

**Disrupting Illicit Supply Networks:  
New Applications of Operations Research and Data Analytics to  
End Modern Slavery**

**Workshop Report and Proposed Research Agenda**

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## Executive Summary

An interdisciplinary workshop was funded by NSF (CMMI-1726895) and conducted in 2017 that brought together scholars from operations research (OR) and data analytics with scholars from human trafficking to address the following questions toward the goal of developing a research agenda.

1. What are the implications for supply chain stakeholders of including the social aspects of network design in studies of illicit networks like modern-day slavery?
2. Which modeling and analytic methods are best suited to develop and evaluate evidence-based interventions designed to disrupt illicit network operations economically and/or logistically?
3. How can we improve our ability to identify and collect data about individuals victimized within illicit networks?
4. How do we deal methodologically with “deeper” objectives, e.g., the triple bottom line that includes economic, environmental, and societal goals?

The following research agenda is proposed. It should be kept in mind that the proposed agenda attempts to build on an extensive foundation of research from contributing fields that include criminology, law, social work, economics, business, engineering, mathematics, and computer science in a way that integrates those contributions toward further advancement in the targeted problem domain of human trafficking. There are no inherent priorities among these agenda items. Rather, in fact, there are potential synergies to be obtained from coordinated investigation across the entire agenda.

**Create additional interdisciplinary, collaborative working groups.** Workshop participants recognized that more conversation and contemplation are needed to allow collaborators from disparate disciplines to learn how to more effectively share knowledge and expertise. An environment that would nicely complement this workshop would be the formation of one or more working groups as nascent collaboration teams. These working groups would each be formed around a narrower scope than the present workshop. Such scopes might be chosen from the themes explored by the workshop or proposed by aspiring teams. Illustrative examples include foci on case studies of organizations with leadership positions in antitrafficking efforts, the development of interdiction models, and the development of sustainable supply chain design and management models. In addition to researchers, representatives from organizations already involved in antitrafficking efforts should be included in the working groups.

**Conduct qualitative studies to explore quantitative parameterization of the problem space.** Such studies would not be designed to collect definitive, projectable data. Rather the objective would be to learn deeply from a smaller number of ecosystem participants, using, for example, in-depth interviews to construct a retrospective cohort. The data collection goal would be an exploration of the parameter space and the achievement of saturation on the ranges of possibility for those parameters. The idea proposed here envisions collecting enough data to ensure that analysis and modeling efforts are informed by real-world evidence.

**Conduct large longitudinal studies to understand system and participant trajectories.**

Building on manifestations of trafficking that are better understood, e.g., child sex trafficking vs. labor trafficking, collect definitive behavioral and experiential data that will allow the trajectory of ecosystem participants to be more fully elucidated. Recent studies have focused on repeated cross-sectional designs to estimate and update data, but few studies have followed ecosystem participants over time. Longitudinal studies might include both retrospective and prospective elements. Such studies allow insights about incidence, prevalence, and harms to be better understood as hazards with cumulative impact over time.

**Create data fusion projects.** Extant data are all too rare, but they do exist. However, those data are almost always isolated into the domains of the agencies and organizations that have collected them primarily because those data have been collected for the mission of the group doing the collecting. While there are efforts underway to develop common schema for merging data and collecting data in the future, substantial needs exist for common terminology and coding schemes, as well as improved understanding of the data that are needed to address the problem. These data needs are at present elusive because modeling efforts specifically for this domain are nascent.

**Develop modeling and analysis approaches tailored for this problem domain.** Exploratory efforts are needed to allow researchers to “carve out” tractable problems for investigation. It is through these exploratory efforts that the true data needs for solutions will be elucidated. For example, solutions in the problem domain may often take the form of an intervention, and thus must include a specification of outcomes and the metrics for those outcomes. The achievement of desirable outcomes is supported by understanding the decisions that must be made to achieve those outcomes. Some of those decisions are real-time, tactical decisions and some take the form of longer-term policies. As the time scale shifts, so does the relevancy of accounting and controlling for variability. These factors guide the selection of appropriate methods for modeling that system and searching for solutions to that problem.

**Add technology and instrumentation efforts.** Data needed to remediate and ameliorate trafficking include signals that are either only now just being measured or are yet to be measured. In other cases, measurement improvements are needed. In yet other cases, research is needed to assess the broader societal consequences of collecting that data. Such data might prove to be extremely useful, but also might lead to unintended consequences.

**Study the systems where trafficking occurs rather than solely studying trafficking.** The norm for human trafficking is that it occurs conjointly with other behaviors and operations, both licit and illicit. Human trafficking is most often discussed as existing in various labor supply chains, including agriculture, fishing, commercial sex, domestic services, etc. It is a primary mechanism for providing lower cost, exploitable labor to these activities. However, for the same reasons, human trafficking coexists with drug trafficking, warfare, child abuse, environmental crimes, and terrorism. Research on human trafficking must necessarily embrace these intersections.

The body of this report describes the workshop from inception to execution and develops this research agenda in more detail.

## Introduction

Social science researchers and human trafficking advocates believe that if policymakers and abolitionists fully understand how widespread the phenomena of forced labor and sex trafficking are in developing and industrialized countries, public awareness and political pressure could eradicate it. Undoubtedly, efforts to end modern slavery must involve effective interdiction and judicial sanctions. Nonetheless, although the best estimates using sophisticated statistical methodologies find the number of human trafficking victims continuously rising, increased public awareness has not resulted in reduced incidence and prevalence rates. Innovative and timely research strategies are needed to develop approaches that disrupt illicit supply networks that include human trafficking.

In recent years, human trafficking research has become primarily focused, if not stuck, on measuring the prevalence of modern slavery and characterizing the nature of, risk factors for, and impact of the activity (Baldwin, Eisenman, Sayles, Ryan, & Chung, 2010; Bales, Hesketh, & Silverman, 2015; Banks & Kyckelhahn, 2011; Busch-Armendariz 2011, Busch-Armendariz, Nale, Kammer-Kerwick, Kellison, Torres, & Nehme, 2016; Campbell, Dworkin, & Neumayer, 2009; Choi 2015; Clawson 2007; Dank 2014, Datta & Bales, 2013 & 2014; Farrell, McDevitt, Perry, & Fahy, 2010; ILO 2012; Kutnick, Belser, & Danailova-Trainor, 2007; Nelson, Schmotzer, Burgel, Crothers, & White, 2012; Owens, Dank, Bañuelos, Farrell, Pfeffer, Bright, Heitsmith, & Mcdevitt, 2014; Zhang, Spiller, Finch, & Qin, 2014; Zhang 2012, to name just a few). Other research has examined policies to remediate the problem, both from the perspective of assessing the efficacy of existing laws and making recommendations for improved remediation (Adams & Owens, 2000; Cho, Dreher, & Neumayer, 2014; Clawson 2006; Clawson, Dutch, & Lopez, 2008; Farrell 2009; Halter 2010; Hodge 2014; Huey, Broll, Hryniewicz, & Fthenos, 2014; Small, Adams, & Owens, 2008; Verhoeven & Gestel 2011; Young 2012). A third research stream has advanced theoretical frameworks for structuring the problem toward identifying evidence-based interventions and legislation (Lee & Aos 2011; Gould 2010; Luty, Lanier, & Africa, 2002; Weitzer 2013).

