Prospectus

Understanding the Network of Relationships between Land & Water Use and Society in the Mekong River

(Technical Topic)

Development of Hydropower as an Energy Source and its Effects on Long-Standing Societal Norms

(STS Topic)

By

Jacob Kuchta

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Technical Project Team Members: Christopher Pufko, Charlie Rowe, Scott Stoessel, Jake Walsh

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.

Signed: _____

Approved: _____ Date _____

Rider Foley, Department of Engineering and Society

Approved: _____ Date _____

Venkataraman Lakshmi, Department of Engineering Systems and Environment

Introduction

The Mekong River region is one of the most biodiverse regions in the world, rivaled only by the Congo and the Amazon. The Mekong is the longest river in Southeast Asia, the seventh longest in the Asian continent, and the 12th longest in the entire world. It flows 4,350 km through both dry plains and luscious rainforest and acts as an irreplaceable resource to the six countries which it winds through: China, Laos PDR, Vietnam, Thailand, Myanmar, and Cambodia (Jacobs, 2019). Millions of citizens have relied on the Mekong River for agriculture, aquaculture, and transportation for hundreds of years. These areas of Southeast Asia have continued to urbanize and develop, and the demand for energy, as well as agricultural and aquacultural production, is on the rise. In a 2017 study by J. Sabo, there was found to be an estimated 60 million people dependent on the Mekong for food, water, and energy (Sabo, 2017, p.1). Critical to this urbanization and economic growth in the region has been the creation of hydropower infrastructure as well as sand-mining for concrete production. However, these technological developments have posed threats to the sustainability of local communities. Sabo states that, "Hydropower development is crucial to the region's economic prosperity and is simultaneously a threat to fisheries and agriculture that thrived in the natural-flow regime," (ibis). Steps towards sustaining the river's natural qualities must be taken with the increasing threat from climate change on ecosystems worldwide, as well as with the continued negative effects of hydropower development on wildlife & biodiversity. So, my technical portion of this paper will dive into the analysis of the land and water use in the Mekong to model the dynamics and relationships of influential actors in the Mekong river system as a whole. Very closely tied, the STS portion of my paper will explore the development of hydropower as an energy source as it relates to the long-standing societal norms of the region. The goal is to analyze both current infrastructure and proposed infrastructure development in the region and its effects on the lives

of the local people, business, and cultural tradition. I will research the technical topic above with the help of my capstone team members (fellow systems engineers): Charlie Rowe, Christopher Pufko, Scott Stoessel, and Jake Walsh with UVa Engineering Systems & Environmental professor Venkataraman Lakshmi acting as an advisor and a resource for data collection in the Mekong Region. We will use the computing power available to us to create a quantitative model of economic, social, and environmental effects of hydropower & sand-mining implementation in the Mekong, using Python software.

Land & Water Use in the Mekong Region

From China to Vietnam, the Mekong River is the lifeblood of Southeast Asia and offers a glimpse into the long history and diverse cultures of the region. For thousands of years, the rapids and falls have been the lifeline for populations that depend on it for survival. The Mekong has long been regarded as the foundation of Southeast Asia's economic growth and prosperity (Avalon, 2017, p.1). However, there are now several factors that are leading to an environmental change in the Mekong region and of these drivers, there exist three that have impacts throughout the economies of the region: hydropower development, climate change, and sand-mining. The influence of these three particular drivers on those reliant on the Mekong is increasing at a rapid pace due to the push by governments in the region to urbanize and develop. Moreover, there are three specific industries dependent on the Mekong in which the social and economic effects of these drivers is felt most heavily: farming, fishing, and energy production. The World Wildlife Fund (WWF) indicates that the Mekong region is currently facing a defining point in its history where proposed developments and imminent environmental changes will directly impact economic performance for decades to come (World Wildlife Fund, 2016, p.1).

Global Climate Change & Hydropower in the Mekong Region

Large scale climate change is negatively affecting the industries native to the Mekong river region. Wassmann, a climate change expert at the International Rice Research Group, reported that roughly 78% of land in the Vietnamese Mekong Delta in the year 2000 was used for rice production, and most of the land in the Delta is less than two meters above sea-level (Wassman, 2004, p.90). Wassmann goes on to estimate that a one-meter increase in sea level caused by climate change would result in a loss of $17 Billion in GDP from the agricultural sector in Vietnam (Wassman, 2004, p.92).

