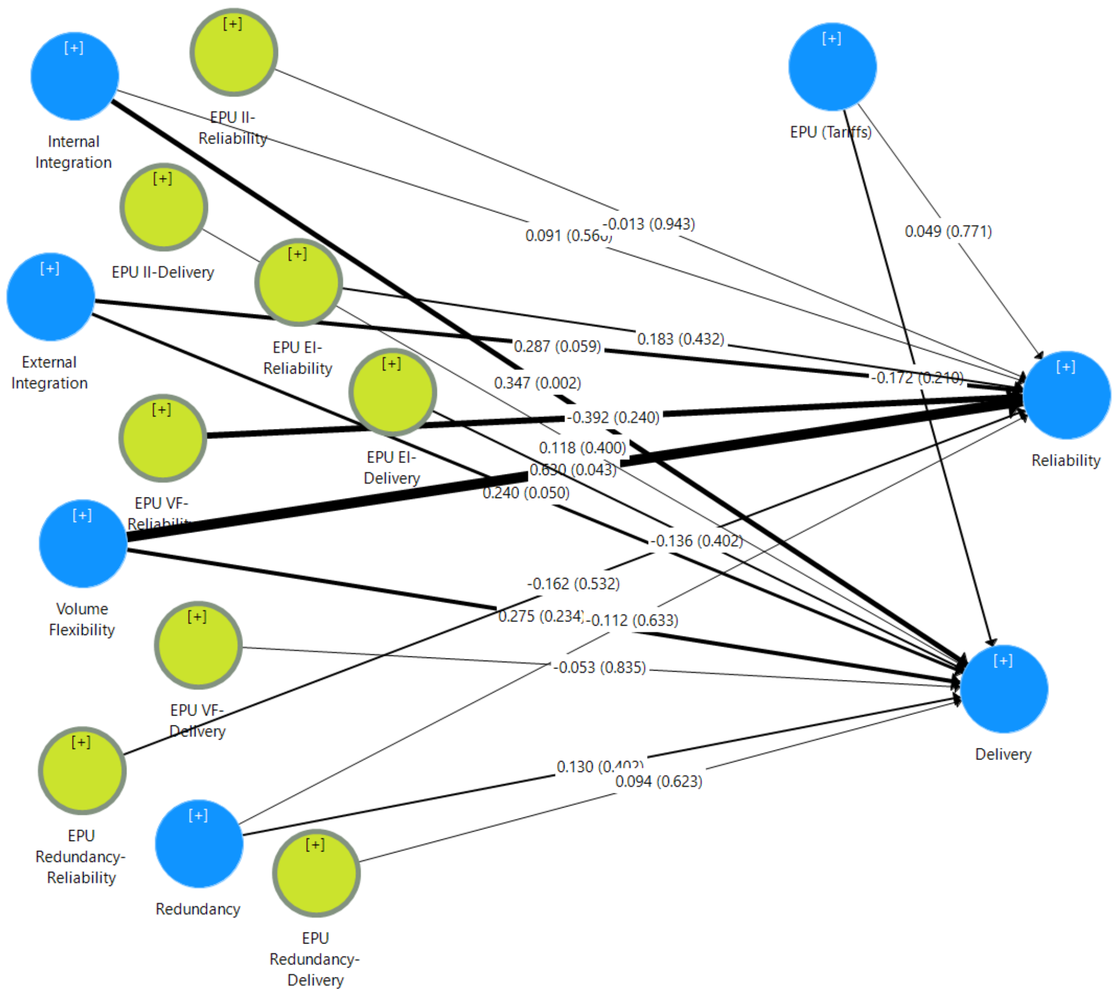

Figure 26 Structural Equation Modeling Analysis – With EPU as Moderator and Experience Low

Table 14 Moderated Structural Equation Model - Path Correlations and p Values – Experience Low

	Path Coefficients	
	Reliability	**Delivery**
Independent Variables		
Internal Integration	0.091	0.347***
External Integration	0.287*	0.240**
Volume Flexibility	0.630**	0.275
Redundancy	-0.112	0.130
EPU (Tariffs)	0.049	-0.172
EPU (Tariffs) X Internal Integration	-0.013	0.118
EPU (Tariffs) X External Integration	0.183	-0.136
EPU (Tariffs) X Volume Flexibility	-0.392	-0.053
EPU (Tariffs) X Redundancy	-0.162	0.094
Adjusted R^2	0.345	0.539
Notes *n=51, effects are significant at: *p < 0.10, **p < 0.05, *** p < 0.01*		

The sensitivity analysis for work experience resulted in only three significant paths for the high work experience level, and four for the low experience level, which is less than the six significant pathways supported by the moderated analysis inclusive of all of the data. Adjusted R^2 values were slightly higher than the full model for the low and high levels of experience. The sensitivity analysis, therefore, utilizing high and low levels of work experience did not show any effects on the significance of the pathways.

3.8 – Summary of the Results

This results section is divided into two main subsections. The first subsection relates to demographic analyses and how it enables this study to be generalized to a larger population. The second section focuses on the results of the partial least squares regression.

3.8.a Demographics

Survey respondents were typically male (85%) 35 years of age or older (95.9%), with more than 50% of the respondents having more than 15 years of experience. More than 90% of the respondents represented utilities serving less than 50,000 customers, with more than 60% of those serving 10,000 or fewer customers, the majority of those being residential (75%). More than 65% indicated they had pipes that were at least 25 years of age, which was a combined water and wastewater number. More than 70% reported they produce their own water, and when needed, 44.8% buy water. 81% of the respondents collect wastewater, 62% treat wastewater. More than 95% of the respondents maintain their own network, and more than 80% indicated they do not own other utilities. More than 95% of the respondents indicated budgeting, MRO, and pipe, and valve decisions are made locally.

3.8.b Results of the Partial Least Squares Regression

The partial least squares regression analysis was run in multiple parts, with and without moderators. The model run without moderators supported H1 - Internal Integration to Reliability (0.259, $p < 0.05$), H2 - Internal Integration to Delivery (0.371, $p < 0.01$), H4 - External Integration to Delivery (0.233, $p < 0.01$), H5 - Volume Flexibility to Reliability (0.231, $p < 0.05$). H6 - Volume Flexibility to Delivery (0.221, $p < 0.01$), H8 - Redundancy to Delivery (0.154, $p < 0.05$), and H9 - EPU(Tariffs) to Reliability (-0.164, $p < 0.05$). Once the moderator EPU was applied, six of the seven relationships were still significant, except for H9 - EPU (Tariffs) to Reliability relationship (-0.145, $p > 0.10$), and none of the moderated relationships (H11 - H18) were proven to be significant.

3.8.b.1 Internal Integration

In reviewing the items for Internal Integration, I5, I6, and I8, it was observed that all of these were primarily focused on more granular activities such as team meetings, teamwork, and individual accountability, and the excluded items were more focused on interdepartmental issues. A review of the titles submitted by the individuals surveyed demonstrates a broad range of responsibilities, from individual plant operators to town managers and public works and executive directors, perhaps implying that there is limited organizational awareness beyond an individual's own level of responsibility. Despite this fact, the analysis showed the relationships of H1 - Internal Integration to Reliability (0.259, $p < 0.05$) and H2 - Internal Integration to Delivery (0.371, $p < 0.01$) to both be significant, thus suggesting an increase in Internal Integration does significantly impact a water utility's ability to consistently deliver water to their customers, and when there are issues, the greater the degree of Internal Integration, the greater the water utility's ability to reliably address those issues.

3.8.b.2 External Integration

Only one of the two hypotheses for this construct was proven to be significant, namely H4 -External Integration to Delivery (0.233, $p < 0.01$). The items comprising External Integration were focused on the water utility's relationship with suppliers. Supplier relationships are critical to maintaining consistent production levels necessary to deliver the expected volume of water as well as to treat any wastewater generated by the customers. Given the need to ensure that the respective treatment plants and their distribution and collection systems function as expected to ensure the water utility meets customer demand, an External Integration relationship with Delivery would seem reasonable. As the Reliability items describe internal capabilities, the data suggests that supplier relationships may be less impactful to a water utility's internal competencies, thus the H3 - External Integration-Reliability relationship was not supported.

