Bridging the Gap:
Using Actor Network Theory to Map Sociotechnical Forces in Air Pollution-Affected Communities

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

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Introduction:

Air pollution is a clear and present danger not only to the environment, but to individuals and communities as well. Nitrogen dioxide, one of the most common pollutants emitted from power plants, factories, and vehicles alike, has been linked to dire health issues such as lung & breast cancer (Vermuelen et al, 2019 & White et al, 2019), infertility (Gaskins et al, 2019), and complications with pregnancy and birth defects (Ji et al, 2019), to name only a few. The World Health Organization states that air pollution is the single largest global environmental health risk (Delmas & Kohli, 2020), and Oxford University attributes almost 5 million deaths worldwide in 2017 to air pollution (Ritchie & Roser, 2019) as shown in the figure below.

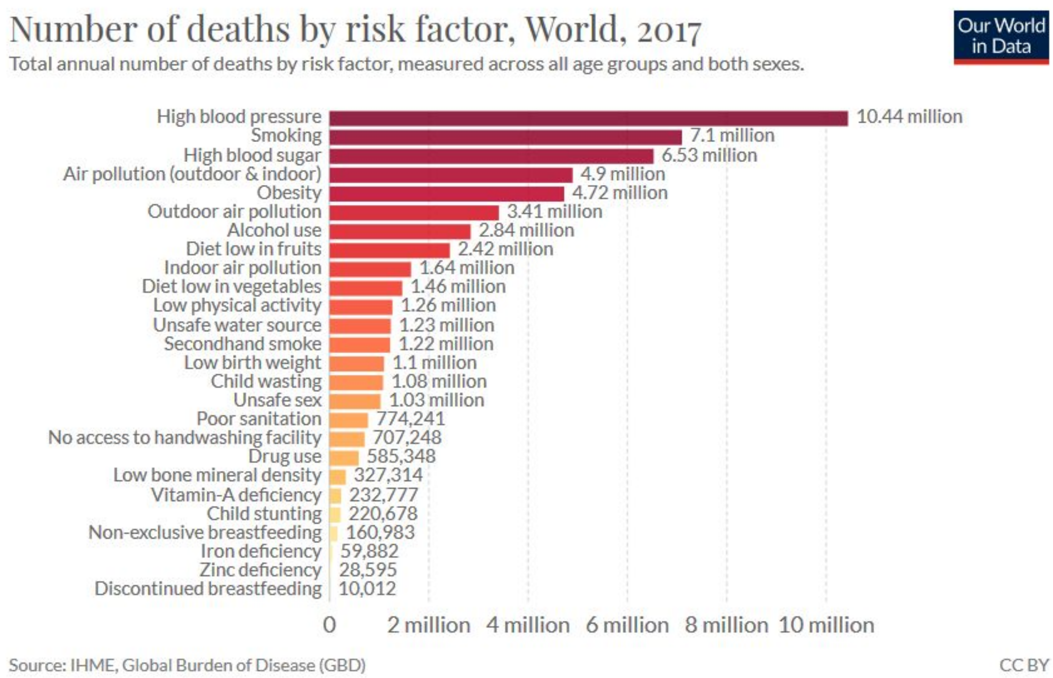

Figure 1: Number of deaths by risk factor (Ritchie & Roser, 2019). Air pollution is the fourth largest contributor to deaths worldwide, and the number one risk factor for low-income households.

While much research has been done into the adverse health effects on large populations, far less is known about the local and community-wide effects of air pollution, as well as the organizational and cultural steps that need to be taken to protect against these adverse effects. Administrations are moving to address these negative effects, but such top-down initiatives must be met by movement from the bottom; that is, individuals and communities must be educated and motivated to mitigate air pollution in order for tangible change to take root. The high death rate attributed to air pollution is not due to a lack of scientific information regarding its adverse effects. Rather, it is due to a lack of information and education on healthy practices coupled with a cultural and systemic rigidity that makes it difficult for the most vulnerable groups to mitigate the adverse health effects of air pollution. In this paper, I demonstrate that Actor Network Theory can be a powerful tool to analyze communities affected by air pollution and identify the organizational, technical, and cultural factors that help or hinder air pollution reformation. To this end, I explore three studies on communities affected by air pollution, examine the attempts to disseminate and communicate pertinent information to the communities involved, and assess the effectiveness of these measures and their feasibility when transplanted across countries and cultures.

