The societal influences and impact on hydropower implementation in the Mekong River region

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By

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

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Introduction

The Mekong River provides incredible value for the economy and food security in China and multiple Southeast Asian countries. In Cambodia, fish harvested from the Mekong River accounts for around 65-75% of the total protein in the population's diet (Dugan et al, 2005). The total value of fisheries in the Lower Mekong Basin is estimated at $1478 million USD (Dugan et al, 2005). While agriculture and aquaculture are important to the population of these countries, hydropower is a fast growing industry that will have sweeping effects across the region. Hydropower plants are created by building a dam which utilizes the flow of water to turn turbines, which in turn create electricity. These dams heavily alter the flow of water and can hold back sediment from flowing downstream. While additional hydropower plants will likely serve as an economic boost for these countries, there are potential unintended side effects due to dam-building in these regions.

Dam-building alters the flows of river, which can promote the invasion of non-native species, leading to a reduction in biodiversity (Sabo et al, 2017). These changes can have effects on regions such as the Vietnamese Mekong River Delta, where 80% of the population relies on rice cultivation for their livelihood (Wassmann et al, 2019). For the population of the region that relies on fishing for food security as well as financial reasons, a model of the Dai fishery in Cambodia estimated that a 1-meter drop in water flow leads to a loss of around 2,500 tons in total catches (Dugan et al, 2005). This emphasizes the importance that river flows can have on the food security in the region, where fish is a large portion of the population's dietary intake.

Studies regarding the effects of increased hydropower usage are important due to the large economic value that the Mekong River provides in this region. There are large portions of the population that live as subsistence fisherman. In 2009 it was estimated that around 5 million people in Yunnan, a province in southwestern China, relied on agriculture to feed themselves and their families (Molle et al, 2009). For these previously listed reasons it will be important to further analyze the effect of dam-building on the economy of the region. This Capstone project focuses on analyzing agricultural, aquacultural, and hydropower data that is available in order to figure out how to optimally implement and maintain hydropower plants in the Mekong River region. While the main topic that the Capstone addresses is the change in economic value due to hydropower implementation, the societal influences that surround the project cannot be ignored. In order to provide proof, the STS topic of this research paper will seek to show that societal forces exist that influence hydropower infrastructure development, and hydropower in turn directly impacts the local populace.

Case Context

Hydropower is currently the leading source of renewable energy worldwide (Sabo et al, 2017). By implementing hydropower without prior research, the Mekong River could become less productive for agricultural and aquacultural use due to changes in flow and segmentation of the river. An assessment by the Mekong River Commission estimated that the economies of the lower Mekong countries will lose around $7 billion if the currently planned hydropower projects are constructed (Beech, 2019). In 2009 there were six hydropower projects in operation and six more under construction in Laos (Molle et al, 2009). In 2017, the Laos News Agency reported that there were 46 running hydropower plants with 54 more planned or under construction (Phomnuny, 2017). This huge leap in hydropower production in the region provides important economic value through the export of electricity, but also adversely affects food security in the Lower Mekong region. Dam operations in the Sesan River, a major tributary of the Mekong

River through central Vietnam and Cambodia, have led to a decline in fish population, which directly impacts the livelihood of the population in this region (Piman et al, 2013). Currently, there are few detailed studies on the effects of recent dam development due to the rapid pace that hydropower plants are being built, which leads to improperly placed hydropower plants. According to interviews with the local population in Cambodia, after the construction of the Ialy Reservoir, fishery yields dropped to around 10-30% from previous year's yields (Groner, 2006). This is one example of how an improperly implemented hydropower plant can negatively affect the local population. Due to the lack of a current technological solution, there is dire need for a better method.

While the decline of fish populations and diversity in the Mekong region is well documented, there are steps that can be taken in order to reduce the impact of future dam-building on the economy and food security in these regions. It would be incredibly difficult to attempt to remove dams in these regions in order to reverse the consequences on agriculture and aquaculture. In order to minimize the impact of future hydropower implementation, there needs to be proper statistical analysis in order to negate the adverse effects. In a data driven approach, researches estimated that by properly implementing hydropower plants, they could potentially exceed pre-dam fishery yields (Sabo et al, 2017). While this may be overly optimistic due to the impact of past hydropower implementation, it provides hope that there is a way to optimally implement plants in the Lower Mekong Region. There are aggregate data sets online that track the agriculture and aquaculture yields across the world. By implementing these data sets into statistical models and accounting for the effects that climate change and previous hydropower implementation has on food security, the capstone team can begin to formulate a plan to properly coordinate future dam-building.