Few studies have approached such illicit networks from a dynamic systems theoretical perspective that allows the social justice challenge to be represented as a mathematical system that can be analyzed in terms of decision variables to help guide, control, and constrain behavioral dynamics toward desired goals. One such example, albeit exploratory in nature, is Kóvári & Pruyt (2014), who used a systems dynamic simulation methodology to examine the effectiveness of policies meant to control sex trafficking in the context of prostitution. Brandenburg, Govindan, Sarkis, & Seuring (2014) use content analysis to review the literature on mathematical models for sustainable supply chain management, concluding that there are numerous possibilities for expanding the “types of tools and factors considered in formal modeling efforts.” Eskandarpour, Dejax, Miemczyk, & Péton (2015) performed a systematic review of supply chain network design research and included a call to action that recommends ways of better evaluating the impact of a supply chain on all its stakeholders, including employees, customers, and local communities, all with the goal of improving social sustainability. Martin & Lotspeich (2014) conducted a benefit-cost analysis to assess the return on investment of an intervention designed to divert young women from sex trafficking victimization. Aronowitz, Theuermann, & Tyurykanova (2010), Fearon & Hoeffler (2014), Jakobsson, & Kotsadam (2015), and Wheaton, Schauer, & Galli (2010) have assessed trafficking

through a business model or economic system lens. Martin & Pierce (2014) and Zhu, Gorman, Horel (2006) used data analytics and statistical models to examine the location of “hot spots” for trafficking and other illicit activities. Konrad, Trapp, Palmbach, & Blom (2016) conceptually explore how techniques from OR and data analytics can be applied to human trafficking, recognizing key challenges that include the partial observability of victims, adaptability of the traffickers, limitations in data availability, and constraints on resources to combat the problem.

Solutions to remediate the effect of illicit networks like human trafficking are inherently interdisciplinary, typically involving the fields of criminal justice, social work, social science, economics, healthcare, and law. Such systems are dynamic; they involve exploitation and victimization of some members of the ecosystem, and they commonly involve intersections between licit and illicit activities as well as intersections among several illicit activities. Such systems are also often hierarchical, distributed, nonstationary networks of interconnected activities and participants, and they involve intersectional decision making by perpetrators, victims, and/or bystanders. Highly common among such systems is a paucity of data due in large part to the hidden aspects of the crime and the partial observability of the population of interest.

This report addresses the opportunity to apply advances from the fields of operations research (OR), management science, analytics, machine learning, and data science toward the development of disruptive interventions against illicit networks. Such an extension of the current research agenda for trafficking would move understanding of such dynamic systems from descriptive characterization and predictive estimation toward improved dynamic operational control. Further, we recommend focusing efforts toward developing potential solutions to the problem of human trafficking by using a sustainable supply chain design and management lens wherein we desire to disrupt certain exploitive and harmful activities and dynamics while enhancing other constructive and beneficial economic activities and behaviors. As discussed in Brandenburg et. al. (2014), we adopt a triple-bottom-line perspective to purposefully address economic, environmental, and social considerations into our approach. This report is heavily informed by the insights shared by the 48 participants of the workshop. Any errors or omissions relative to input from the workshop are the fault of the authors.

This report attempts to:

- Examine the structure and nature of illicit networks like human trafficking within analytic and modeling frameworks for sustainable supply chains;
- Explore the form and complexity of viable, real-world solutions using methodologies;
- Assess the characteristics and amount of data needed to model and analyze the problem;
- Propose a research agenda to guide the efforts of interdisciplinary teams of scholars to develop methods and solutions.

More specifically, we address the following broad research questions:

1. What are the implications for supply chain stakeholders of including the social aspects of network design in studies of illicit networks like modern-day slavery?
2. Which modeling and analytic methods are best suited to develop and evaluate evidence-based interventions designed to disrupt illicit network operations economically and/or logistically?

3. How can we improve our ability to identify and collect data about individuals victimized within illicit networks?
4. How do we deal methodologically with “deeper” objectives, e.g., the triple bottom line?

## The Workshop

### Locations

The workshop consisted of two meetings, the first held in Austin, TX (May 5<sup>th</sup> and 6<sup>th</sup> 2017) and the second held in Washington DC (December 1<sup>st</sup> and 2<sup>nd</sup> 2017).

The first meeting, hosted by the Institute on Domestic Violence and Sexual Assault (IDVSA) at The University of Texas at Austin, brought together an interdisciplinary team of scholars to explore ideas for developing and applying operational research methods to disrupt illicit networks. Austin has long had one of the most active anti-trafficking coalitions of non-profit organizations in the country, including Allies Against Slavery. For the past 15 years, IDVSA in the Steve Hicks School of Social Work at the University of Texas at Austin has created a significant body of published research around human trafficking by building an interdisciplinary research team of scholars from the fields of economics, social work, victim services, trauma, nursing, and information science. The human trafficking portfolio team holds expertise in both quantitative and qualitative methodologies and has worked closely with law enforcement investigators and prosecutors from the federally funded task forces in Texas on numerous projects.

The second meeting assembled the same set of researchers (their schedules permitting) to develop a ground-breaking research agenda based on the findings and outcomes from the first meeting. In addition, holding the second meeting in Washington enabled organizers to invite representatives from federal agencies (e.g., Department of Homeland Security and National Science Foundation), and national advocacy and abolition groups like Polaris, to participate in the workshop and respond and react to the ideas presented by the research team, increasing the social impact of the research.

### Workshop Organizers and Credentials

As workshop organizer and principal investigator, Dr. Busch-Armendariz has extensive knowledge about human trafficking, having served as the PI on more than 60 externally funded research and training projects, totaling approximately \$8.5 million dollars of external funding. Most recently, she has led a 4-year project funded by Texas Governor’s Office to determine the prevalence and economic impact of human trafficking in Texas. Those studies blended research approaches involving qualitative (interviews with human trafficking victims, law enforcement, prosecutors, social services, coalition and task-force members) and quantitative methodologies (surveys). She is the University Presidential Professor at The University of Texas at Austin, Steve Hicks School of Social Work, founding director of the Institute on Domestic Violence and Sexual Assault (IDVSA), and Associate Vice President for Research at The University of Texas at Austin. She is a licensed social worker with 17 years of experience and a well-published scholar. She is the first author of a textbook on human trafficking (Busch-Armendariz, Nsonwu, & Heffron, 2018).

As co-organizer and co-investigator, Dr. Matt Kammer-Kerwick has a background in Operations Research (OR) and data analytics as well as human trafficking. He is a Research Scientist at the Bureau of Business Research (BBR) at The University of Texas at Austin and is a co-principal investigator with Dr. Busch-Armendariz on the Texas Human Trafficking Mapping Project (Busch-Armendariz, Nale, Kammer-Kerwick, Kellison, Torres, Nehme 2016) and Cultivating Learning and Safe Environments, an empirical study of prevalence and perceptions of sexual harassment, stalking, dating/domestic violence, and unwanted sexual contact (Busch-Armendariz, Wood, Kammer-Kerwick, Kellison, Sulley, Westbrook, Olaya-Rodriguez, Hill, Wachter, Wang, McClain, & Hoefler 2017). He worked for more than 20 years as a research-based business strategy consultant before joining BBR and IDVSA to study human trafficking, sexual assault, domestic violence, and other social justice problems. His dissertation focused on near-optimal control of stochastic discrete-event dynamic systems.

