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A TRANSDISICPLINARY, SURVIVOR-CENTERED APPROACH FOR CREATING A SYSTEM DYNAMICS MODEL OF CLOSED-BUYER SEX TRAFFICKING NETWORKS

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Industrial Engineering

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by
Kemonte Yow
May 2024

Accepted by:
Thomas Sharkey, Committee Chair
Tugce Isik
Yongjia Song
Emily Tucker

ABSTRACT

One of the largest drivers of sex trafficking operations is the demand for commercial sex. To date, research from a quantitative side typically focuses on understanding how to best identify and remove victims from their trafficking situation and then support their healing and recovery. This may be because this is where data exists (in limited forms) to support quantitative modeling. This thesis broadens that scope to understand how demand for commercial sex impacts trafficking operations. In particular, this research implemented a transdisciplinary, survivor-centered approach to build a system dynamics model of a closed-buyer sex trafficking network, which is a network where a trafficker controls who purchases sex through a vetting process. It offers a proof of concept of what a potential validated system dynamics model could yield in terms of analytical capabilities. This work has integrated the expertise of a survivor-centered advisory group through the entirety of building the model, leading to many novel trafficking insights obtained through a 'systems thinking' lens. These insights present future paths for research and illuminates a new way of thinking in terms of sex trafficking operations.

DEDICATION

This paper is dedicated to my mother who has constantly been there for me. Her love and support has been consistent throughout my academic journey. The lessons she's taught me about being selfless is one of my biggest motivators for wanting to pursue research. Her consistent reminders to keep God first has kept me grounded throughout my journey. She has given so much to me throughout my life that I want to dedicate something to her that also means a lot to me. So here's to you, Momma!

ACKNOWLEDGMENTS

I am beyond grateful to my advisor, Dr. Thomas Sharkey, for his continued support and invaluable guidance throughout this research journey. Dr. Sharkey's dedication and passion for scientific inquiry have served as a beacon, illuminating the path towards becoming a better researcher.

I am indebted to the members of the advisory group and research team for their trust, wisdom, and openness. Their diverse perspectives have transformed and expanded my understanding of the world, leaving a profound mark on my academic and personal growth. I am incredibly grateful for the opportunity to work with such an inspiring group of individuals, and I will carry the lessons learned from our discussions with me always. I recognize that my research cannot capture all the complexities of the lived experiences of trafficking victims and survivors. Therefore, I have been incredibly fortunate to be guided by our survivor-centered advisory group which includes Tonique Ayler, Teresa Forliti, Joy Friedman, Mikki Mariotti, and Christine Nelson. I also am thankful for Dr. Lauren Martin, who helped to lead our advisory group meetings and Vanessa Voller, who helped to coordinate and run them.

I extend my appreciation to my esteemed committee members, Dr. Tugce Isik, Dr. Yongjia Song, and Dr. Emily Tucker, for their insightful feedback and encouragement. Their expertise and guidance has been crucial in shaping the direction of this research.

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CHAPTER ONE

INTRODUCTION

Human trafficking is the act of using force, fraud, or coercion to compel someone to perform sexual acts, labor, or service against their will (United States. Office of Justice Programs. Office for Victims of Crime, 2017). When a minor is involved in a commercial sex act, force, fraud, or coercion does not have to be shown because the person is underage (United States. Office of Justice Programs. Office for Victims of Crime, 2017). Individuals who are economically disadvantaged or have a problematic home life are at higher risk to be targeted by traffickers (Hickle, 2017). Human trafficking is not just a problem abroad, but it is a problem right here at our shores and is one of the biggest criminal enterprises in the United States. Human trafficking exists in two main components: labor trafficking and sex trafficking. Sex trafficking occurs when a victim is forced to perform sexual act with a buyer by the trafficker.

First, we will discuss the term victims. Victims are those who are subject to exploitation. Victims of domestic sex trafficking are often confused as willing participants in the commercial sex market and, therefore, may be falsely imprisoned within the criminal justice system. There are federal laws that have been put into place to protect trafficking victims and prohibit them from facing criminal charges, but they often fail (Baird, 2019). There is also a negative stigma around domestic sex trafficking victims because the narrative is they are choosing to be in their situation, leading to being blamed (Baird, 2019). This is typically false because traffickers take victims away from the family and friends and coerce them into sex trafficking. It is not until recently that society

has begun to shift to a victim-centered approach to combat sex trafficking (Baird, 2019). It has been estimated that victims' friends and family make up almost 40% of the initial recruitment into domestic sex trafficking (Horning et al., 2020) which complicates how the victim perceives their entry into trafficking.

Traffickers are individuals or a group of people that are exploiting victims. Traffickers often find individuals that are vulnerable due to instability in their home life or without a support system (Herrington & McEachern, 2018). Typically, they will go through the process of grooming victims over time before they begin to introduce a victim to trafficking. During this process, traffickers make sure the victims feel safe to begin forming a bond to control them. A trafficker may have a victim recruit more victims by implementing the same process that was done to recruit them, thus creating a cycle. Traffickers will often use a variety of techniques to coerce and control victims, from physical violence to emotional manipulation. An example control method that a trafficker will use is the victim's children (Hickle, 2017). They will threaten to take the children away from them if they do not cooperate or try to leave, which results in the victims staying to protect the child (Barrick et al., 2023; Hickle, 2017). This is just one example of tools a trafficker uses to manipulate victims but there are many more that have been identified through current research efforts (Barrick et al., 2023). The median time a trafficker will spend in this industry is roughly 4 years (Horning et al., 2020).

Buyers are researched far less often than traffickers or victims due to varying opinions on buyers' responsibility in trafficking operations (Demand Aboliton, 2018). Buyers come from multiple backgrounds and demographics and various income levels

(Martin et al., 2017). They primarily encounter traffickers through the internet, in-person solicitation or word-of-mouth networks (Martin et al., 2017). Most buyers are typically male but there are some instances where women or couples buy sex. According to a study, only 6.2% of men have bought sex within the past 12 month and 20% will throughout their lifetime (Demand Aboliton, 2018). The majority of buyers who purchase sex do not purchase sex often and the ones that do purchase sex regularly account for nearly 75% of market transactions (Demand Aboliton, 2018). Roughly 6% of those who purchased sex illegally reported being arrested for it (Demand Aboliton, 2018). The biggest deterrent for most buyers from buying sex is the risk of being arrested and police presence (Demand Aboliton, 2018). Yet, it has been reported that buyers are only arrested 2% of the time compared to when victims are arrested. (Jeffs, 2013). We now provide an overview of domestic sex trafficking, which will be the focus of our proposed system dynamics modeling approach to better understanding trafficking.

Domestic Sex Trafficking

Sex trafficking is becoming widely known as an exploitation-based crime across the globe (Herrington & McEachern, 2018). In 2010, Kevin Bales, a leading scholar in the field of human trafficking, estimated at least 50,000 people were being trafficked within the United States (Baird, 2019). This was over 14 years ago, and more details are still being found, uncovering the full scope and size of domestic sex trafficking industry. It is sometimes difficult to find consistency in data among research in this field because local policies are different from city to city, there is a lack of training among law enforcement or design errors in the research process (Herrington & McEachern, 2018).

From what has been studied, it is estimated that ninety-nine percent of sex trafficking victim are female and half of trafficking victims are children, with most of the adult victims having their first experience with trafficking as minors (Jeffs, 2013). It is estimated that only one buyer of commercial sex is penalized for every fifty victims that are penalized (Jeffs, 2013). One study suggests that the average time a victim spends in the commercial sex market is 7 years (Jeffs, 2013). This is contradicted by Hickle (2017) who estimates the time a victim spends in the life is anywhere between 2 and 31 years with an average of 14.7 years (Hickle, 2017). This is one example where there is a lack of consistency in data and it demonstrates how the population included in the research process influences its conclusions. One explanation for this difference in this case is the fact that the study conducted by Jeffs (2013) was focused on punishing buyers and traffickers in Utah, while the study conducted by Hickle (2017) focused on the Southwestern United States.

There is a wide range of data that attributes to the way that victims and buyers interact in the domestic sex trafficking network. This further shows the uncertainty around data in this field. One example of this is the economics of domestic sex trafficking. One study based in Harlem focused on traffickers' work decisions and economic returns listed the weekly profits of a trafficker ranging from $60 to $100,000, with a maximum value of $31,500 when removing the biggest outlier (Horning et al., 2020). Another article focusing on demand of sex trafficking cited the average price per act between at $74 to $227 based on the venue in which the sex buyers find the commercial sex (Demand Aboliton, 2018). A similar study done by Dank et al. (2014)

shows these prices depend on the type of sex act, geographical location and time with the prices ranging from $75 to $2500. What this demonstrates is that the more factors that are introduced in the data the further we get from a common median, resulting in having to scope down a model or imposing stricter its assumption to make a quantitative model, like one of the goals of this thesis. These authors also note that the number of acts per day per victim is determined on monetary limits set by trafficker, meaning that a victim could only do one act and be done for the day or be forced to over ten acts per day (Dank et al., 2014). Raphael et al. (2010) did a study in Chicago and cited the average number of acts as ten as well as with a range from 2 to 20, further showing the data is highly contextual dependent.

There are multiple diverse types of "business models" that a domestic sex trafficking network may operate under. Four examples of domestic sex trafficking business models are: a closed sex buyers' network, street prostitution, brothels & brothel-like, and escort services (Martin et al., 2017). Escort services are a predominately online marketplace and take a relatively small amount of capital to implement (Martin et al., 2014). These type of markets help to reduce risk for sex buyers seeking opportunities to purchase sex. Brothel and brothel-like model sex trafficking are typically described as sex trafficking networks which pose as legal businesses (Martin et al., 2014). Typically, these type of operations have buyers coming to a central location to engage in sexual activities. Victims often live at this location which is overseen by a male entity (Martin et al., 2014). Street prostitution is a model in which victims are seen walking the streets or a specific public area under watch of a trafficker/facilitator nearby (Martin et al., 2014). A

study done in Harlem said that this is a business model that is often avoided by younger traffickers due to its higher risk (Horning et al., 2020). This is typically the most visible business model to both buyers and law enforcement. The last business model we see is a closed sex buyers' network. This model is special in the fact that there is a restriction on who is allowed to buy because the buyers are pre-screened or 'vetted' (Martin et al., 2014). Newer traffickers are more likely to use this business model because they will try to avoid having strangers as clients (Horning et al., 2020). This thesis will present a system dynamics modeling approach to understand how victims and buyers interact in a trafficking operation that implements a closed sex buyers' network business model. We now provide an overview of system dynamics and how it has been applied to sex trafficking and related problems in the past.

System Dynamics

Campuzano & Mula (2011) defines system dynamics-based simulation models as, "mathematical models (abstracts) that are dynamic (interactions that vary with time), linear or nonlinear, stable (tend to return to their initial condition after being disturbed) or unstable, of a stable state (repeated with time) or are transitory (the system's nature is modified with time)" (Campuzano & Mula, 2011). System dynamics is used to model several different issues including diseases (Hirsch et al., 2010), epidemics (Bagni et al., 2002), energy usage (Aslani et al., 2014) and water crises (Sun et al., 2017).

Employing system dynamics will let us model how variable changes could impact sex trafficking networks. Most approaches to modeling sex trafficking are victim or trafficker focused. Through discussion with our research team's survivor-centered

advisory group, we realized that it would be important to view domestic sex trafficking from a perspective that includes the importance of buyers (Dimas et al., 2022; Barrick et al., 2023). Our working hypothesis is the following impact: if buyers in the system are reduced, the motivation for traffickers to continue to traffic victims. However, based on the data issues present with studying sex trafficking networks, we have initially chosen to scope our focus to sex trafficking networks that operate under the closed-buyer network operations.

System dynamics has not really been used to model domestic sex trafficking in detail. However, there are a few examples research teams using system dynamics to understand human trafficking across the globe. One example in which we see system dynamics used is understanding labor trafficking in the seafood industry (Konrad et al., 2023). Konrad et al. (2023) conducts a case study in Thailand to create a system dynamics model that helps model interventions to reduce forced labor and labor trafficking. Brelsford & Parakh (2018) also used system modeling approach to look at the Overseas Filipino Workers economic system with respect to human trafficking. They used scenario simulations to find the cause-and-effect relations between "government policies, overseas workers options, hiring companies, and the economy" (Brelsford & Parakh, 2018).

We see an example of system dynamics used in sex trafficking by Senft et al. (2019) in a study based in Maharashtra, India. Their article notates the importance of demand reduction in reducing the number of victims in a system (Senft et al., 2019). Our work differs in that we will focus on domestic sex trafficking using a transdisciplinary

approach, but their work helps show that system dynamics can be used in this space and provides additional analysis on the impacts of demand reduction. While the model they build is impactful, it could have been furthered by applying a transdisciplinary approach which provides a more in-depth look at influences in the system from a lens of domain expertise that would not be available by looking at current data.

Grimes et al. (2011) display a similar concept where their work is focused on a sex trafficking model in Washington, D.C., but they also do not use a transdisciplinary approach to sex trafficking. This article focuses on a very high-level model of human trafficking, which is also different from our model where we model a specific closed-buyer network. They do an excellent job of modeling the network for policy implementation like Brelsford & Parakh (2018) but do not consider past research with data analysis considering it largely unreliable (Grimes et al., 2011). Instead, to populate initial data they used information from "undercover metro PD Vice," giving them more of a first-person perspective (Grimes et al., 2011) for a very specific location and viewpoint in terms of sex trafficking knowledge. This route makes it harder to validate the rates that are entered into the model or the "effectiveness" with which certain variables are considered, which could cause issues in policy recommendation.

We have found a similar issue with the data collection process in scoping the model to a closed-buyer network of sex trafficking with the state of current literature. A major contribution of our research is to involve our survivor-centered advisory group in each step of the modeling process (see Chapter 2) which, to the best of our knowledge, has led us to be the first to bring in survivor knowledge into system dynamics modeling.

We populated the model with data based on current research, but additional efforts are needed to fully validate the data. As a result, this is not the focus of the contribution of our work. There were benefit in using system dynamics and the thinking involved to further the work on sex trafficking since it allowed the survivor-centered advisory group to offer new knowledge about the operations of closed-buyer networks. We present the resulting system dynamics model and initial analysis using incomplete data. The system dynamics model needs to undergo additional validation before we would justify its use for implementation. However, as mentioned previously, a system dynamics mindset has offered new insights into sex trafficking.

Contributions of this Thesis

This work seeks to build on the approach taken by Clark et al. (2024). In their work, they build a realistic network interdiction model and use transdisciplinary research to advance the work in a practical sense by ensuring that the assumptions and limitations are carefully understood and the collected data is reliable for a certain scope. The work of Clark et al. (2024) is the result of transdisciplinary research processes applied to the core network interdiction model created by the Master's thesis Clark (2022). In this thesis, we are intentionally bringing in a survivor-centered advisory group, who are domain experts and many of them are survivor-leaders, through all phases of the modeling process rather than build a model first and ask for their inputs after the model was complete, like Clark (2022) did. This further allows us to gain better insights on trafficking operations that may not have been considered through a pure operations research perspective. Our time and conversations with the advisory group and

implementation of system thinking has allowed us to conceptualize certain operations within domestic sex trafficking in new ways. Implementing this thinking in transdisciplinary research will help to create better, more informed research and data collection methods. We find that viewing the entire system as a whole has allowed us to gain new insights to individual pieces of the operations including: how traffickers deal with instability in the system (circuits and trafficker partnerships and/or networks), factors that may influence a traffickers decision making process (control and recruitment), and the way buyers interact with different victims within the system (green and veteran victims).

