2016

Overcoming Human Trafficking via Operations Research and Analytics: Opportunities for Methods, Models, and Applications

Renata A. Konrad
Worcester Polytechnic Institute

Andrew C. Trapp
Worcester Polytechnic Institute

Timothy Palmbach
University of New Haven, tpalmbach@newhaven.edu

Comments

Overcoming Human Trafficking via Operations Research and Analytics: Opportunities for Methods, Models, and Applications

ABSTRACT

Human trafficking is a transnational complex societal and economic issue. While human trafficking has been studied in a variety of contexts, including criminology, sociological, and clinical domains, to date there has been very little coverage in the operations research (OR) and analytics community. This paper highlights how operations research and analytics techniques can be used to address the growing issue of human trafficking. It is intended to give insight to operations research and analytics professionals into the unique concerns, problems, and challenges in human trafficking; the relevance of OR and analytics to key pillars of human trafficking including prevention, protection, and prosecution; and to discuss opportunities for OR and analytics to make a difference in the human trafficking domain. We maintain that a profound need exists to explore how operations research and analytics can be effectively leveraged to combat human trafficking, and set forth this call to action to inhibit its pervasiveness.

1. INTRODUCTION

Human trafficking is a complex issue affecting society and the global economy, involving the commercial exchange and exploitation of humans for the purpose of receiving benefits or monetary gain. It transcends national borders, is prevalent in both impoverished and wealthy countries, and undermines fundamental human rights as well as a broader sense of global order (Winterdyk, Perrin, & Reichel, 2011). Human trafficking is a modern form of slavery, and constitutes a human rights violation and a global public health crisis (Gajic-Veljanoski & Stewart, 2007). One of the fastest growing crimes, between 27 million and 35.8 million individuals worldwide are estimated to be trapped in some form of human trafficking. Human trafficking is an extremely profitable enterprise. Forced labour and sexual exploitation generate an estimated $150 billion (U.S.) globally in illegal profits each year (Office, 2012) making it one of the largest sources of profit for global organized crime, after illicit drugs and weapons trade (Haken, 2011). While there may be uncertainty as to its extent, one thing is certain: it is an enormous global problem, and *rapidly increasing*.

The year 2010 marked the tenth anniversary of the United Nations' *Protocol to Prevent, Suppress and Punish Trafficking in Persons*. In response to this milestone international treaty, a number of countries have enacted laws and policies to prosecute human traffickers, provide assistance and protection to trafficked persons, and otherwise prevent this criminal activity. At the same time, academic researchers and scholars have sought to enhance the understanding of both the nature and extent of trafficking in persons at the local, national, and international level of those involved in forced labor and sexual exploitation, as well as develop evidence-based research to support more effective public policy responses.

While the exploitation of humans for gain has a long and infamous history, until recently it was mainly classified as slavery, and has a history of endorsement and acceptance by some political groups and people in power. Outside of this context, in recent years such abuse on human rights has become much more secretive, and is now mainly referred to as human trafficking. Generally speaking, scholarly work on this more modern and clandestine phenomena has emerged rather recently, in the late 1990s (Winterdyk et al., 2011), and has been studied in the context of criminology (Farrell, 2009; Kenyon & Schanz, 2014), sociological research (Capous Desyllas, 2007; Jordan, Patel, & Rapp, 2013; Kenyon & Schanz, 2014), international studies (Aradau, 2004), and more recently in clinical domains (Logan, Walker, & Hunt, 2009; C. L. Miller, 2013).

Operations research (OR) and related analytical tools – such as machine learning, artificial intelligence, and data mining – all share the ability to find solutions to complex problems, including finding better ways to improve the allocation of scarce resources, detecting potentially useful patterns in data, and predicting future trends and behaviors. Such techniques can not only help to recommend the best actions, but also to analyze trade-offs and various scenarios. While it stands to reason that human trafficking is an area ripe for application, to date the authors are aware of only a few isolated studies in which these effective tools are applied to human trafficking. Namely, analytics-based methods have been applied to identify victims (Kennedy, 2012; Latonero, 2011; Lesniewski, 2014) and to identify trafficking circuits (Ibanez & Suthers, 2014). In this article we aim to bring awareness to many of the difficulties inherent in human trafficking research, as well as to highlight potential areas where operations research and analytics professionals can make a profound difference.

