QUANTIFYING THE ECONOMIC IMPACT OF THE GRAND ETHIOPIAN RENAISSANCE DAM ON THE NILE RIVER BASIN

IMPLICATIONS OF THE GRAND ETHIOPIAN RENAISSANCE DAM ON THE ENVIRONMENT AND SOCIETAL STABILITY OF THE REGION

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

By
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November 1, 2021

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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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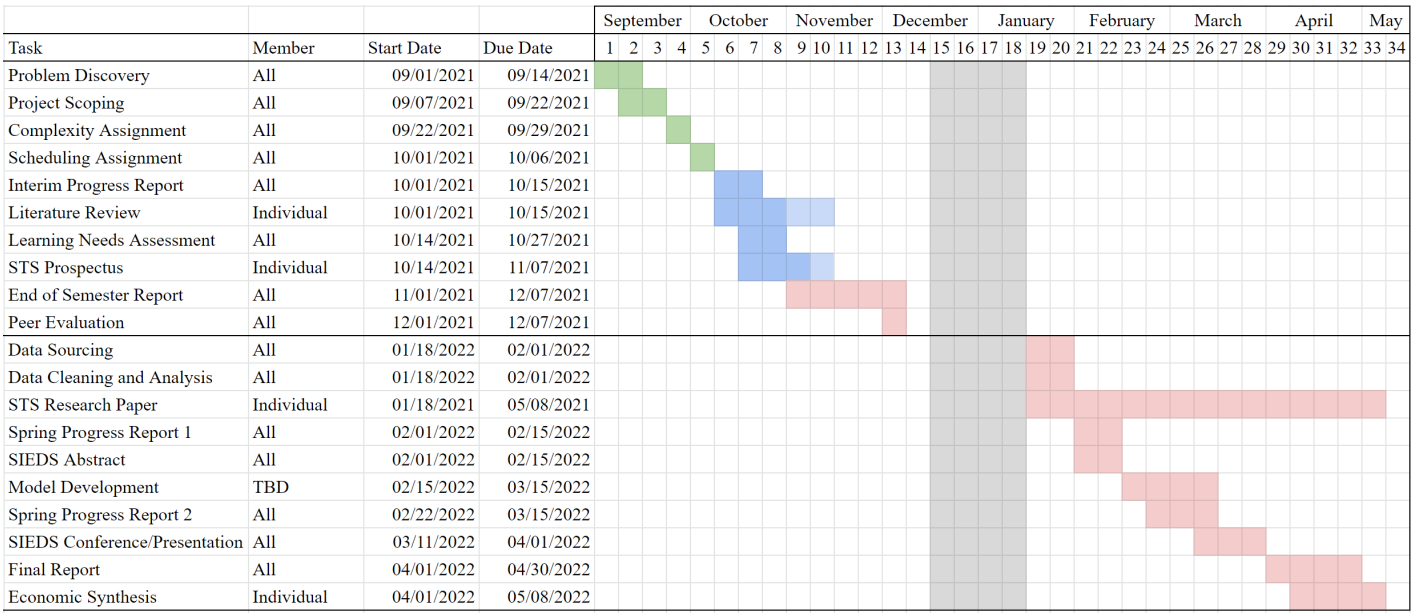
The Nile River plays a pivotal role in the lives of those residing in the region. In the past decade, Ethiopia has designed and began constructing the Grand Ethiopian Renaissance Dam (GERD) which stands to be the largest hydropower plant in the entirety of Africa (Roussi, 2020). As Sudan and Egypt depend on the Nile headwaters which flow through Ethiopia, the GERD has become a source of tension between these countries.

Therefore, through the thesis project the technical report will look to quantify the future impact of the GERD on the economies of the surrounding countries while the STS research will look to understand the environmental impacts of the GERD and the implications these effects may have over the stability of the region. As a result, the technical report and STS research paper will be tightly coupled. The intention is to have the technical report provide a projection for the quantifiable economic impact of the GERD while the STS research paper will enhance the understanding of the influence the dam will have on the region.