### Workshop Plan

The meetings were planned to be very dynamic, interdisciplinary sessions that included presentations from thought leaders from the problem domain and methodology experts, as well as brainstorming discussions involving 25 – 30 scholars.

Broadly, the agenda for the two meetings covered:

1. Discussing connections between human trafficking research and OR/Data Analytic methods and applications;
2. Identification of research streams to pursue;
3. Proposing specific research projects to be funded;
4. Facilitation of connections among researchers and advocates.

See appendices for specific agenda details.

The workshop agendas and reading materials were published online to ensure they served as a source of expertise for researchers, practitioners, and policymakers in attendance. Each workshop was 1.5 days, with a group dinner after the first full day, and concluded after lunch on the 2<sup>nd</sup> day in time for attendees to travel home that afternoon.

The Austin meeting was attended by 29 participants and the DC meeting was attended by 37 participants, with 19 of those being new to the workshop in DC. Ten participants to the Austin meeting were unable to attend the DC meeting. In total, 48 unique participants provided insights to the workshop with 38% of participants attending both meetings. Additionally, at least 17 participants are known to have begun collaborations between and after the two meetings. See appendices for participant details.

### Austin Meeting

The Austin meeting was by design exploratory and intended to allow participants to get to know each other as well as become familiar with the interdisciplinary perspective taken as individuals and as scholars from disparate backgrounds. The workshop commenced with a historical briefing by Ambassador Lou C. deBaca (Retired) about human trafficking and included a review of the Signal International labor trafficking case (Kellison and Kammer-Kerwick, 2017; Brickley, 2015; and Rather, 2011). Participants spent time in breakout sessions and group discussion. The meeting

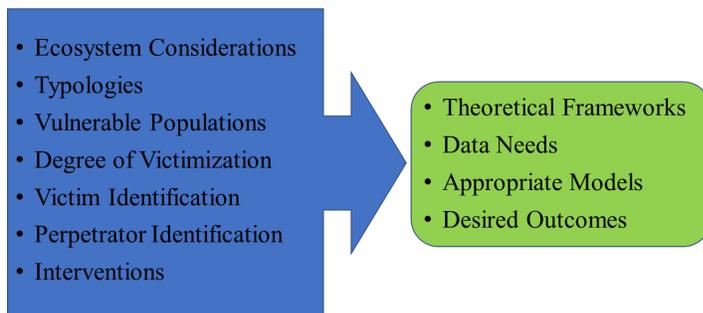
coalesced around the need to further explore and develop the following research themes in the second meeting.

- Framework Development
- Decision Makers and Their Goals
- Dynamic Systems and Controls
- Vulnerabilities and Taxonomy
- Inventory of Datasets
- Lifecycle and Disruption Targets
- Big Data/ Transactional Data
- Adjacent Models

### DC Meeting

The DC meeting framed the discussion around the goal of exploring the various types of research seen as fundamental toward developing the basis for solutions to human trafficking. Seen in Figure 1 below, the discussion was prompted with a view of the problem as an ecosystem with various classes of participants wherein interventions might be applied to disrupt the illicit activities. These considerations were discussed as needing to connect to or otherwise inform theoretical frameworks for better understanding how to address the problems faced, the modeling approaches needed to develop appropriate solutions, and the data needs of those approaches.

### Strawman List of Brainstorming Prompts



*Figure 1 Strawman List of Brainstorming Prompts for DC Meeting*

Toward that goal, the DC meeting was organized around a series of thought provoking presentations given during the first day. These presentations were selected to be either from adjacent problem domains that share some of the characteristics of human trafficking as an illicit network or as examples of novel methodologies or technologies developed specifically for the problem domain of human trafficking.

#### Presentations from Adjacent Problem Domains

*Criminal Network Analysis Across the Physical, Cyber, and Social Dimensions*, Anthony Stefanidis, GMU, Director CINA COE. This presentation discussed the strategy and organization of efforts at George Mason’s DHS COE for criminal networks.

*Systems Models of the Markets and Supply Chains for Illegal Drugs*, Jonathon Caulkins, CMU. This presentation included highlights from a series of studies that elucidated the structure and

operational models for drug traffickers. One key takeaway for the workshop was a recommendation to seek different perspectives on the problem that might provide new, effective solutions. For example, a focus on source suppliers at earlier stages of the illicit drug supply chain was more effective than the traditional focus on consumers or the retail dealers. See Caulkins et al. (2016) for more information.

*Interdicting Nuclear Smugglers*, David Morton, Northwestern. This presentation reviewed a stochastic programming approach to allocating a finite number of nuclear material detectors to maximize the likelihood of detection of smuggling activities. One key takeaway for the workshop was to focus initially on a smaller, more manageable problem definitions rather than trying to address all aspects of the problem. See Morton et al. (2007) for more information.

#### Presentations from Human Trafficking

*Estimating the Size and Scope of the Underground Commercial Sex Economy in US 8 Cities*, Meredith Dank, John Jay and Bilal Khan, Nebraska Lincoln. This presentation reviewed findings from a novel study that combined survey methods with extant secondary sources used as proxies in a mathematical optimization formulation to estimate the size of sex trafficking. See Dank, Kahn, et al. (2014) for the full report.

*Memex: Novel Search and Indexing Technology Targeting HT*, Wade Shen, DARPA, Memex Program Manager. This presentation gave an overview of the history and developmental progression of the Memex program and how it was developed specifically to address data indexing and fusion on online data with other sources of information about sex trafficking.

## Human Trafficking as an Illicit Network

Human trafficking was chosen as a focal example of an illicit network, as mentioned above, because it possesses many of the core characteristics of illicit networks in general and because it often intersects or is coincident with other illicit networks. For example, in recent years, the illegal and unreported fishing “industry” has been flooded with human trafficking cases. The fact that fishing activity takes place at sea makes it difficult to monitor working conditions and pay, creating a breeding ground for abuse, isolation, and exploitation (Wen, 2013; Sutton & Siciliano, 2016). In a second example, human and drug trafficking are frequently linked. Recent drug raids in the United Kingdom uncovered multiple cases of human trafficking where women and men were forced to transport drugs across borders (Press Association, 2017). As a last example, smuggling and human trafficking, though different, often coincide. Migrants are often smuggled across borders for the financial gain of the individual transporting them. These instances can be distinct and separate from the exploitation of those individuals, but it can also provide the means to an end – an individual is asked to pay for transportation into another country, they are smuggled in, and then they are taken advantage of and forced into different forms of labor or sexual exploitation (UNODC, 2018). With that said, human trafficking is itself a broad and highly nuanced problem domain.

Although the workshop focused on human trafficking as a focal example of an illicit network, a broader perspective on illicit networks has been presented in other literature. A report by the

National Defense University (2015) is a collection of articles that include among illicit networks drug smuggling, illicit arms trade, counterfeit goods, natural resources, and cultural property in addition to humans. The perspective taken across that collection is national security, with significant attention devoted to nation state vulnerabilities from “deviant globalization” by illicit actors. An entire chapter is devoted to illicit supply chains (Chapter 4 by Duncan Deville) Criminology literature also focuses on illicit networks. Examples include Malm & Bichler (2015) and Bouchard & Amirault (2013). These authors introduce special issues in two criminology journals. Both collections focus on illicit networks from the perspective of social network analysis. Other examples exist as well. Across the literature reviewed within this space, the perspective is broad across domains of illicit activity while being more focused on SNA methods to understand and fight the associated crimes. These views are simultaneously complementary and divergent from the view adopted by our workshop.