Despite a growing awareness of human trafficking, the research community at large continues to struggle with basic measures of its size and extent. Due in large part to its underground nature, human trafficking is a difficult crime to detect and gather relative statistics (Gozdiak, 2011). Data commonly used to estimate the prevalence of human trafficking are lacking in scope and quality (Gozdiak, 2011). Furthermore, the coordination amongst multiple agencies and information systems typically required to identify victims and prosecute traffickers is generally lacking. Descriptive statistics, and effective coordination and cooperation of agencies at all levels are essential to curb this invasive problem and ultimately improve society.

There is a need for quantitative research that would provide an understanding of the operations of the trafficking phenomenon, to develop methods of deterring its prevalence, and ultimately inform and transform policy. Given the fact that services to trafficked persons are in their infancy (Jayson, 2013) and evidence-based clinical and sociological research in the area is burgeoning, a profound opportunity exists to examine how operations research and analytics can be used effectively to combat human trafficking. Recently the Executive Director for United Nations Office on Drugs and Crime issued a plea to social scientists to help generate logical categories and the statistical information needed for evidence-based approaches to address the crime of human trafficking (Crime), 2014).

This article provides a perspective on the challenges and opportunities that emerge for operations research and analytics community in the field of human trafficking.

Our objectives are to (i) illustrate the issues in combating human trafficking, (ii) survey existing OR/ data analytics literature, (iii) suggest future research directions, and (iv) act as a tutorial for interested researchers. We believe operations research and analytics have significant application to combatting this pervasive and horrifying global problem

To be clear, this paper is not intended to demonstrate case studies in human trafficking – indeed, these are lacking – but rather to illustrate the potential for significant contributions from operations research and analytics professionals and broadly speaking, how their knowledge and methods can be used to address this pervasive and horrifying global problem.

In the following section we provide the reader with some background on human trafficking. A discussion of the challenges the operations research and analytics community is likely to encounter is presented in Section 3. Section 4 suggests research directions classified into four broad categories while Section 5 concludes the paper. Appendix A should direct interested researchers to a sample of organizations and human trafficking related resources as a starting point.

2. BACKGROUND ON HUMAN TRAFFICKING

In this section we define the term *human trafficking* and illustrate the pervasiveness of the problem.

2.1 What Is "Human Trafficking"?

The definition of human trafficking varies according to jurisdictions and individuals ("Protocol to prevent, suppress and punish trafficking in persons, especially women and children, supplementing the United Nations convention against transnational organized crime," 2002). In general, it is defined as holding a person in _involuntary servitude_ (domestic, labor or sexual servitude) by force, coercion or debt bondage (Sigmon, 2008; Skinner, 2008). Worldwide, victims range from child soldiers and child brides, to housekeepers, nannies, farm laborers, prostitutes and beggars (Feingold, 2005; Logan et al., 2009). Human trafficking is frequently defined as sex trafficking (Crime), 2014); while sex trafficking is substantial, it is estimated that labor and domestic trafficking make up more than 68 percent of the population of trafficked people worldwide (Farrell & Fahy, 2009; Office, 2012). (Logan et al., 2009) classify the different ways in which humans can be trafficked: born into slavery or debt bondage (where children inherit the debt of the parents); kidnapped, sold and/or physically forced, or tricked into slavery (coercion and debt bondage).

The exploitation may involve any of the following (Logan et al., 2009): sex work, sex laboring, pornography, entertainment (exotic dancing, etc.), domestic labor, agricultural/construction/mining labor, factory labor, food service industry, begging as well as commercial fishing.

3

2.2 Why Is Human Trafficking an Issue?

Human trafficking has always existed in various forms but was not considered a serious social problem until recently, as evidenced by official discourse and media reporting (Cwikel & Hoban, 2005; Gulati, 2011). Human trafficking is a largely clandestine activity; as such, measuring its prevalence is both difficult and complicated (Farrell, McDevitt, & Fahy, 2010; Kangaspunta, 2007; State, 2013). Table 1 provides various sources estimating the number of human trafficking victims, both worldwide and within the United States. While the estimates vary from year to year, clearly there exists in modern day society a significant population that is at-risk and vulnerable to human trafficking, and this population is not being reduced. Alarmingly, (State, 2013) reports that less than 1 percent of the total estimated number of people trafficked have been identified. There is a tremendous gap between the estimated number of people trafficked and the number of victims identified and the number of people arrested for the actual crime of human trafficking(Clawson, Dutch, Solomon, & Grace, 2009).