The rest of this thesis is organized as follows. Chapter 2 provides an overview of the iterative process of working with the survivor-cented advisory group (henceforth, known as "the advisory group" or the AG) and how our system dynamics model evolved through this collaboration. Chapter 3 provides an overview of the knowledge that was obtained about sex trafficking through the "system dynamics" mindset and working with the AG. Chapter 4 provides an overview of the final system dynamics model and provides potential sample analysis that could be obtained through its application, should more verified, reliable data becomes available. Chapter 5 concludes the thesis.

CHAPTER TWO

CO- PRODUCTION OF MODELING RESEARCH DIRECTIONS

Preliminary Measures

Our research efforts are a combined effort of our operations research team (OR) and our advisory group. Our survivor-centered advisory group (AG) has over 90 years of experience in survivor advocacy, social service, and healing and some members of the advisory group are survivor-leaders themselves. The goal of implementing this form of research is to communicate the stories and lived experiences of domestic sex trafficking victims and survivors authentically, accurately, and ethically, while also building realistic abstract models to help understand how to better disrupt sex trafficking networks. There were two major phases of our work with the advisory group: the preliminary phase which identified a research question and preliminary modeling direction and then an iterative process phase where we move between the OR team advancing the model and critiques by the AG to improve the realism of the model. Through the exploration of these critiques, we found that there are gaps in present data and knowledge of sex trafficking, which our discussions with the AG helped to fill.

There were four steps that were taken during our preliminary phase: (1) gaining advisory group input on research directions, (2) deciding on a research question, (3) deciding on a methodology and (4) creating a preliminary model.

The iterative process involves a three-part approach for the team: (i) Advisory Group feedback; (ii) OR Group Implementation; and (iii) collective understanding on the implementation. The advisory group feedback consists of the advisory group offering

suggestions on things that our current model is missing or research areas that we have not looked at that could be beneficial. The OR group uses these qualitative inputs and modeling suggestions to change the model so that it is more accurate or discusses the limitations of the model if we are not able to capture a suggestion. Following the changes, we reconvene with the advisory group to ensure that they understand the direction the OR group chose and why it was chosen based on their initial feedback. This is a crucial step because if the direction the OR group chooses is misleading to those seeing it or misrepresents the operations within the system, then our entire model becomes less likely to be an accurate representation of the experiences of sex trafficking victims. Figure 1 provides an overview of our modeling processes.

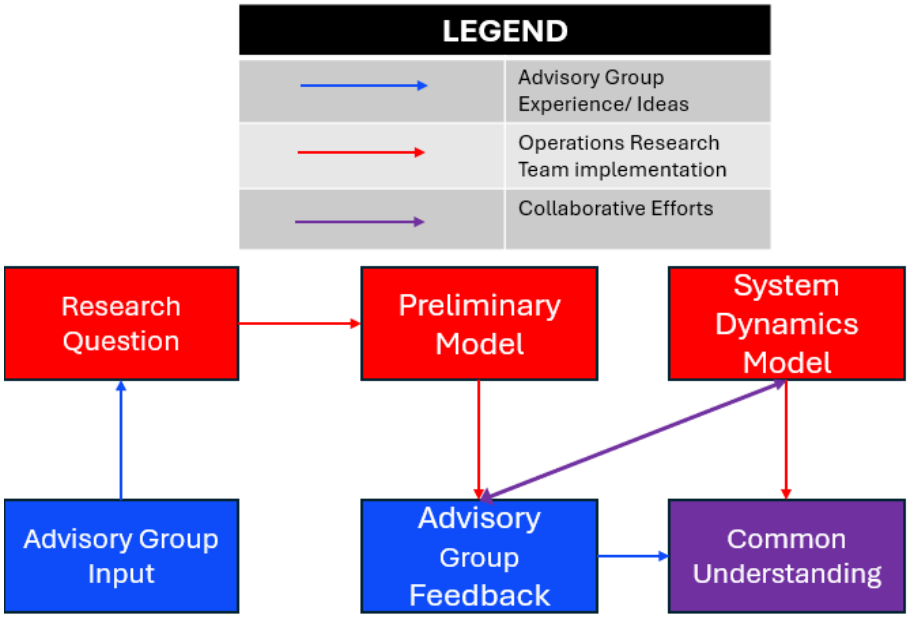

Figure 1: Survivor-centered transdisciplinary research process

In this chapter, we will focus on the preliminary phase of the research process.

Advisory Group Input on Research Direction

In October 2022, we had a retreat with the advisory group where we discussed the previous research that had been done by our team and gathered their input on future directions, they believed we should go next. A concept that stood out was demand reduction, the idea that they had was "if there is no demand, there is no need for victims." Traffickers typically go into the human trafficking because it is profitable with less risk than drug trafficking, but if we take away the demand that makes it profitable then traffickers are more likely to leave the field (Senft et al., 2019).

This helped to pose our initial research question: Can we model the interactions between buyers and victims in sex trafficking networks, and if so, how does changes in demand influence the number of victims and vice versa? These questions led us to pitch to them the idea of using system dynamics to capture these interactions. We made a preliminary systems dynamics model, which we presented to them in November 2022. However, this was not the only research direction that we pitched in November 2022.

Research Question & Methodology

Most researchers in the field of human trafficking have created victim-centered models (Dank et al., 2014). We initially considered exploring this option given greater access to data, but ultimately wanted to make a joint decision between us and the advisory group. We went into our November 2022 meeting with this mindset presenting two options, Systems dynamics & EPI/Disease modeling, as a path forward for us and the advisory group based on the conversations following the retreat.

Our research team has worked closely with the advisory group on understanding the recruitment of victims into sex trafficking as apart of a different project (Martin et al., 2024). This recent work consisted of an implementation of a Markov chain approach to analyze effective strategies to disrupt recruitment. The Markov Chain study models the state and transitions that a victim may go throughout their time being trafficked, which is similar to the concept of EPI/Disease modeling and system dynamics models. In particular, we could examine an EPI-like model where the 'infected' state models being actively trafficked. We could also examine a system dynamics model that incorporates the different states and transitions that a victim could be in, along with similar states for traffickers and buyers. Overall, the familiarity with the Markov Chain of the advisory group led us to consider these modeling processes moving forward.

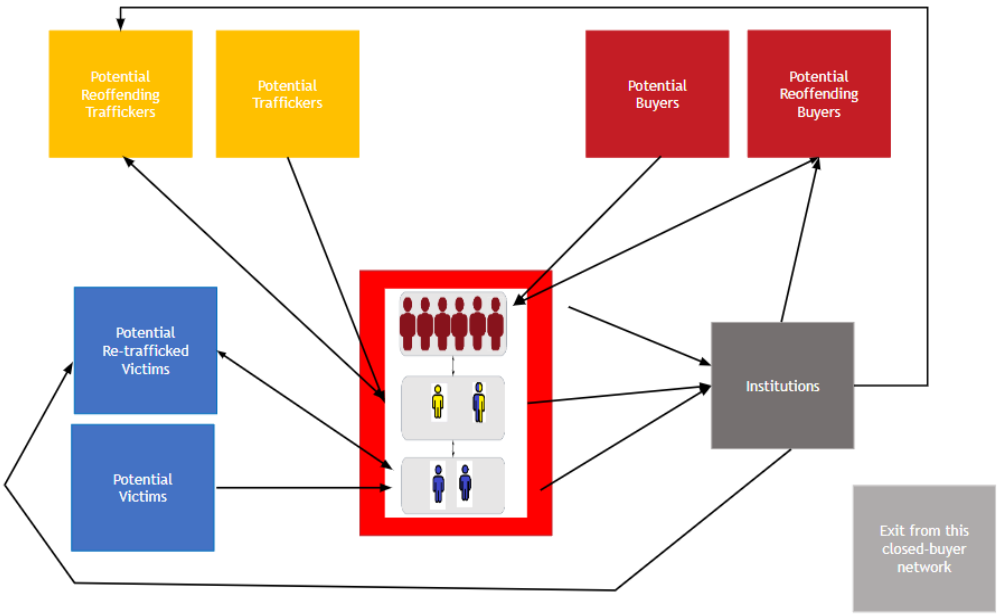

Figure 2: Preliminary concept of a system dynamics model.

The first idea we wanted to pitch to the advisory group was focused on the demand reduction conversation from our retreat. Given the complexities of interactions between the buyers and the victims, the OR team thought that a system dynamics approach could be used as the methodology to examine demand reduction. In the area of human trafficking, previous system dynamics model acknowledged that demand reduction has been confirmed as a potential path forward in the academic literature (Brelsford & Parakh, 2018; Senft et al., 2019). Using system dynamics, we can implement transition rates that are dependent on various aspects of the entire system, as we are looking at populations of people flowing through the system at any point in time. Figure 2 provides an initial model of the interactions between traffickers, victims, and buyers that we would later convert to a system dynamics model. The commercial sex market is in the red box in the middle of the diagram, with individuals being able to exit at any point.

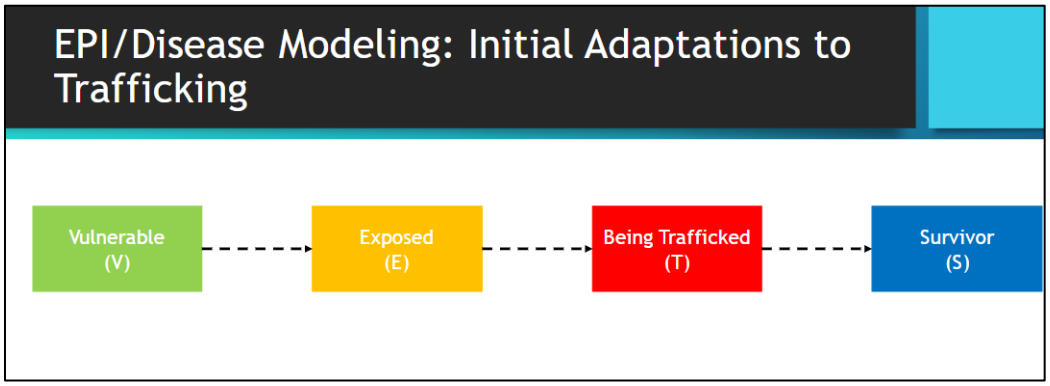

Figure 3: Preliminary pitch of EPI/Disease modeling presented to the advisory group.

The second methodology we considered using was the EPI/disease modeling. Using this model, we could measure the effectiveness of resources in preventing victims

from becoming trafficked by gaining understandings of the vulnerabilities that help traffickers exploit victims. We also explain to the advisory group how this could be a potential use of demand reduction by going through these states from a buyer's perspective to find preventative measures that would detour them from the sex trafficking market. Figure 3 is the model we presented to the advisory group to help them understand what this model could look like.

During this process we have seen how important it is to properly communicate ideas during transdisciplinary research. While in the OR world, we see familiar models and transitions, we sometimes forget to see the reality of the model and make it practical for individuals outside of the field to understand. When we were explaining the ideas that we were implementing, it led to some initial confusion about the ideas that we were trying to get at. This led to comments along the lines of:

> *"I'm just thinking that it might be helpful to see an actual scenario of this because I'm one of those people, I need to see it. Like the traffickers and victims going through the motions. Because relationships are different amongst all these players."* (Advisory Group Member, November 2022 AG Meeting).

This idea echoed throughout the group with nods of approval but there was still a lack of understanding between the OR team and the advisory group on what *they meant by scenarios*, so we asked for further clarity resulting in the comment:

> *"Something that came to mind when we say scenarios is how people were introduced to the life, like what do people know when they go in. So, I think about the movie Pretty Woman. Okay? And looking at that and putting that into this*

formula vs. the movie Monster and looking at those. Because one is a real-life story vs one is someone's imagination. Because you can look at the impact of this once they're in it." (Advisory Group Member, November 2022 AG Meeting).

We understood that we had to make the model presentation more understandable and relatable in order to ensure that the AG could help critique it. This understanding helped us to understand how important using illustrations and applying them accurately are incredibly significant. An illustration could be used as someone's map to understand the work we are doing from an analytical perspective, who do not come from a similar academic background. Given our goal of having the AG critique the work, it would also be used to help analyze how accurate the conceptualizations, assumptions, and data were in the model.

During this discussion we began to find and discover ideas that would help us better understand the system that we were trying to model to make us better informed on how we should properly scope the model. The first comment that came to us was, "traffickers can also be buyers." This idea was also mentioned by Martin et al. (2017) and was brought up because in our model (see Figure 2) we made a distinct difference between the traffickers and buyers. However, the answer to the question "how do you disrupt the system when a trafficker is also a buyer?" is not immediately clear within our framework. This is because the way you implement interdictions in the model is based on the assumptions of it.

Another major theme that came up during this meeting was the idea of displacement. Displacement is the idea of implementing interdictions in one area that

would cause a trafficker or operation to move its illicit activites to other places or adapt its operations, without the operations being significantly disrupted. While we were considering the disruptions that could possibly be made according to previous research, one of our advisory group members mentioned that online platforms is a major opportunity:

> *"I don't know if this would go here but another disruptor that we can disrupt if we play our cards right is with online and in the media. One of the biggest pimps out there is* [listing social media platforms] *you know, whatever online platform. Those platforms are buying and selling our folks just as fast as pimps and there is a way to handle and disrupt that. Media and hotels, stuff like that, just throwing that out there, I don't know where this fits in the equation."* (Advisory Group Member, November 2022 AG Meeting).

This insight is important because while in our model and analysis it may look like our interdictions are having an impact when, in reality, we may not have a way to model the displacement that our actions are causing. It gives us another potential unintended consequence of disruptions in the system and allows us to think about how to consider the impacts of displacements within our model.

Following these conversations, we revisited the modeling ideas that we pitched to the advisory group at the conclusion of the meetings and the idea of demand reduction was emphasized once again:

> *"Probably what we will have to do is pick one and do proof of concept with it."* (Academic Team Member, November 2022 AG Meeting)

"Buyers, buyers!" (Advisory Group Member, November 2022 AG Meeting).

Therefore, our co-produced research direction (with the advisory group) suggested that utilizing system dynamics was the way forward.