Defining the Problem: The Gap Between Knowledge of Issues & Knowledge of the Solution

As mentioned in the introduction, air pollution is already known to cause a variety of major and minor health issues. In East Asia, lung cancer rates are the highest in the world, even when controlling for nonsmokers (Vermuelen et al, 2019). In a recent joint study conducted by public health research institutions in the US, Singapore, and China, researchers found that nonsmoking women living in the Chinese province of Xuanwei have some of the highest lung cancer rates in the world. Residents of Xuanwei live predominantly in rural areas, and the majority work as subsistence farmers, using coal and other solid fuels to heat their houses, cook meals, and power equipment. The study demonstrated a strong correlation between the high rate of exposure to the byproducts of these fuels and the rate of lung cancer among nonsmoking women in the province. But while the study concludes with this correlation, we can draw further valuable inferences. The individuals' awareness of the long-term danger of burning these fuels is irrelevant; the culture, livelihood, and lifestyle of these subsistence farmers has naturally progressed to the point that the burning of these fuels and the health complications they cause is an inherent and apparently immutable part of their lives.

Poland accounts for only 5.4% of the population of Europe, but is home to 33 of the 50 most polluted cities in Europe (Price et al, 2018). With a significant population of at-risk citizens (due to age and/or medical conditions), air pollution contributes to the deaths of over 45,000 Polish citizens a year, as of 2015 (European Environmental Agency, 2015). In an attempt to understand risk factors and classify the types of individuals at risk from air pollution, the Medical University of Warsaw conducted a survey among hospital patients identified to be at "high risk of adverse health effects from air pollution (Price et al, p. 46)". The survey scored each patient in "Awareness [of the risks of air pollution]" and "Personal Protection and Access to Information" (Price et al, p. 47). While Awareness scores were high across a range of ages, genders, and education levels, the study found that all participants scored significantly lower in Personal Protection. Despite over 80% of respondents reporting they "considered pollution dangerous", only 20% agreed that they had sought out additional information (Price et al, p. 50). Only 43% of the participants agreed they knew where to find information, and less than 30% knew when official pollution alerts had been issued. Most alarmingly, a third of patients did not agree that it was even possible to check a pollution forecast (Price et al, p.50). The figure below shows in detail the results of the "Personal Protection" segment of the survey.