Source of Estimate	Estimate of Human Trafficking	Geographic Level
Global Slavery Index (2013)	28, 300,000 - 31,300,000	Worldwide
U.S. Department of State (2013)	26,000,000	Worldwide
U.S. Department of State (2006)	4,000,000	Worldwide
International Labour Organization (2012)	20,900,000	Worldwide
International Labour Organization (2009)	12,300,000	Worldwide
U.S. Department of Health and Human Services (2009 report based on 2001 data)	199,000 (Minors only)	Within the U.S.
Wilson, Walsh & Kleuber (2006)	50,000	Trafficked into the U.S.
Clawson, Layne & Small (2004)	14,500-17,500	Trafficked into the U.S.
Wyler & Siskin (2011)	17,000	Trafficked into the U.S.

Table 1 Estimates of Human Trafficking victims, adapted from (Jayson, 2013) See my comment at end of note box.

2.3 Classification of Activities to Combat Human Trafficking

Activities to fight human trafficking have been classified into three broad categories: *Prevention*, *Protection*, and *Prosecution* – the "3P" paradigm – by the United Nations Protocol to Prevent, Suppress and Punish Trafficking in Persons, Especially Women and Children (Palermo Protocol) and the United States' Trafficking Victims Protection Act (Persons, 2011). In 2009, former United States Secretary of State Hillary Rodham Clinton proposed a fourth category, *Partnership*, as critical to fight human trafficking(Office to Monitor and Combat Trafficking in Persons, 2009).

Prevention involves public awareness and educational campaigns aimed at conveying the nature and gravity of human trafficking, potentially providing alternative vocational opportunities for at-risk persons, in particular women and girls (Persons, 2011). *Protection* includes the rescue, rehabilitation, and reintegration of victims into society. Activities may include training to recognize possible human trafficking victims as well as the provision of shelters for rescued victims (Persons, 2011). *Prosecution* refers to the just enforcement of anti-trafficking laws and punishment of those convicted of trafficking; it may also involve improving the prosecution rate of alleged offenders by creating or maintaining current legislation related to human trafficking (Persons, 2011). The *Partnership* category refers to the critical necessity of collaboration and information sharing, both within and across geographical and political boundaries, to successfully fight this epidemic (Office to Monitor and Combat Trafficking in Persons, 2009). This four-fold classification provides a convenient way to categorize our discussion in Section 4 of ways in which operations research and analytics can aid to counter human trafficking.

There is a severe lack of technical solutions to analyze, make impact assessments and assess decisions related to human trafficking. The pressing need to counter the exploitation of humans, in an environment with limited resources suggests that quantitative operations research methods, together with appropriate statistical methodology, should be well positioned to support counter human trafficking initiatives. In the next section we explore many of the inherent challenges of applying operations research and analytics techniques to this type of work.

3. CHALLENGES IN THE APPLICATION OF OPERATIONS RESEARCH AND ANALYTICS TO HUMAN TRAFFICKING

Knowledge about the dynamics and structure of human trafficking is needed for the analysis, development and implementation of effective counter-trafficking strategies. However, the heterogeneous and complex nature of this phenomenon make it extremely difficult to understand, let alone model and predict human trafficking patterns (Amin, 2010) and design effective interventions. To give a reader a sense of the complexity of the issue, we present an illustrative example. In Afghanistan there is a centuries old tradition in which pre-pubescent and adolescent males are used for entertainment and sexual exploitation. This practice is known as Bachi Bazi. While this practice is against local rule of law, both civil and religious, it is tolerated and allowed to flourish in many regions. Despite the advances of the US military and Afghan government over the Taliban this problem was not addressed or corrected. The long tradition, cultural, and political influences have created an environment where the practice of Bachi Bazi can flourish, and it is very difficult to identify the all of the relevant dynamics and networks that are the framework from which this atrocity thrives (Kapur, 2014).

In this section, we outline the challenges facing Operations Research and Analytics practitioners in applying their skills to the realm of human trafficking.