Scoping

In the time between our November 2022 and May 2023 advisory group meetings, it became clear that a system dynamics model that tried to capture the entire commercial sex market (and all relevant sex trafficking networks) would be unrealistic. During this time, we realized it was best to focus on a closed-buyer network (an updated overview of this idea is shown in Figure 4) because there are various decision-making criteria that a trafficker goes through that influences the demand entering in the system and there is little known information about how individual traffickers act based on current research (Barrick et al., 2023), let alone understanding how traffickers choose to enter the commercial sex network. Focusing on a closed-buyer network allowed us to scope the model appropriately in the sense that we felt we could be able to gather enough data to populate it. At this point we knew we needed to effectively communicate the more in-depth ideas behind system dynamics and system thinking to the AG for them to be able to understand how their feedback would influence the model

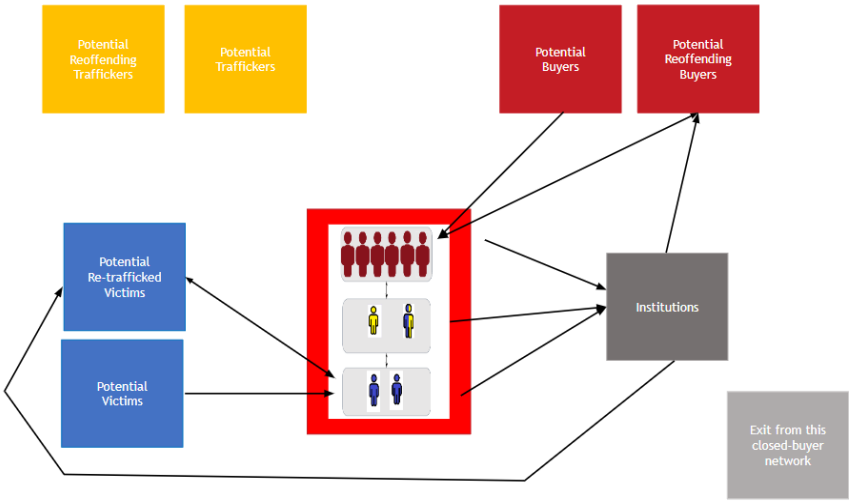

Figure 4: High level model of a closed-buyers network

First Steps of Co-Modeling Process

In May 2023, we had another meeting to further discuss the preliminary model in Figure 4 more in-depth and to further explain how system dynamics work. We provided the advisory group with a pre-reading before the meeting so that we could communicate common terms and definitions outside of their expertise that would be necessary for the meeting. We found that this allows for increasingly productive discussions because we could review any questions from the pre-reading early in the meeting in order to be closer to the common ground necessary to co-produce the modeling assumptions and context.

We began our meeting discussing ideas from the pre-reading and answering any questions there may have been about the document. We recognized that the advisory group already understood the methodology of a Markov chain, so we wanted to build off of this concept. Applying the feedback that we received on the importance of examples and illustrations from the November 2022 AG Meeting, we used that feedback in our

explanation of going from understanding a Markov Chain to systems dynamics and systems thinking.

Systems Dynamics Illustration

In order to demonstrate the differences between 'Markov Chain thinking' and 'system dynamics' thinking, we used an illustration applying both ways of thinking to a playground. We first explained how a Markov Chain model goes through an individual moving from state to state as capturing how a kid would move to distinct parts of the playground (see Figure 5).

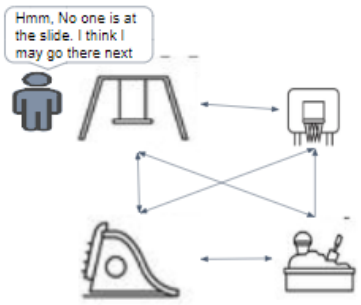

Figure 5: Part I of the playground illustration to the advisory group from a Markov Chain perspective.

We then explained that systems dynamics on the other hand would look at the entire system over time focusing on populations of people rather than focusing on individual elements. It would look at how these individual elements interact and can cause changes to other parts of the system. We used the example of how the likelihood of

a kid moving through the playground would change because of where other children are in the system like in Figure 6.

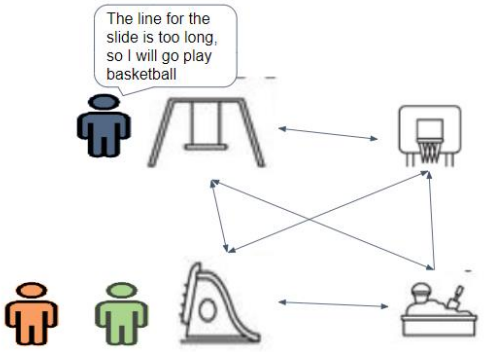

Figure 6: Part II of playground illustration to the advisory group to help explain system dynamics.

We then moved this idea further by examining how different populations of people could be within a single system, creating even more dependencies and interactions. We used the example of children in different grade levels all playing on the playground at once, shown in Figure 7, to illustrate how different populations would interact with one another.

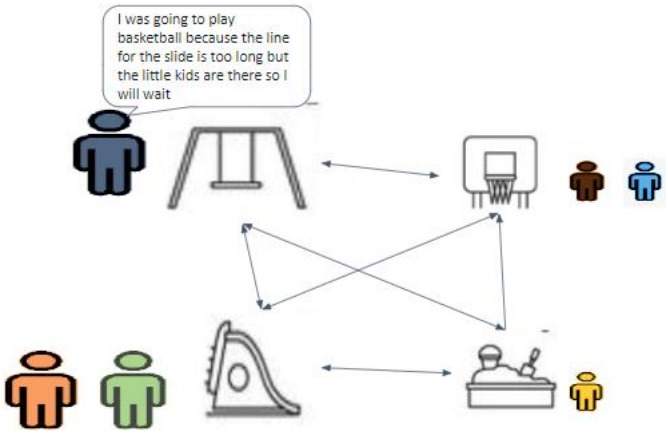

Figure 7: Part III illustration to explain concept of system dynamics with multiple populations.

This illustration made it possible for us to explain how the system dynamics work for the advisory group to get how the model operates. We then went into what this meant for our model for sex trafficking and also clarified that we understand that victims do not have a choice in how they move like we see in the playground illustration. The advisory group responded well to the illustration being used:

> *"Yes, absolutely. I am very excited to do this. Kemonte, I want you to know that when I said I was looking at this and have lots of questions, its because I really... it was very good, it was very well done."* (Advisory Group Member, May 2023 AG Meeting).

This led them to questions on the inner-workings of our system dynamics model rather than on how system dynamics models work, which showed that they understood the concept and system that we were attempting to build together.

> *"Are we going to get a chance to comment on those interdictions? Because in the homework we were talking about some of those."* (Advisory Group Member, May 2023 AG Meeting)

This demonstrated a common understanding of the modeling approach we were attempting to use and allowed us to move forward into our iterative process to co-produce a system dynamics model of a specific sex trafficking operation.

CHAPTER THREE

INTEGRATED CO-MODELING PROCESS: IMPLICATIONS & INSIGHTS FOR SEX TRAFFICKING

Following our preliminary work mentioned in Chapter 2, we entered our iterative process applying system thinking. In this chapter we will discuss the details of the iterative process in three parts: background & meeting overview, modeling & terminology changes and trafficking insights. The background and meeting overview section will discuss a high-level view of the meeting and background information that was important to the discussion we had during the meeting. The modeling and terminology changes section reviews modeling changes and vocabulary changes we used to describe certain parts of the system. The trafficking insights section shares the information that we found beneficial, and the knowledge gained through our discussions with the advisory group on sex trafficking operations.

Phase II: May Meeting

Background and Meeting Overview

Once it was made clear what we were trying to accomplish by using system dynamics, we moved from modeling the bigger picture we see in Figures 2 and 4 to understanding the dynamics of specific operations within the system, especially within the commercial sex market. Our first focus was on how interactions between buyers and victims were facilitated with the network. Figure 8 provides an overview of a trafficking operation where one victim (the left one) can communicate directly with buyers, whereas Figure 9 provides an overview of a trafficking operation where all communications must

be between the trafficker (or the main girl[1]) and the buyers to facilitate the buyer-victim interaction. This was followed up by asking the advisory group about the balance of supply-demand in the market, such as the ratio of the number of buyers to victims or the ratio of the number of victims to buyers. Finally, we discussed the idea behind a closed-buyers' network (shown in Figure 4) and its definition with the advisory group

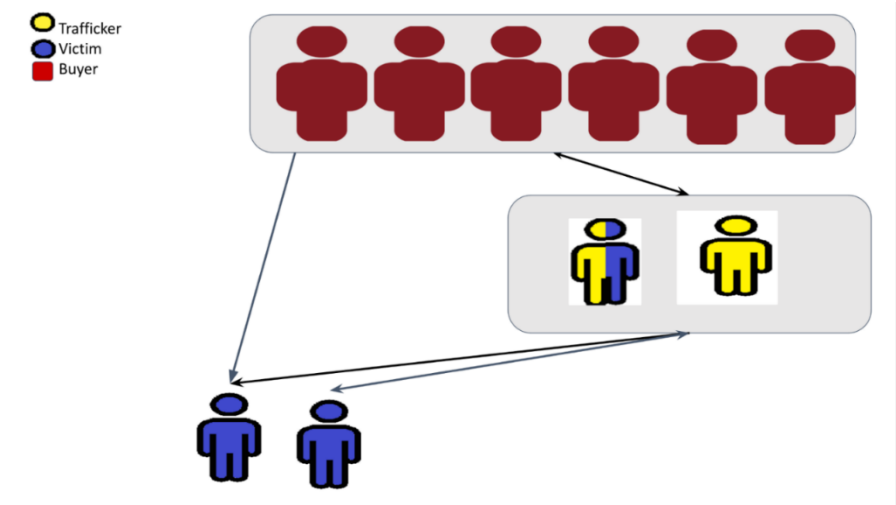

Figure 8: A potential understanding of communications within a closed-buyers network.

[1] In the academic literature, this role is commonly referred to as a "bottom." We will soon discuss why we use the term 'main girl' instead.

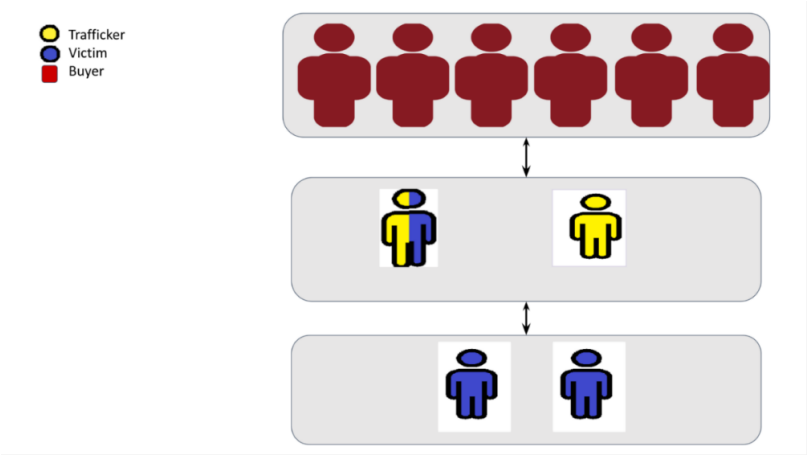

Figure 9: Alternate potential understanding of communications within a closed-buyer's network.

Modeling & Terminology Changes

As previously mentioned, during our preliminary scoping activities, we realized that a closed-buyer network would be an appropriate start to applying system dynamics to sex trafficking. A member of the advisory group also suggested that we begin by focusing on a single network rather than a local market to further scope the context of our model. These two understandings provided sufficient enough reasoning to move forward with the closed-buyer network. We provided this information to the advisory group and began with a working definition that a closed-buyer network is a system in, "which a trafficker only interacts with a vetted list of buyers." One of our qualitative researchers mentioned closed-buyers network have been discovered in the past but are harder to disrupt if everyone cooperates:

> *"Okay so I would look at case files at the MPD and this person would reach out to buyers and make a relationship and so they weren't posting online but reaching out to buyers. Like it says here, there was like a vetted list of people who*

> *were sex buyers and so those people would reach out to them and say, "We're having a party, we want this" or he would reach out to them. This guy worked for Siemens, a large company, he worked on a loading dock, he had a legitimate job and he used it to build his network of buyers. The thing is that it is undetectable if everyone keeps their mouth shut."* (Academic Team Member, May 2023 AG Meeting).

Essentially, what occurs in a closed-buyers network is that a trafficker controls the demand that enters the network through a vetting process. In other words, a buyer can only participate in the network should the trafficker first 'approve' them. In addition to defining closed-buyer networks, we received feedback on the overall system dynamics thinking (see Figure 4). A change that we made to the model as a result of this feedback was to update colors that were being used for the arrows and the boxes for institutions. Initially, we used black arrows to represent transitions in some figures but then used them as influences within the market and had a single box representing individuals that were going into different institutions (i.e., prisons). Our updates included individual 'institution' boxes for each type of person considered in the figure and, similarly, color-coded arrows to represent the movement of a person between different states. This seems like a minor change, but without it there was major confusion, which could be a barrier to collective understanding between all members of the team.

Additionally, we changed the color of the buyers to avoid contributing to any current stigma around buyers. One member of the advisory group asked:

> *"Can we change the color of the buyers?; I think it is kind of a subliminal message that only Brown people are buyers."* (Advisory Group Member, May 2023 AG Meeting).

As researchers, qualitative or quantitative, we have a responsibility to ensure that we do not unintentionally contribute to these stigmas and working with domain experts and an advisory group ensures that we mitigate the potential to do so. This further seeks to emphasize the importance of proper and detailed modeling.

The last thing we discussed was the term used for victims who are forced to oversee or recruit more victims into the system, who are commonly referred to as "Bottoms." This is historically a street term that is being shortened from its original version which was/is used to degrade victims and has been used by numerous researchers. Our advisory group does not believe that term properly represents the role of this person. They prefer the term main girl (or main chick) and we have included this term in our research.

Trafficking Insights

When asked about the direct interactions between buyers and victims(e.g., Figure 8), the conversation was divided. What we found is that some traffickers did not feel that they had the control over a victim to be able to allow them to interact directly (and without supervision) with buyers. One member noted that traffickers could view this as a way of victims getting additional money, reducing a victim's potential to continue being trafficked by saying:

"*What would stop you [a victim] from just having that person be a sugar daddy?"* (Advisory Group Member, May 2023 AG Meeting).

Another member disagreed because they thought that this was more organic and could lead to more profit for the trafficker by increasing the amount of "regular" buyers. Regular buyers are buyers who return consistently for a specific victim. This AG member emphasized:

> *"That's how you [traffickers] get your regulars. It doesn't matter if you're main or one of the wife in-laws [other victims]."* (Advisory Group Member, May 2023 AG Meeting).

The academic research team initially thought that for a closed-buyer network that all buyers are regulars. However, we have learned that even in a closed-buyer network this is not necessarily true, but the way that new buyers find out about this network is different because they find the network through someone who was already connected to it at some point in time.

This led to additional insights into buyers' behavior and recruitment. Buyers may not prefer to interact with the same victims consistently, which could lead to buyers leaving the network and/or interacting with other commercial sex markets. This idea is highlighted with the following observation:

> *"Yeah, unless the regulars are looking for something new, want younger girls, etc., so they might be in multiple closed networks."* (Advisory Group Member, May 2023 AG Meeting).

This is of particular importance to understand what may drive a trafficker operating a closed-buyer network to be consistently recruiting new victims. If the trafficker does not consistently have an influx of new victims into the operation, then their buyers may be purchasing commercial sex elsewhere. Further, understanding this idea means that many different trafficker networks could be dependent on the same population of demand so focusing on demand of one network could disrupt demand for an entire market.