The previously proposed statistical model and data analysis can help to alleviate the problem by providing an outline for implementing hydropower plants that are currently still in the planning phase. While there is no way to stop the inevitable boom of hydropower in the region, evidence based decision making can serve to strategically place dams in order to lessen the negative consequences on flow rates in the Lower Mekong Basin. The location of dams as well as their size are important factors in assessing the changes in flow rate that the river will experience (Piman et al, 2013). It is important to correctly assess how a change in a dam's size and location will affect the flow rates of surrounding regions. Due to the impact that fisheries have on countries such as Cambodia, it is necessary to come up with an improved method for assessing when and how to properly construct hydropower plants. The proposed technological solution will utilize coded analysis done on aggregated agricultural and fishery data from software such as Google Earth Engine. By looking at the agricultural and aquacultural data before and after hydropower plants are built in specific regions, trends that negatively affect the region can be found and future hydropower implementations can avoid these pitfalls.

STS Topic

Analyzing the connections between the human, social, and technical elements of hydropower implementation will utilize the Social Construction of Technology framework. This framework argues that development of technology is driven largely by the social groups, rather than determined by the technology. In their paper, "The Social Construction of Facts and Artifacts", which formed the basis for the Social Construction of Technology framework, Pinch and Bijker sought to make the argument that, "It is people, not machines that design, build, and give meaning to technologies and ultimately decide which ones to adopt and which ones to reject" (Pinch and Bijker, 1984). Through their definition of interpretive flexibility, which is discussed later in this section, Pinch and Bijker establish the importance of people's relationship with technology in establishing its relative value. Figure 1 is an illustration showing the connection between the various social groups, e.g. governments, local population, and private companies, which connect to the artifacts, which in this case are the various technologies related to hydropower. This illustrates visually the relationship between social groups and an individual artifact, with this relationship encompassing their problems with respect to the artifact as well as the different ways in which it might benefit them. Pinch and Bijker utilize this introduction of a social group and its perceived problem to develop a framework that can identify different solutions. The idea behind this is that for a proper solution to be identified, the social context in which the problem exists needs to be considered. As an example, for a citizen of a Lower Mekong country who has been displaced due to the recent construction of a dam, the solution considered should take into account the social context. This social context may include the consideration of the concept of ancestral land rights in Cambodia or the communist social norms in Laos. These differences in social context impact the way in which a solution would help, or worsen a situation.

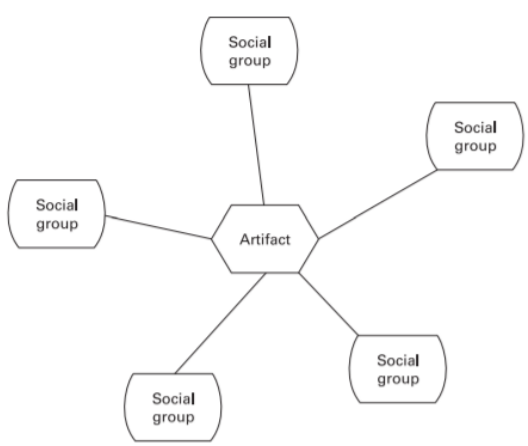

Figure 1. Relationship between an artifact and various social groups (Pinch and Bijker, 1984).

Through this framework, we will be able to use Pinch and Bijker's definition of "interpretive flexibility", meaning the broad array of possibilities in a technologies' early stages of development (Pinch and Bijker, 1984). For example, a Laotian government official or a Chinese investor may view hydropower implementation in the region as a net positive due to the money made from the sale of electricity. A Laotian citizen or dam construction worker may view it negatively due to injuries or displacement from their home. There needs to be a give and take between opposing viewpoints in order for the technology to be successfully implemented. Each of the various stakeholders will have different input on the requirements of the technology. These different requirements will all be borne out of the social context in which the stakeholder's needs were developed. Pinch and Bijker also define the concept of the "stabilization" of an artifact, or in other words the "disappearance" of problems (Pinch and Bijker, 1984). Rather than solving the problem in the true sense of the word, the authors argue that the social groups simply need to "see the problem as being solved". This idea concept is significant going forward because there is still time to change the way in which stakeholders "see" the technology. For someone who has been displaced from their home, there may not be any way to truly stabilize the artifact in their eyes. However, with many dams still in the planning or construction phase, decision makers have the ability to truly take into consideration the social context in which they are developing this technology. For decision makers that simply want to solve energy crises in their country, this stabilization may take the form of a different kind of renewable energy such as solar or wind. This consideration of social context is important specifically to this research because of the power dynamics that exist in these Southeast Asian countries. Chinese industry, both due to its wealth and location upstream on the Mekong River, is relatively high up in its ability to influence the construction of hydropower dams. A local rural citizen of a Lower Mekong country doesn't have the ability to make any significant influence on the requirements of the technology. The measurements used to measure inequality, including Gross National Income (GNI) and the GINI index will be analyzed through a separate STS framework. This framework is based on the work of Susan Cozzens on Innovation and Inequality (Cozzens, 2008). In this framework, Cozzens argues that innovation systems, in this case renewable hydropower energy, often "are organized in ways that reproduce and even amplify inequalities between individuals, households, and groups" (Cozzens, 2008).