For this workshop, discussions focused on human trafficking as a disruptable illicit activity that can occur on its own but commonly occurs in an otherwise legal supply chain. Additionally, the resilience of the supply chain to such illicit activity might be increased through prophylactic measures. As pointed out by Basu (2014), illicit operations are by necessity among the most adaptive and flexible due to the inherent uncertainty and risks associated with conducting business. As such, efforts to disrupt illicit operations within a supply chain perspective should recognize formidable levels of resistance and adaptation. Below we provide some examples to provide context for this supply chain point of view and want to note here that our adopted focus is a matter of practicality rather than any attempt at minimizing the effect of aspects of human trafficking that are omitted from this point of view. More specifically, Dell et al (2017) emphasize that the

*conditions under which individuals who are trafficked must endure can result in a number of physical, emotional, psychological, social, mental health and physical health problems, substance use, legal and immigration issues, economic and housing challenges and difficulties reintegrating into society (p. 2).*

The chosen examples are just a snapshot of what individuals who have been trafficked may endure, and we hope to not minimize those experiences with our research but focus on unique avenues to address the problem and help those individuals reclaim their identity.

We begin with illustrative examples taken from Owens et. al. (2014), who focus on labor trafficking, and Martin and Pierce (2014), who focus on sex trafficking. As reported by Owens et. al., domestic servitude cases commonly involve a single perpetrator or a small group of exploiters of an individual victim or small number of victims. Some victims were smuggled into the US and trafficked by the smuggler whereas other victims were handed off to another who then trafficked the victims. Cases involving larger numbers of victims, including those with guest worker visas placed in various labor industries, involved more sophisticated organizations that include intermediary recruiting and placement agencies working with or for organizations with varying degrees of awareness and knowledge about the exploitation of the workers. Farming cases reported in their study are characterized as often involving multiple parties without a centralized operation. For example, a trafficker of agricultural workers often utilized the services of smugglers. This type of network is described as a supply chain where all the participants knew each other and worked cooperatively without being part of a centralized or hierarchical organization.

Martin and Pierce (2104) similarly surveyed the landscape of sex trafficking as an industry operating under economic principles including supply, demand, and a process through which products and services are developed, managed, and delivered. In addition to victims, they identify buyers and facilitators as other participant categories with this operating model. They recognize that such a broad view of a business model is incomplete without including an underlying segmentation structure, based on victimization risks and vulnerabilities or, alternatively, the business model of the traffickers. Examples here include escort services, brothels, street-based commercial sex, and closed sex buyer networks. They conclude that more insights are needed to better understand the complexities and interactions between market structure, forces, segments, and operational functions toward the goal of disrupting those operations and demand structures. Noteworthy is that the data studied by Martin and Pierce reveal that facilitators and victims often share vulnerabilities, including child neglect, runaway experiences, and other interactions with law enforcement.

By comparison, the sex trafficking cases reviewed by Martin and Pierce (2104) appear to share similarities with the smaller of the networks seen in the labor cases reviewed by Owens et. al. (2104). They differ in that the nature of the labor is commercial sex rather than domestic servitude and that the recruitment is more locally focused and less likely to target immigrants. These examples are just that, examples, and our review of them is not intended to represent an exhaustive survey of victim and perpetrator typologies. They do demonstrate the utility of framing human trafficking within the context of a business model and supply chains, and they provide examples of the types and levels of real world complexity that need to be addressed by modeling and analytic methods developed and applied to remediate this broad, complex, and dynamic problem.

Workshop participants considered how the ambiguities, complexities, intersections, and conflicting goals of such systems described above might best be captured by OR and data analytic models and approaches from an ecosystem operational perspective that recognizes that most illicit activities, in general, and human trafficking, specifically, occur within or at the edges of licit networks. Additionally, human trafficking as a focal point invited our participants to embrace a victim or survivor centric perspective in our discussions. Specifically, how might incentives, penalties, or constraints induce or force operational systems to function in a manner that is socially sustainable? How might such approaches yield solutions that allow network stakeholders to broaden their view of the system to embrace long-term social justice goals over a narrower, more myopic operational view that often relegates such considerations into ignored or overlooked externalities?

Disruption and increased resilience will require interventions that target a range of supply chain dimensions. An initial list of interventional targets for human trafficking includes, but is not limited to, the following:

- Increase law enforcement interdictions, investigations, and prosecutions;
- Improve service delivery for victims;
- Decrease the number of potential victims by reducing recruitment effectiveness;
- Decrease the supply of potential victims by preempting recruitment propensity and addressing root causes of risk factors;

- Decrease demand for goods and services supplied by illicit networks;
- Decrease demand through consumer education;
- Decrease demand through education of society in general;
- Increase operating costs of traffickers by disrupting or destabilizing business locations and networks;
- Increase judicial penalties for conviction and plea agreements
- Increase victim participation during investigation and prosecution phases through improvements to victim services
- Decrease the number of victims in active trafficking situations by providing incentives to self-identify
- Shrink the illicit network by coordinating anti-trafficking efforts with other coincident criminal activities like murder, drugs, child porn, and gang activity in general

Development and application of OR and data analytic models and approaches also requires data - a recognized limitation to current anti-trafficking research and program development. Data needs include:

- Survey techniques to address/identify victims;
- Instrumentation and real-time data collection from/about operations;
- Data fusion and warehousing of existing and newly collected data from a variety of federal, local, NGO, and operational sources.

The nature and extent of available data also influences the utility of various models and methods. At a very high level, OR and data analytic models and approaches take very different perspectives on the system being studied and convey very different data requirements compared to other descriptive or cross-sectionally predictive approaches. Advances are being made that allow these methods to be further expanded and applied to human trafficking and other illicit network problems. Some examples include:

- Mathematical programs, while highly varied from problem to problem, encapsulate the system being studied as a system of equations and inequalities with an objective function that is used to maximize the utility of the solution. Mixed linear integer programs have emerged as a common modeling frame for sustainable supply chain design and management problems. Those models provide a starting point for the structures needed to address illicit networks.
- Stochastic models and stochastic optimization expand consideration to the common circumstances of uncertain dynamics and outcomes. Such models require deeper understanding of the sources of variability and the pattern of that variability over the range of possibility. In practice, such models can be combined with simulation as means of exploring the system being studied. System dynamic and agent-based simulation have emerged as analytical approaches well suited to the complexities of operational systems.
- Machine learning, cognitive computing, and natural language processing are all approaches that have seen rapid progress in recent years due to advances in computational infrastructure and the accrual of large amounts of data. They have proven beneficial in data rich environments wherein predictors can be mapped to known (or labeled) outcomes. While the potential to collect data that might be predictive of trafficking is increasing rapidly, connecting those predictors to outcomes remains a challenge. Additionally, the success of these methods at prediction has come at the

expense of elucidating the mechanisms driving the connection between prediction and outcome. Machine learning has also recently come under scrutiny as algorithms have learned implicit biases contained as artifacts in the datasets used to train the algorithms.

- Advanced sampling and survey methods have been developed and borrowed from other fields that deal with study populations that are hard to observe and the collection of data that is highly nuanced both in terms of a lack of common vernacular as well as being potentially traumatizing to collect. Respondent driven sampling and capture-recapture sampling are examples. Algorithms to fit generalized linear mixed models have greatly expanded the types of random, repeated, and clustering effects that can be specified in statistical models. A range of link functions, distributional assumptions, multistage generating processes, and techniques for censored or otherwise missing data have greatly expanded the types of real-world complexity that can be included in predictive models.