The technical report will be written over the course of two semesters under the guidance of Professor Venkataraman Lakshmi of the Engineering Systems and Environment Department. The report is sponsored by the World Bank and the U.S. Department of State. The report will be written jointly with Charlie Bass, Matt Fitzsimmons, Tommy Lam, and Adam O'Neill. The first semester will be spent developing requirements and sourcing data while the second will consist of the modeling and analysis of economic implications of the GERD. The culmination of this project will take the form of both a technical report and a presentation at the annual SIEDS conference. The STS research paper will be written independently over the same time period with its final form being that of a scholarly article. The approximate timeline is shown below in Figure 1. The chart includes major deliverables and documents which will be completed over the course of the thesis project.

Thesis Project Timeline: Gantt Chart



Task	Member	Start Date	Due Date
Problem Discovery	All	09/01/2021	09/14/2021
Project Scoping	All	09/07/2021	09/22/2021
Complexity Assignment	All	09/22/2021	09/29/2021
Scheduling Assignment	All	10/01/2021	10/06/2021
Interim Progress Report	All	10/01/2021	10/15/2021
Literature Review	Individual	10/01/2021	10/15/2021
Learning Needs Assessment	All	10/14/2021	10/27/2021
STS Prospectus	Individual	10/14/2021	11/07/2021
End of Semester Report	All	11/01/2021	12/07/2021
Peer Evaluation	All	12/01/2021	12/07/2021
Data Sourcing	All	01/18/2022	02/01/2022
Data Cleaning and Analysis	All	01/18/2022	02/01/2022
STS Research Paper	Individual	01/18/2021	05/08/2021
Spring Progress Report 1	All	02/01/2022	02/15/2022
SIEDS Abstract	All	02/01/2022	02/15/2022
Model Development	TBD	02/15/2022	03/15/2022
Spring Progress Report 2	All	02/22/2022	03/15/2022
SIEDS Conference/Presentation	All	03/11/2022	04/01/2022
Final Report	All	04/01/2022	04/30/2022
Economic Synthesis	Individual	04/01/2022	05/08/2022

Figure 1. Timeline of Thesis Project: Gantt Chart. (Keith, 2021)

QUANTIFYING THE ECONOMIC IMPACT OF THE GRAND ETHIOPIAN RENAISSANCE DAM ON THE NILE RIVER BASIN

The primary goal of the technical report is to model the economic implications of the GERD on the surrounding region. This region, commonly known as the Nile River basin, constitutes nearly one-tenth of the total surface area of the continent (Hurst, Smith, & El-Kammash, 2021). As shown below in Figure 2 on page 3, the Nile River basin encompasses the countries which lie along the banks of the Nile and its two primary deltas: the Blue Nile and the White Nile. The dam itself is located along the Blue Nile delta and resides within the country of Ethiopia, the location of the Blue Nile's headwaters (Lewis & Heavens, 2019). For the technical report, due the large scope which the Nile River encompasses, research will be focused on the

Blue Nile delta and the countries of Ethiopia, Sudan, and Egypt. In order to accomplish the goal of quantifying the economic impact of the Grand Ethiopian Renaissance Dam, the implications of the dam will be modeled for each country and synthesized into a cumulative model. This final model will project future GDP output following the completion of the dam under various scenarios which will be developed to simulate both management strategies as well as environmental conditions. Management strategies will refer to how water is allocated to various industries while environmental conditions will realistically include wet, dry, and normal precipitation years.