Research Question and Methods

The first research question that this thesis will seek to answer is: How do social forces influence hydropower implementation in the Mekong River region? The second question is: How does the construction of dams affect the local populace? One of the main primary sources for the technical portion will be counts of events for hydropower implementation in the Mekong River region. Incomplete but valuable data on hydropower dams is available through the Consultative Group for International Agricultural Research (CGIAR), a global partnership engaged in research about food security. Fishery data was found through the World Bank's data catalog. Much of the analysis was based on the combination of data from different resources. Various tools were used to analyze the data including Tableau, Minitab, and Excel. This data will be organized according to Social Construction of Technology framework in order to attempt to draw conclusions about the social dynamics surrounding hydropower technology. Using this framework, stakeholders were organized and work was done to attempt to assess the impact of hydropower on each social group. Statistical analysis was done in order to attempt to identify correlations between hydropower dam implementation and other variables such as GINI. The GINI coefficient, a statistical measure of income inequality, will be used in order to attempt to quantify inequality in the region. A low GINI index 0 (0%) means that the country is perfectly equal, and a high GINI index 1 (100%) means that the country is perfectly unequal (Monitor, 2015). GINI data will be analyzed through the framework of the work of Susan Cozzens, a researcher with work focused on innovation and inequality (Cozzens, 2008). The work of Susan Cozzens, along with the data collected, shows an issue with overreliance on macro-economic data such as the GINI coefficient that does not tell the full story in regards to these countries. Although the data comes from official sources such as the World Bank, many of the data sets are the result of aggregation of multiple resources. Due to this, the estimation methods are likely different depending on the source that is used.

Results

Issues with the data led to problems making concrete data-based conclusions. The results do not offer much in terms of a conclusive connection between hydropower dams and variables such as crop and fishery yields in answer to the second proposed research question. Macro-level data was used rather than micro-level such as household surveys due to issues with availability. For example, fishery data includes all fish captures including fish farms and ocean capture for the entire country. Without a way to separate data that is specific to the Mekong, the data used and analysis is critically flawed. The GINI index itself is a source of controversy and has several limitations. The informal economic sector, which tracks employment that is neither taxed nor tracked by the environment is not included in the GINI index calculations. For most developing countries, around 90% of the employment is accounted for by this sector (Chitiga et. al, 2014).

The following analysis will seek to show the difficulty in establishing links between hydropower and aspects such as fisheries and income inequality. In the past 20 years over 500 hydropower dams have been commissioned. Total electricity generation capacity has increased by around 37,000 MW in this same time frame. Figure 2 illustrates the total hydropower capacity (MW) since 2000 for each country in the Lower Mekong River region.