3.8.b.3 Volume Flexibility

This construct comprises both water and wastewater capabilities, with only the item addressing capacity based on increasing water demand (VO4) excluded from the analysis. Approximately 50% of the respondents indicated they buy water when needed, thus rendering additional capacity needs moot. Both the H5 - Volume Flexibility to Reliability (0.231, $p < 0.05$) and H6 - Volume Flexibility to Delivery (0.221, $p < 0.01$) hypotheses were supported. This would suggest that utilities need to ensure that they can treat their customer's required water and wastewater demand to avoid any public health crises. This analysis suggests that an increase in Volume Flexibility enhances Delivery and Reliability for a water utility.

3.8.b.4 Redundancy

In reviewing the items for this construct, it was observed that items such as designing in redundancy (RE2), as well as excess collection and distribution system capacity (RE1 and RE3), were excluded from the analysis. Items that seem to be more affected by an individual's performance, such as inventory and safety stock, were included. Delivery items address external capabilities, and the data suggests that these are significantly impacted by Redundancy, namely, the H8 - Redundancy-Delivery relationship (0.154, $p < 0.05$) was supported. The data also suggests that Redundancy does not have a significant impact on a water utility's Reliability as the H7 - Redundancy-Reliability relationship was not supported.

3.8.b.5 EPU – Direct and Indirect Effects

None of the EPU direct or indirect relationships in the moderated model were supported, which could be attributed to several reasons.

- The full impacts of material tariffs have not yet been realized.
- There is an impact of the competitive public bidding process on suppressing material costs to utilities.
- There is a mitigating impact of utility redundancy in terms of treatment, distribution, and collection capacity. Utilities might only experience these impacts when they were at or near production capacity.

- There is availability of substitute pipe materials such as polyethylene, polybutylene, polyurethane, and PolyVinylChloride (PVC).
- The degree to which utilities expect to address these issues through capital improvement projects
- The extent to which utilities believe this increased costs will persist, given the potential for changes in trade policy.
- Given the complex organizational structure of the larger utilities combined with their respective municipal budgeting processes, it might prove difficult for any one individual to fully discern the impact of the cost increases created by the material tariffs and their associated impact on a utility's ability to perform it's MRO functions successfully.

3.8.b.5.a EPU as a Moderator – Full impacts of tariffs has not been realized

Given the complexity of the water utility supply chain, it is difficult to define exactly how long it will take for the material tariffs to impact a water utility. In reviewing the responses to item EPU2, "The full effect of the iron, steel and aluminum tariffs implemented in March 8, 2018, has occurred", more than 60% of the respondents answered neither agree nor disagree, while only 18% responded that the full effect has occurred. The data suggests, therefore, that there may need to be additional time for the tariffs to take effect before we see EPU having a significant impact on any of the relationships in the model.

3.8.b.5.b EPU as a Moderator – Impact of public bidding on suppressing material cost increases

Water utilities often conduct competitive bidding processes as a means to acquire the necessary materials needed for MRO, including pipes, valves, and fittings (Abbott & Cohen, 2009). Suppliers interested in obtaining this business may choose to lower their profit margins to offset raw material cost increases driven by material tariffs. As such, a utility may not then realize the impact of the material tariffs given the supplier buffering effect.

3.8.b.5.c EPU as a Moderator – The mitigating impact of redundancy or excess design capacity

Water and wastewater treatment and distribution systems are often designed with excess capacity both to address the peak demand from the varying daily flows, anticipated future needs arising from population growth, and the need to ensure that there is always capacity to meet additional customer demand and to avoid any public health crises (Eddy et al., 2013; Edzwald, 2011; Spellman, 2003; Tchobanoglous & Burton, 1991). Given this excess capacity, the water utility may not have reached a point at which they would need additional volume, and therefore can continue to operate without incurring any additional costs from material tariffs.

3.8.b.5.d EPU as a Moderator – The availability of alternate materials

Water utilities can, in some cases, substitute different piping materials depending on the required size of the pipe, discharge pressure requirements, and the availability of alternative materials, such as polyethylene, polybutylene, polyurethane, and PolyVinylChloride (PVC). Pipe longevity can also have an impact in terms of the choice of materials (Spellman, 2003). Assuming that a utility decides to substitute materials, the effect of material tariffs, specifically iron, steel, and aluminum, is rendered moot.

3.8.b.5.e EPU as a Moderator – Capital Improvement Projects

Based on the size of a project, the urgency, and the availability of funds, a water utility might choose to implement a capital project to address a system need, such as the replacement of a water main or and upgrade to a treatment plant rather than to address it through MRO activities (Grigg, 2003). As this research is only focused on MRO activities, capital projects would be out of scope.

3.8.b.5.f EPU as a Moderator – Waiting for a policy change

Presidential elections occur every four years, and as such, the option exists to perform minimal work to maintain a system with the hope of an administration change, and a subsequent shift in trade policy, with the potential elimination of material tariffs. Although this might be considered somewhat risky, this could be a viable option depending upon the water utility's immediate need.

Chapter 4 - Conclusions, Discussions, and Future Considerations

4.1 Conclusions and Discussions

Water utilities across the United States are facing the challenges of having to maintain their aging infrastructure to ensure the highest levels of service quality, both in terms meeting customer demands for treating and delivering drinking water and collecting and treating wastewater. They also must perform these operations reliably and consistently to ensure that public health is maintained and the environment is protected. Although there are water supply and wastewater treatment alternatives for residential and commercial customers, such as private wells and septic systems, these options aren't always available or viable for customers. Local regulations, availability of groundwater, or regulatory moratoriums to decrease and ultimately eliminate the environmental impact of local treatment systems can be reasons why residential or commercial customers may decide to use a water utility's services. Utilities endeavor to support their distribution and collection networks, and water and wastewater treatment systems to the best of their ability through preventative maintenance programs, periodic upgrades, and capital improvement programs. Despite this effort, utilities may experience delivery failures, sewage overflows, and plant capacity issues resulting from aging pipes, seasonal impacts, and weather events such as flooding and extreme temperatures. Budgets to undertake these MRO activities typically come from enterprise funding generated by user fees regulated by public utility commissions. These regulatory agencies may decide to limit the extent to which water utilities can recover their full MRO costs. Water utility MRO budgets are created annually by utilizing the utility's previous experience and their best estimates as to the coming year's maintenance, repair, and operations (MRO) requirements. Utilities can rely on internal and external integration, as well as redundancy and water and wastewater volume flexibility, to ensure they effectively and efficiently meet their customer's water and wastewater demand.

The goal of this dissertation was to identify the significance of the relationships between a water utility's Internal and External Integration, Volume Flexibility, and Redundancy and a water utility's Reliability and Delivery. An additional goal was to identify if there is any significant impact of EPU as a moderator in the form of material tariffs on these relationships. The descriptive analyses and partial least squares regression results collectively helped demonstrate the significance of some of those relationships while characterizing the aspects of those utilities, including the size of the customer bases, and the experience levels and age ranges of the personnel in those respective operations.

The descriptive analyses show a significantly male-dominated industry, with experience levels, split reasonably equally between employees newer to the industry and seasoned veterans. Respondents indicated that budgeting, MRO, and pipe and valve purchasing decisions were made locally, which aided the analysis in that individuals responding to the survey were closer to the process, and therefore would seem to be better informed. The range of size of utilities also helped to ensure good representation. However, the mix of responses was more skewed to the larger utilities, suggesting that these firms may have had more available resources to respond to this survey.

The partial least squares regression analysis showed that internal integration and volume flexibility were impactful to both water utility reliability and delivery, while external integration and redundancy only significantly affected delivery. And although there was a significant relationship between economic and political uncertainty and reliability in the base model, there were no significant effects in any of the EPU moderated relationships.