3.1 Data Issues: Lack of Comprehensive Data and Reluctance to Share Data

Reliable data is crucial for even the most basic decision analysis. While techniques exist to circumvent poor or missing data (estimation, removal, as well as stochastic and robust approaches, etc.), operations research and analytics techniques are dependent upon data as model input. Given the well-documented, clandestine and multifarious nature of human trafficking (Gozdiak, 2011), very little reliable data on the distribution of victims, traffickers, buyers, and exploiters exists (Kangaspunta, 2007). Data that does exist can be inaccurate, missing or worse, false; and simply enhancing data collection techniques and methodologies is too often insufficient (Senior Policy Operating Group, 2012). Human trafficking often begins with fraudulent and unscrupulous labor recruitment, such as charging recruitment fees and confiscating identity documents. Such practices render a person vulnerable to servitude; worsen in situations in which the victim is in a foreign country and/or in a situation in which labor rights and laws are not respected. Such circumstances make data gathering exceedingly challenging and resource-intensive.

Gathering data on "hidden" populations (victims, traffickers, and buyers) is difficult for a number of reasons (Farrell et al., 2010; Hepburn & Simon, 2010; J. R. Miller, 2008). First, there is an absence of a sampling frame for the population, so there is little understanding of what the cohort of trafficked individuals is, or what conditions define the group. Second, because the trafficked persons are involved in illegal or illicit activities, they are not typically willing to cooperate or participate in studies that would help to provide the information needed to determine how they came to be trafficked or traffickers. Additionally, existing trafficking victims are kept under tight control by their trafficker or other "handler" and are unable to self-report or cooperate with researchers. Further, trafficking victims may not cooperate due to fear of retribution or shame.

Because data analysis of both trafficked persons and traffickers typically involves data from multiple sources and jurisdictions, data collection is often hampered by data ownership, privacy, unwillingness to share, or simply not knowing what data is available. Personal biometric data is valuable to help identify the victim's as well as assist with investigations and prosecutions. However, many countries, including the United States, have significant privacy concerns and regulations concerning biometric data, most specifically DNA databases. Criminal data is collected by authorities and institutions, while data on victims is collected by non-governmental organizations (NGOs) and service providers. Because each collects data for its own purposes, data is fragmented, dispersed and not shared. At the same time, these different sources of data are necessary to provide a more complete picture of the human trafficking process. For example, suppose a female is identified as a potential trafficked person for sexual exploitation in an Emergency Department of a hospital in the United States. This person could have been originated from Nepal, trafficked through a hub in India, and brought to the United States on a work visa. Her trafficker could be operating a legally registered business in one state, but the victim was arrested in another state for prostitution. In such a case various federal and local agencies would have collected some data about the particular individual (Allen, Karanasios, & Norman, 2013), and it is not difficult to reason that her plight could have been alleviated, if only information had been judiciously shared.

3.2 Asymmetric Information

Anti-human trafficking efforts are characterized by asymmetric information in which one party has superior information than the other, and can be viewed as a market with imperfect information. As traffickers want to conceal their (illegal) activities from law enforcement, potential clients (that is, the consumers of trafficked humans) have only imperfect information on the "quality" of the services they are to buy. In economic terms, the client is at a disadvantage as the trafficker can engage in price discrimination by exploiting the differences amongst customers' willingness or ability to pay (Bilger, Hofmann, & Jandl, 2006). Further, in many case the market for human trafficking services is not dominated by a large criminal structure with monopolies; but rather there often exists a complex market for highly differentiated trafficking services (Bilger et al., 2006). A small body of theoretical economic literature considers the impact of imperfect information of victims and traffickers (Bilger et al., 2006; Friebel & Guriev, 2006; Tamura, 2010).

From a victim prevention point of view, law enforcement does not have the same information as traffickers due to the secretive nature of human trafficking. There is typically a delay in information revelation which traffickers know and may exploit. For example, traffickers may easily create, and recreate, new profiles on social media, in their efforts to recruit victims online. This makes it difficult for law enforcement to pursue prosecution.

3.3 Adaptations of Traffickers and Exploiters Resulting from Increased Enforcement Activities

The covert nature of human trafficking necessarily requires that some methods traffickers use to recruit and sell trafficked persons change dynamically. In a somewhat simple example, a trafficking ring daily advertises an individual on a particular website; however a small detail associated with the advertised name or phone number is changed every few hours to elude law enforcement. This subtle change would make it difficult for basic pattern matching tools to track repeated advertisements. Domestically, traffickers will utilize transit lodging, such as motels and hotels, to set up operations for sexual exploitation. These mobile operations are very difficult to identify and conduct enforcement activities upon as they usually operate for only a few days before to relocating to another destination (Dean, 2011). A more extensive example of how trafficker adapt their methods would be the use of decommissioned cargo ships to move trafficked persons (Chandler, 2015). Frontex, the European Union's border control agency, claims that this recent trend "extends the human-trafficking season" by making it possible to move people across routes and during season previously not possible.