## Proposed Research Agenda

### Need for Theoretical Frameworks Appropriate for Illicit Networks

Any research agenda will benefit from a fundamental grounding within one or more theoretical frameworks. As a problem domain, human trafficking has been best understood in research literature as a public health crisis, a modern-day form of slavery, and a social justice concern, but it has not yet been assessed using a specific theoretical framework (Haase, 2014; Alvarez & Alessi, 2012; Zaharia, 2009). Busch et al. (2009) created typologies of traffickers. This work draws on actions taken by different types of traffickers, and taken one-step further, could incorporate social work theories to describe these people's actions. Looking at human trafficking through the lens of Social Conflict Theory (Vahabi, 2010), Routine Activity Theory (Cohen & Felson, 1979), Rational Choice Theory (Hechter & Kanazawa, 1997), and more broadly, Reactive Attitudes (Ciurria, 2014) and Moral Responsibility (Mandisa, Lutya, & Lanier, 2012) might be possible ways to help stakeholders learn how to best address the problem. Also see Aronowitz (2010, Chapter 3), Clawson (2006), and Polaris (2017) for additional discussion of business models for trafficking.

While it has been argued that business models historically lack a theoretical foundation from an economic perspective, they are recognized imperially as essential to success in competitive markets (Teece, 2010). Further, many facets of the referenced social science theories have been part of theories in used in business that broaden the perspective from simple economic, supply/demand, bottom-line goals to include ethical, environmental, and societal goals (Harrison & Wicks, 2013; Steurer, 2006; Wartick & Cochran, 1985). Stakeholder theory and broader views of ecosystems in the context of business operations and society have converged within theories of sustainability and the articulation of the triple bottom line (Ozanne et al., 2016; Gimenez et al., 2012). The systematic review by Eskandarpour, Dejax, Miemczyk, & Péton (2015) of supply chain network design research included a call to action that recommends ways of better evaluating the impact of a supply chain on all its stakeholders, including employees, customers, and local communities, all with the goal of improving social sustainability. In another systematic review, Alexander et al. (2014) found that within rational decision theoretic approaches, Analytic Hierarchy Process (AHP), Multiple-Criteria Decision Analysis (MCDA), Analytic Network Process (ANP), and Multiple Integer Linear Programming (MILP) have all

proven to be useful techniques for structured problems. Recent developments allow Expert Systems, Artificial Intelligence, Neural Networks, and Genetic Algorithms to make progress in less structured problems. However, there is recognition that even among these advances significant challenges remain relative to the incorporation of social impacts within mathematical models. Common considerations to date include issues like overtime, burnout, health, safety, etc. (Chen & Anderson, 2014; Türkay et al., 2016).

## Research Framework

Discussions at and between the two workshop meetings collectively identified the following research themes as the initial framework for a research agenda. While there are some logical connections between the themes discussed, the order of presentation is not intended to indicate any form of prioritization among the themes. It is worth noting that workshop participants encourage that research on all themes include a perspective that recognizes the short- and long-term needs of victims and survivors. Solutions to disrupt the problem should also include the needs of those impacted by the illicit behaviors.

1. Integrative study of ecosystems that include illicit and licit components.
2. Improved identification of victims, perpetrators, and relevant operational environments.
3. Development of acute interventions, including but not limited to the initial targets listed earlier. Victim-centered interventions should explicitly include exit costs and appropriate duration for restorative care.
4. Enhancement of sustainable systems management strategies that include antitrafficking components explicitly.
5. Formulation of operational models with objective functions that capture multiple and conflicting goals.
6. Frameworks for data collection, management, and sharing.
7. Embrace intersectionality and nuance.

Research should delineate all participants within the ecosystem and the connections between those participants. Visible components, partially visible, and hidden should be considered. A common scenario is the mix of licit and illicit components in the same ecosystem. Research should involve deeper study of vulnerable populations, perpetrators, and the patterns and cycles of victimization. Research should also include deeper study of, and the intersections between, illicit operational models.

Identification research should address victims, perpetrators, and the situations or operations where exploitation and victimization occur. There have been significant advances in the development of theory and tools for identifying victims using validated screening and experience measurement tools (VERA Institute of Justice, 2014; Covenant House, 2013; and Dank et al., 2017). Progress has also been made in the study of perpetrators and the business models used for exploitation and trafficking (Busch et al., 2009; Polaris, 2017; Barrick, 2014). Valuable advances might include increased understanding of the degree or extent of victimization, longitudinal cycles of victimization and perpetrating behaviors, and intersectional antecedents.

Interventions should be trauma informed and be based on evidence. Research on interventions should include measurement and evaluation activities to assess benefits and costs. More research

is needed to better understand survivor access to services, the substantial exit costs, and the time needed for victim recovery. Here also, intersectional dynamics, victim typologies, and perpetrator operating models should be considered. The interventional targets listed earlier all have the potential for evidence-based optimization to better serve specific vulnerable populations or disrupt specific operational models of exploitation.

HT often exists within (or at the edges of) licit systems. Efforts should include optimization of the operation of the licit business while disrupting or suppressing the illicit part. In this area, questions remain regarding how to frame multicriteria objectives that include ethical behavior and human rights. For example, current triple bottom line models currently can maximize profit, minimize greenhouse gas emissions, and minimize employee turnover and burnout. How can these approaches be extended to include the effects of wage theft and forced labor? What are the benefits to organizations at the top of supply chains to ensuring their entire supply chain is operating ethically? These challenges are substantial, but advocates recommend that governments and industry would increase their ability to remediate human trafficking if efforts focused more broadly on the subtle and often invisible abuses of power that accompany trafficking (Taylor, 2018).

Extant data are rare and disjointed. Additionally, most available data have been collected for other purposes than the research envisioned here. What types of data are necessary for OR and analytic models? What types of data are desired that would allow for more complete models to be developed? How much data is needed vs desired? Collecting data about humans also has unique cautions and concerns. These issues are amplified for studies among the vulnerable populations that are most commonly targeted for human trafficking. Participation in research has increased potential to retraumatize victims and, unless measures are proactively included in project planning, the process can also increase the risks of additional harms from their trafficker.

Research should emphasize the varying degrees of victimization experienced in trafficking and the various patterns of vulnerability behind those degrees of victimization. Research should consider the differences among a “normal” labor relationship, a situation of labor exploitation, and a human trafficking case. Other relevant issues include barriers to exit and concerns associated with degrees of victimization when thinking about solutions. Research should embrace ethical considerations associated with the study of victims, including but not limited to traumatization and agency in decision making.

### Research Agenda

These themes combine, often in an overlapping fashion, to form the following proposed research agenda. It should be kept in mind that the proposed agenda attempts to build on an extensive foundation of research from contributing fields that include criminology, law, social work, economics, business, engineering, mathematics, and computer science in a way that integrates those contributions toward further advancement in the targeted problem domain of human trafficking. There are no inherent priorities among these agenda items. Rather, in fact, there are potential synergies to be obtained from coordinated investigation across the entire agenda.

Create additional interdisciplinary, collaborative working groups.