The results of this empirical research suggest that utilities were not significantly impacted by the introduction of material tariffs, even when controlling for individual experience levels, especially in that the last occurrence of the imposition of material tariffs which occurred 16 years prior in 2002 during the George Bush presidency. This result could be attributed to a number of factors:

- The full impacts of material tariffs have not yet been realized. The impact of the competitive public bidding process on suppressing material costs to utilities, the mitigating impact of utility redundancy in terms of treatment, distribution and collection capacity in that utilities might only experience these impacts when they were at or near full production capacity.
- The ability to draw down existing inventory. Utilities may have considerable inventory of pipes and valves that they could use and therefore defer purchases of new supplies, which may reflect the impact of the material tariffs. More than 70% of the respondents indicated that they have inventory needed to change a pipe or valve in their system (RE4), they can easily increase their inventory levels if needed (RE5), and they maintain sufficient stock of pipe and valve inventory (RE6).
- The availability of substitute pipe materials such as polyethylene, polybutylene, polyurethane, and PolyVinylChloride (PVC) that can be used in place of iron and steel components.

- The degree to which utilities expect to address these issues through capital improvement projects, namely, obtain enterprise and/or federal funds to design and implement upgrades to existing infrastructure. These projects were not included in this research.
- The extent to which utilities believe this increased costs will persist, given the potential for changes in trade policy. Presidential elections in the United States are held every four years, and it may be possible that decision-makers might anticipate a change in elected leadership and a subsequent change in trade policy.
- Given the complex organizational structure of the larger utilities combined with their respective municipal budgeting processes, it might prove difficult for any one individual to fully discern the impact of the cost increases created by the material tariffs and their associated impact on a utility's ability to perform it's MRO functions successfully.

4.2 Research Limitations

It was decided to limit the survey to three bordering states in the Mid-Atlantic region, namely North and South Carolina, and Virginia, to minimize the impact of regional or national effects while ensuring an adequate number of responses. Initially, the goal of this research was to examine the comparative efficiencies of utilities using a data envelopment analysis. Given the shortage of available data to perform this analysis, it was then decided to move to a survey, which was more qualitative and included self-reporting. The survey was also conducted by email over a short time frame, six weeks, which may have impacted response rates. Several respondents replied via email and telephone that they wanted further confirmation that this was a legitimate survey, given their concerns over potential spam and possible attempts to penetrate their information systems. The list of survey respondents obtained from the state regulatory agencies and their websites contained numerous errors. Not all of the contacts were able to respond as they indicated by email that they would need to forward the survey on to those individuals in their utilities that were better informed on the water utility operations.

4.3 Future Considerations

Given the significance of ongoing MRO challenges faced by utilities in terms of ensuring adequate budgets to maintain and upgrade aging infrastructure, utilities must find ways to be more efficient and effective in their operations. This challenge is especially true when faced with the public opposition to implementing rate increases to offset increasing costs resulting from material tariffs. Existing excess capacity, combined with the availability of substitute materials, could provide a near term solution to this challenge. Rising demand from an increasing population will necessitate addressing inadequate treatment capabilities, lack of available space to expand distribution and collection capability, the costs of construction to add capacity, and the need for larger capacity pipes and valves. The challenges could be further impacted if these material tariffs are to persist long term. Longitudinal research could prove to be useful, assuming that material tariffs were to continue and that there was sufficient time for these effects to occur and become visible and impactful to utility personnel. It would also be desirable to expand this research nationally to increase the number of respondents and to provide additional insights into any regional or national effects. Refining and improving the list of survey respondents could also prove useful for increasing the number of respondents and the quality of their responses. Finally, given the importance of capital projects to water utilities in ensuring adequate production, distribution, collection, and treatment capacity, it could be beneficial to research the impacts of material tariffs on water utility capital projects. And as this research was more qualitative, it might also be possible to do a comparative efficiency study using data envelopment analysis to compare a water utility's costs with their outputs and to other utilities.

Prior research has reviewed the impact of natural and man-made disasters such as tsunamis, hurricanes, and strikes on supply chains of publicly traded companies. Although there has been research performed on the effects of EPU on firms in terms of trade policy, there has been little research on EPU's impacts on the supply chains of non-profit, regulated public utilities. Also, existing research on the effects of material tariffs has been historically focused on for-profit publicly-traded firms as their data is more readily available given regulatory reporting requirements. Although water utilities are non-profit monopolies, they are also regulated, and therefore unlike a pure monopoly, they may not be able to pass on costs and raise rates at will. For this reason, their budgets are limited to some degree by public willingness to fund water and wastewater operations through bonds as well as their ability to raise rates to cover increasing costs. Given the infrastructure funding deficit faced by water utilities nationally combined with the ongoing challenges to adequately fund MRO activities and upgrades, water utility managers could benefit greatly from this line of research to better inform decisions and to support policies aimed at improving water reliability and delivery for their respective utilities.

This research contributes new knowledge to this body of research in that it provides needed insights into not for profit, publicly owned, regulated monopolies, namely water utilities. We have previously defined the function of Resource Orchestration Theory (ROT) as it "describes and examines the roles of managerial actions in the process of structuring a firm's resource portfolio, bundling the resources to build relevant capabilities, and leveraging these capabilities to eventually realize a competitive advantage" (Hitt et al., 2011, p. 64). As explained previously, although publicly owned water utilities are, by definition, not for profit monopolies, they are subject to regulations. As such, water utilities cannot merely pass costs on to their consumers, and therefore must behave as if they are operating in a competitive environment. As indicated by the ASCE in their 2017 infrastructure report ("Report card for America's infrastructure," 2017), there is a one trillion dollar gap in infrastructure spending nationally. As a result, water utilities must find more efficient and effective ways to deploy their scarce resources. The imposition of material tariffs could ultimately raise costs long term for water utilities, and as such, there arises a need for this research to enable utilities to put facts to what so far has been a qualitative discussion.

5.0 References

2018 Consolidated Appropriations Act. (2018).

Abbott, M., & Cohen, B. (2009). Productivity and efficiency in the water industry. *Utilities Policy, 17*(3-4), 233-244. doi:10.1016/j.jup.2009.05.001

Alesina, A., & Rodrik, D. (1994). Distributive Politics and Economic Growth. *The Quarterly Journal of Economics, 109*(2), 465-490. doi:10.2307/2118470

Ambulkar, S., Blackhurst, J., & Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management, 33-34*, 111-122. doi:10.1016/j.jom.2014.11.002

Anwandter, L., & Ozuna, T., Jr. (2002). Can public sector reforms improve the efficiency of public water utilities? *Environment and Development Economics, 7*(4), 687-700. doi:10.1017/S1355770X02000414

AWWA. (2018). AWWA 2018 State of the Water Industry.

AWWA. (2019). *2019 State of the Water Industry Report*. Retrieved from

Baker, S. R., Bloom, N., Canes-Wrone, B., Davis, S. J., & Rodden, J. (2014). Why Has US Policy Uncertainty Risen Since 1960? *American Economic Review, 104*(5), 56-60. doi:10.1257/aer.104.5.56

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring Economic Policy Uncertainty. *The Quarterly Journal of Economics, 131*(4), 1593-1636. doi:10.1093/qje/qjw024

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management, 17*(1), 99-120. doi:10.1177/014920639101700108

Barroso, A. P., Machado, V. H., Barros, A. R., & Machado, V. C. (2010). Toward a resilient Supply Chain with supply disturbances. In (pp. 245-249): IEEE.

Berenriche, Y., & Kadi, D. A. (2015). Reliability analysis of supply chain for contingency operations. In (pp. 509-519): International Institute for Innovation, Industrial Engineering and Entrepreneurship - I4e2.

Bernanke, B. S. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics The Quarterly Journal of Economics, 98*(1), 85.

Bhaduria, S. (2018). How Tariff-Proof Is Your Supply Chain Strategy. *Industry Week*.