Phase III: June Meeting

Background and Meeting Overview

In June 2023, we implemented the suggested changes by the advisory group from the May 2023 meeting by making the buyers color gray, moving forward with the model that can have direct interactions between victims and buyers over time as we see in Figure 10. The insights we looked at in May into buyer behavior caused us to wonder how great an impact this will have on the entire system. We went into this meeting with a number of questions on operations within the market:

1. What is the number of victims to number of buyers?
2. Does the amount of money made affect the number of victims to number of buyers?
3. How often do buyers in this network purchase commercial sex?
4. How often does a trafficker recruit?
5. What is the max number of buyers (estimate), the trafficker will have to avoid risk?

6. How does this change when the victim to demand/buyer ratio is either higher or lower than it should be?

Many times, when we ask these questions, the answer is "it depends" but we tried our best to establish the most prevalent pattern to be able to move forward. The "it depends" answer is a common theme that occurred during the work of Clark et al. (2023) and the Markov Chain model-building discussed in Martin et al. (2024). These answers help to consider the proper context and scoping of our model, along with properly identifying its limitations.

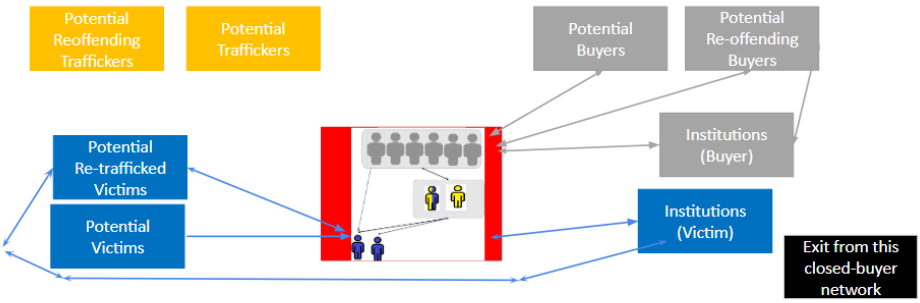

Figure 10: Updated closed-buyer network model for June 2023

Model & Terminology Changes

Here we added characteristics to the model that would represent "new victims" and "established victims." This would help us to better depict the recruitment effort of traffickers and to also help create a basis for understanding how victims would go on circuits. We also began modeling circuits in the system. Circuits are discussed in our trafficking insights section in detail. A quick overview on circuits is that they happen

when a victim is sent to a different city so a trafficker can generate profit from a different pool of buyers than what is present in the current city.

Trafficking Insights

Most of our conversations during this meeting were on the idea of how the traffickers deal with different types of instability (e.g., too much demand or too many victims). When we look at this from the demand side, we find that if there is too much demand for a trafficker to fill, then the trafficker will outsource the demand to another trafficker and receive a commission for it. This situation is highlighted:

> *"If you take an example, there are 100 buyers, closed network is out-calls services, within that group there. Are 5 companies/pimps/orgs that hangout together so with all the victims in each org, if they run out buyer doesn't want to wait what will happen. The out-call service will call another sister org we want one half of the initial fee or something like that."* (Advisory Group Member, June 2023 AG Meeting).

The significance of understanding this is that we see that traffickers operate within a network of their own. In a way, this means that there is never a point where there is too much demand. Traffickers operating in networks also make them more adaptable. They are able to learn from each other and change their operations based on law enforcement patterns, allowing them to better counter efforts implemented to diminish their networks. Understanding how these traffickers will adapt due to these networks is important if we want to implement interdiction and reduce diminishing marginal returns.

When focusing on the situation when the number of victims is larger than a desired ratio with the number of buyers, the advisory group focused on a trafficker adaptation that would send some victims on "circuits" (Freeman et al., 2022; Keskin et al., 2021) Our understanding of circuits developed from understanding that some trafficking operations are mobile and operate using a so-called "stick and move" method. Mobile operations make a network harder to interdict because these operations do not stay in one area long enough for a pattern to be identified. An advisory group member said:

> *"It's called "stick and move" – catch all the payers [buyers] you can, and then move to next town, be the new girl, all still working within same vetted community."* (Advisory Group Member, June 2023 AG Meeting).

In general, a circuit will involve a victim, or group of victims, visiting several areas outside of their original city and sell commercial sex there.

The reason these operations are successful is because they satisfy the request of buyers (who consistently purchase) for "new girls." This also gives us information about how networks work in individual cities because traffickers want to maximize their profit. Another member of the advisory group mentioned that:

> *"They always want a new girl because new girls make all the money."* (Advisory Group Member, June 2023 AG Meeting).

Although our questions focused on instability in the systems this helped us better understand recruitment. Traffickers would like to maintain their current demand (i.e., their buyers) and the way that they do that is through constant recruitment of new

victims. This emphasizes why demand reduction is important because if there is no demand to motivate the traffickers to make these decisions, there is less likelihood they will recruit. Past literature ((Martin & Lotspeich, A benefit-cost framework for early intervention to prevent sex trading, 2014) and the advisory group have both mentioned the relative ease with which traffickers recruit victims into the system, which will be captured in our system dynamics model. The role of circuits is also important for traffickers in the sense that victims that have not been on a circuit yet would be considered "new" to buyers on the circuit. This led us to dive deeper into the details of what the length of a circuit could be:

> *"Could be weekend, month or season… it depends"* (Advisory Group Member, June 2023 AG Meeting).

When asked where the circuit occurs, the answer was similar, "it depends." We do know through our conversation that some cities are more likely to receive more victims.

From this conversation, we moved forward to discussing market operations and how victims may exit the trafficking environment. In Figure 10, we have two ways to exit since we knew data on all possible exits would be sparse. One of the members of the advisory group suggested that we add more of these factors by saying:

> *"Pregnancies, incarceration, occasional surgeries take [victims] out of the market for a minute too."* (Advisory Group Member, June 2023 AG Meeting).

When victims exit the closed-buyer network by other means, there are times that victims will feel like they do not have a better option than returning to trafficking because their experience within the network leaves it hard for them to have a normal life. An

important example of this is when a victim is removed from trafficking through a negative encounter, such as being arrested for a crime they were forced to commit while being trafficked. This emphasizes the work done by those who advocate for vacatur laws such as Devaney (2021). A member of our advisory group mentioned that:

> *"You work until you are no longer profitable to the pimp, he just needs to have skin in the game, …, if you don't have pimp, can't find no work or money. The person will go back to the brothel* [or other trafficking environment], *because it is all taken care of."* (Advisory Group Member, June 2023 AG Meeting).

This leads us to consider what traffickers consider profitable. Along these lines, we posed the question: How much does a victim have to make to be considered profitable to the trafficker? How many buyers will achieve this number? Well, the answer to the second question according to the advisory group is, "it depends." The traffickers set quotas and the number of acts that the traffickers require for a victims depends on the buyers.

> *"It also depends in calls and outcalls. 10 in a 24-hour period, big buyer who spent a lot of money, hit my quota and then, bigger fish, vary on what kind of buyer you have."* (Advisory Group Member, June 2023 AG Meeting).

We also learned that buyers would request certain individuals or certain types of acts. A buyer may still purchase a sex act if the trafficker is unable to meet their request; however, this may impact the buyer's behavior in terms of interacting with the trafficker in the future. Since traffickers understand the buyers' preferences, they may factor this into their recruitment in order to be able to meet the varied preferences of different

buyers. but will accept anyone unless they are looking for a "special request" or "fantasy." Disrupting recruitment could significantly impact the trafficker's operations; however, there may be unintended consequences associated with this. One advisory group member suggested the importance of understanding what would happen to those victims that still ended up in a trafficking operation. In particular, fewer victims for the same number of buyers could result in a situation where the buyers have more power, thus making the situation worse for a victim still in the trafficking operation. This unintended consequence may be true any time interventions reduce the number of victims in a trafficking operation. It does not mean that interventions should not occur; however, it speaks to the importance of a well-rounded view of what the impacts of well-meaning interventions are.

Phase IV: July Meeting

Background and Meeting Overview

We went into our July meeting proposing Figure 11 in order to explain how we adapted the trafficking operations with the various states a victim could be in. The left side of the figure shows a circuit, while the right side shows the original city, i.e., the primary area of operations for the trafficking. We added states to capture established victims and new victims to the model. We wanted to gain feedback on the updated model and understand if there were any big influences that we may have missed.

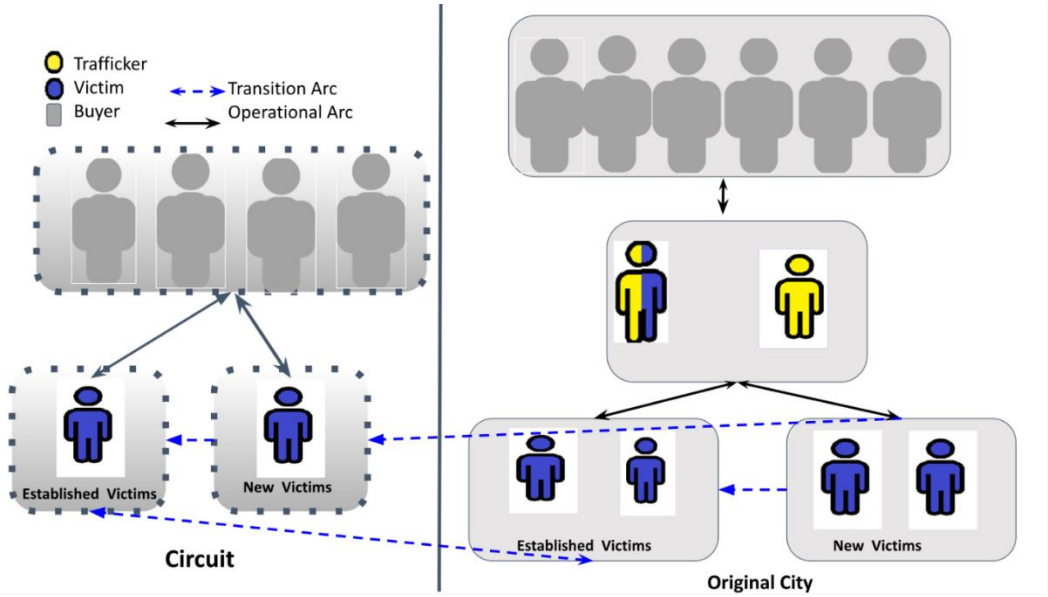

Figure 11: Closed-buyer network operations with circuits implementation.

Model & Terminology Changes

We had a discussion on the best terms for new victims and established victims. The terms "seasoned" or "veteran" were the ones that stood out the most in the advisory group's thinking for established victims. Further, the advisory group preferred the term "green victim" to describe a new victim and suggested that we could use different colors to represent the green victims. At this time, we would use the term 'green victim' to describe someone that is new to the trafficking operation and the term 'veteran victim' to describe someone that has been part of the trafficking operation for a certain amount of time.

Trafficking Insights

After our initial implementation of circuits, we wanted to review this concept to ensure that we were fully grasping the idea. During our conversation on how to improve circuits and understanding of circuits, we discussed individuals called "renegades" by the

advisory group. These individuals leave the network by forming their own trafficking network or working alone in the commercial sex market.

> *"Established victims who go to different states who are not in the circuit go into different cities and create their own place."* (Advisory Group Member, July 2023 AG Meeting).

This is relevant because it shows another consequence for trafficking victims, who may not have a clear way of returning to a normal life. In other words, it demonstrates that a victim may end up selling commercial sex after leaving a trafficking situation as a means to survival. Alternatively, a victim may end up actively trafficking others as a path to leave their own trafficking situation. Again, it is important to ensure that as we begin to think of ways of intervening in these situations that we also think about the unintended consequence of each intervention. In pulling victims out of a system, we must ensure that they have a way back to as close to normal life as possible. We also learned when the victim is on a circuit and physically separated from a trafficker, there is an increased chance of a victim being rescued because it makes it harder for traffickers to monitor them.

Phase V: Finalization & Data Collection

Transition to Implementation

The last step we took was to show the advisory group the changes one more time for final confirmation, especially in terms of the visualizations around green and veteran victims. The advisory group approved, and we moved forward with Figure 12. We began to use this model to build out the system dynamics that is discussed in detail in Chapter 4

of this thesis. We then focused on identifying relevant academic literature that could shed some light into quantitative data that could be used in the system dynamics model.

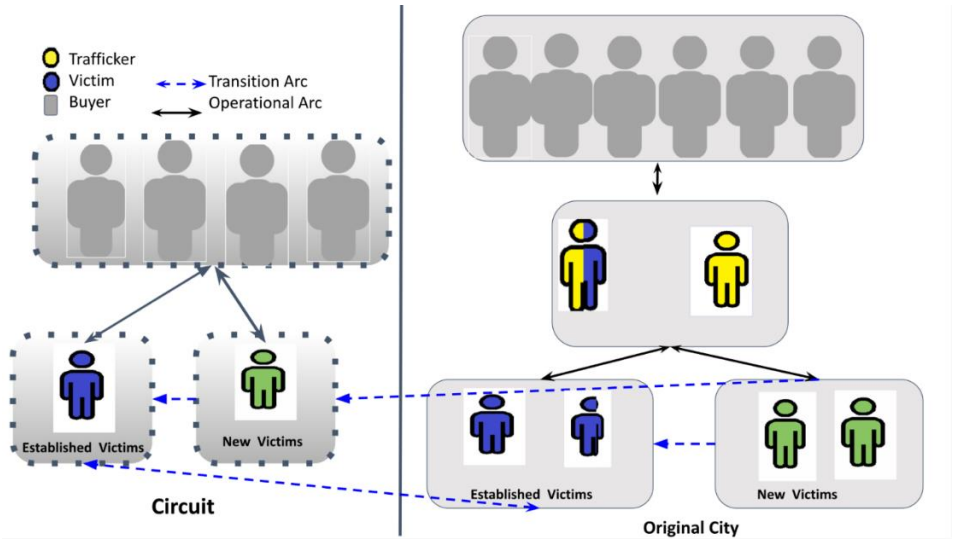

Figure 12: Finalized model of operations within the closed-buyers network with circuit implementation.

Data Collection

Between August and January 2024, we took a deep dive into current research on sex trafficking to be able to provide us information to build our system dynamics equations. We were mainly focusing on secondary analysis of existing data. This model of data collection is fairly common in analytical research into human trafficking due to the nature of the topic (Dimas et al., 2022). We pieced together data from multiple sources and areas based on the known data issues in human trafficking, this led us to realize that it would be difficult to fully populate the system dynamics model. Dimas et al. (2022), Barrick et al. (2023), and Kosmas et al. (2024) have explained the depth of the issues and limitations of current data for populating OR models. However, the system dynamics-based thinking integrated with the AG expertise helped to generate significant

insights into sex trafficking operations, which we highlight in this chapter. We will further discuss a proof of concept of applying the system dynamics model with the identified data in Chapter 4; however, given the significant limitations of the collected data, the obtained insights from the system dynamics are at an exceedingly early stage of the validation and verification process. However, the discussion of data with the advisory group helped to provide one more set of insights into sex trafficking.