Figure 2. Map of Nile River Basin. (Morsy, Abdelatif, & Mostafa, 2021)

The Grand Ethiopian Renaissance Dam is currently projected to produce 6,450 MW of power per year, thus doubling the power production of Ethiopia as a whole (El-Fekki & James, 2021). In order to do so, the dam will have a total storage volume of 74 billion cubic meters (GERD Coordination Office, 2020). As previously stated, this means that the Grand Ethiopian Renaissance Dam stands to become the largest dam on the continent (Roussi, 2020). Consequently, the dam will have great influence over the economy and societal stability of Ethiopia as well as the downstream nations of Sudan and Egypt. In total, the three countries combine for a population of more than 270 million people (World Bank, 2020). The significant number of people who may be impacted by the GERD's construction means that understanding

the impact of the dam is crucial for developing well designed management strategies for the future. To best develop models to project the effects of the Grand Ethiopian Renaissance Dam, the research will rely heavily on previous work in the field. This research will place particular emphasis on the tradeoffs between hydropower production and agricultural yield. This research will culminate in a conference report which will be presented at the annual SIEDS conference.

PREVIOUS WORK IN MODELLING THE IMPACT OF HYDROPOWER FACILITIES

Many case studies have investigated the impact of hydropower infrastructure. In the case of the High Aswan Dam, Oven-Thompson, Alercon, and Marks conducted research which identified a direct inverse relationship between hydropower production and agricultural yield (Oven-Thompson, Alercon, & Marks, 1982, p. 1605). The conclusions of their research provided projections for changes in hydropower allocation and the resulting change in agriculture (~~Oven-~~Thompson, Alercon, & Marks, 1982, p. 1608). For their results, they also included management strategies providing results under optimal management as well as suboptimal (Oven-Thompson, Alercon, & Marks, 1982, p. 1609).

The primary limitation of the research conducted by Oven-Thompson, Alercon, and Marks with regards to the development of the technical report is that the results fell short of projecting the economic impacts. Building off of the tradeoff methodology, Kahsay's research developed a model where the input was changes in water allocation with the predicted value being economic impact instead of agricultural yield or power production alone (Kahsay, et al., 2019, pp. 76-77). This research provides a more robust model which combines both a partial equilibrium model and a general equilibrium model which examines the Grand Ethiopian

Renaissance Dam (Kahsay, et al., 2019, p. 76). Specifically, the partial equilibrium model is used to forecast water allocation and then includes it in the general equilibrium model for the economic output of the Nile River basin (Kahsay, et al., 2019, p. 79).

This methodology is then expanded in research conducted by Matthew Knowling. Knowling's research is once again conducted on the GERD with the final output being a projection of GDP, but the environmental model is expanded to include changes in land use (Knowling et al., 2019, p. 2). This can be seen in Figure 3 where the environmental model produces an output which acts as parameters in the economic model.