Blome, C., Schoenherr, T., & Rexhausen, D. (2013). Antecedents and enablers of supply chain agility and its effect on performance: a dynamic capabilities perspective. *International Journal of Production Research, 51*(4), 1295-1318. doi:10.1080/00207543.2012.728011

Bode, C., Wagner, S. M., Petersen, K. J., & Ellram, L. M. (2011). UNDERSTANDING RESPONSES TO SUPPLY CHAIN DISRUPTIONS: INSIGHTS FROM INFORMATION PROCESSING AND RESOURCE DEPENDENCE PERSPECTIVES. *The Academy of Management Journal, 54*(4), 833-856. doi:10.5465/AMJ.2011.64870145

Boissoneault, L. (2019). The Cuyahoga River Caught Fire at Least a Dozen Times, but No One Cared Until 1969. Retrieved from https://www.smithsonianmag.com/history/cuyahoga-river-caught-fire-least-dozen-times-no-one-cared-until-1969-180972444/

Borges, M. A. V. (2015). An Evaluation of Supply Chain Management in a Global Perspective. *Independent Journal of Management & Production, 6*(1). doi:10.14807/ijmp.v6i1.211

Bourgeois, L. J. (1980). Strategy and Environment: A Conceptual Integration. *The Academy of Management Review*, *5*(1), 25-39. doi:10.2307/257802

Bowen, L. (2015). Rethinking the Optimal Tariff Theory. *Chicago Policy Review*.

Braunscheidel, M. J., & Suresh, N. C. (2009). The organizational antecedents of a firm's supply chain agility for risk mitigation and response. *Journal of Operations Management*, *27*(2), 119-140. doi:10.1016/j.jom.2008.09.006

Caballero, R. J. (1991). On the Sign of the Investment-Uncertainty Relationship. *The American Economic Review*, *81*(1), 279-288.

Cabrera, E., Estruch-Juan, E., & Molinos-Senante, M. (2018). Adequacy of DEA as a regulatory tool in the water sector. The impact of data uncertainty. *Environmental Science & Policy*, *85*, 155-162. doi:10.1016/j.envsci.2018.03.028

Carvalho, H., Azevedo, S. G., & Cruz-Machado, V. (2012). Agile and resilient approaches to supply chain management: influence on performance and competitiveness. *Logistics Research*, *4*(1-2), 49-62. doi:10.1007/s12159-012-0064-2

Carvalho, H., Maleki, M., & Machado, V. C. (2012). The links between supply chain disturbances and resilience strategies. *International Journal of Agile Systems and Management*, *5*(3). doi:10.1504/ijasm.2012.047653

Charles, R. D., P;Guttikona, A;O'Connor, K. (2015). Supply Chain Risk A Utility Company Perspective. *MIT Sloan Management Review*.

Child, J. (1972). Organizational Structure, Environment and Performance: The Role of Strategic Choice. *Sociology*, *6*(1), 1-22. doi:10.1177/003803857200600101

Chopra, S., & Sodhi, M. S. (2004). Managing risk to avoid supply-chain breakdown: by understanding the variety and interconnectedness of supply-chain risks, managers can tailor balanced, effective risk-reduction strategies for their companies. *MIT Sloan Management Review, 46*(1), 53.

Christopher, M., & Peck, H. (2004). Building the Resilient Supply Chain. *The International Journal of Logistics Management*, *15*(2), 1-14. doi:10.1108/09574090410700275

Clean Water State Revolving Fund. (1987).

Corrado, C. J. (2011). Event studies: A methodology review. *Accounting & Finance, 51*(1), 207-234. doi:10.1111/j.1467-629X.2010.00375.x

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., & Handfield, R. B. (2007). The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities. *Decision Sciences, 38*(1), 131-156. doi:10.1111/j.1540-5915.2007.00151.x

Davarzani, H., Sander de Leeuw, P. D. P. P., Zanjirani Farahani, R., & Rahmandad, H. (2015). Understanding econo-political risks: impact of sanctions on an automotive supply chain. *International Journal of Operations & Production Management, 35*(11), 1567-1591. doi:10.1108/ijopm-01-2013-0021

Deane, J., Ragsdale, C., Rakes, T., & Rees, L. (2009). Managing supply chain risk and disruption from IT security incidents. *Operations Management Research, 2*(1), 4-12. doi:10.1007/s12063-009-0018-2

Dinc, I. (2005). Politicians and banks: Political influences on government-owned banks in emerging markets. *Journal of Financial Economics, 77*(2), 453-479. doi:10.1016/j.jfineco.2004.06.011

Downey, K., Hellriegel, D., & Slocum, J. (1975). Environmental Uncertainty: The Construct and Its Application. *Administrative Science Quarterly, 20*(4), 613-629. doi:10.2307/2392027

Downey, K., & Slocum, J. (1975). UNCERTAINTY - MEASURES, RESEARCH, AND SOURCES OF VARIATION. *Academy of Management Journal, 18*(3), 562.

Drazen, A. (2000). The Political Business Cycle after 25 Years. *National Bureau of Economic Reserach, 15*, 75-117.

Drinking Water State Revolving Fund. (1997).

Drinking Water State Revolving Fund 1997. (1997).

Duncan, R. (1971). THE EFFECTS OF PERCEIVED ENVIRONMENTAL UNCERTAINTY ON ORGANIZATIONAL DECISION UNIT STRUCTURE: A CYBERNETIC MODEL. In: ProQuest Dissertations Publishing.

Duncan, R. (1972). Characteristics of Organizational Environments and Perceived Environmental Uncertainty. *Administrative Science Quarterly, 17*(3), 313-327.

Eddy, M., Burton, F., Tchobanoglous, G., & Tsuchihashi, R. (2013). *Wastewater engineering: treatment and Resource recovery*: McGraw-Hill Education: New York, NY, USA.

Edzwald, J. K. (2011). Water quality & treatment : a handbook on drinking water. *Water quality and treatment*.

Engau, C., & Hoffmann, V. H. (2011). Corporate response strategies to regulatory uncertainty: evidence from uncertainty about post-Kyoto regulation. *Policy Sciences, 44*(1), 53-80.

Escalating Tariffs: Timeline and Potential Impact (IN10943). *Escalating Tariffs*.

Falco, G. J., & Webb, W. R. (2015). Water Microgrids: The Future of Water Infrastructure Resilience. *Procedia Engineering, 118*(C), 50-57. doi:10.1016/j.proeng.2015.08.403

FEDERAL WATER POLLUTION CONTROL ACT. (1972).

Gaonkar, R. S., & Viswanadham, N. (2007). Analytical Framework for the Management of Risk in Supply Chains. *IEEE Transactions on Automation Science and Engineering, 4*(2), 265-273. doi:10.1109/tase.2006.880540

Gerwin, D. (1993). Manufacturing Flexibility: A Strategic Perspective. *Management Science, 39*(4), 395-410.

Giaccotto, C., & Sfiridis, J. M. (1996). Hypothesis testing in event studies: The case of variance changes. *Journal of Economics and Business, 48*(4), 349-370. doi:10.1016/0148-6195(96)00019-7

Gligor, D. (2018). Performance implications of the fit between suppliers' flexibility and their customers' expected flexibility: A dyadic examination. *Journal of Operations Management, 58-59,* 73-85. doi:10.1016/j.jom.2018.05.002

Graham, S. (2018). Antecedents to environmental supply chain strategies: The role of internal integration and environmental learning. *International Journal of Production Economics, 197,* 283-296. doi:10.1016/j.ijpe.2018.01.005

Grigg, N. S. (2003). Water, Wastewater, and Stormwater Infrastructure Management. In (Vol. 95, pp. 144). Denver: American Water Works Association.