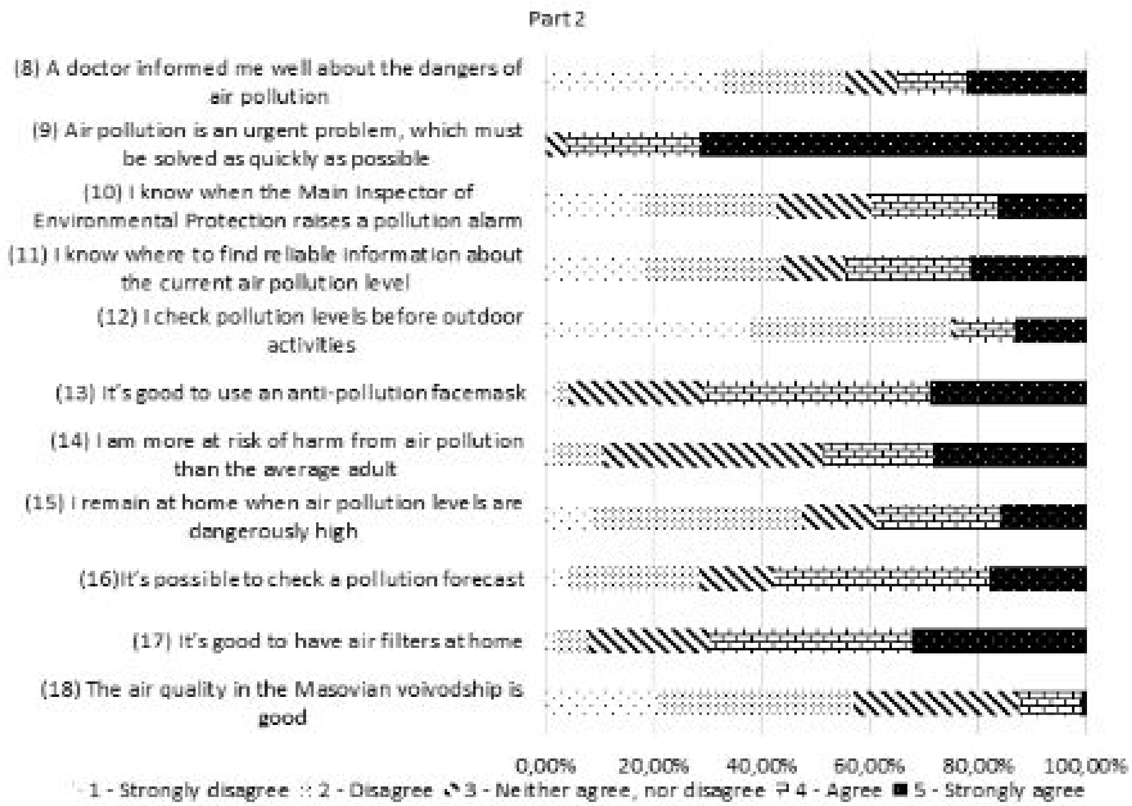

Figure 2: Responses to the "Personal Protection and Access to Information" (Price et al, p. 51). The results show a divide between awareness of the problem and knowledge of effective safety practices

It is important to note that this study controlled for gender, age (under 65 years and over 65 years old), and level of education ("primary education" or "secondary or higher" - Price et al, p. 51). Notably, participants over 65 years and participants with only primary education scored significantly lower than the younger and more educated groups - indicating that higher education and 'technological literacy' could both be barriers to personal protection and prevention of the harmful effects of air pollution. In other words, the highly technical nature of resources on air pollution, as well as the unintuitive complexity of new technological media, is a stronger barrier than the content of the information itself.

The methods used to communicate critical information about air pollution and its risks are as important as the content being communicated. Price et al. briefly mention a smartphone app, “Kanarek”, brought up by three participants as a source of air pollution information - the app presents data from the Polish Chief Inspectorate of Environmental Protection as notifications, widgets, and simple graphs (Price at al, p. 51). While this is not expanded upon in the Warsaw study, smartphone apps are a promising avenue for communicating air pollution & health information.

Pre-existing research on methods of communicating air pollution and health information builds on human behavioral theory, centering on motivation, triggering behavioral change, and forming habits (Delmas & Kohli, 2020). In their research, Delmas & Kohli developed an app that could communicate real-time air pollution data and recommend healthy practices. They then used the app to study how constant exposure to both air quality information and health tips influenced users’ daily habits through user-feedback surveys built into the app. The app, AirForU, utilizes two main elements to facilitate changes in users’ intentions and behavior.The first element helps users to learn the importance of air pollution health problems. In Delmas & Kohli’s words, “realizing there is a problem helps people develop intentions to change their behavior (p. 281)”. The second element gives users the ability to learn helpful health protection tips. This “helps people realize how they can affect the problem (Delmas & Kohli, p. 281)”.

The combination of real-time pollution data and instructions on how to modify behavior provides a mechanism by which users are able to associate pollution data with their personal situation, and use the constant stream of information and tips to build better habits. This pattern of behavioral change is expanded upon in the image below.

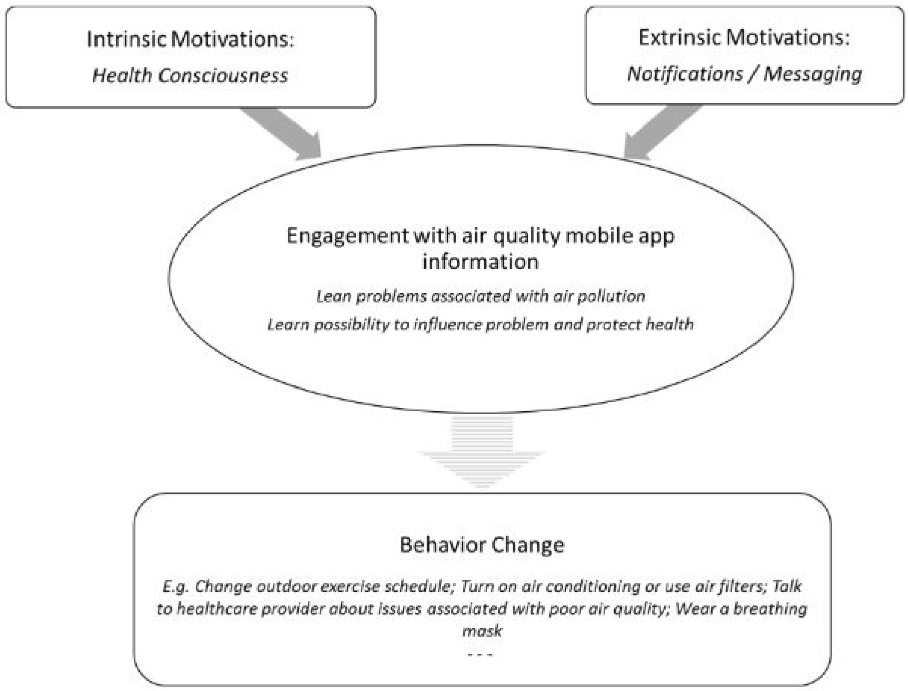

Figure 3: Engagement with air quality mobile application (Delmas & Kohli, 2020). The users' intrinsic motivations of health-consciousness couple with the app's extrinsic motivations to encourage behavioral change.