Finalizing The Model

In January 2024, we reviewed the current model and data collection efforts as they stood. Our goal was also to try to fill in some of the gaps that were left in the data to make our model more dependable. While we could not complete these gaps, we did learn more about operations on the trafficking system we were trying to model. This began by discussing another way that green and veteran victims could be interpreted, and this was through the lens of trust. The level of trust (control) a traffickers feel they have will determine the limits placed on trafficking victims, especially in terms of how they interacted with buyers:

> *"Sending someone on their own is a sign a trust, whether new and need someone and they needed to put more eyes on them, a lot of privileges were taken away green sent out to be trusted to not that far."* (Advisory Group Member, January 2024 AG Meeting).

This led us to further view the difference between green and veteran victims as ones who may not or may be trusted to facilitate interactions between themselves and

buyers (e.g., in Figure 8, the left victim would be a veteran victim and the right victim would be a green victim).

This further helped us to understand other ways traffickers control victims, and this happens through surveillance. Through surveillance, victims come to fear resources that they would normally see as helpful. This causes resources to be less impactful than they otherwise would be. Finding ways to overcome this is another important idea to consider when trying to help victims and survivors of trafficking.

> *"The levels and severity of security and surveillance, fear, you don't who to trust, who's people are, not trusting instilled in one"* (Advisory Group Member, January 2024 AG Meeting).

The idea of surveillance could also influence how traffickers may prefer closed-buyer networks since the buyers have been previously vetted and may be able to help the trafficker with surveillance of victims.

Even circuits have some level of surveillance for them to occur. The discussions in January have allowed us to understand traffickers will even communicate with other known traffickers in the area to keep watch of the victims they have sent there. This means that when a victim is potentially caught for crimes related to trafficking, they are likely under the same pressures that they would be in the origin city although the trafficker is not physically present. This could potentially decrease the chance that a victim would be recognized by law enforcement as a trafficking victim.

In addition to understanding the surveillance of circuits, we gained more insight on what could cause a trafficker to initiate a circuit. From our initial conversation, we

believed that it would be primarily due to instability in the system, but there are more reasons a trafficker would initialize a circuit that become harder to model with system dynamics although they occur. Examples of these reasons are holidays and big events (conferences, concerts, etc.). These types of situations bring in a large number of people in one area and the trafficker may try to capitalize on this fact. Our advisory group suggested that you may move to a city that has an event going but the extent to which multiple traffickers move into an area for an event is less well-known. For example, it is often thought that a surge of traffickers move into the city hosting the Super Bowl, but this has been shown to be a misconception (Martin & Hill, Debunking the Myth of 'Super Bowl Sex Trafficking': Media hype or evidenced-based coverage, 2019). Another reason that triggers a circuit is if law enforcement pressures in one area become too high, then they will move to another city for a period of time given the illusion that trafficking in the area has decreased.

We also discussed buyers, buying habits to understand other ways outside of literature people may attempt to purchase commercial sex. In Chapter 4, we discussed the impact of the various buying types that are mentioned throughout the advisory group and other research articles in building out data scenarios for our system dynamics models. The thoughts of our advisory group included:

> *"per paycheck, weekly, daily and others and they need that release before they go home, more paycheck to paycheck biweekly."* (Advisory Group Member, January 2024 AG Meeting).

Summary of the Impacts of the Iterative Process to Co-Build a System Dynamics Model for Closed-Buyer Networks

Using systems thinking to understanding closed-buyer networks has allowed us to gather new knowledge and insights into sex trafficking. Using this information, future research can now begin to focus on building the bridge between current data gaps and current trafficking operations. While we do find that a few of the gaps depend on the trafficker, filling in the other gaps makes analyzing "it depends" questions less challenging for future research that seeks to model certain types of sex trafficking operations. This is where system dynamics could be more beneficial with the use of scenario-based simulations for policy implementation and resources accommodations for trafficking victims and to promote demand reduction. We now summarize the insights and knowledge gained through our collaborative research with the AG. Table 1 provides an overview of the modeling and terminology changes and the trafficking insights on a month-by-month basis. It is important to note that the trafficking insights help to offer additional areas of exploration for more qualitative and empirical research.

Meeting	Modeling & Terminology Changes	Trafficking Insights
November-2022	_____	Displacement through social media is a relevant yet understudied area
May-2023	A closed-buyer network is a system in which a trafficker only interacts with a vetted list of buyers" Updated colors that were being used for the arrows and the boxes for institutions for clarity We changed the color of the buyers to avoid contributing to any current stigma around buyers	How traffickers control interactions between buyers and on the perceived control of a victim and how trustworthy that victim is Regular (buyers who always return) are not the only type of buyers in a closed-buyers network. The buyers that do enter will go through some type of vetting process.
June-2023	Defined new victims and established victims in the system We implemented circuits into the model	If a trafficker does not have enough demand they will initialize a circuit If a trafficker has too much demand for them to fill then they will utilize outsourcing to another trafficker Traffickers possibly operate within a trafficker network of their own making, which allows them to be more adaptable Some trafficking operations are mobile and operate using a so-called "stick and move" method Victims are consistently recruited to fill the demand of buyers Circuits vary in length Trafficking victims will sometimes return to their trafficker if they feel like they do no thave a way of returning to a normal life. The exact number of buyers to victims is difficult to determine because traffickers set quotas for each victim. However, the number of buyers is always greater than the number of victims
July-2023	Term veteran is now used for established victim Term Green is used for new victims and would change the color of green victims in the system	Renegades are individuals who break away from the network and start their own network or work for themselves. Circuits offer a increased chance of rescue a victims but this is not always the case
Janurary 2024	_____	Green vicitms could refer to perceived control or denote the length of time a victim is in a system Traffickers have a way of montoring victims on circuits Circuits are initiated because instability in demand, law enforcement presence or select events.

Table 1: Summary of changes & insights from co-modeling process

Victim-Buyer interactions

One major topic of understanding is victim-buyer interactions. We learned from our discussions that victim-buyer interactions are dependent on two aspects: time and perceived control. Time is the length of time that a victim has been with a trafficker or in a city. Perceived control is the amount of trust that a trafficker has in their control over the victim; when a trafficker feels they have more control than they begin to loosen the

restriction they have on the victim since the victim is likely to act how the trafficker would expect them to act. The perceived control is dependent on many outside factors, for example, traffickers usually keep more restrictions on those who have substance use disorders because their disorder may make them more susceptible to making mistakes (e.g., losing money after a transaction).

Regulars are what keep some trafficking networks profitable. These are individuals who consistently return to the trafficker many times for a specific victim. Regulars provide a consistent flow of revenue; however, some traffickers are skeptical of how regulars should interact with a specific victim. This is because they do not want the victim getting money directly from the regular, which could result in the trafficker losing control over the victim.

If there is instability in the buyer to victim ratio, one of two things will likely happen: outsourcing or circuits. These are both in their own way a form of displacement in the trafficking operation. When the ratio of buyers to the number of victims is greater than the desired ratio, traffickers will outsource the demand of the buyers to other trafficking operations or individuals and receive a fee in return. This observation also lets us know that traffickers are connected in their own way to be able to outsource demand to another operation. Traffickers being connected makes them more adaptable, which could possibly result in diminishing marginal returns in interdictions to trafficking operations. When the ratio of buyers to the number of victims is less than the desired ratio, a trafficker may observe that they are not making as much money as they could from a

particular victim and could send the victim on a circuit. This means that the victim is visiting other cities and participating in the commercial sex market in them.

Buyers

We gathered information on buyers and buyer behavior in several areas. The first was that we have learned that, even in a closed-buyer network, all buyers being regulars is not true in all situations. However, the way that new buyers find out about this type of network is through someone who was already connected to it at some point in time.

Buyers who are not regulars prefer to interact with the new victims, or victims they have not seen before, which could lead to buyers leaving the network and/or interacting with other commercial sex markets. This is of particular importance to understand what may drive a trafficker operating a closed-buyer network to be consistently recruiting new victims. If the trafficker does not consistently have an influx of new victims into the operation, then their buyers may be purchasing commercial sex elsewhere, thus potentially causing a vulnerability to the trafficking operation if the buyer is arrested outside of it because this could point back to the original trafficker (Martin et al., 2014). Furthermore, understanding this idea means that many different trafficking networks could be dependent on the same population of demand, so focusing on demand of one network could disrupt demand for an entire market.

Circuits

A circuit will involve a victim, or group of victims, forced to visit several areas outside of their original city and sell commercial sex in them. When understanding circuits, one of the biggest things to understand is what situations will trigger a circuit. A

circuit could be triggered by world events or instability in the system. Many people think any event with a large number of people will lead to trafficking operations increased in the area, but although it happens at some events, it does not happen at every event (Martin & Hill, Debunking the Myth of 'Super Bowl Sex Trafficking': Media hype or evidenced-based coverage, 2019). Instability happens when traffickers are not able to make the profit that they would like because of the lack of demand (e.g., not enough buyers) in an area for a period of time. The circuit allows the trafficker to take advantage of a different buyers' pool. There are some organizations whose complete operations are based on circuits, making it harder for law enforcement to intervene because there isn't a pattern developed for them to notice. The reasons these operations often work are because they satisfy the desire of buyers to interact with new victims.

The length of circuits often varies greatly, lasting anywhere from a week to months. A big influence on this is the presence of law enforcement in the circuit city or the origin city. Increased pressure from law enforcement will cause the trafficker to move their operation.

Further, the composition of the victims that go on the circuit will depend on their experience. It may be required that a green or inexperienced victim will be accompanied by a veteran or established victim. Alternatively, a green or inexperienced victim may be sent to a city where their trafficker knows another trafficker who can supervise them in the new city. Further, it may be that the main girl will accompany a group of victims on a circuit.

Trafficking Victims

These conversations have also led to a better understanding of recruitment operations and the impacts of trafficking operations on victims. One surprising observation is that traffickers will constantly be recruiting more victims in the system to fill the desire of buyers within a closed-buyer network for new encounters. Victims are also taken out for healthcare issues and imprisonment, making a greater need for constant recruitment for traffickers since these factors are harder to predict. Traffickers typically achieve their recruitment goals with ease (Martin & Lotspeich, A benefit-cost framework for early intervention to prevent sex trading, 2014), meaning there is no real barrier that they face in these recruitment operations.

Victims that are in the trafficking operation will exit the system for many reasons. Unfortunately, due to forced criminality many of these exits may end up being negative outcomes. Victims are often punished long term for their experience in trafficking, some not being able to return to a normal life because they are left with a criminal record for a lifetime. Vacatur laws would be able to help these situations, but they are not common yet (Devaney, 2021), and it may be difficult for victims to navigate the requirements of such laws to clear their criminal record. When victims do not feel like they have a way of living a life outside of trafficking they return to their trafficker, which would likely cause them to feel less confident in the systems in place that attempt to provide help. Some trafficking victims branch out on their own and join the commercial sex market, while some start their own operations feeling it is the only way to protect themselves. We must

have a way of preventing this from happening so victims are not punished for the duration of their lives because of their time being exploited in a trafficking operation.

CHAPTER FOUR

SYSTEM DYNAMICS MODELING

The focus of this chapter is to present a proof of concept of how our co-created system dynamics model could be used, if more reliable data for its key equations and parameters becomes available. We emphasize that this proof of concept provides limited insights into trafficking operations since input data was either unreliable or was pieced together from numerous different scopes in terms of previous research.

The tool that we used to implement the system dynamics model was Vensim. Vensim allows us to understand the cause-and-effect relationship of the domestic sex trafficking network that we are modeling and the long-term behavior of the system. The best way to describe our implementation is that it is a various relevant variables that the observer selects from those available in the real system (Campuzano & Mula, 2011). This is because we are not able to model all the variables in the domestic sex trafficking network but those that are available based on the data sources and expert experience.

Terminology

To be able to properly explain the system dynamics model we must define certain terminology used to name the variables in the model. Many of these terms were discussed with our advisory group to determine the name that would accurately portray the variables that we are referencing:

- **Green Victims** – There are two ways of understanding what green means in the context of a victim. The first is whether a victim is new to a specific trafficking network or not. Buyers are more likely to buy or pay more if a

victim is new to the specific network in which they are purchasing commercial sex. The other way green can be used is to describe the level of "trust" a trafficker has with a victim. Trust in this sense is most closely defined as a control that the trafficker feels they possess over the victim or how well the trafficker feels the victim could operate independently. Under this definition, a victim could remain green the entire time they are with a trafficker, if the trafficker never feels they have confidence in the control they have over the victim or the ability of the victim to independently interact with buyers. The way we will use green for this model will refer to the length of time a victim is in a specific network.

- **Veteran Victim** – A veteran, also known as an established victim, is a victim who has more experience within a certain network. These victims may be placed in a recruiting role or forced to monitor the other victims in the network. Some of these victims may have "regulars" as buyers in their network who specifically seek them out for one reason or another. Like green victims, veteran victims can be defined as either the length of time they are in the network or the level of control a trafficker feels they have or a victim. Here, we use time as the determining factor for a veteran victim.
- **Buyer**- A buyer is anyone who is purchasing commercial sex in this sex trafficking network during a specific month. Buyers are known to buy weekly, bi-weekly, monthly, quarterly, or once (Demand Aboliton, 2018).

The buyers that buy quarterly or once will be cycled out during the next time stamp because they will not be purchasing commercial sex in that month. This stock is directly related to buyers in the original city rather than overall buyers. This will allow us to understand how demand reduction in the original city influences the trafficking network.

- **Circuit**- A circuit is when a victim or group of victims is sent to a different city or town. A trafficker does this to capitalize on demand that is available in a different area to maximize profits or when continuing to operate in the origin city is determined to be difficult (with difficult either referring to situations where there is less demand in the origin city than the available number of victims or when there is increased intervention efforts). Typically, for green victims to go on a circuit there is at least one circuit veteran with them so that the trafficker feels that they have control over the victims while they are in a different area, or a green victim will be sent to a known trafficker in a different area. In the initial system dynamics model, we do not model the former situation.
- **Circuit Trigger** – This happens when the ratio of the total number of victims in the original city to the total number of buyers in the original city is larger than some pre-determined ratio for an extended period of time. In other words, a circuit is triggered when the demand for commercial sex in the origin city could have been met with fewer victims. In general, circuits may be triggered any time a trafficker sees an opportunity to increase

revenues in another area, such as holidays or major events in a different area. However, for our model, a circuit is triggered any time victims to buyer ratio is off for longer than three months.

- **Negative Exit-** A negative exit in this model is defined as a victim being arrested for a crime that was related to them being trafficked. Forced criminality of sex trafficking victims is a relative new area of research (e.g., Clark et al., 2024) and may result in arrests for criminal activities outside of prostitution-related offenses. This type of exit is known to complicate the long-term recovery and healing of survivors since it is often a barrier to employment and affordable housing (Devaney, 2021). As of recent this has led to a push for vacatur laws, which will vacate previous convictions of trafficking victims allowing them a chance at a better life (Devaney, 2021).
- **Positive Exit-** A positive exit is defined as a victim leaving their trafficking experience due to resources, trafficking policies, and/or situations that will better support their recovery and healing from their trafficking experiences.
- **Involuntary Exit-** An involuntary exit is a buyer leaving the system for any reasons besides their own will. For our model, we have focused on incarceration rates but there may be other ways that buyers could exit beyond their own will. Past research cites this rate at .02 times the rate of removal of victims (Jeffs, 2013).