Grönroos, C. (1984). A Service Quality Model and its Marketing Implications. *European Journal of Marketing, 18*(4), 36-44. doi:10.1108/EUM0000000004784

Gulen, H., & Ion, M. (2015). Policy Uncertainty and Corporate Investment. *Review of Financial Studies*. doi:10.1093/rfs/hhv050

Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics, 87*(3), 333-347. doi:10.1016/j.ijpe.2003.08.003

Haimes, Y. (2006). On the definition of vulnerabilities in measuring risks to infrastructures. *Risk Anal, 26*(2), 293-296. doi:10.1111/j.1539-6924.2006.00755.x

Haimes, Y., Crowther, K., & Horowitz, B. (2008). Homeland security preparedness: Balancing protection with resilience in emergent systems. *Systems Engineering, 11*(4), 287-308. doi:10.1002/sys.20101

Haimes, Y., Matalas, N., Lambert, J., Jackson, B., & Fellows, J. (1998). Reducing Vulnerability of Water Supply Systems to Attack. *Journal of Infrastructure Systems, 4*(4), 164-177. doi:10.1061/(ASCE)1076-0342(1998)4:4(164)

Hair, J., Black, W., Babin, B., & Anderson, R. (2010). Multivariate Data Analysis: a Global Perspective. 7. global ed. In: Pearson, Upper Saddle River [inter alia].

Hair, J., Hult, G., Ringle, C., & Sarstedt, M. (2016). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed. ed.): Los Angeles : SAGE.

Hair, J., Ringle, C., & Sarstedt, M. (2011). PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice, 19*(2), 139-152. doi:10.2753/MTP1069-6679190202

Hair, J., Sarstedt, M., Pieper, T., & Ringle, C. (2012). The Use of Partial Least Squares Structural Equation Modeling in Strategic Management Research: A Review of Past Practices and Recommendations for Future Applications. *Long Range Planning, 45*(5-6), 320-340. doi:10.1016/j.lrp.2012.09.008

Hair Jr, J., Black, W., Babin, B., & Anderson, R. (2010). Multivariate Data Analysis: a Global Perspective. 7. global ed. In: Pearson, Upper Saddle River [inter alia].

Handley, K., & Limao, N. (2012). TRADE AND INVESTMENT UNDER POLICY UNCERTAINTY: THEORY AND FIRM EVIDENCE. *Working paper series.*(17790), ALL.

Henderson, G. V., Jr. (1990). Problems and solutions in conducting event studies. *Journal of Risk and Insurance, 57*(2), 282. doi:10.2307/253304

Henry, C. (1974). Investment Decisions Under Uncertainty: The "Irreversibility Effect". *amereconrevi The American Economic Review, 64*(6), 1006-1012.

Hertz, S. (2010). Dynamics of Alliances in Highly Integrated Supply Chain Networks. *International Journal of Logistics Research and Applications, 4*(2), 237-256. doi:10.1080/13675560110060009

Hitt, M. A., Ireland, R. D., Sirmon, D. G., & Trahms, C. A. (2011). Strategic Entrepreneurship: Creating Value for Individuals, Organizations, and Society. *Academy of Management Perspectives, 25*(2), 57-75. doi:10.5465/amp.25.2.57

Ho, K. (2003). Trading Rights and Wrongs The 2002 Bush Steel Tariffs. *Berkeley Journal of International Law, 21*, 825-846.

Homsy, G. C. (2018). Capacity, sustainability, and the community benefits of municipal utility ownership in the United States. *Journal of Economic Policy Reform*, 1-18. doi:10.1080/17487870.2018.1515014

Huber, G., O'Connell, M., & Cummings, L. (1975). Perceived environmental uncertainty: Effects of information and structure. *Academy of Management Journal (pre-1986), 18*(4), 725. doi:10.2307/255375

Ivanov, D., Sokolov, B., & Dolgui, A. (2013). The Ripple effect in supply chains: trade-off ‘efficiency-flexibility-resilience’ in disruption management. *International Journal of Production Research, 52*(7), 2154-2172. doi:10.1080/00207543.2013.858836

Johnston, M. (2007). A Review of the Application of Event Studies in Marketing. *Academy of Marketing Science Review, 2007*, 1.

Jones, R. A., & Ostroy, J. M. (1984). Flexibility and Uncertainty. *The Review of Economic Studies, 51*(1), 13-32. doi:10.2307/2297702

Julio, B., & Yook, Y. (2012). Political Uncertainty and Corporate Investment Cycles. *The Journal of Finance, 67*(1), 45-83.

Khalaf, M. A., & El Mokadem, M. Y. (2019). The relationship between internal integration and manufacturing flexibility in the Egyptian industry. *International Journal of Quality and Service Sciences, 11*(1), 16-33. doi:10.1108/ijqss-06-2017-0052

Lawrence, P. R. (1967). *Organization and environment : managing differentiation and integration*. Boston: Division of Research, Graduate School of Business Administration, Harvard University.

Lawrence, P. R., & Lorsch, J. W. (1967). Differentiation and Integration in Complex Organizations. *Administrative Science Quarterly, 12*(1), 1-47. doi:10.2307/2391211

Li, S., Rao, S. S., Ragu-Nathan, T. S., & Ragu-Nathan, B. (2005). Development and validation of a measurement instrument for studying supply chain management practices. *Journal of Operations Management*, *23*(6), 618-641. doi:10.1016/j.jom.2005.01.002

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling nonresponse in social science research. *Journal of Agricultural Education, 42*(4), 43-53.

Livingston, A. Bottled Water vs. Tap Water – Facts & 4 Reasons to Drink Tap. Retrieved from https://www.moneycrashers.com/bottled-water-vs-tap-water-facts/

Livingston, A. (2019). Bottled Water vs. Tap Water – Facts & 4 Reasons to Drink Tap. Retrieved from https://www.moneycrashers.com/bottled-water-vs-tap-water-facts/

Longo, S., Hospido, A., Lema, J. M., & Mauricio-Iglesias, M. (2018). A systematic methodology for the robust quantification of energy efficiency at wastewater treatment plants featuring Data Envelopment Analysis. *Water Res, 141*, 317-328. doi:10.1016/j.watres.2018.04.067

Lucas, R. E., & Prescott, E. C. (1971). Investment Under Uncertainty. *econometrica Econometrica, 39*(5), 659-681.

Majd, S., & Pindyck, R. S. (1987). Time to build, option value, and investment decisions. *Journal of Financial Economics*, *18*(1), 7-27. doi:https://doi.org/10.1016/0304-405X(87)90059-6

Mandal, S. (2012). An Empirical Investigation into Supply Chain Resilience. *IUP Journal of Supply Chain Management, 9*(4), 46-61.

Manuj, I., & Mentzer, J. T. (2008a). GLOBAL SUPPLY CHAIN RISK MANAGEMENT. *Journal of Business Logistics, 29*(1), 133-155. doi:10.1002/j.2158-1592.2008.tb00072.x

Manuj, I., & Mentzer, J. T. (2008b). Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management, 38*(3), 192-223. doi:10.1108/09600030810866986

Matthews, J. (2016). Disaster Resilience of Critical Water Infrastructure Systems. *Journal of Structural Engineering, 142*(8). doi:10.1061/(asce)st.1943-541x.0001341

Matthews, J., Piratla, K., & Matthews, E. (2014). Disaster Resilience of Drinking Water Infrastructure Systems to Multiple Hazards. In G. R. Bell & M. A. Card (Eds.), *Structures Congress 2014* (pp. 2312-2317). Reston, VA: American Society of Civil Engineers.

McWilliams, A., & Siegel, D. (1997). Event Studies in Management Research: Theoretical and Empirical Issues. *The Academy of Management Journal*, *40*(3), 626-657. doi:10.2307/257056

Metcalf, & Eddy. (1972). *Wastewater engineering: collection, treatment, disposal*. New York: McGraw-Hill.

Nekarda, C. J., & Ramey, V. A. (2011). Industry Evidence on the Effects of Government Spending. *American Economic Journal: Macroeconomics, 3*(1), 36-59. doi:10.1257/mac.3.1.36

Pagell, M., & Krause, D. R. (1999). A multiple-method study of environmental uncertainty and manufacturing flexibility. *Journal of Operations Management, 17*(3), 307-325. doi:https://doi.org/10.1016/S0272-6963(98)00049-7

Parker, R., Fried, J. (1986). Barriers to United States-Canada Trade: Problems and Solutions. *Proceedings of the Annual Meeting, 80*, 326-348.

Peterson, P. (1989). Event Studies: A Review of Issues and Methodology. *Quarterly Journal of Business and Economics, 28*(3), 36.