3.4 Lack of Resources to Combat Problem

Despite the pervasiveness of human trafficking, resources to combat the problem are severely lacking. Between 2001 and 2011 USAID, the U.S. governmental agency primarily responsible for administering civilian foreign aid, programmed only $179.9 million in counter Trafficking in Person activities in 68 countries and Regional Missions(Development, 2013).

The Office to Monitor and Combat Trafficking in Persons, under the US Department of State, conducts an annual open and competitive grant application and review process. In 2014, for example, this office received applications from non-governmental organizations requesting more than $100 million in assistance; awarding just over $18 million to fund 41 grants (America, 2014). However, in recent years the Office has issued a majority of its funding to a single entity that will provide a host of services in one specific country to help address that country's shortfalls relevant to their efforts to address issues of trafficking in persons within their borders. While there may be some advantages in centralizing resources, in most cases it would seem quite unlikely that any singular NGO or agency would have the capacity to best address each of the identified problems. As a result, that grantee engages in a non-competitive sub-granting role. Further, this overall methodology makes it very difficult for newly emerging entities to obtain funding to employ novel, or tested but underutilized, methodologies.

On the other hand, environments with scarce resources are exactly the type in which operations research and analytics-based methods thrive. These methods can find ways to accomplish the most within limited budgets, or alternatively, to achieve desired outcomes with minimal expenditures. These methods further allow for powerful follow-up analysis, for example revealing how much investment would be necessary to achieve a greater level of outcome, etc..

In Appendix A we list agencies which fund anti-human trafficking measures.

3.5 Limited Societal Interfaces

Most trafficking victims have little to no contact with professionals who could help (e.g. health care workers, police, and social services). Yet any victim contact with society presents an opportunity for rescue (in the best case) and at minimum some data collection to support anti-trafficking efforts.

Medical professionals are uniquely positioned to aid anti-trafficking efforts. An encounter with the healthcare profession may be one of only very few contacts with the outside world for adult trafficking victims (Bespalova, Morgan, & Coverdale, 2014). For example, suppose a man who comes to an emergency room with high blood pressure, dehydration, respiratory problems, and skin infections and states that he works in agriculture; this could be indicative of human trafficking, and should be further assessed. Studies have shown that between 28 and 50 percent of trafficking victims sought care from medical professionals while still in captivity (Dovydaitis, 2010). Further studies conclude that trafficking victims are more likely to talk to medical staff than police (State, 2013). This may be because law enforcement has insufficient training to distinguish between "voluntary" prostitution and human trafficking (Batsyukova, 2007).

While such professionals are in a unique position to prevent, identify, and rescue trafficking victims, they may unfortunately be unaware, or inadequately prepared, when they do encounter such an individual. This lack of awareness impedes the ability of accurate data collection and its subsequent use in analytical techniques. It is further compounded by the relatively infrequent interaction with the local community

and society at large, and this lack of access to the subjects can hinder the accurate understanding necessary during the modeling process of analytical activities.

Measures to counter human trafficking are cross-functional. Consequently, data and information needed to support research and initiatives in this area appear in a wide variety of agencies, reports, and academic journals. The multi-party nature required to combat trafficking makes it challenging to develop, evaluate and implement traditional OR and analytics models. Despite these challenges, we believe that there are many opportunities for members of this community to apply their skills in countering human-trafficking. In the next section, we suggest a number of open opportunities to do so.

4. OPEN RESEARCH OPPORTUNITIES: FIGHTING HUMAN TRAFFICKING WITH OPERATIONS RESEARCH AND ANALYTICS

A number of fundamental concepts from the operations research and analytics domains, broadly speaking, can be leveraged to fight human trafficking. In what follows, we outline some key research areas in human trafficking and for each review relevant work in the area, and suggest possible techniques from operations research and analytics to aid in their resolution. We structure our presentation around the four "Ps" outlined in Section 2: *Prevention*, *Protection*, *Prosecution*, and *Partnership*.