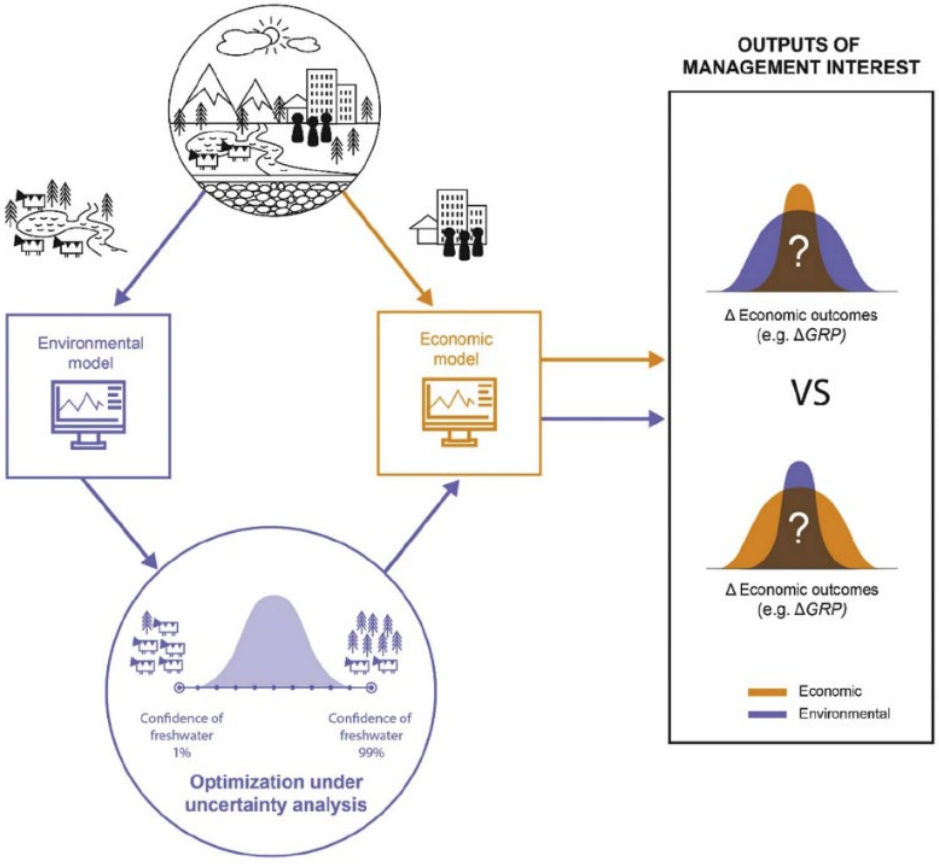


Figure 3. Diagram of Environmental and Economic Combination Model. (Knowling, et al., 2020)

While in this case only one particular factor, land use, was included in the environmental model there is potential to include additional factors such as changes in pollution or water availability. It is important to note that with the introduction of multiple models, as shown in Figure 3 on page 5 by the fact that the environmental model directly contributes to the economic model, there are additional degrees of uncertainty.

DEVELOPMENT OF MODEL FOR GRAND ETHIOPIAN RENAISSANCE DAM

Building off of research that has previously be conducted, multiple models will be built and synthesized to understand the implications of the Grand Ethiopian Renaissance Dam. The dam will influence multiple areas which all contribute to the economic productivity of the region. As shown in Figure 4, research will focus on the Grand Ethiopian Renaissance Dam's effect on land use, water availability, agricultural resiliency, and hydropower production.

The effects on each of these subjects will be modelled to create data for which the economic model will use as input. Contributing models will be developed independently utilizing GIS data before being synthesized in the general economic model. The models will be tested using historical data and the final goal will be to project environmental factors for the coming decades and then run the economic model with the projected environmental data. Additionally, scenarios such as drought and floods will be developed to model specific events which could happen in the future.