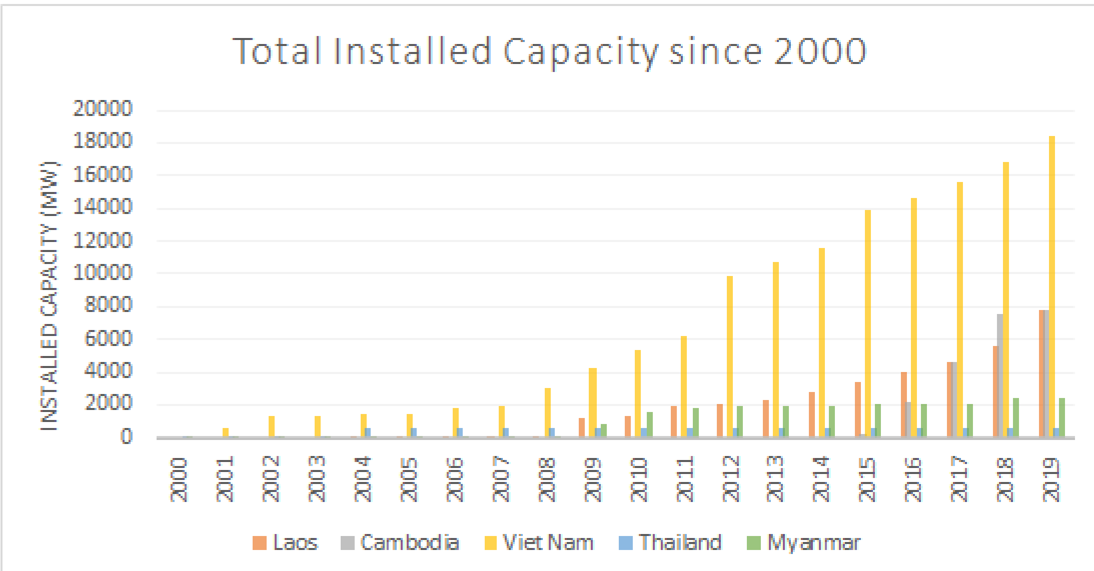

Figure 2. Total Installed Capacity since 2000 (CGIAR, 2019 and EGAOT, 2019) (Analysis by Christopher Pufko, 2020)

Figure 3 illustrate the trend of fishery yields over time for countries in the Lower Mekong Basin. There does not appear to be a specific change in trend over the last 10-15 years when hydropower implementation began to ramp up. It is impossible to draw any conclusions from this analysis because of misreporting of data and issues with the usage of macro-level data.

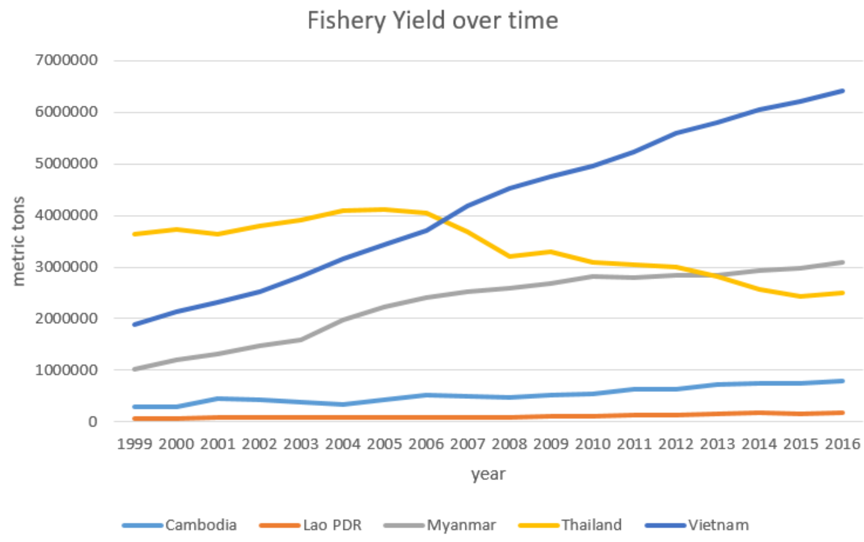

Figure 3. Fishery Yield over time (World Bank, 2019)

There is a mixed correlation between the GINI coefficient and hydropower. For Laos, a communist country, there is a significant negative correlation between development of hydropower and the GINI coefficient. This means that government officials and other members of the upper class likely receive most of the profit from the construction of dams. On the opposite end of the spectrum, Thailand's construction of hydropower infrastructure correlates with a decrease in the GINI index. Figure 4 illustrates this change, with the installed capacity coefficient representing a positive or negative correlation. The coefficient column shows a positive or negative relationship between Installed Capacity since 2000, and the GINI coefficient. The top table shows a positive coefficient representing a positive relationship between Installed Capacity and the GINI coefficient in Laos. This effect flips in the bottom table which shows the data for Thailand. Due to the lack of availability of data and the previously mentioned issues with the GINI coefficient and macro-level data, this research does not offer a concrete conclusion about the relationship between hydropower and income inequality.

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	33.929	0.901	37.66	0.001	
Installed Capacity since 2000	0.001281	0.000304	4.21	0.052	1.00

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	42.64	1.36	31.25	0.000	
Installed Capacity Since 2000-T	-0.00691	0.00262	-2.64	0.020	1.00

Figure 4. Regression results for GINI against installed hydropower capacity.