Workshop participants recognized that more conversation and contemplation are needed to allow collaborators from disparate disciplines to learn how to more effectively share knowledge and expertise. An environment that would nicely complement this workshop would be the formation of one or more working groups as nascent collaboration teams. Individual working groups might be formed around a narrower scope than the present workshop. The chosen scope might be taken from the themes explored by the workshop or be new ideas proposed by aspiring teams. Illustrative examples include foci on case studies of organizations with leadership positions in antitrafficking efforts, the development of interdiction models to fit specific supply chain topologies, the extension of sustainable supply chain design and management models toward specific antitracking goals, etc.

Additionally, foundational antitrafficking efforts are already underway and should be leveraged by working groups in their future planning. For example, the California Transparency Act was passed in 2010, the UK Modern Slavery Act was passed in 2015, and the Shrimp Sustainable Supply Chain Task Force was established in 2014 before being renamed under a broader scope in 2016 as the Seafood Task Force. Representatives from organizations already involved in antitrafficking efforts should be included in the working groups. Corporations like Costco and Walmart, as just two examples of huge consumer brands with extensive and deep supply chains, have played pivotal roles in these movements.

Providing funding to support working groups created for this research agenda will allow involved researchers to identify corporate and governmental partners for collaboration, identifying areas for research that go beyond those recommended here. Such planning support greatly enhances collaborators' productivity and the longevity of the collaboration, allowing working group participants to allocate time during the funded period for both face-to-face meetings and collaborative work in between those meetings.

Conduct qualitative studies to explore quantitative parameterization of the problem space. Such studies would not be designed to collect definitive, projectable data. Rather the objective would be to learn deeply from a smaller number of ecosystem participants, using for example, in-depth interviews to construct a retrospective cohort. The data collection goal would be an exploration of the parameter space and the achievement of saturation on the ranges of possibility for answers to research questions asked. The idea proposed here envisions collecting enough data to ensure that analysis and modeling efforts are informed by real-world evidence. Accordingly, data collection might focus on achieving saturation in the themes uncovered in the exploration (Bowen, 2008). Saturation can often be achieved with between 10 and 15 interviews per homogeneous population segment (Guest, Bunce, & Johnson, 2006). While the required effort for this kind of goal can vary, the focus should be on learning more about the ecosystem rather than simply collecting more data for the purpose of statistical projection.

Conduct large longitudinal studies to understand system and participant trajectories.

Building on manifestations of trafficking that are better understood, e.g., child sex trafficking vs. labor trafficking, collecting definitive data behaviors and experiences allows the trajectory of ecosystem participants to be more fully elucidated. Recent studies have focused on repeated cross-sectional designs to estimate and update data, but few studies have followed ecosystem

participants over time. Longitudinal studies might include both retrospective and prospective elements. Such studies will benefit from common measures for detecting victimization and exploitation as well as common measures for better understanding the context and consequences of those experiences. Recent years have brought the beginnings of convergence in trafficking screening and experience measurement tools (e.g., VERA Institute of Justice, 2014; Covenant House, 2013; and Dank et al., 2017), which might provide a foundation for the envisioned longitudinal studies. Such studies allow insights about incidence, prevalence, and harms to be better understood as hazards and their cumulative impact over time.

#### Create data fusion projects.

Extant data are all too rare, but they do exist. However, those data are almost always siloed into the domains of the agencies and organizations that have collected them primarily for the purposes of the organization. Obvious examples include law enforcement investigations protecting data for ongoing, open cases. Healthcare providers and NGOs desire, and in fact are usually required, to protect the privacy of patients and clients. Data collected by academics are often anonymous as required to protect human subjects. Historical efforts to fuse multiagency data have produced limited success but have provided a vision for moving forward (Human Smuggling and Trafficking Center presentation, 2016; Busch-Armendariz et al., 2017). There are efforts underway (e.g., at OTIP at HHS) to develop common schema for merging data and collecting data in the future (Fedorschak et al., 2014; Farina, 2014; Office on Trafficking in Persons, 2017). Needed are common terminology and coding schemes, but also essential is improved understanding of the data that are needed to address the problem. These data needs are presently elusive because modeling efforts specifically for this domain are nascent.

#### Develop modeling and analysis approaches tailored for this problem domain.

While it might be tempting to apply existing models and methods to the problem of human trafficking, among the greatest challenges recognized by workshop participants was that within this problem domain there are many overlapping problems, as captured in the themes articulated above. Exploratory efforts are needed to allow researchers to partition the problem space into tractable problems (and subproblems) for investigation. The problem space can be partitioned in a number of different ways; examples include operational model (e.g., sex vs. labor trafficking), time frame (e.g., acute vs. chronic), decision making goals (e.g., single vs. multiple objective), and by how uncertainty is captured (e.g., deterministic vs. stochastic vs. robust), just to name a few.

Relative to mathematical modeling considerations is the need to understand whether real world data support the idea that certain human trafficking dynamics can be modeled as a stochastic process. Can management of this process be approached as a stochastic optimization problem (e.g., Wu et al, 2017; Ghosh and Saha, 2012; Younes & Simmons, 2004; Zhuang & Li, 2012; Kammer-Kerwick et al., 1992 and Kammer-Kerwick, 1993)? Can other aspects be modeled and solved as mixed linear integer programs (MILPs) (e.g., Türkay et al, 2016) with optimization tools like CPLEX or GAMS while conjointly incorporating economic, ecological, and societal goals? Can other perspectives be better modeled through a dynamic system (e.g., Kóvári & Pruyt, 2014) or multiagent simulation approach (e.g., Naivinit et al, 2010; Naqvi & Rehm, 2014)? Can hybrid approaches (like Ivanov et al, 2009) be developed wherein simplified mathematical optimization programs provide directional guidance for more complicated dynamic

systems and multi-agent simulations? Together, such analytical rigor can lead to evidence-based heuristics that can support improved policies.

Modeling research should focus on efforts to expand the objectives commonly incorporated in OR analysis. As an example, in addition to economic objectives, Türkay et al. (2016) include both environmental and social factors in their triple-bottom-line sustainable supply chain management model. The overarching model is formulated as a MILP, with environmental and social objectives ultimately recast as additional constraints. These 2<sup>nd</sup> and 3<sup>rd</sup> level objectives are currently based on available research on, for example, the restrictions on greenhouse gas emissions and managing overtime. While much is known about greenhouse gas and carbon caps, less is known about the deleterious effect of too much overtime on workers' standard of living. Additionally, no models we have reviewed have mathematically incorporated terms into the objective function for the impact of repeated cycles of exploitation, a pattern all too common among trafficking victims.

It is through these exploratory efforts that the true data needs for solutions will be elucidated. For example, solutions in the problem domain may often take the form of an intervention, as discussed in the themes presented earlier. Intervention design must include a plan for establishing efficacy, and thus must include a specification of outcomes and the metrics for those outcomes. The achievement of desirable outcomes is supported by understanding the decisions that must be made to create the desired outcomes. Some of those decisions are made in real-time in tactical situations and some take the form of longer term policies. As the time scale shifts, so does the relevancy of accounting and controlling for variability.