In addition to rising sea levels, the Mekong region is severely at risk of facing further industrial challenges due to average temperature rise. Tuan Ahn Lu of the Research Institute of Climate Change explains how, "temperature rise in the upstream region of the Mekong River may affect the flood regime of the Mekong Delta, which may lead to an extension of the current boundaries of flooding patterns" (Wang et al, 2017, p.207). Projected increases in temperatures, changes in precipitation & flooding patterns, and reductions in water availability may all result in reduced agricultural productivity.

There are numerous ecological factors involved with hydropower development and changes to the ecology of the Mekong has serious implications for fishing and farming communities. There are currently 58 different dams & related hydropower structures on the Mekong with 120 more proposed projects in place. Scientists warn that this will imperil the already fragile river system. Hydropower development in the Mekong, specifically, has been the topic of research and analysis by several environmental scientists in the last 10 years. One of these research endeavors was carried out by Jory Hecht, a hydrologist with the United States Geographical Survey. In Hecht's report, he uses the standard seasonal characterization of the wet

season as June to November where there is a significant increase in rain, and the dry season from December to May where average rainfall significantly decreases (Hecht, 2018, p.2). Following the idea of a changing ecological nature of the system, he goes on to state that, "reduced wet season flows and increased dry season flows will potentially damage the river's ecological productivity and the livelihoods of the people dependent upon it," (Hecht, 2018, p.3). In addition, he reports a reduction in vital nutrient transport and an increased risk of saltwater intrusion, the beginnings of a process called oligotrophication.

Now, it is important to take a closer look at what may be causing a reduction in wet season flows and an increase in dry season flows, as well as a reduction in nutrient levels. Hydropower infrastructure has been identified as the source of these irregular patterns. Long P. Hoang, a Postdoc researcher for Water Systems and Global Change at Wageningen University, has researched and reported on this very issue. Hoang has quantified potential flow changes in response to hydropower infrastructure as, " +160% in the dry season and -40% in the wet season," (Hoang, 2017, p.601). As more and more research is done on the region, it is clear that hydropower development in upstream locations of the river is altering the natural flow of the river, augmenting agricultural cycles with production levels of local industry feeling the consequences. It is my capstone team's mission to quantify the economic effects, specific to every country in the region, from an increase in electric supply and a decrease in farming and fishing production in the Mekong, as well as the environmental effects, in a manner which can be presented effectively to parties involved with the future planning of the region.

In the northern regions of the Mekong, the push to plan, construct, and implement hydropower is bigger than ever. This can be attributed to China's insufficient reserves of fossil fuels and the government's preference for energy independence; hydropower plays a large part in

the energy policy of the country. The pace in which hydropower infrastructure is growing in the region rationalizes the necessity for an understanding of the dynamic nature of interconnected elements throughout the Mekong. To gain this understanding of the complexities of this fragile system, one must study and quantify the economic, societal, and environmental impacts of these technologies as they related the system as a whole. It is then that a clearer understanding of the land and water use in the Mekong can be attained.

The Connection Between Actors in the Region

The Mekong River region system can be modeled by a network of stakeholders and artifacts in order to gain a greater understanding of the interactions at work. As industrial development in the region continues to have more influence, stakeholders in the system are those entities in charge of design and implementation of these projects: governments (local and national), private firms, and hydroelectric power companies. The Mekong River itself must be identified as a non-physical artifact in this system as its role is integral to the network as a whole. Furthermore, the residents and societies of the Mekong river basin who have inhabited the region for centuries act as non-physical artifacts in the model, and this is the group most directly affected by the implementation of these technological systems in the region. Those technological systems, namely hydroelectric infrastructure and sand-mining sites, act as the physical artifacts in the Mekong river region model. The non-physical artifacts defined above are very dependent upon the decisions made by stakeholders when implementing & introducing these physical artifacts into the system. Governments or private entities developing hydropower and sand-mining infrastructure directly impact the flow & ecology of the Mekong. When the natural state of the Mekong is altered, the millions of inhabitants of the region reliant upon the river for their livelihoods & resources are at risk of experiencing life-altering consequences.