While this research has failed to properly define links between hydropower and metrics such as income inequality or fishery yields, there are tens of thousands of rural citizens who have been directly impacted by dam construction. When a Laotian saddle dam collapsed due to substandard construction, thousands of residents of Northern Cambodia were displaced from their home due to flooding (Olarn et al, 2018). When the Lower Sesan 2 finished construction in 2018, the entire village of Srekor in Stung Treng, Cambodia was submerged by floodwater (Gyorvary et. al, 2018). The people being impacted the most by the continued shortages of electricity are the rural citizens of these countries. According to a press release by the World Bank in 2018, around 30% of rural households in Cambodia rely on off-grid power such as rechargeable batteries (Bou, 2018). While this is a staggering number, the same report concludes that the energy crises is being slowly solved, and this can be partially attributed to the increase of hydropower capacity.

Discussion

The broad idea behind studying the effect of hydropower implementation on the Mekong River region is that the impoverished riparian population of these countries is bearing the brunt of the issue. The data and analysis however does not back up this conclusion. The Social

Construction of Technology framework was used to organize the data. Through Pinch and Bijkers definition of interpretive flexibility, the views of different stakeholders can be analyzed. A northern Cambodian citizen who was displaced from their village due to flooding, is likely not able to see the positives in the dam's construction. Likewise, rural citizens of these countries who still do not have access to consistent electricity will likely view the dam infrastructure in the same way. However, a Laotian government official or Chinese investor who is profiting from the dam's construction will have a completely different view. This theory of SCOT informed my analysis by giving me a format to analyze the various ways in which stakeholders are impacted by the technology. Susan Cozzens framework of innovation and inequality informed my analysis by introducing me to issues with innovation increasing inequality, however issues with data such as the GINI coefficient led to issues with statistical conclusions. In the data sets used in this research there exists multiple discrepancies that point to the limitations of the data collection methods, even in the most recent years. Some countries have years where data is not reported or is reported as the exact same value in multiple years. Often data collection methods are suspect and numbers can vary wildly depending on the researcher. It is often found in research articles that numerous papers will utilize the same numbers based on a paper that is considered inaccurate. While the World Bank and FAO provided the most complete data sets, the data itself is aggregated from multiple sources which utilize completely different data collection methods.

In order to move the research forward in the future I would take a more narrow approach to data collection and analysis. The more general method that was taken led to the analysis being too broad to properly answer either of the research questions. This broad view was intentional, and while it did not back up anecdotal claims such as fishery or crop yields decreasing, it may point to a larger problem surrounding data collection methods in these Southeast Asian countries.

This could be an interesting topic to tackle for future researchers who want to build upon the analysis. One of the most interesting topics of the analysis was the connection between hydropower development and income inequality (GINI), however it was difficult to collect proper data for some of the countries to make any sort of connection. The fact that much of the data is from official reports from governments makes it susceptible to misreporting whether intentional or unintentional.

I will use this research to advance my engineering practice because it has given me an interest in renewable energy, primarily in countries that are suffering from energy crises such as Cambodia**.** In 2016 only 50% of Cambodia’s population had access to electricity. By 2019, the percentage that had access to electricity grew to 80% (Phoumin, 2019). Much of this change is due to the increased implementation of domestic hydropower production. This research has also given me valuable skills in data collection and research. I am going to work in Technical Consulting in the future, and one of the primary pieces of knowledge that I will take with me is the framework Social Construction of Technology, and its careful consideration of stakeholders.

Conclusion

This research seeks to quantify the impact of hydropower infrastructure on the rural inhabitants along the Mekong River in Southeast Asia. This data was almost impossible to work with because of the problematic nature of maro-level data in the Southeast Asian region as well as issues with specific metrics such as the GINI coefficient. This lack of significance, however, does not prove that hydropower infrastructure does not negatively impact rural citizens. There are rural citizens that are being displaced from their villages and homes due to flooding directly connected to hydropower dams. Next steps should include narrowing the view of the research to focus on specific areas or industry that could be impacted by hydropower infrastructure. By narrowing the focus the researchers will be able to establish cause effect relationships between specific dams and their impacts. Studying micro-level data such as household surveys will likely provide less problematic data sets and analysis. The take away message from this work should be that it serves as a case study on the incorrect way to collect and manage data when availability is minimal. The issues that affected this research project will not go away anytime soon, and therefore a different approach may be needed to establish this cause and effect relationship.

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