- **Voluntary Exit-** A voluntary exit is when a buyer leaves the system for a period based on their own will or fear of punishment. Buyers who do not buy monthly, bi-weekly, or weekly are also in this population because they will not be in the system for that time. These types of buyers will flow through the vetting process when it comes to their re-entry.
- **Overall Negative Exit Rate-** This parameter is used to represent the impact of victims being arrested for any crime related to actions they are forced to during their time being trafficked.
- **Victim Resources** – parameter modeling how victims may receive help through victim advocacy programs or impacts of trafficking policies.
- **Resources Benefit Factor** – parameter modeling the estimated impact of victim advocacy programs to reduce the number of victims within a domestic sex trafficking network.
- **Trafficking Policy Focus** – Parameter modeling how trafficking policies can shift overall negative exit rates and create more positive exits. Data for this parameter is limited because different geographical locations have different trafficking related policies.
- **Recruitment-** The process of a trafficker acquiring and coercing new victims into their network. A trafficker can recruit/re-recruit victims as various levels of experiences based on their needs.
- **Vetting Process-** The process a trafficker goes through to acquire new buyers within the closed-buyer network.

Variables

Before we discuss the term variable, it is important to remember that although we use the word variable for the mathematical modeling context, we are still talking about humans, who suffer emotional and physical abuse at the hands of their trafficker. This has been noted several times throughout this thesis, but it is essential that the victims are not diminished due to abstract terms. One way of doing this is by clearly defining what each variable means. We will begin by discussing the key variables in the model. Our key variables in the system dynamics model are Green Victims, Veteran Victims, Circuit Green Victim, Veteran with Circuit Experience (a veteran victim who is in the origin city but has been on a circuit), Circuit Veteran Victims, Total Victims and Buyers. All these variables except total victims are level variables or "stocks" in our model. Level variables increase or decrease based on the value of the variable in the previous time period and the equation used to define it. These variables require an initial value for the model to simulate without errors being produced. In Figure 9, which depicts the Vensim implementation of our system dynamics model, the level variables are denoted by the rectangle shapes embedded in the middle of the model. They are represented in either green (green origin/circuit city victims), blue (veteran victims at different stages), or gray (buyers) to help show what they represent within the model. The level type variables are often connected to a flow depicted by the black arrows in Figure 9.

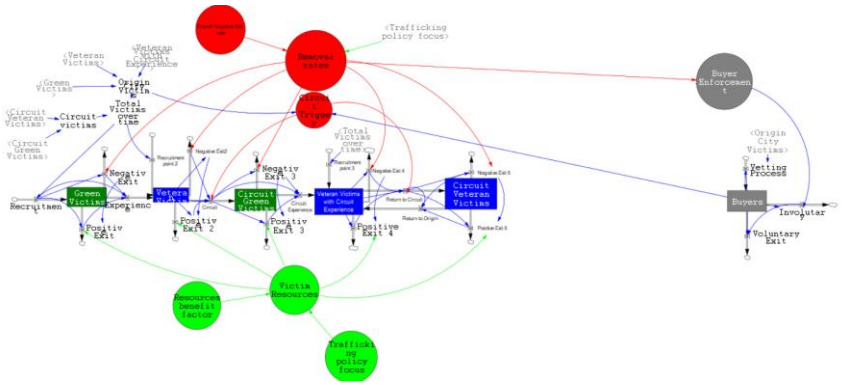

Figure 13: Vensim dynamics simulations model

Flows are simply a rate in which a stock is filled or depleted. These equations are essential to properly define the way the model operates. For our victim-related stocks, they each have a positive exit and a negative exit portraying the two types of ways a victim can leave the system. Buyers have similar ways of exiting which are either involuntary or voluntary exits. There are three flows for recruitment that model the three different recruitment points into this domestic sex trafficking network: a flow into green victims (depicting victims new to this population of buyers), veteran victims (depicting victim who are not new to this population of buyers but haven't been on a circuit), and veteran victims with circuit experience. The flows between stocks are either time dependent or related to the ratio of victims and buyers within the system. The flow into the buyer's stock is through the vetting process which is dependent on the number of victims in the origin city. Flows typically connect stocks together or a stock and an extraneous variable together.

An extraneous variable is a variable that is outside the scope of what we are trying to model. For example, in reality, victims may be recruited from several different

populations and the number of current victims in each population would be an extraneous variable. We use this term for variables that will influence the data in our model but are still outside the scope of what system we are trying to depict.

Another type of variable is an auxiliary variable. An auxiliary variable keeps no memory of the past time step, it updates based on the present values of the variables in the equation. One example of this in our model is the total victim's variable, which gives us the present value of the number of victims at any point in time.

The last type of variable that we use are constant variables. Regardless of the time step, this parameter maintains its value. This variable does not depend on any other variable. If the equation for this parameter has any other variable in the system, it automatically becomes an auxiliary variable.

Data, Equations, & Output

Data collection and equation formulation was based on data found in articles within recent years and the implementation of our iterative research process with the AG (see Chapter 2). We began by trying to create a system dynamics model that best simulated trafficking networks based on current research available. Our next step was to monitor impacts in the system by changing certain variables and parameters. We simulate the system for 100 months or 8.33 years. The reason we chose this is because there is a broad range for how long traffickers operate within the industry, but 8 years has been included in most ranges and should be sufficient for an established trafficker.

One of the limitations of system dynamics is that because it looks at the long-term behavior of a system, there are intricate details that can be difficult to capture. This

usually would not matter as much, but in the domestic sex trafficker network, many decisions are dependent on life events that do not align with the long-term behavior but could have a substantial impact on the system.

Stocks, flows and influences of victim operations.

Our data collection found that the average number of victims in a system is six victims, so we initialized the model with six total victims (Horning et al., 2020). Victims have two ways of exiting the system: positive exits and negative exits. We calculated the total number of victims by adding the number of original city victims and circuit victim stock. Figure 1 shows the number of victims in the system through the entirety of the simulation on ten separate runs where we randomized the noise seed. These numbers fluctuate with a max of eleven and minimum of four victims in the system at any given time. The figures show that on average the model will produce results that are similar to known domestic sex trafficking parameters with respect to the number of victims. The results show a similar distribution in terms of numbers and proportion for origin city victims and circuit city victims so we show only one graph for simplicity.

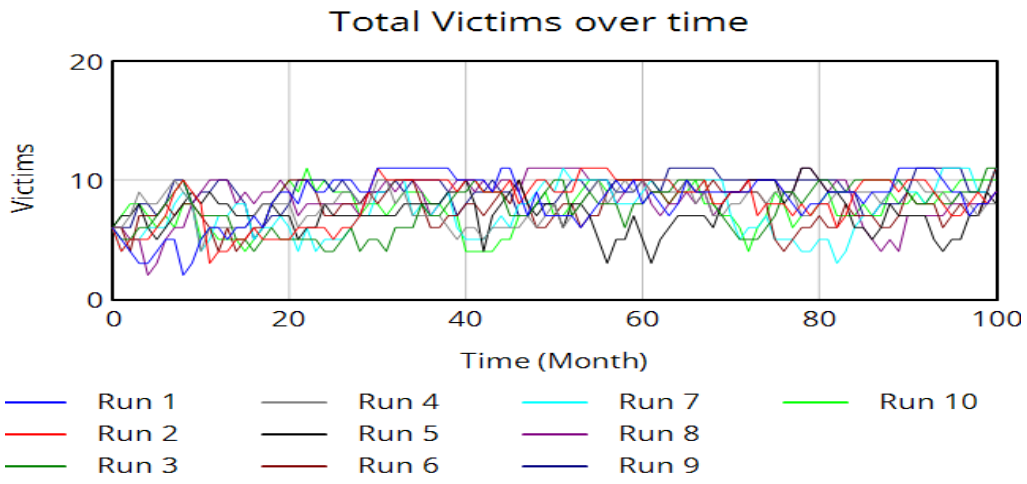

Figure 14: Total victims for 10 different runs.

The green victim stock receives input from recruitment. Green victims are reduced by negative exits, positive exits but can also flow into to the veteran victims' state based on the amount of time spent in the green victim state. The experience flow, i.e., the number of victims entering the veteran victims' state, is found by taking the number of victims that were green but not taken out of the system by positive or negative exits.

Veteran victims operate like green victims except for the fact that for a veteran victim to move on to a different stock variable in the system a circuit must be triggered. As mentioned before, a circuit is the trigger within the system when there is imbalance between victims and buyers.

The veteran with circuit experience level builds off veteran victims in the sense that it represents veteran victims who have already been on a circuit. This stocks receives input from circuit green victims, recruitment point three and circuit veteran but has

similar outputs to veteran victims, with the return to circuit flow also being triggered by the circuit trigger variables.

These three variables make up the original city victims auxiliary variable which has an influence on how many buyers are vetted from month to month based on the "unused capacity" of the victims determined by the trafficker. This variable has a range from 1 to 10 with an average just over six, moving like the total victim variable. Figure 15 displays this variable and what we see is that there is a lot of volatility for this variable.

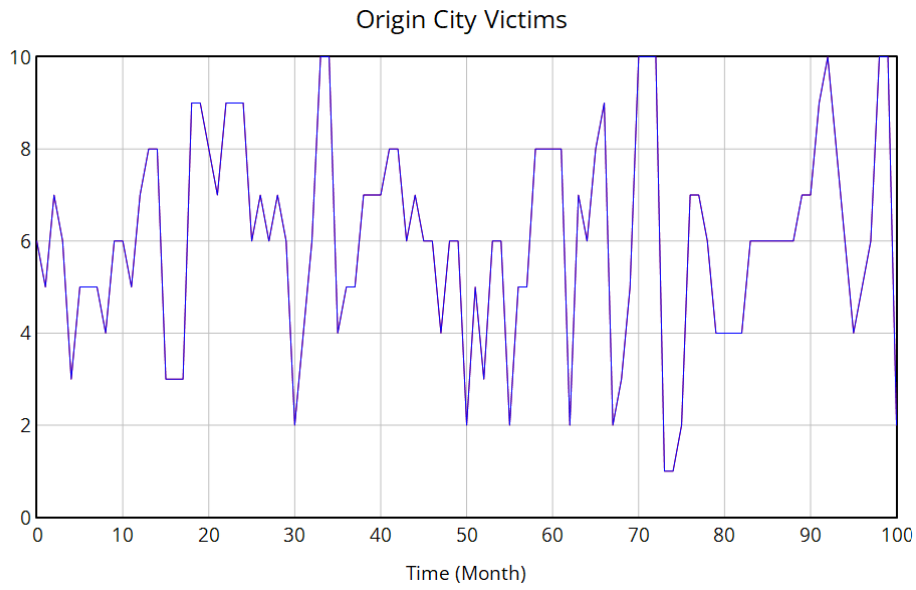

Figure 15: Number of Origin City Victims over 100 months.

Circuit Green Victims and Circuit Veteran victims operate in the same way, and they make up the circuit victims' node. These two variables do not have a recruitment input, and both receive input based on the circuit trigger variable. Victims on a circuit return to the origin city based on a determined time, given that they are not taken out of the system by either a positive or negative exit. There is a lot less volatility in Figure 16

for circuit victims than we see in the origin city victim's variable. This is due to these operations being time based and victims going into circuit based on system instability. Recruitment would likely increase volatility in these variables as well, but our current focus is on recruitment being based in the origin city rather than a trafficker recruiting outside of the origin city. However, recruitment of victims outside the origin city is a possibility that could be modeled, but little is known about how often a trafficker would recruit from the cities in a circuit.

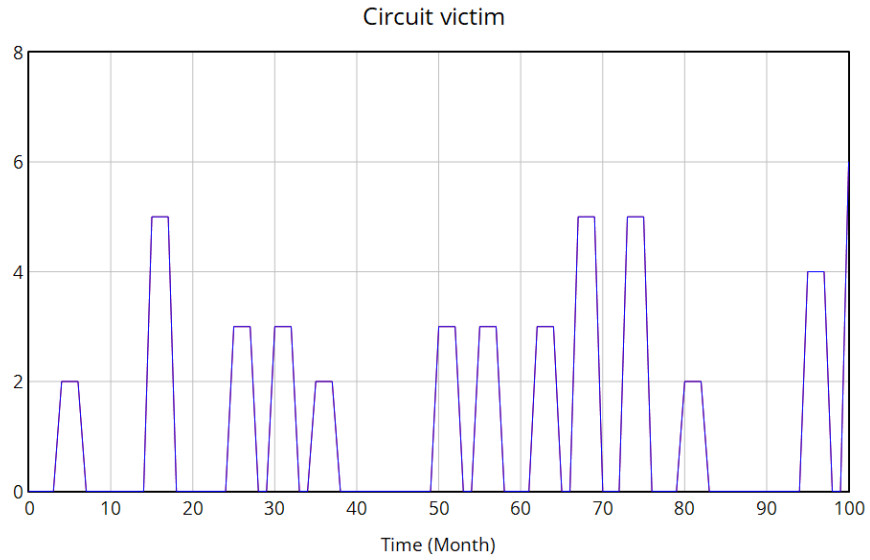

Figure 16: Number of circuit victims over 100 months

Stocks, flows and influences of buyer operations.

The buyer system is made up of four parts. buyer stock, the vetting process, involuntary and voluntary exits. The buyer stock accepts inputs from the vetting process and outputs through involuntary and voluntary exits. Involuntary variables are influenced by buyer enforcement which gives that rate at which buyers are removed. The involuntary variable influences voluntary exit because most buyers in a closed-buyer

system are connected to other buyers in the system. This leads to a “fear of punishment” which would likely lead to other buyers potentially leaving the system as well (Demand Aboliton, 2018). The voluntary exit equation is dependent on the scenario that is applied. For this thesis we looked at five potential buyer systems. The following five scenarios are defined by four distinctive characteristics: the number of acts victims are forced to participate in per day, total market transactions within that system per month, baseline buyers needed for that number of transactions and whether vetting is guaranteed.

Scenario #	Victims act per day (avg)	Total market transaction	# of buyers required	Vetting Guaranteed
Scenario one	4	672	508	Yes
Scenario two	4	672	336	Yes
Scenario three	3.667	660	499	Yes
Scenario four	3.667	660	330	Yes
Scenario five	4	672	508	No

Table 2: Explanation of considered buyer scenarios

We used two pieces of data to determine what each scenario should look like. For scenarios 1, 2, and 5, we used 4 acts per victims per day (average) and assumed that a victim is forced to work 7 days per week and 4 months in a month. Using the average number of victims a trafficker is likely to have would result in a total of 672 total market

transactions per month for these variables. The other way that we calculated total market transactions was using busy/slow days to find the average act per day. In our discussions with the advisory group, they said that days around paychecks are more likely to be busier days, while the rest of the month be a little bit slower. Assuming that buyers are paid on the 1st and 15th, we assume this would result in ten busy days and twenty slower days. On the busy days, we estimate there will be an average of seven acts per day per victims, while on slower days this average will be two. This would result in 110 acts per victim per month and a total of 660 market transaction per month for a trafficker.