Peterson, R. A., & Kim, Y. (2013). On the relationship between coefficient alpha and composite reliability. *The Journal of applied psychology, 98*(1), 194-198. doi:10.1037/a0030767

Peuscher, D. (2016). *The Resource Orchestration Theory as contributor to Supply Chain Management: an assessment on its applicability.* University of Twente,

Pindyck, R. (1982). Adjustment Costs, Uncertainty, and the Behavior of the Firm. *amereconrevi The American Economic Review, 72*(3), 415-427.

Pindyck, R. (1991). Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature, 29*.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J Appl Psychol, 88*(5), 879-903. doi:10.1037/0021-9010.88.5.879

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management, 20*(1), 124-143. doi:10.1108/09574090910954873

Rees, J. A. (1998). Regulation and private participation in the water and sanitation sector. *Natural Resources Forum, 22*(2), 95-105. doi:10.1111/j.1477-8947.1998.tb00717.x

Report card for America's infrastructure. (2017). *Report card for America's infrastructure.*

Reuters. (2016). Toyota, Other Major Japanese Firms Hit by Quake Damage, Supply Disruptions. Retrieved from http://fortune.com/2016/04/17/toyota-earthquake-disruptions/

Rice, J. B., Jr., & Caniato, F. (2003). Building a secure and resilient supply network.(Response)(Industry Overview). *Supply Chain Management Review, 7*(5), 22.

Riley, J. M., Klein, R., Miller, J., & Sridharan, V. (2016). How internal integration, information sharing, and training affect supply chain risk management capabilities. *International Journal of Physical Distribution & Logistics Management*, *46*(10), 953-980. doi:10.1108/ijpdlm-10-2015-0246

Ringle, C., Wende S., and Becker J. (2018). *SmartPLS* 3. Retrieved from www.smartpls.de

Ringle, C., Wende S., and Becker J. (2018). (2018). *SmartPLS* 3. Retrieved from www.smartpls.de

Romano, G., & Guerrini, A. (2011). Measuring and comparing the efficiency of water utility companies: A data envelopment analysis approach. *Utilities Policy, 19*(3), 202-209. doi:10.1016/j.jup.2011.05.005

Santa-Clara, P., & Valkanov, R. (2003). The Presidential Puzzle: Political Cycles and the Stock Market. *JOFI The Journal of Finance, 58*(5), 1841-1872.

Santos Bernardes, E., & Hanna, M. D. (2009). A theoretical review of flexibility, agility and responsiveness in the operations management literature. *International Journal of Operations & Production Management*, *29*(1), 30-53. doi:10.1108/01443570910925352

Scholten, K., Sharkey Scott, P., & Fynes, B. (2014). Mitigation processes – antecedents for building supply chain resilience. *19*(2), 211-228. doi:doi:10.1108/SCM-06-2013-0191

Sethi, A. K., & Sethi, S. P. (1990). Flexibility in manufacturing: A survey. *International Journal of Flexible Manufacturing Systems, 2*(4), 289-328. doi:10.1007/BF00186471

Sheffi, Y., & Rice, J. B., Jr. (2005). A supply chain view of the resilient enterprise: an organization's ability to recover from disruption quickly can be improved by building redundancy and flexibility into its supply chain. While investing in redundancy represents a pure cost increase, investing in flexibility yields many additional benefits for day-to-day operations. *MIT Sloan Management Review, 47*(1), 41.

Slack, N. (1987). The Flexibility of Manufacturing Systems. *International Journal of Operations & Production Management*, *7*(4), 35-45. doi:10.1108/eb054798

Spellman, F. R. (2003). Handbook of water and wastewater treatment plant operations. *Water and wastewater treatment plant operations*.

Stradling, D., & Stradling, R. (2008). Perceptions of the Burning River: Deindustrialization and Cleveland's Cuyahoga River. *Environmental History, 13*(3), 515-535. doi:10.1093/envhis/13.3.515

Stupak, J. M. (2018). Economic impact of infrastructure investment. In ([Library of Congress public edition]. ed.). Washington, D.C: Congressional Research Service.

Swamidass, P. M., & Newell, W. T. (1987). MANUFACTURING STRATEGY, ENVIRONMENTAL UNCERTAINTY AND PERFORMANCE: A PATH ANALYTIC MODEL. *Management Science, 33*(4), 509.

Tabucchi, T., Davidson, R., & Brink, S. (2010). Simulation of post-earthquake water supply system restoration. *Civil Engineering and Environmental Systems, 27*(4), 263-279. doi:10.1080/10286600902862615

Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics, 103*(2), 451-488. doi:10.1016/j.ijpe.2005.12.006

Tang, C. S. (2007). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics Research and Applications, 9*(1), 33-45. doi:10.1080/13675560500405584

Tchobanoglous, G., & Burton, F. L. (1991). *Wastewater engineering treatment, disposal and reuse*: McGraw-Hill, Inc.

Teece, D. P., G. (1994). The Dynamic Capabilities of Firms:

An Introduction. *International Institute for Applied Systems Analysis, 94*(103).

Thanassoulis, E. (2000). The use of data envelopment analysis in the regulation of UK water utilities: Water distribution. *European Journal of Operational Research, 126*(2), 436-453. doi:10.1016/S0377-2217(99)00303-3

Tintner, G. (1941). The Theory of Choice Under Subjective Risk and Uncertainty. *Econometrica, 9*(3/4), 298-304. doi:10.2307/1907198

Trump, D. (2018). Presidential Proclamation 9705.

Urciuoli, L., Mohanty, S., Hintsa, J., & Gerine Boekesteijn, E. (2014). The resilience of energy supply chains: a multiple case study approach on oil and gas supply chains to Europe. *Supply Chain Management: An International Journal, 19*(1), 46-63. doi:10.1108/scm-09-2012-0307

USEPA. (2019a). Basic Information about Your Drinking Water. Retrieved from https://www.epa.gov/ground-water-and-drinking-water/basic-information-about-your-drinking-water

USEPA. (2019b). Municipal Wastewater. Retrieved from https://www.epa.gov/npdes/municipal-wastewater

USEPA. (2019c). Septic Systems Overview. Retrieved from https://www.epa.gov/septic/septic-systems-overview

Venkatraman, N., & Prescott, J. (1990). Environment-Strategy Coalignment: An Empirical Test Of Its. *Strategic Management Journal, 11*(1), 1. doi:10.1002/smj.4250110102

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management, 22*(2), 195-219. doi:10.1108/01443570210414329

Wagner, S. M., & Neshat, N. (2010). Assessing the vulnerability of supply chains using graph theory. *International Journal of Production Economics, 126*(1), 121-129. doi:10.1016/j.ijpe.2009.10.007

Walding, S. (2005). Performance Measurement in the Australian Water Supply Industry. In (Vol. WP012005): University of Queensland, School of Economics.

Walski, T. (1988). Reliability engineering & system safety (Online). *Reliability engineering & system safety (Online)*.

Wang, Y., Gilland, W., & Tomlin, B. (2011). Regulatory trade risk and supply Chain strategy. *Production and Operations Management, 20*(4), 522. doi:10.1111/j.1937-5956.2010.01167.x

Water Data and Tools. (2019). Retrieved from https://www.epa.gov/waterdata

Wernerfelt, B., & Karnani, A. (1987). Competitive Strategy Under Uncertainty. *Strategic Management Journal, 8*(2), 187-194.

White, R. (1960). Municipal budgets. *Journal of Accountancy (pre-1986), 109*(000004), 55.

Williams, B. (2018). Escalating Tariffs: Timeline and Potential Impact (IN10943). *Escalating Tariffs*.

Yazdani, A., & Jeffrey, P. (2012). Applying Network Theory to Quantify the Redundancy and Structural Robustness of Water Distribution Systems. *Journal of Water Resources Planning and Management, 138*(2), 153-161. doi:10.1061/(ASCE)WR.1943-5452.0000159

Yukins, C. (2010). Barriers to International Trade in Procurement after the Economic Crisis. *West Government Contracts Year In Review Conference*.