Analyzing Using a Framework

The interconnection between the development of hydropower and the local inhabitants of the Mekong can best be understood using the framework of Interactive Sociotechnical Analysis (ITSA). This framework is notably outlined in the paper *Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis* (Harrison et al, 2007, p. 542-549). Harrison demonstrates in this article is that there is a necessity for the study of the relationships among new elements, workflows, and organizations. Specifically, he emphasizes using Interactive Sociotechnical Analysis (ISTA) to highlight the recursive and iterative nature of these relationships and their potential for producing unintended consequences. This framework highlights the user interpretation of a technology's features & the interdependence of social and technical systems, as well as the recursive relation of a system's subcomponents with the user. Harrison uses Health Information Technology (HIT) infrastructure as an example of how ISTA can be a pivotal tool in examining the actual uses of HIT against the uses intended or envisioned by designers or managers. One case stated of how the social system is producing unintended consequences of the technology is how, "extensive reporting requirements lead physicians to cut & paste whole reports, rather than extracting pertinent facts," (Harrison et al, 2007, p. 545). In essence, the ITSA framework highlights that although technical flaws often cause problems, many harmful or otherwise undesirable outcomes of technological implementation flow from sociotechnical interactions—the interplay between new technology and organization's existing social and technical systems—including their workflows, culture, social interactions, and technologies (Harrison et al, 2007, p. 542).

In the Mekong region, hydropower development is producing several unintended consequences relating to the flow of the river and the inhabitants dependent on it. Hydropower

infrastructure sections off portions of the river, causing several migratory species of fish native to the area & integral to the fishery industry to face extinction. Furthermore, damming the Mekong will impact the region's natural monsoonal flood/drought cycles, block sediment and nutrient transfer which will seriously impact the farming industry of both the river and wetlands, and require tens of thousands of people to relocate because their homes and lands will be flooded (Gilbertson, 2019). In relation to the ITSA framework, the users of these new systems, local inhabitants, have already felt the unintended consequences in the prior iterations of hydropower development. In the Lower Mekong Region, the region most at risk of feeling downstream effects of dam infrastructure, 65-85% of employment is in the agricultural industry (William & Pearse-Smith, 2012, p.78). A survey taken in this region found that one in six households reported having a family member who changed occupation due to the decline of aquacultural productivity while 21% of those households claim to have no option for a second occupation. In one report from Vietnam, inhabitants still able to produce crops and aquaculture downstream from the Yali Falls dam have felt an average household income drop from $109/month to $46/month in the three years following the dam's implementation (ibis). As ITSA is used to analyze innovations not at things, but as elements within an unfolding process of sociotechnical interaction, I look to find benefits to local inhabitants in the Mekong system as well as similar systems across the globe. Hydroelectric infrastructure is implemented as a sustainable energy source, and therefore should yield the benefit of providing electricity to surrounding areas. However, as I have found in case studies, this is often not true in the long-standing rural communities most affected by dams' negative consequences. Along the banks of the Zambezi river in Africa, another developing region of the world using hydroelectric power as an energy resource, local inhabitants are not the actors in the system that are receiving the benefits. The

Kariba dam, one of Africa's largest dams, produces 6,400 GWh of electricity annually, which is an ample amount to supply the surrounding areas. However, years after implementation, tens of thousands of inhabitants displaced by the dam still have no electricity or adequate water supply. Further down the Zambezi in Mozambique, the Cahora Bassa dam is yielding similar negative effects, "Cahora Bassa's capacity of 2,075MW is in principle sufficient to supply the electricity needs of all of Mozambique, but 95% of Mozambicans have no access to electricity. Instead, most of the power is exported at below market price to South Africa. At the same time, reduced river flow has decimated the once lucrative shrimp fisheries in the Zambezi delta, depriving local fishermen of a valuable income," (Thieme, 2012, p.2). Before hydropower was implemented in these developing areas such as the Mekong & the Zambezi, social systems had been established that thrived off of the natural order of the river system for agricultural and aquacultural production. With the help of the ITSA framework, it is now apparent that new hydroelectric technology is affecting long-standing relationships in these social systems (see figure 2).