4.1 Prevention

Prevention involves public awareness and educational campaigns aimed at conveying the gravity of human trafficking primarily to potential victims (Persons, 2011). Awareness and education campaigns can emphasize both primary prevention (reducing vulnerability to trafficking) and secondary prevention (early victim identification and intervention).

Media planning is an operations research and analytics technique used to achieve exposure and awareness while conserving limited resources. The goal is to find the right amount of investments in various media that ensure that specific targets are hit, while minimizing cost outlays. Anti-trafficking initiatives contend with this problem. Various platforms are used for public awareness campaigns, including radio, television, billboards, and social media. (For the interested reader, the United States Office to Monitor and Combat Trafficking in Persons provides examples of anti-trafficking public awareness campaigns funded http://www.state.gov/j/tip/rls/other/2013/215002.htm). The goals of a campaign may include estimates of the exposure, or *reach*, to various segments of the population. Human trafficking often begins with deceptive, fraudulent and unscrupulous labor recruitments. Furthermore, recruitments methods are both adaptive and dynamic. Therefore a key question in media planning for anti-trafficking campaigns is how and when campaigns should change to be effective. An important concern is *wearout*, which represents the effect that, with increasing exposure to the same subjects, the effectiveness of an advertisement generally decreases (Mantrala, 2002; Turner, 2010).

With the advent and growth of social media technology such as Twitter and Facebook, there is rising potential to leverage its infrastructure to increase awareness of human trafficking. A great deal of information is embedded in the interconnected structure of social networks, information that can be harnessed to improve the use of prevention strategies. With respect to the social networks of at-risk persons, such analysis can help to determine which contacts have critical influence over others (Spencer, 2012). This presents an opportunity to predict those nodes and paths that are expected to have the highest likelihood of propagating critical information flow, for example messages that can serve to reduce vulnerability.

There is a need to evaluate the effectiveness of prevention program, yet the anti-human trafficking community lacks the techniques to do so(Crime, 2014) . Particularly, given scarce resources, many programs and donors are not in a position to divert resources away from direct services for victims of trafficking in order to conduct formal program evaluation (Senior Policy Operating Group, 2012). The soft, i.e. social and political, nature of trafficking prevention activities makes this field suitable for Data Envelopment Analysis (DEA). DEA is designed to measure the efficiency of individual decision making units (DMUs), by evaluating how their multiple inputs are used to produce various outputs. For instance a funding agency may wish to evaluate the efficiency of various NGOs public awareness campaigns in which inputs could be dollars funded, man hours and outputs could be measures such as prosecutions, number of police officers trained etc.. DEA can be also used by inefficient organizations to benchmark efficient and best-practice organizations. It has been used in a wide variety of applications, of which just a few include public sector areas such as schools (Charnes, Cooper, & Rhodes, 1978) and (Blackburn, Brennan, & Ruggiero, 2014) and healthcare (Du, Wang, Chen, Chou, & Zhu, 2014). With respect to human trafficking organizations, it may be possible to consider as DMUs various sub-affiliates of NGOs or other governmental offices. While the evaluation of such affiliates may be both revealing and potentially challenging, it could lead the way for improvement and potentially even reforms for those DMUs falling outside of the efficient frontier.

Because of its clandestine nature, it is difficult to predict trafficking activity and translate that into effective policies for prevention. However, the operations research and analytics community has tools such as spatial autocorrelation, and space–time clustering analyses at their disposable which enable the prediction of the temporal and spatial aspects of dynamic problems. These tools have been successfully used to study epidemics (Knorr-Held & Richardson, 2003), crime (Eck, Chainey, Cameron, Leitner, & Wilson, 2005; Johnson & Bowers, 2004), and terrorist activities(Gao, Guo, Liao, Webb, & Cutter, 2013). These techniques can also be applied to human trafficking. Consider that traffickers reportedly increase their profits by transporting victims to cities for commercial sexual exploitation during major sporting events and conventions (Austin, 2011; Wright, 2013). This trend presents an opportunity to conduct spatio-temporal analysis of online classified ads surrounding an upcoming event. The results could benefit law enforcement and policymakers to build consensus as to *where* and *when* they should focus collective prevention (or event protection) efforts.

Prevention could also be viewed in the context of curbing demand in production supply chains. The apparel and food industries are both known to exploit child and sweatshop labor (Baron, 2001; Rice, 2001). One method to curb demand for products produced in such circumstances is through the use of certification programs such as GoodWeave and Fair Trade. Such programs allow companies that pass inspection to attach a logo certifying that their product is made without child and/or forced labor (McDonagh, 2002).