Yukins, C. (2017). The Trump Administration's Policy Options in International Procurement.

Zeithaml, V. A. (1990). Delivering quality service : balancing customer perceptions and expectations.

Zhang, Q., Vonderembse, M. A., & Lim, J.-S. (2003). Manufacturing flexibility: defining and analyzing relationships among competence, capability, and customer satisfaction. *Journal of Operations Management, 21*(2), 173-191. doi:10.1016/S0272-6963(02)00067-0

Zsidisin, G. A., Hartley, J. L., Bernardes, E. S., & Saunders, L. W. (2015). Examining supply market scanning and internal communication climate as facilitators of supply chain integration. *Supply Chain Management: An International Journal, 20*(5), 549-560. doi:10.1108/scm-10-2014-0364

6.0 Appendix

6.1 Survey on the Effects of Tariffs on Water Utilities

Key Definitions	
Network	A system of pipes, valves, and pumps to deliver drinking water or to collect wastewater
Local	Within your utility
Central	Offsite locations, e.g., in another city, state or country
MRO	Maintenance, Repair, and Operations

Thank you for agreeing to take this survey. Please check the box that best fits with your understanding of your water utility.

Part I: General Information

Job Title: ____

Gender: ☐ Male ☐ Female ☐ Prefer Not to Answer

Age: ☐ < 25 years ☐ 25 - 34 years ☐ 35 - 44 years ☐ 45 – 54 years ☐ > 55 years

Years of water utility experience: ☐ <1 ☐ 1 – 3 ☐ > 3 – 5 ☐ > 5 – 10 ☐ > 10 – 15 ☐ > 15 – 25 ☐ > 25

What type of water utility do you work for? ☐ Community ☐ Non-Public ☐ Non-Transient Non-Community ☐Transient Non-Community

How many customers does your utility serve? ☐ <1000 ☐ >1000 to 10000 ☐ >10000 to 50000 ☐ >50000 to 100000 ☐ >100000 to 250000 ☐ > 250000

What percentage is residential customers _____ and business customers ______

What is the average age of your piping and valving system? (your best guess is okay)
☐ 0 – 10 years ☐ >10 years to 25 years ☐ >25 years to 50 years ☐ > 50 years

	Yes	No	NA
We produce our own drinking water	☐	☐	☐
We buy drinking water from other utilities	☐	☐	☐
We are responsible for collecting wastewater	☐	☐	☐
We treat our wastewater	☐	☐	☐

We maintain our own network for delivering drinking water ☐ ☐ ☐
We own other water utilities ☐ ☐
Budgeting decisions are made: ☐ Local ☐ Centrally elsewhere
MRO decisions are made: ☐ Local ☐ Centrally elsewhere
Pipe/valve purchasing decisions are made: ☐ Local ☐ Centrally elsewhere

Part II Your Organization

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
All departments within our water utility are connected by a central information system (e.g., enterprise resource planning)	☐	☐	☐	☐	☐	☐
We use cross-functional teams to solve problems	☐	☐	☐	☐	☐	☐
Communications from one department to another are expected to be routed through ''proper channels''	☐	☐	☐	☐	☐	☐
Internal management communicates frequently about goals and priorities	☐	☐	☐	☐	☐	☐
Our water utility does not encourage openness and teamwork	☐	☐	☐	☐	☐	☐
When problems occur in our water utility, finding someone to blame is more important than finding a solution	☐	☐	☐	☐	☐	☐
Formal meetings are routinely scheduled among various departments	☐	☐	☐	☐	☐	☐
When problems or opportunities arise, informal, face-to-face meetings never occur	☐	☐	☐	☐	☐	☐

Part III Your Suppliers and Customers

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
Our customers give us feedback on quality and delivery performance	☐	☐	☐	☐	☐	☐
Customers frequently share their water volume needs with our water utility	☐	☐	☐	☐	☐	☐
Our water production plans are shared with our customers	☐	☐	☐	☐	☐	☐
Joint planning with suppliers is important for us	☐	☐	☐	☐	☐	☐
We give our suppliers feedback on quality and delivery performance	☐	☐	☐	☐	☐	☐
We strive to establish long term relationships with our suppliers	☐	☐	☐	☐	☐	☐
Information integration with suppliers in the supply chain is important.	☐	☐	☐	☐	☐	☐
Our supply chain employs rapid response initiatives (e.g., continuous replenishment (CR), vendor managed inventory (VMI), Just In Time deliveries)	☐	☐	☐	☐	☐	☐
It would be difficult for us to replace our suppliers	☐	☐	☐	☐	☐	☐

Part IV Water Production & Wastewater Treatment

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
We can operate efficiently at different levels of water production	☐	☐	☐	☐	☐	☐
We can quickly change the quantity of water produced	☐	☐	☐	☐	☐	☐
We can vary water output as required (daily, monthly, seasonally)	☐	☐	☐	☐	☐	☐

We always make sure we have some additional water production capacity beyond our peak demand	☐	☐	☐	☐	☐	☐
We can operate efficiently at different levels of wastewater treatment	☐	☐	☐	☐	☐	☐
We can quickly change the quantity of wastewater treated	☐	☐	☐	☐	☐	☐
We can vary wastewater treatment capacity as required (daily, monthly, seasonally)	☐	☐	☐	☐	☐	☐
We always make sure we have some additional wastewater treatment capacity beyond our peak demand	☐	☐	☐	☐	☐	☐

Part V Water Distribution & Wastewater Collection

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
We can quickly change over our distribution or collection lines if a line is out of service	☐	☐	☐	☐	☐	☐
We think of building redundancy at the design stage	☐	☐	☐	☐	☐	☐
We have sufficient alternate force main/gravity line capacity if we lose a force main/gravity line	☐	☐	☐	☐	☐	☐
We have the inventory needed to change a pipe or valve in our system	☐	☐	☐	☐	☐	☐
We can easily increase our pipe and valve inventory levels if needed	☐	☐	☐	☐	☐	☐
We maintain sufficient safety stock of pipe and valve inventory	☐	☐	☐	☐	☐	☐

Part VI Existing Tariff Impacts

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
The iron, steel and aluminum tariffs implemented on March 8, 2018 have caused a major disruption to our supply chain	☐	☐	☐	☐	☐	☐
The full effect of the iron, steel and aluminum tariffs implemented on March 8, 2018 has occurred	☐	☐	☐	☐	☐	☐
We have fully addressed the impacts of the iron, steel and aluminum tariffs implemented on March 8, 2018	☐	☐	☐	☐	☐	☐
We feel the need to be alert at all times for possible supply chain disruptions caused by material tariffs	☐	☐	☐	☐	☐	☐
Material tariffs are creating a fast-changing environment	☐	☐	☐	☐	☐	☐
Our material cost and expenses are reasonably predictable	☐	☐	☐	☐	☐	☐
The possibility of future material tariffs is a major source of uncertainty	☐	☐	☐	☐	☐	☐

Part VII – Maintenance & Customer Responses

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
We solve our water supply problems quickly	☐	☐	☐	☐	☐	☐
We solve our water supply problems right the first time (correctly and completely)	☐	☐	☐	☐	☐	☐
We solve our water supply problems in the time promised to our customers	☐	☐	☐	☐	☐	☐
We consistently keep our maintenance records up to date	☐	☐	☐	☐	☐	☐
Our maintenance records are accurate	☐	☐	☐	☐	☐	☐

Part VIII – Water Delivery & Wastewater Collection

	Strongly disagree	Disagree	Neither Agree Nor disagree	Agree	Strongly Agree	NA
We provide our customers with the volume of water they require	☐	☐	☐	☐	☐	☐
Our customers receive water when they need it	☐	☐	☐	☐	☐	☐
We rarely have to ration or restrict water usage	☐	☐	☐	☐	☐	☐
We treat all of our customers wastewater	☐	☐	☐	☐	☐	☐
We can collect all of our customer's wastewater	☐	☐	☐	☐	☐	☐

Thank you for completing this survey and for your support of this project. Is there anything additional you would like to add that was not covered by this survey? Please add your comments below.