While the purpose of this research is broader in scope, the same general idea applies; Localized air quality data is most valuable to those affected by it; i.e., if the data shows a cyclical rise and fall of air pollution around a large freeway during rush hour, then the communities that stand to gain the most from this information are those homes and businesses alongside the freeway. But how do we bridge the gap between providing personal information and helping at-risk populations develop better habits and practices to protect against the harmful effects of air pollution? In the next two sections, I will first explain proper methodology for using Actor Network Theory to analyze communities affected by air pollution. Then I will demonstrate this method's effectiveness by using it to analyze, compare, and contrast the three communities present in the aforementioned studies.

Drawing the Blueprint: The Interplay Between Culture, Organization, and Technology

Actor Network Theory, a theoretical approach to social theory pioneered by Bruno Latour, Michael Callon, and John Law in the 1970's, distances itself from earlier systems of sociotechnical analysis by eschewing deterministic explanations of technological and social forces and movements. Instead it looks at sociotechnical phenomena as a web - a network - of interconnected actors: individuals, organizations, and cultures all involved with and influencing each other. It is particularly notable for being the first sociotechnical analysis framework to include nonhuman technical artifacts in its analysis of social forces. Latour further expands upon this critical concept in his work, "Where are the Missing Masses? The Sociology of a few Mundane Artifacts". Latour's central idea of this article is that, in order to understand what role a technology artifact plays in its broader network, one must examine what human work it replaces (Latour, p. 154-155). This frame of mind works equally well for simple artifacts (a door replacing the human action of knocking a hole in the wall and then sealing it back up each time they want to enter or exit the room) or intricate technologies (an air quality smartphone app replacing the human process of experimentally determining the harmful effects of air pollution, pinpointing the locations and intensity of said pollution, and then synthesizing healthy personal habits and medical practices to mitigate its negative effects).

However, Latour goes beyond simply ascribing human actions to technical artifacts. By creating these technologies to replace human action, he argues, we attribute to them human characteristics and morality - the idea of technological anthropomorphism (Latour, p.159). This is not the idea of morality as a sense of good and evil, but rather the idea that as a technology completes an action, it also endorses that action. A pneumatic door porter that automatically closes an opened door has the same (or even greater) authority as a sign telling people to close the door in the sense that it is even more effective at enforcing its sign than a simple verbal reminder (Latour, p. 160). The larger concept that technology is created by humans and, as such, is influenced by the bias and morality of its human creators, is central to any analysis that encompasses both human and nonhuman actors. Using Latour's theory of technical artifacts and anthropomorphism, I will explore not only the human and technological actors present in all three aforementioned studies, but the drawbacks and implications of the environments and social forces in which those technologies arose. Additionally, Arnold Pacey provides three excellent perspectives from which to view actors: cultural, organizational, and technical. Sociotechnical forces can influence and be influenced by the culture of the time and place, the manner in which an authoritative institution behaves, and the technical processes that lead to and from these sociotechnical forces (Neeley, p. 40-42). A visualization of these perspectives is provided below.

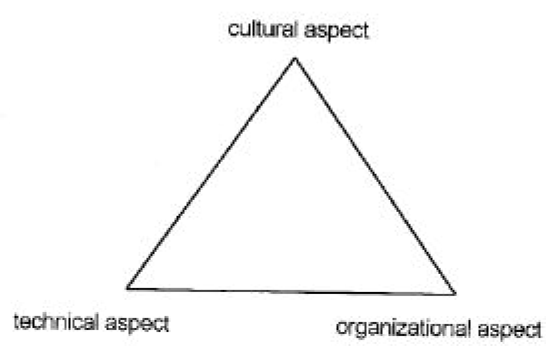

Figure 4: Key elements of any set of technology related practices (Neeley, p. 42, adapted from Pacey's Culture of Technology). The perspectives from which social forces act and react can be used to classify actors within an actor network.