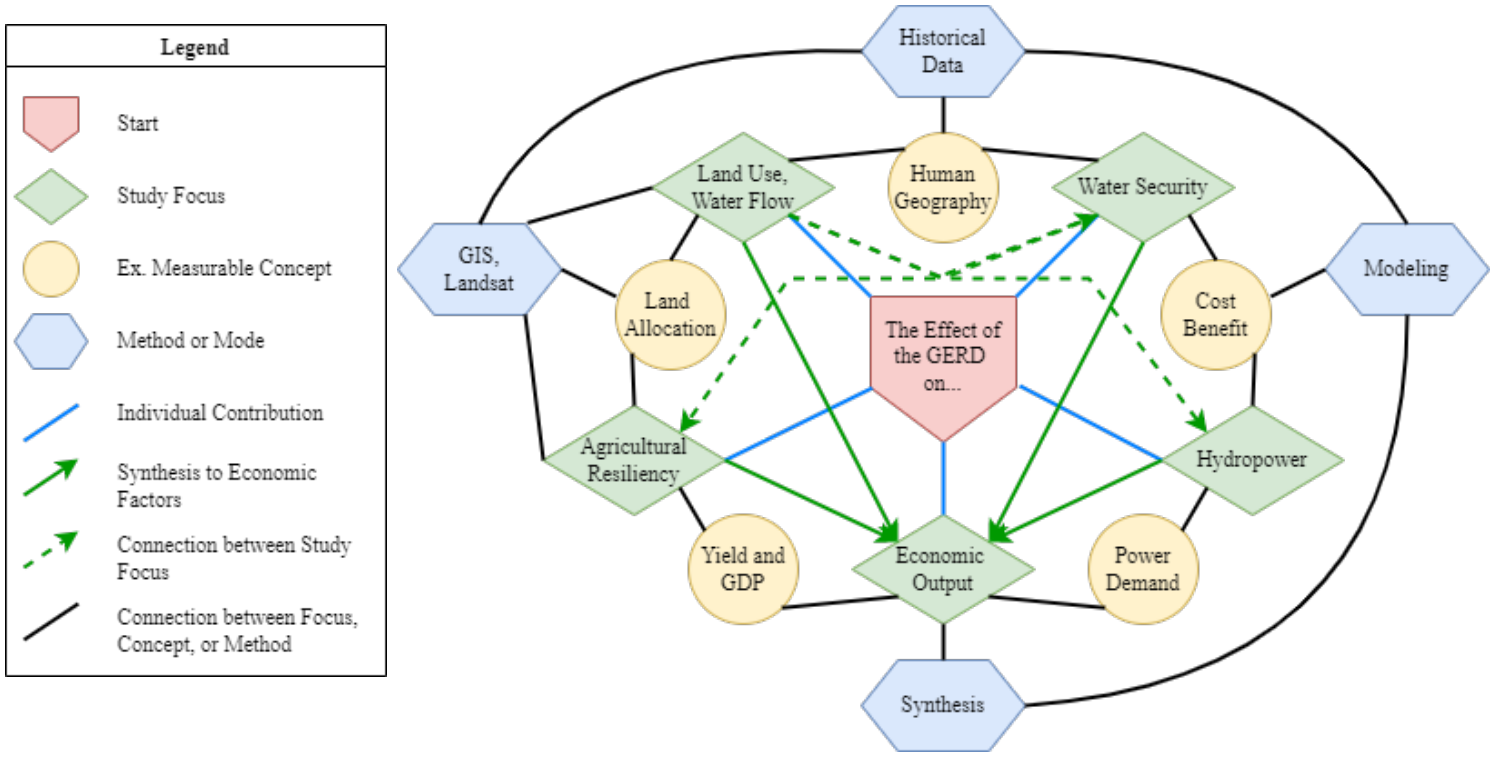


Figure 4. Problem Scoping Diagram: Grand Ethiopian Renaissance Dam. (Keith, et al., 2021)

IMPLICATIONS OF THE GRAND ETHIOPIAN RENAISSANCE DAM ON THE ENVIRONMENT AND SOCIETAL STABILITY OF THE REGION

In addition to having a substantial impact on the economies of the Nile River basin, the Grand Ethiopian Renaissance Dam will have significant impacts on the surrounding environment and social stability of the region. The primary goal of the STS research paper will be to investigate the primary environmental concerns regarding the Grand Ethiopian Renaissance Dam and how social stability will be affected. This research, which will take the form of a scholarly article, will be primarily based on previous research and case studies. Previous research regarding the Grand Ethiopian Renaissance Dam typically investigates environmental concerns

alone. Examples include dam location which raises concerns of dam failure as a result of geological and topographical factors (Mohamed & Elmahdy, 2017, pp. 341-342). The STS research paper will expand upon this by using Actor Network Theory (ANT), introduced by Law and Callon, to investigate the relationships between environmental concerns and the societal structure of the Nile River basin (Law & Callon, 1988, pp. 284-297). Using the Grand Ethiopian Renaissance Dam as the central technology, the environment surrounding the dam can be visualized similar to the depiction in Figure 5. Figure 5 places four main areas of influence in the four corners of the diagram: economics, environment, political stability, and societal stability.