6.2 Sample Electronic Invite

A Fraher – Doctoral Research Survey – Email Invite

Sample email introduction

Dear ______

My name is Andy Fraher, I am working toward a doctorate in business administration at the University of North Carolina, Charlotte (UNCC) and would appreciate your assistance in completing my dissertation research, I am working to understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers. You have been identified as someone who may be engaged with the operation and/or maintenance of drinking water treatment and or distribution systems, and/or wastewater collection and treatment systems for your water utility.

Below is a link to the survey that should take no more than 10-15 minutes to complete. All results received from the survey were secure, and will not be shared with any marketers or consumers as required by UNCC's Institutional Review Board (IRB), Study #xx-xxxxx. If you have any questions about the survey, you may contact me, Andrew Fraher, afraher@uncc.edu or contact my faculty advisors, Moutaz Khouja (mkhouja@uncc.edu), or Kexin Zhao (kzhao2@uncc.edu). The survey were open until xx/xx/xxxx.

[Link here]

Your participation is very important to obtaining results that will help understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers. If you feel there are personnel in your water utility that may be better qualified to respond to this survey please feel free to forward this invitation to them.

Thank you for your help with this important research.

Email follow up

Dear _____

My name is Andy Fraher, I am working toward a doctorate in business administration at the University of North Carolina, Charlotte (UNCC) and would appreciate your assistance in completing my dissertation research, I am working to understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers.

Approximately two weeks ago I had sent you an email requesting your help with my dissertation research, and am following up to ask you if you could complete that survey by xx/xx/xxxx so that I can include your responses in this important study.

Thank you for your participation.

6.3 Sample Physical Survey Script

Hello, my name is Andy Fraher, I am working toward a doctorate in business administration at the University of North Carolina, Charlotte (UNCC) and would appreciate your assistance in completing my dissertation research, I am working to understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers. I am looing to speak with personnel who may be engaged with the operation and/or maintenance of drinking water treatment and or distribution systems, and/or wastewater collection and treatment systems for your water utility.

Are you involved in any of these activities?

If no - Thank them for stopping

If yes, ask may I ask you to fill out this brief survey? It should only take about 10-15 minutes of your time. You can either do it here with me asking the questions or you can fill it out yourself, or if you are pressed for time you can take it with you and return it at your earliest convenience. If you decide you do not want to complete it could you also please return it to me so I can track non-responses?

And then I would thank them for their time.

6.4 Physical Consent Form

Consent to be Part of a Research Study

Title of the Project: How Tariff-driven Economic and Political Uncertainty Affect Water Utilities' Service Quality

Principal Investigator: Andrew Fraher, Doctoral Candidate, University of North Carolina Charlotte

Faculty Advisor: Dr. Moutaz Khouja, Professor of Operations Management, University of North Carolina Charlotte

Faculty Advisor: Dr. Kexin Zhao, Professor of Management Information Systems, University of North Carolina Charlotte

You are invited to participate in a research study. Participation in this research study is voluntary. The information provided is to help you decide whether or not to participate.

<u>Why are we doing this study?</u>

The purpose of this study is to understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers.

<u>Why are you being asked to be in this research study?</u>

You are being asked to be in this study because you are knowledgable in this area, and your feedback is critical to the advancement of this research.

<u>What will happen if you take part in this study?</u>

If you choose to participate in this study, you were asked to complete a survey that consists of 76 questions

Your time commitment were about 20 minutes.

<u>What benefits might you experience?</u>

This study will gather valuable input from you to better understand the impact of iron, steel, aluminum, and other tariffs on your water utility. In addition, this study could inform future material tariff policy decisions.

<u>What risks might you experience?</u>

There is no known risk, and please leave any indicator blank that you are unable to answer.

<u>How will your information be protected?</u>

We do not ask you for your name or your utility's name. Given we do ask you for other unique identifiers including your title, gender, age, years of experience, type of utility in which you are employed as well as some characteristics of your utility, we will separate this identifying information from the rest of your responses and store it in a password-protected, encrypted file that will only be accessible by the primary investigator and their supervisors in order to protect your confidentiality.

We plan to publish the results of this study. We will separate any identifying information from the rest of your responses and store it in a password-protected, encrypted file that will only be accessible by the primary investigator and their supervisors in order to protect your confidentiality.

<u>How will your information be used after the study is over?</u>

After this study is complete, study data may be shared with other researchers for use in other studies without asking for your consent again or as may be needed as part of publishing our results. The data we share will NOT include information that could identify you.

<u>Will you receive an incentive for taking part in this study?</u>

No incentive were provided for taking this survey.

<u>What are your rights if I take part in this study?</u>

It is up to you to decide to be in this research study. Participating in this study is voluntary. Even if you choose to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer. We reserve the right to utilize or discard incomplete surveys

Who can answer your questions about this study and your rights as a participant?

For questions about this research, you may contact the principal investigator Andrew Fraher at afraher@uncc.edu, or either of the faculty advisors, Dr. Moutaz Khouja at mkhouja@uncc.edu, or Dr. Kexin Zhao at kzhao2@uncc.edu

If you have questions about your rights as a research participant or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704-687-1871 or uncc-irb@uncc.edu.

6.5 Online Consent Form

Consent to be Part of a Research Study

Title of the Project: How Tariff-driven Economic and Political Uncertainty Affect Water Utilities' Service Quality

Principal Investigator: Andrew Fraher, Doctoral Candidate, University of North Carolina Charlotte

Faculty Advisor: Dr. Moutaz Khouja, Professor of Operations Management, University of North Carolina Charlotte

Faculty Advisor: Dr. Kexin Zhao, Professor of Management Information Systems, University of North Carolina Charlotte

You are invited to participate in a research study. Participation in this research study is voluntary. The information provided is to help you decide whether or not to participate.

Why are we doing this study?

The purpose of this study is to understand the effects of iron, steel, aluminum, and other tariffs on a water utility's ability to reliably produce and deliver water to their customers.

Why are you being asked to be in this research study?

You are being asked to be in this study because you are knowledgable in this area, and your feedback is critical to the advancement of this research.

What will happen if you take part in this study?

If you choose to participate in this study, you were asked to complete a survey that consists of 76 questions

Your time commitment were about 20 minutes.

What benefits might you experience?

This study will gather valuable input from you to better understand the impact of iron, steel, aluminum, and other tariffs on your water utility. In addition, this study could inform future material tariff policy decisions.

What risks might you experience?

There is no known risk, and please leave any indicator blank that you are unable to answer.

How will your information be protected?

We do not ask you for your name or your utility's name, and we will not collect your IP or email address. Given we do ask you for other unique identifiers including your title, gender, age, years of experience, type of utility in which you are employed as well as some characteristics of your utility, we will separate this identifying information from the rest of your responses and store it in a password-protected, encrypted file that will only be accessible by the primary investigator and their supervisors in order to protect your confidentiality.

We plan to publish the results of this study. We will separate any identifying information from the rest of your responses and store it in a password-protected, encrypted file that will only be accessible by the primary investigator and their supervisors in order to protect your confidentiality.

How will your information be used after the study is over?

After this study is complete, study data may be shared with other researchers for use in other studies without asking for your consent again or as may be needed as part of publishing our results. The data we share will NOT include information that could identify you.

Will you receive an incentive for taking part in this study?

No incentive were provided for taking this survey.

What are your rights if I take part in this study?

It is up to you to decide to be in this research study. Participating in this study is voluntary. Even if you choose to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer. We reserve the right to utilize or discard incomplete surveys

Who can answer your questions about this study and your rights as a participant?

For questions about this research, you may contact the principal investigator Andrew Fraher at afraher@uncc.edu, or either of the faculty advisors, Dr. Moutaz Khouja at mkhouja@uncc.edu, or Dr. Kexin Zhao at kzhao2@uncc.edu

If you have questions about your rights as a research participant or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704-687-1871 or uncc-irb@uncc.edu.