In addition to understanding the circumstances that allow air pollution awareness and activism to flourish or fail, I explore the factors of success of Delmas & Kohli's air pollution smartphone app and whether this success can be applied to other scenarios. In order to achieve this, I use the framework laid out in Arnold Pacey's "The Culture of Technology". In his chapter on innovative dialog, Pacey begins a discussion on cultural exchanges of technology. Drawing from examples both successful - such as Inuits' adoption of snowmobiles and high-powered rifles in their traditional livelihood of fur trade (Pacey, p. 143), and unsuccessful - such as the failed introduction of western-style concrete grain silos in Africa, which overheated and caused grain to spoil (Pacey, p. 151), Pacey establishes that a technology's success or failure relies as much on a culture's ability and willingness to adopt and integrate it as the merits of the technology itself - reinforcing the importance of the 'Cultural' perspective of technology. The ability to comprehend the essence of a technology apart from its cultural influences (What Pacey labels "Collaborative Innovation" [p. 151-152]) is vital for distinguishing the intrinsic innovations of a technology from the cultural and organizational factors that may stifle it or allow it to flourish.

The first step in my analysis is identifying the actors in each scenario. Prout defines actors as any "source of an action regardless of its status as a human or non-human" (Prout, p. 201). Since most definitions of actors are intentionally vague (due to the inherent flexibility of actor network theory), we will begin by categorizing the actors as organizational, cultural, or technical. Next, a rudimentary actor network diagram will be created for each study. In the case of the Warsaw and Xuanwei studies, the actor networks focus more on the participants in each study and the social forces that impact them throughout their respective studies. In the case of

AirForU, Delmas & Kohli's experimental air pollution smartphone app, the actor network centers around the technical aspects of the app itself (in other words, the innovations that allowed it to succeed), as well as the organizational and culture aspects (i.e. the infrastructure and cultural values that let the app flourish). Finally, the three actor networks will be compared and contrasted towards the goal of understanding the success of AirForU. Pictured below is a simple visualization of my three-step method.

Figure 5: Method map. The method I have developed to generate and analyze actor network theories can be broken into three elementary steps.

As mentioned previously, analyzing the actor networks of each scenario is only half of the research process. After the actor networks for each scenario are categorized and constructed, each must be analyzed for its own merits and restrictions. I use Pacey's concept of Collaborative Innovation to further distance the innovations of the technology from the aspects of its culture and organization and explore these relationships within and between each distinct actor network. While success cannot be quantified in any of these situations, I expect to find enough qualitative evidence in each scenario to support or refute the success of a similar app to Delmas & Kohli's AirForU. Ultimately, the intention of this process is simply to demonstrate its own effectiveness; as long as useful conclusions can be drawn, I have demonstrated the viability of using Actor Network Theory to compare and contrast air pollution-affected communities.

Building the Bridge: the Importance of Infrastructure and Environment

Upon categorization and construction of actor networks, a few notable discoveries stand out. I will first briefly discuss the actor networks of each individual study, then explore the similarities and differences between them, and finally assess the feasibility of an air pollution resource similar to AirForU in the context of the other two studies.

The Actor Network for the Xuanwei Lung Cancer Study is pictured below:

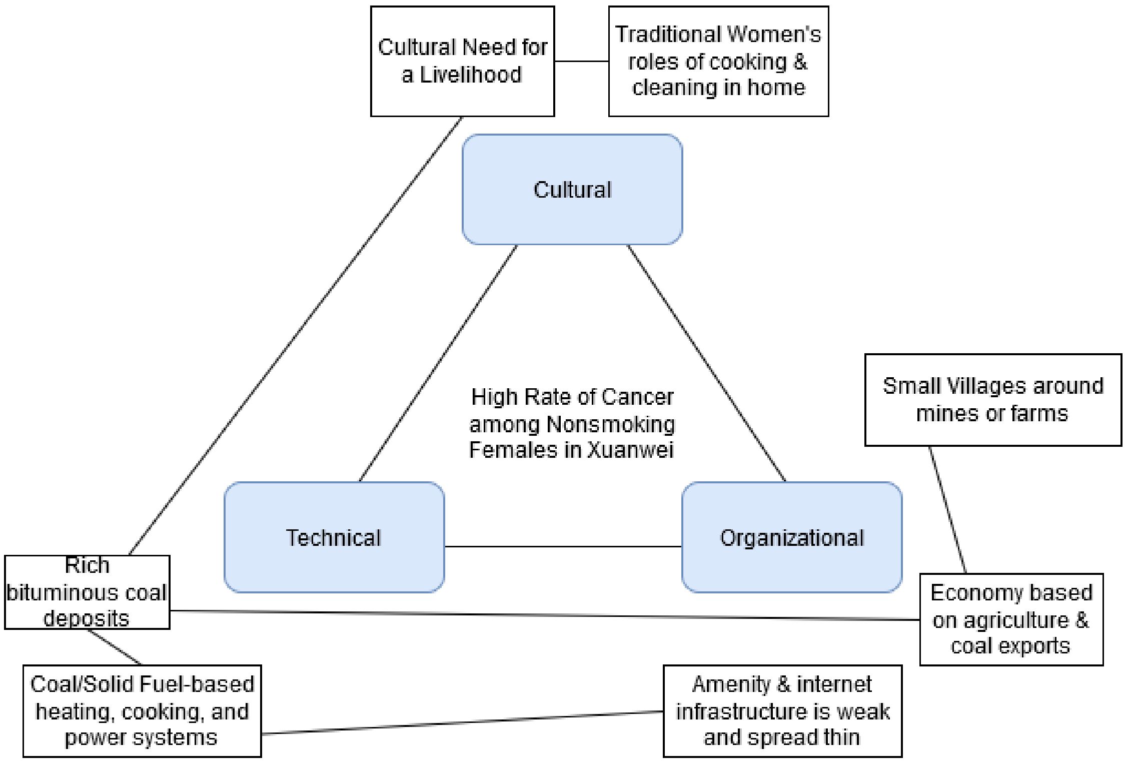

Figure 5: Actor Network for the Xuanwei Lung Cancer Study. The province's economy is primarily based on coal and agriculture exports.

Xuanwei is a relatively rural province of China with large natural deposits of bituminous coal; these two factors contribute to an economy based on agriculture and coal exports, as well as a social organization based around small villages near coal mines or farmland. This rural geography coupled with a sparse population lends to a lack of amenity and internet infrastructure throughout the province, causing much of the population to turn towards short term options for heating, cooking, and powering homes; the majority of these options involve burning the bituminous coal that is so plentiful in Xuanwei. Bituminous coal burns particularly dirty, releasing a large number of dangerous chemicals into the air. This couples with the more traditional roles of women in the rural regions of China (Attané 2012) - Xuanwei included - lending to them staying inside for larger portions of the day and subsequently breathing in more of these pollutants. Within this context, the astronomical lung cancer rate among female residents of the province comes as no surprise.

The more urban environment of Warsaw and its heavier reliance on manufacturing and transportation to support its economy gives it a substantially different actor network diagram, as shown below.