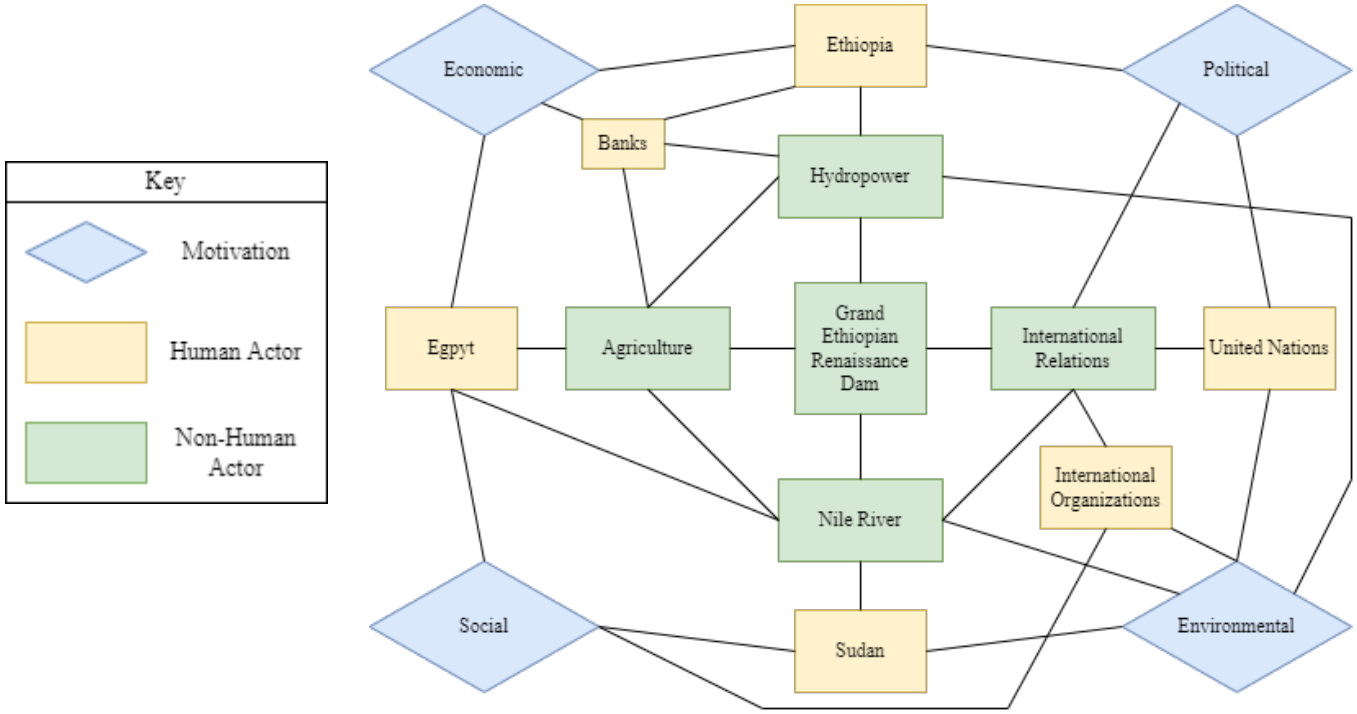


Figure 5. Actor Network Diagram: Grand Ethiopian Renaissance Dam. (Keith, 2021)

The World Bank reports that the 2020 gross domestic product (GDP) per capita in Egypt is approximately 3547.90 USD while Ethiopia and Sudan rank near the bottom with GDPs per capita of 936.30 and 595.50 USD, respectively (World Bank, 2021). The World Bank also reports that these weak economies have major reliance on agriculture with Ethiopia having the

highest at 35.5 percent of GDP (World Bank, 2021). The central role the Nile has within the region means that the GERD will influence the livelihoods of some of the poorest countries in the world. Therefore, understanding the future ramifications that the Grand Ethiopian Renaissance Dam will have on the region is crucial to determine how to best look out for the future of the region.