#### Add technology and instrumentation development efforts.

Data needed to remediate and ameliorate trafficking include some signals that are either only now just being measured or have yet to be measured. In other cases, measurements are occurring, but further improvements are needed. In yet other cases, research is needed to assess the broader societal consequences of collecting data that might prove to be extremely useful but also might lead to unintended consequences. For example, fishing fleets are now increasingly being tracked by satellite primarily for the purpose of managing fishing stocks. This technology also has the potential to inform antitrafficking efforts. Detailed, personal information regarding trafficking victimization and exploitation would allow us to better understand the complexities of human trafficking and associated opportunities for interventions, but such data come with unprecedented risks. The recent allegations of a breach of India's vast biometric database is an example. While such personalized information would greatly assist the tracking of victims and perpetrators alike, such a database also has obvious and unprecedented risks. Blockchain is another example. A technology that has the potential to revolutionize the transparency in supply chains, it also has similar nefarious potential in illicit networks.

Other illicit networks can provide a foundation for ethical considerations and the appropriateness of, or lack thereof, techniques for human trafficking. Tracking technologies commonly employed for smuggled goods and animals are far more challenging to implement among humans. For example, capture/recapture sampling is commonly used to estimate the population sizes for endanger species in the wild. The process involves physically labeling a captured specimen before release so that it can be definitively identified as having been observed

previously when encountered in a subsequent data collection effort. Similar strategies are utilized in multiple systems estimation (Bales et al, 2015), but the reidentification of encountered human trafficking victims is far less certain due to privacy concerns and opt-out choices. As another example, interdiction efforts in the trafficking of the eggs of endangered green sea turtles have involved the use of artificial eggs that include GPS tracking devices (Bale, 2016). A similar process for tracking victim movement in human trafficking networks would likely require leaving a victim under a perpetrator's control after discovery, thereby increasing risk and exposure to harms. Issara, Polaris, Truckers Against Trafficking, IOM, and others provide mechanisms for people to gain access to and to provide information about trafficking. However, most of this information can be described as tips or, at best, allegations. Compared to tracking physically labeled animals and GPS-enabled artificial eggs, most current data collection mechanisms about human trafficking are voluntary and much less definitive.

Study the systems where trafficking occurs rather than solely studying trafficking.

The norm for human trafficking is that it occurs conjointly with other behaviors and operations, both licit and illicit. Human trafficking is most often discussed as existing in various labor supply chains, including agriculture, fishing, commercial sex, domestic services, etc. It is a primary mechanism for providing lower cost, exploitable labor to these activities. However, for the same reasons, human trafficking coexists with drug trafficking, warfare, child abuse, environmental crimes, and terrorism. Research on human trafficking must necessarily embrace these intersections. Research in other areas of illicit networks has taken this approach (e.g., Atkinson & Wein, 2010 look at the intersection of terrorism and a variety of other crimes). Human trafficking research that does so will be more impactful for society, and it will also be able to exploit the fact that some illicit activities are easier to observe than human trafficking is in and of itself. The presence of drugs and weapons in certain settings can be definitive proof of illicit activity, and that clarity may afford an opportunity to delve deeper to observe the more nuanced and ambiguous circumstances that pervade human trafficking. Additionally, much labor trafficking is surrounded by much more prevalent rates of wage theft (Busch-Armendariz et al, 2016; Zhang et al, 2014). Improved methods of detecting and understanding wage theft may afford an opportunity to delve deeper to address concomitant labor trafficking.

## Conclusion

A research agenda has been proposed for OR and data analytic scholars to develop and apply methods and models toward the disruption of human trafficking. This agenda is informed by the authors and participants of a workshop held to explore the needed research. Human trafficking was chosen as the focal problem domain, but this agenda is viable for other illicit network domains as well. Human trafficking shares many of the characteristics of other illicit networks, and in fact trafficking operations often comingle with other illicit network operations. Human trafficking is deserving of special focus among illicit networks because of the human suffering that is present and the magnitude of effort that is required to care for victims and survivors of such suffering.

The proposed agenda is both specific and far reaching, including a call for more discussion about the problem domain; enhanced collection of empirical evidence about how such systems operate;

the development of data collection and data management infrastructures; the advancement of models and methodologies toward design, management, and disruption of networks; and the development of technologies and other instrumentation to better observe such illicit networks and measure the deleterious effects on society and individuals.

The authors strongly encourage researchers to consider a range of projects from across the proposed agenda. With that said, this agenda is proposed fully recognizing that the first item on the agenda is to support further discussion about and development of the research needed to disrupt illicit networks like human trafficking. Forty-eight scholars from interdisciplinary backgrounds spent 4 days dedicated to developing this agenda. We view this proposed agenda as the means to a beginning.

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## Appendices

### Austin Participants

|    | <b>First</b> | <b>Last</b>      | <b>Institution</b>  |
|----|--------------|------------------|---|
| 1  | Noel         | Busch-Armendariz | The University of Texas at Austin                                   |
| 2  | Hamsa        | Balakrishnan     | Massachusetts Institute of Technology                               |
| 3  | Kelle        | Barrick          | RTI International   |
| 4  | Sam          | Blazek           | The University of Texas at Austin                                   |
| 5  | Jonathan     | Caulkins         | Carnegie Mellon University  |
| 6  | Meredith     | Dank             | John Jay College of Criminal Justice                                |
| 7  | Luis         | C.deBaca         | Formerly of the Office to Monitor and Combat Trafficking in Persons |
| 8  | Davina       | Durgana          | Washington DC-Walk Free Foundation                                  |
| 9  | Matt         | Kammer-Kerwick   | The University of Texas at Austin                                   |
| 10 | Bruce        | Kellison         | The University of Texas at Austin                                   |
| 11 | Renata       | Konrad           | Worcester Polytechnic Institute                                     |
| 12 | Wayne        | Lee              | University of Nebraska  |
| 13 | Kayse        | Maass            | University of Michigan  |
| 14 | Lauren       | Martin           | University of Minnesota   |
| 15 | David        | Morton           | Northwestern University   |
| 16 | Jennifer     | Musto            | Wellesley College   |
| 17 | Anna         | Nagurney         | University of Massachusetts   |
| 18 | Jennifer     | O'Brien          | University of North Carolina  |
| 19 | Manolis      | Pountourakis     | The University of Texas at Austin                                   |
| 20 | Dominique    | Roe-Sepowitz     | Arizona State University  |
| 21 | Tariq        | Samad            | University of Minnesota   |
| 22 | Les          | Servi            | MITRE Corporation   |
| 23 | Tom          | Sharkey          | Rensselaer Polytechnic Institute                                    |
| 24 | Diane        | Skubal           | The University of Texas at Austin                                   |
| 25 | McKenna      | Talley           | The University of Texas at Austin                                   |
| 26 | Hüseyin      | Tanriverdi       | The University of Texas at Austin                                   |
| 27 | Melissa      | Torres           | The University of Texas at Austin                                   |
| 28 | Will         | Wood             | The University of Texas at Austin                                   |
| 29 | Kirsta       | Melton           | Texas Attorney General's Office                                     |

## Austin Agenda

Friday, May 5, 2017

|                      |   |
|----------------------|---|
| 8:00 AM to 8:30 AM   | Continental Breakfast                                     |
| 8:30 AM to 9:00 AM   | Keynote Address<br><b>Ambassador Lou C. deBaca</b>        |
| 9:00 AM to 9:30 AM   | Introduction to Workshop                                  |
| 9:30 AM to 9:45 AM   | Small Group Discussions of Trafficking Case               |
| 9:45 AM to 10:15 AM  | Break/Networking Session                                  |
| 10:15 AM to 11:15 AM | Large Group Review of Trafficking Case                    |
| 11:15 AM to 11:45 AM | Breakout Session-Brainstorm on Prompt from Problem Domain |
| 11:45 AM to 12:15 PM | Large Group Review of Prompt                              |
| 12:15 PM to 1:15 PM  | Lunch   |
| 1:15 PM to 3:45 PM   | Breakout Sessions and Large Group Reviews of Prompts      |
| 3:45 PM to 4:00 PM   | Break   |
| 4:00 PM to 5:00 PM   | Review and Initial Discussion of Research Topics          |
| 6:15 PM              | Meet in Lobby to Walk to Restaurant                       |
| 6:30 PM to 9:00 PM   | Dinner  |