The number of buyers for each scenario is dependent on two distinct categories. Some experts note that the breakdown of market transaction of sex buyers is 4.8% only buying once, 23.4% buying quarterly, 39.2% buying monthly and 32.5% buying weekly (Demand Aboliton, 2018). This was the logic we applied to the market transaction for scenario one, scenario three and scenario five and we determined a number of buyers that ensures that their total demand is equal to the total market transactions available. On the other hand, our advisory group suggested that buyers buy twice a month on average. This logic was applied to scenario 2 and 4.

The last category denotes whether there is a guarantee that a trafficker will have enough buyers wanting to purchase sex to vet the missing demand. The logic of this being an uncertainty was only applied to scenario five. This scenario was used to see how great the impact would be if the vetting process was not 100% guaranteed to be effective.

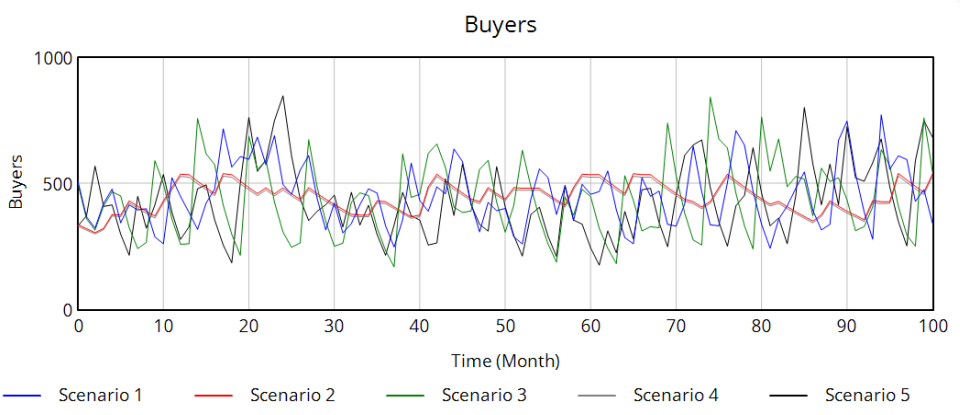

Figure 17: Buyer data for each alternative of the vetting process.

These scenarios are all listed by category and type in table 2. What we found in Figure 17 from using this method is scenario 2 and 4 resulted in a relatively consistent level of demand, denoting no real difference between the two methods. The other scenarios, as expected, had increased volatility because buyers are constantly entering and exiting the system. The reason this is significant is because increasing fluctuations between scenario 1, 3 and 5 leads to a greater chance of exposure for the trafficker. This could potentially help to bring down a trafficker's entire system, with an increased chance of a trafficker making a mistake in the vetting process and being exposed. In Scenario 2 and 4, where buyers are essentially all regular, there is less of a chance of exposure from a practical sense. The decreased volatility in Figure 17 between these two scenarios are a direct result from roughly the low numbers of buyers exiting each month due to most buyers being regulars. The guarantee of demand for the vetting process did not seem to have any major impact on the level of buyers in the network.

Market Operations Influences

Influences in the market that are not caused by the number of victims or buyers are denoted by the circles in Figure 9. Positive victim influences are lime green. In this case, positive influences are those that lead to a positive exit from the victim node. Other Victim influences are red. These are variables that influence a negative exit or victim movement within the system. The buyer system also has its own influences that lead to buyer movement within the system. These are denoted with gray circles.

There are two main constants that have an impact in the positive victim influences. The victim resources are an auxiliary variable that keeps track of these two constants and the flows that they impact. The resources benefit factor is the rate in which victim advocacy/service programs help to influence a positive exit from a victim's trafficking experience. This variable will tell us how impactful resources will be in reducing the number of victims in the system. The trafficking policy focus is a constant that is used to denote positive policy changes that will help to monitor the impact of how policies can influence the number of victims within a network. The trafficking policy focus positively influences victims' protection, therefore reducing the rate of negative exits (e.g., this could signal that the criminal justice system is more attuned to identifying victims of sex trafficking as opposed to arresting them for crimes related to commercial sex).

Other victim influences are the overall negative exit rate, removal rates, and circuit triggers. Overall negative exit rate is a constant that was initialized based on past research data. The removal rate takes the overall negative exit rate and reduces this based

on the policy changes and divides this by five for each state that victims have the potential to go through. This auxiliary variable also influences the buyer enforcement node. Circuit triggers are level variables and represent the level of instability within the system. This variable initializes as zero but increases as buyers outnumber the number of original victims in the system. It influences both the circuit flow and return to circuit flow.

Buyer enforcement is a node that is based on the removal rate of victims. Research shows that buyer enforcement operates at a 1 to 50 ratio to victim incarceration which helps us construct the rate that buyers are pulled out involuntarily (Jeffs, 2013).

Equations

Table 3 shows the equations used for the initial model, along with detailed explanations of their logic where appropriate.

Variable	Equation	Source/Explanation
Recruitment	IF THEN ELSE (Total Victims<10, INTEGER (RANDOM NORMAL (0, 3, 1.5, .5, 0)), 0)	Our discussion with the advisory group shows recruiting for traffickers is relatively easy. So, there is no barrier to a trafficker recruiting new victim when there they do need to recruit but we suspect that there would be a limit to how many victims an individual trafficker could control at one time, so we pause recruiting when total victims are above 10. The average number of victims in a system is 6 but a trafficker will likely not wait until they are at 6 to begin recruitment (Horning et al., 2020). Our equation for recruiting green victims is when a trafficker falls below 10 but 6 at the other recruitment point this is because based on conversation with the advisory group traffickers will tend to try to get "new girls" in often.
Victim Level Variables	Inputs-Outputs	These inputs and outputs vary but general there's flow into these variables and flow out
Negative Exit General Equations	MAX (0, IF THEN ELSE (Removal rate>RANDOM 0 1(), MIN (Green Victim, INTEGER (RANDOM NORMAL (0, 2, 1, 1, 0))), 0))	Since this is an individual network, we don't expect the removal rate to be constant but only to occur at certain times which leads to negative exits so our equation is set to remove victims only at certain random time stamps to help simulate the randomness in which this could happen in reality.
Positive Exit General Equations	MAX (0, IF THEN ELSE ((Victim Resources+0.1*Negative Exit)>RANDOM 0 1(), MIN (Recruitment -Negative Exit, INTEGER (RANDOM NORMAL (0, 3, 1, 1, 0))), 0))	Similar to negative exit, we don't expect victims to be pulled out every time but only during certain time stamps. This likelihood increases based on the victim resources and increase motivation based on negative exits from the system.
Buyers	Inputs-Outputs	There is flow in and flow out
Removal Rate	MAX (0 ,(Overall Negative exit rate-Trafficking policy focus)/5)	The overall negative exit rate that reduced based on the impact of trafficking policy focus during the time.
Vetting process	MAX (0, 85*Origin City Victims-Buyers)	We use several different equations to model this based on data from Demand Abolition, (2018) and domain experts. The reason for this is because again trafficking has a lot of it depends on question but with system dynamics in some situations, we can see how much it depends on matter. We use several different equations to show which factors are most important in the vetting process and the effects on the entire sex trafficking market
Involuntary Exit	MAX(0 ,IF THEN ELSE(Buyer Enforcement>RANDOM 0 1(), MIN(Buyers, INTEGER (RANDOM NORMAL(0, 0.1*Buyers, 1.5, 0.25 , 0))), 0))	This rate is influenced by buyer enforcement and occurs based on the chance that a buyer is caught. Buyers are not caught every time stamp, so the flow is dynamic
Voluntary Exit	MAX(0 , INTEGER((Buyers-Involuntary)*(0.1*Involutary+0.048+0.234)))	This rate operates similar to Involuntary Exit and also considers buyers that will consistently exit the system every month and fear of punishment according to Demand Abolition (2018) research on commercial sex demand.
Circuit Triger	IF THEN ELSE(Origin City Victims*85>Buyers, 1 , -Circuit Trigger)	Circuits are triggered by circuit trigger parameters which denotes how long a trafficker is not receiving the demand they would maximize profit.
Buyer Enforcement	Removal Rate/50	Jeffs (2013) cite the rate buyers are enforced a 1 to 50 that of victims which we use to model buyer enforcement due to minimal research on buyers arrest data
Resources benefit factor	Constant	This parameter is to represents the chances potential resources reduce victims in trafficking networks. Data in this area is sparse and vary from different sources.
Trafficking policy focus	Constant	This parameter is to represent the chances trafficking policy focus reduces victim in trafficking network. Data in this area is sparse and vary from different sources.
Overall Negative Exit Rate	Constant	There are many reasons that a victims could be pulled out of trafficking such as health concerns, and incarceration which leads to a victim's being more likely to be re-trafficked and this constant helps model the chance in which this occurs
Experience / Circuit Experience/ Return to Origin	DELAY FIXED(Recruitment-Positive Exit-Negative Exit, 3 , 0)	These variables are time based. Such as the amount of time a "green" victims spend in a network before they are considering a "veteran." These numbers are different from network to network, but we choose 3. This is also true for the length of circuits because circuits length depends on the trafficker decision making.
Circuit/ Return to Circuit	IF THEN ELSE(Circuit Trigger=3, Veteran Victims-Negative Exit2-Positive Exit 2, 0)	This flow occurs when a circuit is triggered. Although there are a lot of variations in circuits, we thought this was important to consider understanding the idea of displacement.

Table 3: Input equations

Analysis

Sensitivity Analysis

After we concluded that the baseline model was sufficient to capture closed-buyer networks, we began to understand how changes in certain baseline variables would cause an effect on the network. Our approach to this was using sensitivity analysis. Sensitivity

analysis allows us to understand how much a variable is likely to change based on a change in input in the model, which helps to represent different situations and factors in the real world. The two main variables that we used to conduct our sensitivity analysis were the resource benefit factor and the trafficking policy focus. Our sensitivity analysis shows how these variables impact the average total number of victims in the system and the average total numbers of buyers within the system. We conducted our sensitivity analysis by comparing the effects of increasing and decreasing the variables by 20%. In our analysis, we changed only one of these variables at a time.

We initially conducted this analysis with respect to total victims over time. In Figure 18, we use a cumulative run compare graph to help explain this sensitivity. A cumulative graph gives us the sum of the value of the current state and all previous states. The run compare function shows how different simulations deviate from the selected run of focus it is being compared too. A run is a specific scenario that is being simulated based on selected inputs and equations. As shown both the resource benefit factor and trafficking policy focus variables decrease, we see a significant increase in the total number of victims. The greatest change occurred with the decrease in resource benefit factor, resulting in a 14.5% increase in the number of victims. On the other hand, increasing these variables had less than a one percent change to the number of victims. There are multiple reasons for this observation; one is the idea of diminishing marginal returns meaning that as you increase resources the less impactful the variable gets after a certain threshold. The other explanation for this is because there is no barrier to entry with respect to recruitment, it is hard to reduce the number of victims. In fact, we even

see a slight bump above between months 60 to 80 after the lower demand between months 30 to 50 which happens due to over-recruitment after the trafficker does not have enough victims to meet the demand of the buyers. This observation becomes important to consider when we think about how to allocate resources.

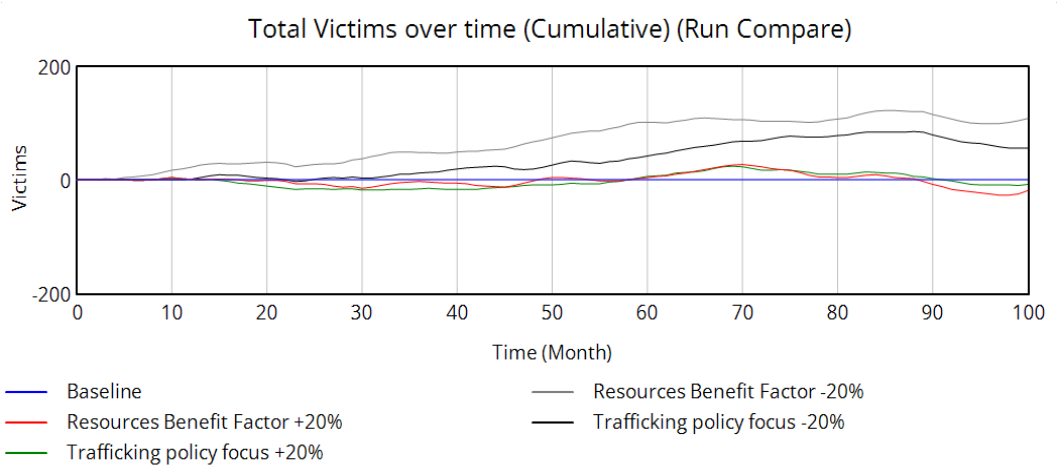

Figure 18: Total Victims cumulative run compare chart for +/- 20% resources benefit factor & trafficking policy focus.

We then analyzed a similar chart with respect to buyers over time. We noticed that the buyer variable is more sensitive to positive changes in both variable and less sensitive in the negative direction. The number of buyers is most sensitive to the resources benefit factor but still shows sensitivity to trafficking policy focus as well. When these variables are increased individually by 20%, the resources benefit factor decreases the number of buyers by 7.36% and the trafficking policy focus decreases the number of buyers by 5.77%. When decreasing these variables, we see an increase of 3.97% in the number of buyers and decreasing trafficking policy focus creates an increase of 6.64%. When mapping out the first order and second-order effects within the system

dynamics model, a factor that influences multiple characteristics simultaneously would have a larger impact.

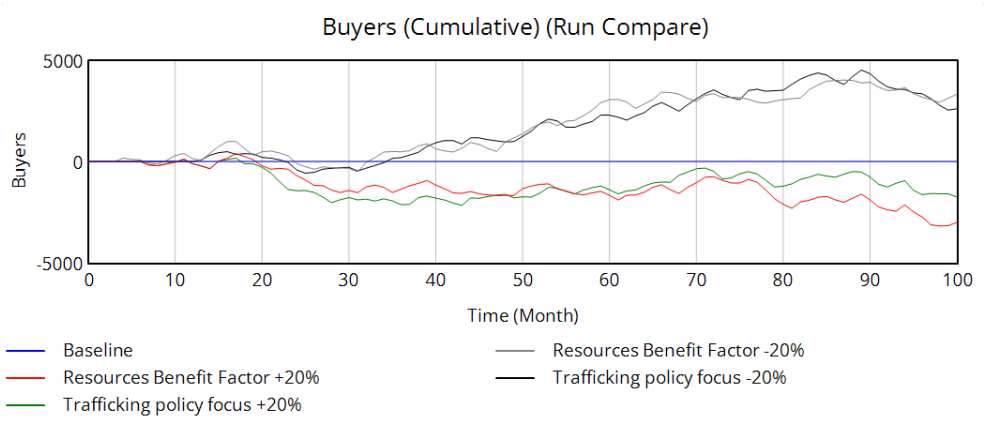

Figure 19: Buyers cumulative run compare chart for +/- 20% resources benefit factor & trafficking policy focus

Dynamics Analysis

In Figure 20, we increased the Overall Negative Exit rate parameter to .9 from a previous rate of .45 to see how total victims over time would be affected. This chart shows, potentially, how forced criminality of victims has a diminishing impact on the effect of resources that are available. Further, it shows somewhat of a "negative feedback loop" where the more quickly victims are pulled out in a negative fashion (i.e., being arrested for a crime they were forced to commit), the more quickly they will be replaced and, therefore, the larger number of victims that will be pulled out in a negative fashion. If validated, this would provide an argument furthering the importance of creating policies that help to avoid the forced criminality of these victims.