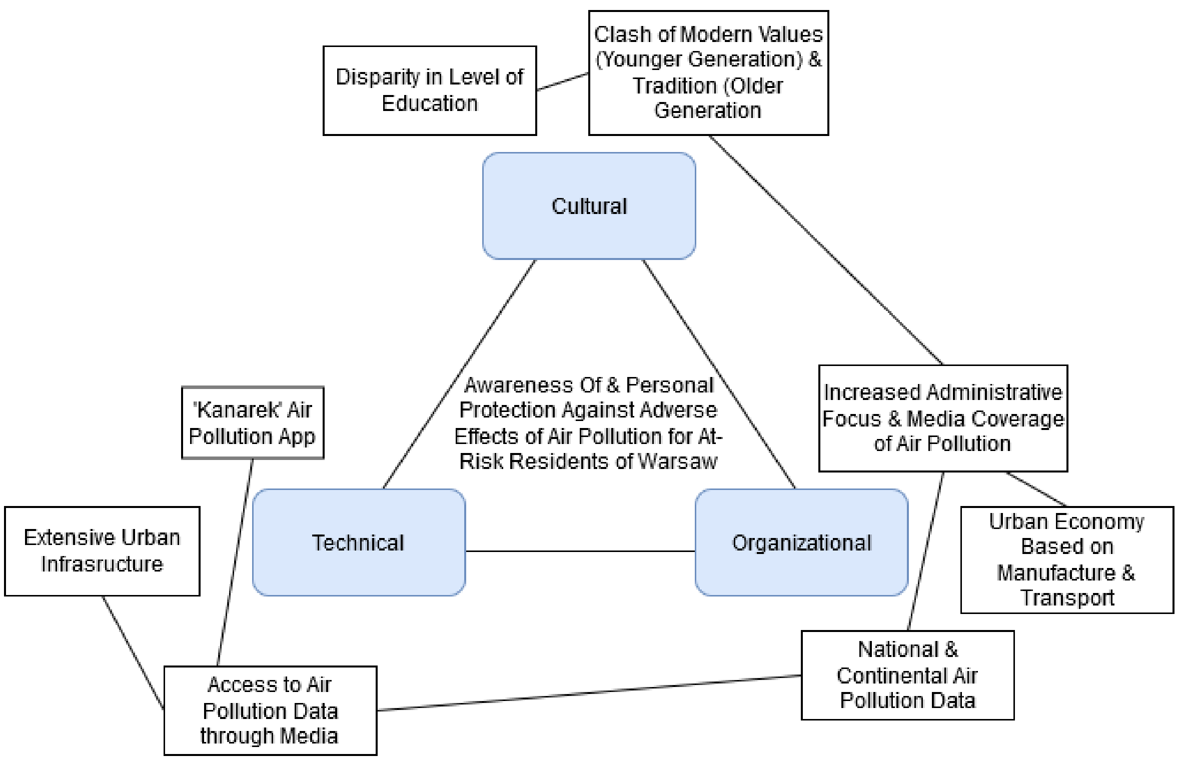

Figure 7: Actor Network for the Warsaw Air Pollution Awareness & Protection Study. Rapid modernization of the manufacturing & transport based economy contribute to increased administrative focus on air pollution.

The most notable aspects are the urban environment of Warsaw and the increased role of media, infrastructure, and internet. As pictured above, another air pollution smartphone app

(Named for the Polish word for canary) was mentioned by participants in the study. Also notable is the increased administrative focus on Air Pollution, potentially due to the more reliable access to pollution data through the Polish Chief Inspectorate of Environmental Protection and the European Environmental Agency.

Lastly, pictured below is the actor network diagram for Delmas & Kohli's AirForU smartphone application.

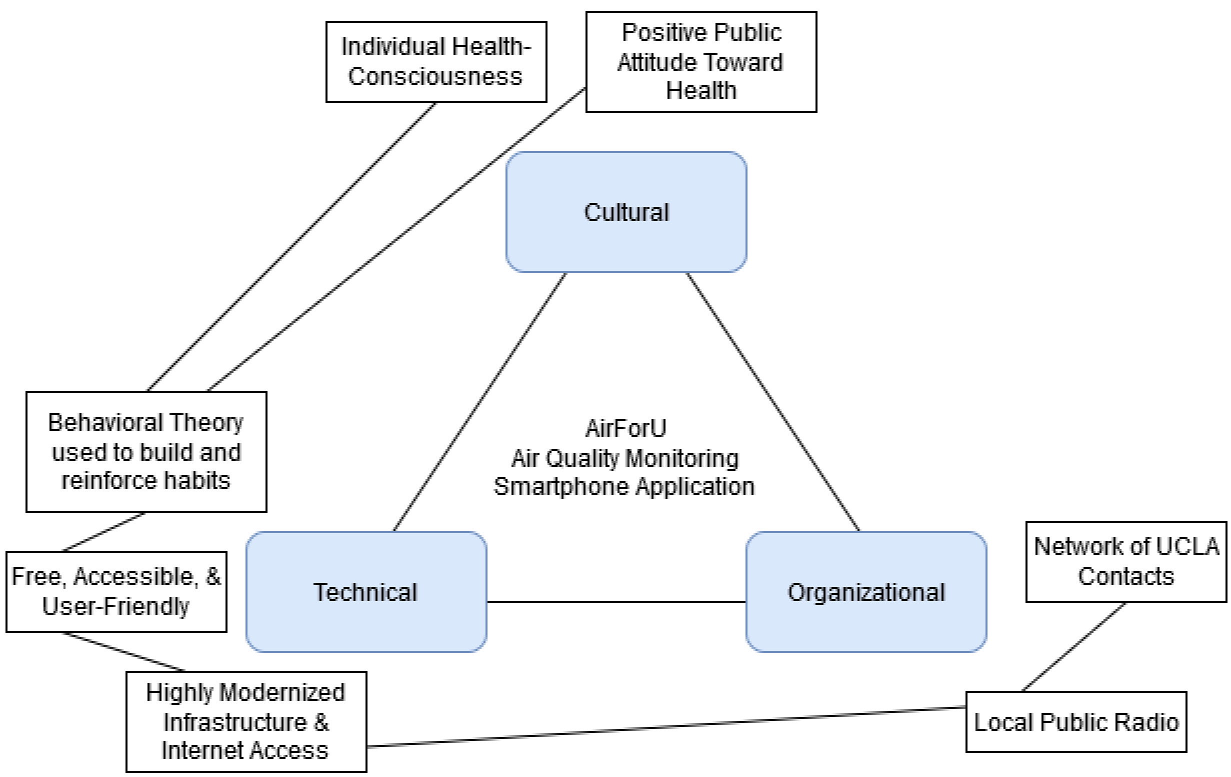

Figure 8: Actor Network Diagram for Delmas & Kohli's AirForU. The health-conscious culture of southern California coupled with the modern local internet and media infrastructure allowed the app to successfully be disseminated and accepted.