Saturday, May 6, 2017

|                      |  |
|----------------------|--|
| 8:30 AM to 9:00 AM   | Continental Breakfast-Classroom 101                                  |
| 9:00 AM to 10:00 AM  | Review and Prioritization of Research Topics                         |
| 10:00 AM to 10:30 AM | Discussion of Potential Approaches, Barriers, and Opportunities      |
| 10:30 AM to 10:45 AM | Break  |
| 10:45 AM to 11:30 AM | Summarize Topics and Discuss Collaboration for Washington DC Meeting |
| 11:30 AM to 12:30 PM | Lunch  |
| 12:30 PM             | End of workshop  |

## DC Participants

|    | <b>First</b> | <b>Last</b>      | <b>Institution</b>                               |
|----|--------------|------------------|--|
| 1  | Brittany     | Anthony          | Polaris  |
| 2  | Hamsa        | Balakrishnan     | Massachusetts Institute of Technology            |
| 3  | Kelle        | Barrick          | RTI International                                |
| 4  | Noel         | Busch-Armendariz | The University of Texas at Austin                |
| 5  | Jonathan     | Caulkins         | Carnegie Mellon University                       |
| 6  | Hongliang    | Chen             | The University of Texas at Austin                |
| 7  | Meredith     | Dank             | John Jay   |
| 8  | Irina        | Dolinskaya       | NSF  |
| 9  | Davina       | Durgana          | Global Slavery Index of the Walk Free Foundation |
| 10 | Deborah      | Goodings         | NSF  |
| 11 | Dixie        | Hairston         | The University of Texas at Austin                |
| 12 | Patrick J    | Hannon           | DHS - Human Smuggling and Trafficking Center     |
| 13 | Layla        | Hashemi          | George Mason University                          |
| 14 | Lefteris     | Iakovou          | Texas A&M Engineering Experiment Station         |
| 15 | Matt         | Kammer-Kerwick   | The University of Texas at Austin                |
| 16 | Bruce        | Kellison         | The University of Texas at Austin                |
| 17 | Bilal        | Khan             | Nebraska Lincoln                                 |
| 18 | Georgia-Ann  | Klutke           | NSF  |
| 19 | Renate       | Konrad           | Worcester Polytechnic Institute                  |
| 20 | Jon          | Leland           | NSF  |
| 21 | Kayse        | Maass            | Mayo Clinic                                      |
| 22 | Lauren       | Martin           | University of Minnesota                          |
| 23 | David        | Morton           | Northwestern                                     |
| 24 | Jennifer     | Musto            | Wellesley College                                |
| 25 | Jennifer     | O'Brien          | University of New Hampshire                      |
| 26 | Beth         | Rabinovich       | Westat   |
| 27 | Laura        | Razzolini        | Alabama  |
| 28 | Hayley       | Reynolds         | Massachusetts Institute of Technology            |
| 29 | Jerry        | Sanders          | DHS - Human Smuggling and Trafficking Center     |
| 30 | Les          | Servi            | MITRE Corp                                       |
| 31 | Tom          | Sharkey          | Rensselaer Polytechnic Institute                 |
| 32 | Wade         | Shen             | DARPA  |
| 33 | Anthony      | Stefanidis       | George Mason University                          |
| 34 | Hüseyin      | Tanriverdi       | The University of Texas at Austin                |
| 35 | Sridhar      | Tayur            | Carnegie Mellon University                       |
| 36 | Melissa      | Torres           | The University of Texas at Austin                |
| 37 | Larry        | Wein             | Stanford   |
| 38 | Paul         | Zador            | Westat   |

## DC Agenda

### Friday, December 1<sup>st</sup>

| Time     | Topic/Task   | Name  |
|----------|--|---|
| 8:30 AM  | Welcome  | Matt Kammer-Kerwick, UT Austin, Organizer                               |
| 8:40 AM  | Purpose and Goals  | NSF   |
| 8:50 AM  | Keynote  | Patrick J. Hannon, DHS, Director Human Smuggling and Trafficking Center |
| 9:20 AM  | Overview of Agenda and Workshop Plan   | Matt Kammer-Kerwick   |
| 9:30 AM  | Memex: Novel Search and Indexing Technology Targeting HT   | Wade Shen, DARPA, Memex Program Manager                                 |
| 10:00 AM | Criminal Network Analysis Across the Physical, Cyber, and Social Dimensions                          | Anthony Stefanidis, GMU, Director CINA COE                              |
| 10:30 AM | Break  |   |
| 10:45 AM | Polaris Overview: Strategic Approaches to Eradicating Modern Slavery                                 | Brittany Anthony, Polaris, Data Researcher                              |
| 11:15 AM | Adjacent Problems: Systems Models of the Markets and Supply Chains for Illegal Drugs                 | Jonathon Caulkins, CMU  |
| 11:45 AM | Estimating the Size and Scope of the Underground Commercial Sex Economy in US 8 Cities, Part 1       | Meredith Dank, John Jay and Bilal Khan, Nebraska Lincoln                |
| 12:10 PM | Estimating the Size and Scope of the Underground Commercial Sex Economy in US 8 Cities, Part 2       |   |
| 12:35 PM | Lunch  |   |
| 1:35 PM  | Adjacent Problems: Interdicting Nuclear Smugglers  | David Morton, Northwestern  |
| 2:05 PM  | Review of Talks  | Moderator: Matt Kammer-Kerwick  |
| 2:30 PM  | Topic Team Update: Framework Paper   | Jon, Kayse, Lauren, Matt, Renate, & Tom                                 |
| 3:00 PM  | Topic Team Update: Extant Databases and Data Sources   | Bruce, Dixie, Hong, Matt, Melissa, & Noël                               |
| 3:30 PM  | Break  |   |
| 3:45 PM  | Small Group Breakout Discussions: Approaches, Barriers, & Strategies                                 |   |
| 4:15 PM  | Large Group Discussion: Moving from Approaches, Barriers, & Strategies to Defining Research Problems | Moderator: Matt Kammer-Kerwick  |
| 6:00 PM  | Adjourn Day 1  |   |

### Saturday, December 2<sup>nd</sup>

| Time     | Topic/Task  | Name                           |
|----------|---|--------------------------------|
| 9:00 AM  | Day 1 Recap and Topic List Survey                                   | Matt Kammer-Kerwick            |
| 9:30 AM  | Small Group Breakout Discussions: Refining Problems and Subproblems |                                |
| 10:00 AM | Large Group Discussion: Refining Problems and Subproblems           | Moderator: Matt Kammer-Kerwick |
| 11:00 AM | Break   |                                |
| 11:15 AM | Large Group Discussion: Set the Agenda and Next Steps               | Moderator: Matt Kammer-Kerwick |
| 12:15 PM | Lunch   |                                |
| 1:00 PM  | Adjourn Day 2   |                                |