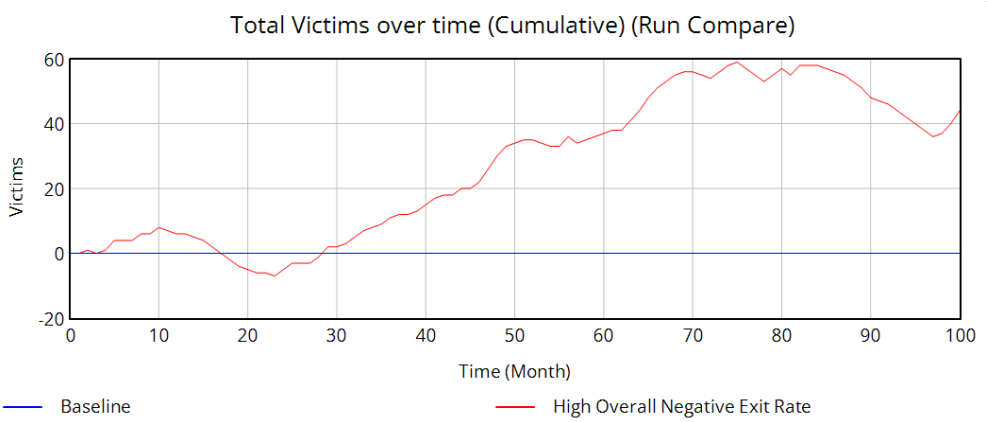

Figure 20: Total victim over time with high over negative rate cumulative run compare chart.

From the baseline, we decided to evaluate what would happen when demand interdictions were added to the system. The two demand interdictions parameter that we added were preventative education measures for buyers and buyer targeting. Preventative education measures create uncertainty in the vetting process for buyers like the fifth scenario in the buyer simulation. In this section, we will change the vetting process by adding a preventative education measure that limits the capacity of buyers that can enter the system to the number of buyers previously in the system plus ten percent, simulating a barrier to entry The other variable is buyer targeting. Buyer targeting is representative of increased efforts by law enforcement to specifically target buyers, such as (sting operations, false online ads, etc.) (Martin et al., 2017). This is a succinct difference from the trafficking policy focus because that policy is focused victims' protection rather than buyer targeting. Buyer targeting influences involuntary exits by increasing buyer enforcement. In this section, we will change the involuntary exit rate by increasing the chance that enforcement is intervening through the buyer enforcement parameter which is initialized at .15.

When we implement only buyer targeting without creating a barrier to entry such as a preventative education measure, we find that the vetting process has an increase of 37% in Figure 21. This graph shows the number of buyers that enter the system over time. An increase in vetting means more exposure to the trafficker resulting in a greater chance of them being caught by law enforcement. While our system dynamics model is set to run for a certain period of time, the long-term effects of this type of policy could potentially be cut short by the traffickers' increasing desperation to fill the rapidly leaving demand. The greatest number of exits are generated from a voluntary exit in Figure 22. The majority of buyers have a fear of being caught and admit that law enforcement presence increasing will deter them from attempting to purchase commercial sex.

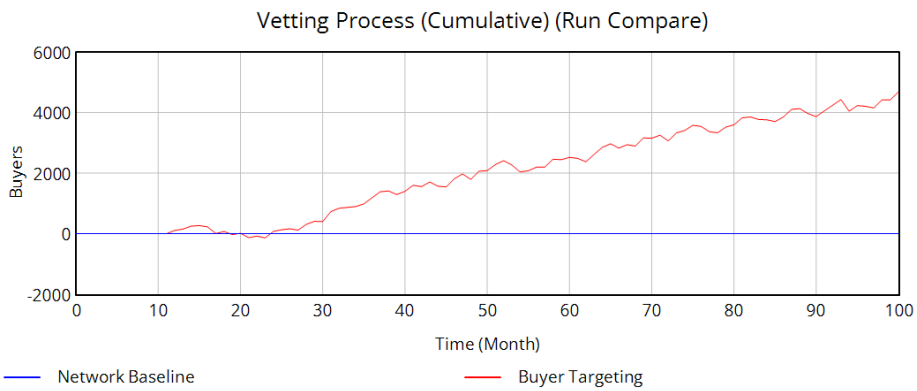

Figure 21: Vetting process cumulative run compare chart for buyer targeting

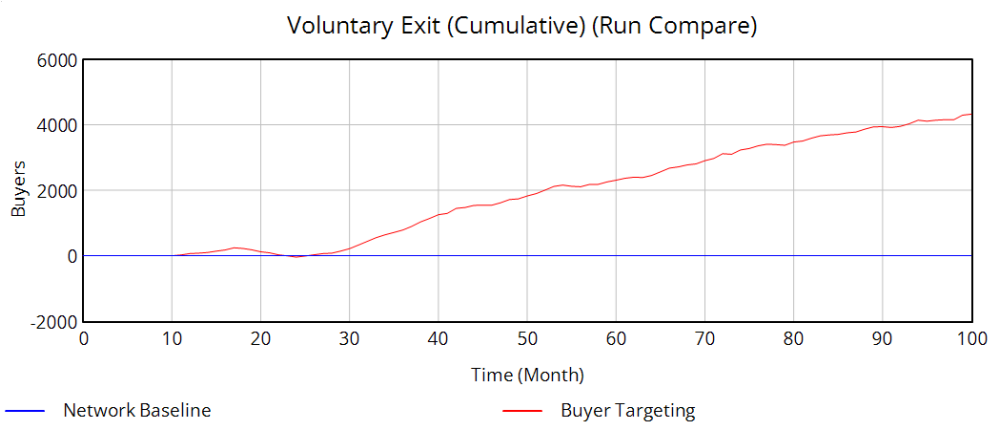

Figure 22: Voluntary exit cumulative run compare chart for buyer targeting

While an increase in exposure to the trafficker would be a great way to interdict traffickers, it still does not result in demand reduction meaning that the trafficker could still have a way of continuing their operations. If we add preventative education measures to create limits on the number of new buyers that enter into the system, then this could create a way of placing limits on the number of new buyers enter the system. When preventative education measures are added, Figure 23 shows that the number of buyers that exist in the system is signficantly lower than the buyers in the baseline. This helps us to avoid unintended consequences from increasing buyer targetting as well but also allows us to understand the idea of displacement through the circuit trigger variable in Figure 24. The circuit trigger shows us instability between supply and demand in the system. If a trafficker is not able to fill their demad in the current city, then we must ask what is preventing the trafficker from moving into a complelely different city with the

victims and continuing operations.

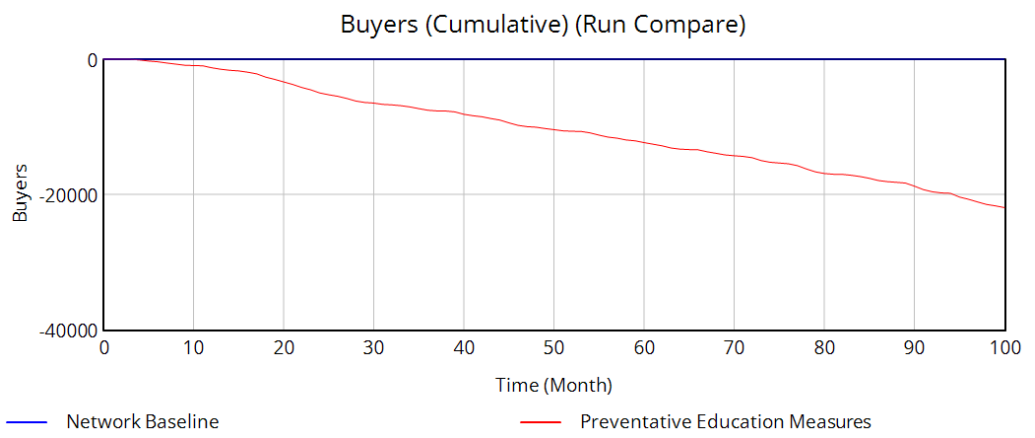

Figure 23: Buyers cumulative run compare chart with preventative education measures.

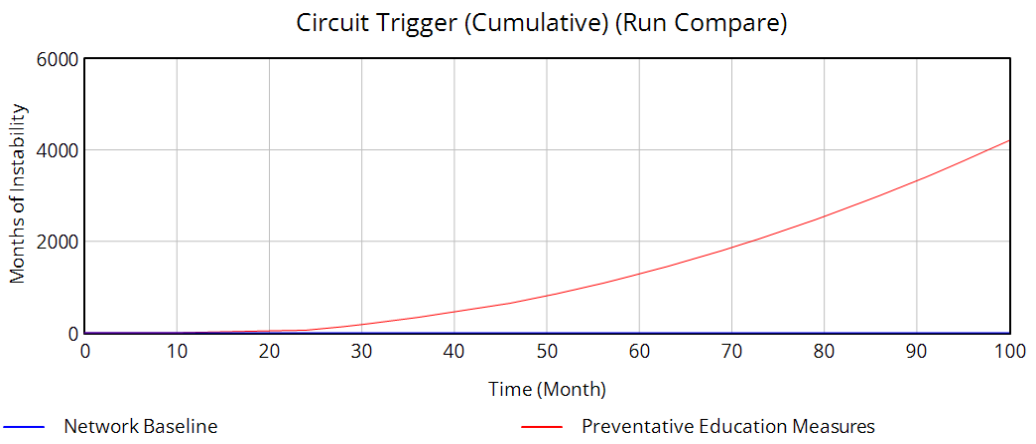

Figure 24: Circuit trigger cumulative run compare chart with preventative education measures.

This chapter was meant to serve as a proof of concept for the type of analysis that could be run for a validated system dynamics model. However, more reliable data in numerous area will have to be gathered prior to validation and this proof of concept actually providing potential insights into anti-trafficking policy. Future work based on this concept analysis could look at multiple of these scenarios simultaneously. The

sensitivity analysis done with our proof of concept could lead to potential policy analysis, once these validation issues are addressed.

CHAPTER FIVE

CONCLUSION

This thesis has yielded many benefits for creating engineering models to help disrupt sex trafficking operations. It explored methods that helped to gather new knowledge on sex trafficking and identify data gaps that are in current literature. System thinking allows us a gain a better understanding of the entire picture of domestic sex trafficking, which helps to create a more realistic model and to ask questions about trafficking in different ways. While system dynamics simulations have potential benefits, it is important to close the current data gaps in knowledge in order to validate a specific system dynamics model. A validated model will help ensure that information that comes out of is accurate and beneficial.

The trafficking system is a complex network that remains operational due to its ability to exhibit control, a consistent flow of profit, and its lack of detection from those that may be able to help disrupt it. Traffickers use surveillance as a means of control over victims, while also consistently recruiting new victims in the systems in order to fill the needs for demand. Traffickers' decision-making is highly dependent on two factors: buyer desires and law enforcement presence. Traffickers are at times able to avoid law enforcement because they have relationships with other traffickers in the area, which helps them stay aware of law enforcement patterns. Traffickers may also quickly adapt their operations, such as implementing circuits, where they move some of their activity in a different area. Circuits also offer the trafficker an ability to move their operations to a different area, making it more difficult for the traffickers' operations to be discovered.

Every interdiction we make has the potential for unintended consequences and to unintentionally cause harm to victims. It is important to make sure that we find a way to explore and understand these unintended consequences because we could be making matters were or more severe for trafficking victims. We believe that by combining engineering models, domain expertise, and the expertise of our survivor-centered advisory group, we have been able to explore issues around the consequences of our research. In addition, policies such as vacatur laws allow us the potential to counter some of these unintended consequence-like victims not feeling like the have way back to a normal life (Devaney, 2021).

Insights & Lessons Learned from Transdisciplinary Research

Transdisciplinary research has many benefits, but it has also come with many lessons learned. The first lesson learned is that context matters. Often, in quantitative research, we tend to focus significantly on the mathematical model we are studying. We may view colors as just colors in our diagrams and illustrations, without thinking about what those colors could mean to someone else because we are focused on the numbers and the data behind them. When collaborating with a team like the one that helped to implement the research discussed in this thesis, it matters which colors are where because it could be telling two different narratives depending on the context. We must recognize that by creating mathematical models of sex trafficking, we are abstracting traumatic lived experiences of victims and survivors. Therefore, working with a transdisciplinary team helps to better understand the context of the problem and the context of how we talk about our mathematical model and analysis.

Our work yields a few different pathways for researchers in the future to move forward. In Table 1, we list the insights of working with our advisory group under a 'systems thinking' type approach and many of these insights are relatively understudied. Filling the gaps in these understudied areas like, how traffickers' control and perform surveillance on their victims and knowledge about how circuits operate, will allow future quantitative researchers to make increasingly accurate models for potential practical implementation. In general, the co-creation of a systems dynamic model with the survivor-centered advisory group helped to identify gaps in academic knowledge about sex trafficking network operations.

Another lesson learned is that there must be a balance in how much we can capture within the model. Although we wish we could model and implement every detail of the commercial market so that we could find the best solution, we reach a point where we must limit the scope of the model. For example, we attempted to limit the scope of the system dynamics model to closed-buyer networks. Yet, we still were not able to populate the model with reliable data. Understanding the limitations of system dynamics, and the data required to populate this class of models, is especially important for us to adhere to these limitations in scope while still properly modeling the system.

Our work has also taught us to be cognizant of the impact we claim. Much of research in this fields builds off research that has already been done (Dimas, Konrad, Lee Maass, & Trapp, 2022). As we build these models, understanding that future research may build on them, it is important to monitor the impact that we claim to make. This is why with the current level of data we do not claim to have a validated system dynamics

model. Rather, we offer a proof of concept understanding it is better to be accurate than to be fast. This was highlighted by our qualitative academic research team as we identified the research area:

> *"we could try and run really fast, but we like to take one step at a time and go the right direction"* (Academic Team Member, November 2022 AG Meeting)

Lastly, the one thing that makes this all possible is the trust and shared language with the survivor-centered advisory group. The topic we are discussing is sensitive and takes much patience and diligence. The operations research group has an onboarding process that consists of reading literature on operations within this space and reflecting on the information. Society has a limited view of what sex trafficking look like because of movies and the media, which only portrays parts of the trafficking experiences. Our onboarding process looks to expand the view of the researcher so that they are more empathetic and understanding in their discussion with the advisory group. It is important that the advisory group feels heard, is heard, and they understand the shared benefits of this research.

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