While each certification program is unique to a particular organization and industry – for example see (Rice, 2001) – inspections must be conducted to ensure that suppliers and manufacturers adhere to the organization's standards. Scheduling these inspections presents an opportunity to apply operations research techniques. Some organizations conduct their own inspections, although there is a movement which favors independent monitoring (and surprise inspections). In both cases inspections are expensive and labor intensive. This problem naturally lends itself to the application of how to optimally deploy scarce inspection resources, which shares many of the same parallels to a "sensor" location problem (Berry, Fleischer, Hart, Phillips, & Watson, 2005; McLay & Dreiding, 2012).

Not all trafficking instances will be prevented. However, the presented approaches can increase the effectiveness of prevention initiatives by improving the allocation of scare resources to more effectively implement program aimed at preventing trafficking.

4.2 Protection

Protection includes the rescue, rehabilitation, and reintegration of victims into society and as such corresponds to activities involving the recognition of possible victims, the interdiction of trafficking networks, and the provision of shelters for rescued victims.

4.2.1 Identification of Victims and Traffickers
Analytics, and in particular social media mining, is one area of quantitative research in which concrete anti-trafficking studies have emerged (Castle & Lee, 2008; Dubrawski, Miller, Barnes, Boecking, & Kennedy, 2015; Latonero, 2011). With the advent of the ability to analyze big data there are many opportunities for operations research and analytics practitioners to apply their skills.

Mobile devices and the internet are of central importance to trafficking activities around the world (Kleemans, 2007; Latonero, 2011) presenting a potential source of data to identify potential victims, the locations, and methods of engagement with the perpetrators (Wang et al., 2012). The benefits of these technologies to facilitate communication and coordination, and provide a (perhaps illusory) sense of anonymity, all unbounded by physical location, are exploited by traffickers to extend their activities. The transnational nature of mobile and internet technologies provides traffickers the opportunity to operate in countries or states with legislative and security loopholes that can be exploited (Galeotti, 2014; L. I. Shelley, 2003). The increased pervasiveness and affordability of mobile devices has led to most traffickers and some victims being in possession of such devices. Traffickers are able to recruit, advertise, sell,

organize, and communicate primarily – or even exclusively – via mobile phone (Latonero, 2011) or the internet (Wang et al., 2012).

While obtaining mobile data may be difficult without a subpoena, some human-trafficking activity leaves traces in the public areas of the Internet. Online, publicly available advertisements of escort services can be reflective of sex trafficking activity (Territo & Kirkham, 2009). Many sex advertisers also use general Web sites such as Twitter and Instagram, while others use chat, social networking, dating, or community Web sites like Facebook, Tinder, or Humaniplex.com (Dubrawski et al., 2015). These sites provide an affordable, abundant, yet arguable underutilized, source of valuable information that could be used to quantify prevalence of trafficking, characterize the involved populations and their modes of operation. Not only can these sites can be used by law enforcement to identify and monitor suspicious activity and build evidence for prosecution, victim services organizations could identify, track and rescue victims.

Machine learning, data mining, link analysis, information retrieval, information integration, and natural language technologies can all be used to develop support systems to automatically compile and correlate information from open internet sources to protect victims. These techniques are about extracting rules from structured, semistructured, or unstructured data and uncovering new patterns that may assist in victim protection. For example, by analyzing the syntax and semantics of the advertisements, it is possible to begin linking specific advertisements to individuals and to different locations. As the trafficker moves the victims from city to city the routes and locations can be tracked and mapped out, possibly revealing an organized network or trafficking ring. (Ibanez & Suthers, 2014) used network analysis to examine online classified ads for adult services to identify trafficking circuits. Such information can be very valuable to law enforcement in uncovering and investigating an organized trafficking network. In another example, (Dubrawski et al., 2015) highlight classification methods to make use of rich, publicly available data sources to gain valuable information concerning prevalence, trafficker behavior, and trends, which can be of benefit not only to law enforcement but also to social workers.