ENVIRONMENTAL CONCERNS OF THE GRAND ETHIOPIAN RENAISSANCE DAM

The GERD also presents numerous concerns with regards to its impact on the surrounding environments. Research in this topic began alongside the conception of the Grand Ethiopian Renaissance Dam project. From 2012, Ramadan's research into the environmental implications of the dam demonstrate how Egyptian water management strategies will have to be altered to the construction of the new dam (Ramadan, et al., 2013, pp. 2-4). From 2021, "Comprehensive Assessment for Potential Environmental Impacts of the Grand Ethiopian Renaissance Dam on Downstream Countries: Itaipu Dam in the Rearview Mirror" provides an overview of unintended environmental consequences of the dam. A few of the main concerns raised include deterioration of water quality, changes in downstream hydrological patterns, and potential for eutrophication of reservoir waters (Morsy, Abdelatif, & Mostafa, 2021, pp. 6-7). The research uses the Itaipu Dam as a case study to provide comparative analysis and reference for the significance of the impact caused by the GERD (Morsy, Abdelatif, & Mostafa, 2021, pp. 5-7). In addition to the concerns listed in Morsy's research, geographic location of the GERD is also a source of environmental concern (Mohamed & Elmahdy, 2017, pp. 1228-1229). The primary concern is due to the fact that there are tectonic concern means that there is increased

risk of dam failure (Mohamed & Elmahdy, 2017, pp. 1228-1230). As a result of these concerns, there are observed ramifications on the societal and political landscape. Already, within the region, tensions have been rising over the filling strategy for the reservoir as there may be substantial impact on the flow of the Nile and displacement of citizens within Ethiopia (Walsh, 2020).

APPLYING HANDOFF MODEL TO UNDERSTAND DOWNSTREAM INFLUENCE

The implications of the Grand Ethiopian Renaissance Dam can also be modelled using the technology handoff model, which is described in the Carlson/Baritaud handout. In this case the two paths which the dam will influence are internal, within the country of Ethiopia, and external, extending through the downstream countries. The internal handoff model can be seen in Figure 6 where beginning with the Grand Ethiopian Renaissance Dam and the engineers, the operators then decide upon the methods for filling the reservoir which then influence those that resided in the area as they are forced to move. From there, when the dam becomes operational, hydropower will then provide electricity for citizens of Ethiopia which in turn will lead to changes in business operation and development of new industry.

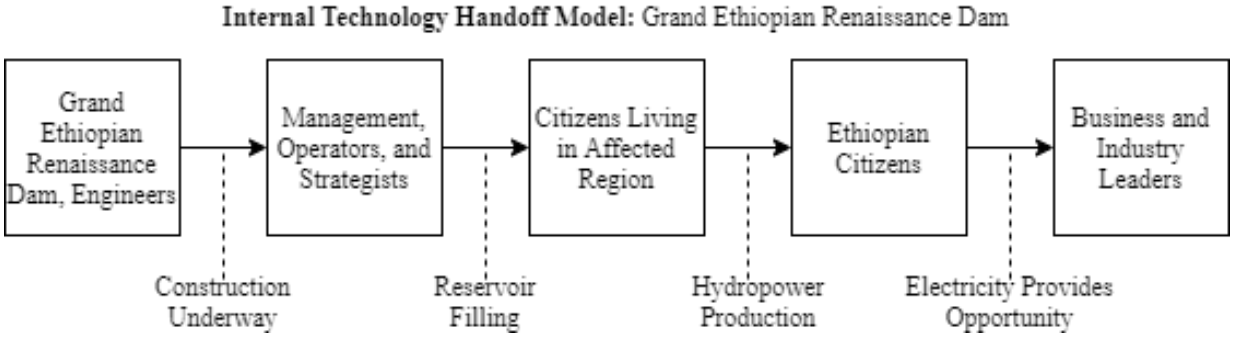


Figure 6: Internal Handoff Model. Actors impacted by Grand Ethiopian Renaissance Dam in Ethiopia. (Adapted by Keith (2021) from Carlson, 2009)

Externally, the risks of the Grand Ethiopian Renaissance are transformed as water flows downstream. This can be seen in Figure 7 where, once again, the dam is placed at the beginning with the initial risks of eutrophication and water borne illnesses affecting those around the reservoir. These are then transformed to risk of dam failure and changing hydrological patterns which will directly impact those in the country of Sudan. These are then finally changed to risks of diminished water quality and decreased water security for citizens of Egypt.