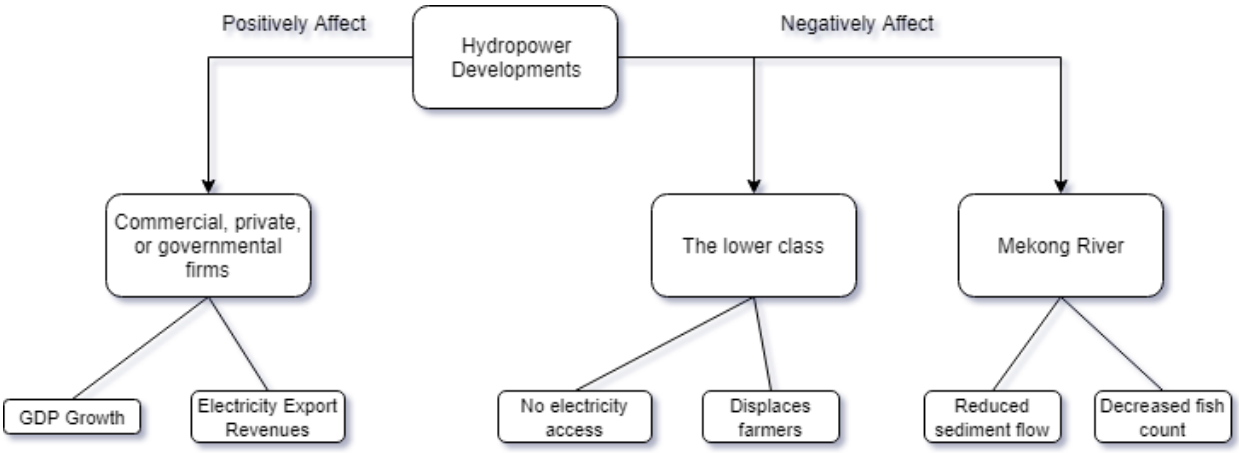

Figure 2: Graphical display of the effects of hydropower developments on key stakeholders & artifacts

It is an important concern that has surfaced over the last 10 years, and stakeholders must be called on to engender a redesign of technological implementation in accordance with interactions of the social system to ensure that hydroelectric use maximizes benefits to all facets of society.

Research Questions & Methods of Analysis

Using statistical methods of data collection and analysis, I will answer the question: How does the development of hydropower as an energy source affect long-standing societal norms? It is imperative that this analysis is completed now due to the rapid pace of hydroelectric development necessary to keep up with the urbanization of developing regions across the globe. This hydroelectric development has already proven controversial when considering the effects on aquacultural and agricultural industries of the low-income areas that surround dam infrastructure, whose ways of life have not been this significantly changed for hundreds of years.

Using surveys, case studies, and policy documents, an understanding of the underlying problems of hydropower implementation will be established. Understanding these issues at hand is crucial in identifying data sets released by various organizations such as the World Wildlife Fund, The Mekong River Commission, and the World Resource Institute that will provide a basis for our model creation. This data on economic effects of hydropower development on all classes of society is the most quantifiable metric in this study, and therefore will be the driving force in the analysis of the research question. Several sets of agricultural data will be used as well and a multi-linear regression model will be created to identify trends of significant indicators of agricultural stability (crop yields, produce price, farm characteristics, total factor productivity, etc.). I will also use data collected from these organizations to take into account geographical discrepancies in the magnitude of economic effects felt, with observations be detailed and investigated. Furthermore, prior literature and case studies will be used to analyze the

environmental effects of climate change on the properties of the river system to predict further how future consequences of hydropower development will be compounded.

Conclusion

The Mekong River region is at a critical point in its existence where hydroelectric development and climate change will directly impact the economic performance & the social system of the region. As governments, commercial entities, and private firms continue to implement hydroelectric technology in the region, the Mekong river is at risk of its natural properties changing forever. In the technical portion of this paper, our team will provide a recommendation about the proper configuration of land and water use by in the region going forward to optimize the implementation of hydropower as a sustainable energy source. This will be achieved through the use of big data analysis of economic data in Python and R to deliver a model in which can be used by developers to predict outcomes of construction and implementation. In the STS portion of my paper, I will provide a holistic report on the effects of the accelerated hydropower construction in developing regions of the globe as it relates to the disruption of traditional societal norms. With the increasing desire to find profitable, sustainable energy sources, inhabitants most directly affected by hydroelectric infrastructure cannot be overlooked by society. The report should be used as a resource in the scholastic community to further move the conversation forward about the most responsible manner in which hydroelectric power should be implemented to maximize benefit for all individuals in society.

Timeline

By the end of this semester, I will have read and analyzed all background research resources to have a plan set forth about which data is most pertinent and necessary to evaluate in

order to build our predictive model for the technical portion. This analysis of background research (case studies, surveys, reports, etc.) will also be beneficial to my STS portion as the two topics are closely intertwined. However, I will research other areas of the globe than the Mekong for my STS portion as I will report on instances of hydropower affecting societal norms throughout the world, not just the Mekong region. Looking forward to next semester, our team will find the exact datasets we will use in analysis with the help of our capstone advisor, Venkataraman Lakshmi, in late January to early February. For the rest of February and the first weeks of March, our team will use clean the data, build data dictionaries, and use hypothesis testing in R and Python to draw key findings and conclusions. We will then compile our findings and write our report, with the goal of completion of the paper by the beginning of April.

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