In a similar vein to the Warsaw Study, AirForU was released in a sociotechnical landscape with everything it needed to flourish. It was designed by a team of researchers at UCLA and disseminated through UCLA's network of technical contacts, as well as through their web resources and local radio stations, allowing for a rapid spread of awareness of the app (Delmas & Kohli, p. 285). Additionally, the modern internet infrastructure of Los Angeles (63% of the study's participants were from California, with 41% residing in the greater Los Angeles Area - Delmas & Kohli, p. 285) allowed for almost ubiquitous access to the app. Lastly, the relatively young and health-conscious demography of Los Angeles (and California) likely played a central role in the fast adoption of AirForU.

Comparing and contrasting the networks of AirForU and the Warsaw Study yields many similarities and a few key differences. In essence, Warsaw is a modern urban environment. While it may not have the exact same internet and media infrastructure as Los Angeles, it is certainly comparable; in other words, it is not unreasonable to suggest that the vast majority of Warsaw's population has access to a smartphone and/or the internet in some form. As mentioned above, a similar air quality forecasting app, 'Kanarek', is present and accessible in Warsaw (and the rest of Poland). However, Warsaw is a much older municipality than Los Angeles, and has modernized relatively recently in its life span. As such, the more modern values of technological literacy and specialized higher education are catching on slowly and skew much more towards the younger demographic (Price et al, 2018). This is demonstrated in the study by the significantly lower "Personal Protection & Access to Information" scores among participants over 65 and participants with only primary education. Still, the strong modern infrastructure, access to unambiguous data from the Polish Chief Inspectorate for Environmental Protection and the European Environmental Agency, as well as the increased administrative focus on air pollution and its consequences indicates that an app similar to AirForU would see success in the scenario given by the Warsaw Study.

The Lung Cancer study in Xuanwei shows a much starker contrast to AirForU's environment than the Warsaw Study. While the study focuses more directly on the social factors contributing to the high lung cancer rate among women in the province, certain differences immediately stand out. First, the region's sparse amenity and infrastructure indicates that internet access may not be widespread or even common. Second, the region's rich coal deposits and fertile soil have shaped the industry and subsequently residents' way of life. The majority of Xuanwei's residents are involved in rural farming or coal mining operations (Vermuelen et al, 2019), and this livelihood involves the burning of pollutant-heavy solid fuels, which contribute to the astronomical cancer rates. The lack of a reliable internet infrastructure would make it difficult to implement an app similar to AirForU that relies heavily on constant internet access, and the lack of alternative livelihoods to the subsistence farming and mining that most residents undertake indicates that the residents would have difficulty changing their routines in a way that would expose them to fewer pollutants. These factors indicate that an app similar to AirForU would likely not succeed in implementation in circumstances similar to rural Xuanwei.

While this is a relatively simple demonstration of the power of Actor Network Theory, I have demonstrated its power to organize chaotic, human-driven, and culturally distinct scenarios in only 3 simple steps. The method I laid out in the previous section has allowed me not only to examine the relationships between factors in each different actor network, but then also compare and contrast each network with each other as well. Using only simple relationships and a few pertinent factors for each perspective, I was able to categorize, explore, and ultimately draw conclusions from the successes and failures of each study.

Conclusion:

In this paper I assert that Actor Network Theory is a powerful tool by which to analyze sociotechnical forces in communities affected by air pollution. To this end, I have demonstrated its effectiveness by using it to analyze three distinct scientific studies on air pollution, and explore the successes and failures of the communities involved.

By discussing three separate studies I demonstrated the first two stages of my method, categorizing and generating actor networks. Then the relative success of AirForU, the UCLA smartphone app, was compared and contrasted to the other two studies using Pacey's concept of collaborative innovation as part of the final stage of my method. I was able to easily draw wider conclusions from three narrow studies, using my method's categorization to highlight important factors such as present technology, available infrastructure, and cultural identity.

The implications of this study are clear: Actor Network Theory is a powerful tool by which to measure a community's receptiveness to air pollution health risk mitigation efforts, and the key indicators in these actor networks are the community's media infrastructure, primary economic drivers, and access to reliable air pollution data. While this study is by no means the definitive work on community air pollution health risk mitigation, it establishes promising paths of research on community-wide air pollution health initiatives through the basis of Latour's Actor Network Theory and Pacey's concept of collaborative innovation.

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