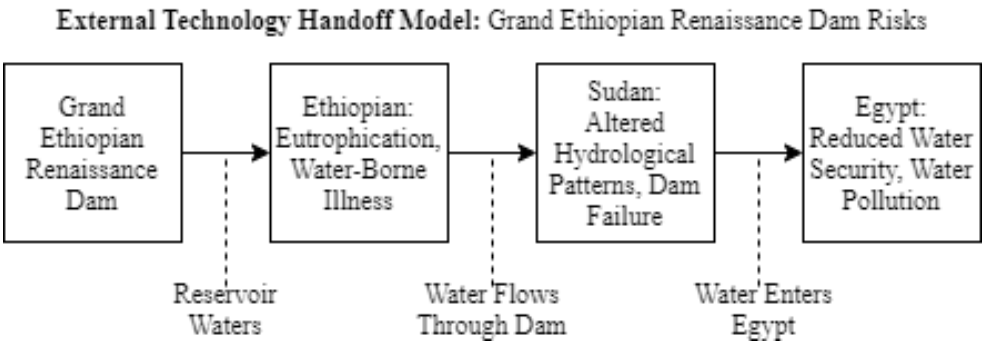


Figure 7: External Handoff Model. Actors and risks passed on by Grand Ethiopian Renaissance Dam in Nile River basin. (Adapted by Keith (2021) from Carlson, 2009)

The environmental concerns raised by the construction of the Grand Ethiopian Renaissance Dam will directly impact millions of lives within Ethiopia, Sudan, and Egypt (Morsy, Abdelatif, & Mostafa, 2021, p. 1). Consequently, tensions have risen between countries and will likely to continue to rise until assurances that risks will be mitigated are formally negotiated (El-Fekki & James, 2021). The primary argument for the dam has been that the power produced will provide opportunity for growth for Ethiopia and the surrounding countries (Mutahi, 2020). However, these agrarian states will be at increased risk of destabilizing due to the fact that the Nile plays such a vital role in providing opportunity for citizens (Morsy, Abdelatif, & Mostafa, 2021, pp. 9-10). The controversy surrounding the Grand Ethiopian Renaissance Dam has already spurred nationalistic movements within the country of Egypt (El-

Fekki & James, 2021). Increased polarity surrounding the dam means that the potential for conflict could grow and put citizens from all parties at risk (Mutahi, 2020).

ANALYSIS OF THE GRAND ETHIOPIAN RENAISSANCE DAM AND ITS INFLUENCE ON THE FUTURE OF THE NILE RIVER BASIN

The Blue Nile River has its headwaters in Ethiopia and flows through Sudan and Egypt before making its way to the Mediterranean. This area, also known as the Nile River basin, is comprised of agrarian states which depend heavily on the waters of the Nile (Mutahi, 2020). Specifically, it is estimated that 90 percent of the freshwater used in Egypt is provided by the Nile (Mutahi, 2020). This dependency on the Nile means that threats to the Nile can be interpreted as threats to the livelihood of the region and the countries within it. Consequently, tensions between the nations of Egypt and Ethiopia have been growing due to increased concerns over water security due to population growth and climate change (Rahman, 2012, p. 35). Now, since the announcement of the GERD project, there is a new source of tension which will influence both the economies and environment of the region having substantial consequences on the societal stability of the region (El-Fekki & James, 2021).

Therefore, the research conducted in this thesis project will seek to provide an understanding of the future ramifications of the GERD on the Nile River basin. The technical report will model the economic impact on Ethiopia, Sudan, and Egypt by projecting GDP for the years following the completion of the dam. This economic model will use projected data from multiple environmental models as parameters and will be tested using historical data. The STS research paper will investigate the environmental concerns of the GERD and the influence these

effects may over the societal stability of the region by using actor network theory. Thus, the combination of the two, the technical report and STS research paper, will provide an understanding of the GERD's influence on the future success and stability the Nile River basin.

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