The prevalence of social media use in trafficking activities naturally leads to an examination of social media mining which is a rapidly growing field at the intersection of computer and social sciences (Zafarani, Abbasi, & Liu, 2014). Drawing upon knowledge from the fields of information retrieval, machine learning, data and text mining, graph theory, and social network analysis, social media mining aims to understand the relationships between individuals embedded in social media networks. These networks are naturally represented as graphs, and as human trafficking continues to expand in social media networks, social media analysis techniques offers a terrific opportunity to identify victims. Tools from data visualization can be used to visualize the results of the analysis (Ghali, Panda, Hassanien, Abraham, & Snasel, 2012). For instance, maps of trafficking hot spot locations or high activity areas could help identifying crime trafficking patterns and recurrences of trafficking related activities.

The uncertainty of whether certain activities are in fact human trafficking is one of the difficulties in apprehending traffickers. Furthermore traffickers are aware that they are vulnerable to law enforcement as a result of the advertisements and postings, and adapt their tactics accordingly. With increased observation the true dynamics of on online trafficking presence may become clearer, but given the

secretive nature of the illicit operations, the shifting, deceptive actions typically employed by traffickers, together with the risk to health and life of the victims, it may be challenging to know when to act. An initial exploration stage might serve as to help better understand the developments. The point at which an investigator might then intervene when tracking a potential victim or trafficker could be modeled as a variant of the *secretary*, or *optimal stopping* problem (Freeman, 1983). Here, the idea is to consecutively observe a sequence of possible choices, with the aim of stopping at the right time.

It is important to note that only a subset of the traffic on most sites can be assumed to be indicative of human trafficking. In a quick study of 1.5 million advertisements (Dubrawski et al., 2015) estimates the likely trafficking prevalence rate of 5.5% of the volume of processed escort ads. Moreover, often posts advertising minors use deceptive and clandestine language to avoid detection by law enforcement and may use fake pictures to portray the subject as older than they are. Further, it is very difficult to discern through posted advertisements and personal interaction, whether or not the victim is in any capacity a willing participant, rather than a victim of fraud, threat, or coercion.

In Section 3, we discussed the dispersion and fragmentation of data, perhaps one of the most challenging aspects of understanding and modeling human trafficking. Neural networks, decision-trees, machine learning algorithms can be used to help discover potential trafficking activities related events *across* different distributed databases and detect crimes and activities associated with human trafficking such as kidnapping, abuse, runaway minors, drug arrests, prostitution, petty thief, pornography, as well as others. Although much of this data is protected by privacy laws, there may be room for collaboration between various stakeholders in this area.

Even though not all trafficking activity is reflected online, we surmise that the publicly available information can be used as an effective, timely, and inexpensive proxy source of data that can be leveraged to enhance quantitative approaches to identify and protect human trafficking victims. Other data sources such as mobile data, law enforcement and medical records also hold promise.

4.2.2 Network Interdiction

Human trafficking is similar to other productions, in that the use of an efficient supply chain is important to its vitality. There needs to be a source for a product (the victim) and a method of getting that product to the consumers (the clients). In human trafficking this model can be as simple as a pimp finding a vulnerable victim on the street and coercing her to advertise herself online for commercial sexual exploitation and then providing the means to complete that business transaction. Alternatively, it may be a complex, transnational organized network where victims are deceived with false job opportunities, transported to a foreign country, their documents are taken and they are forced into exploitive work. The more complex the operation, the larger the network is to support the operation. That said, the larger the network, the more vulnerabilities exist for interdiction and enforcement activities.

Traffickers use a variety of networks, both formal and informal, to carry out their criminal activities examples include transportation, and communication networks. Many traffickers have a "circuit" they work. The circuit may consist of certain cities or locations within a city with which a trafficker might be familiar, or where they may have connections. Traffickers use roadways, ports, and airports between the cities on their circuit. During transit, there is a need to house victims. Large, organized networks use known safe houses, private residences, or will make arrangements with lodging establishments along the route so they can house victims temporarily without raising suspicion, frequently using the same lodging establishments and therefore the same routes. Communication networks are used extensively. Internet and mobile technologies allow traffickers to connect with clients, communicate with other members of their network, locate and secure transportation and lodging and to conduct financial transactions. They may use them to post online advertisements and take photos of themselves for posting which might contain geocoded data or other information which could assist in identifying the location.

Trafficking network are generally constructed with secrecy in mind. For defensive reasons, the configuration may be such that the damage to the network as a whole will be minimized, even if an arc is affected (Dean, 2011). Connections are consciously hidden because of the need for covertness, leaving law enforcements and analysis with incomplete knowledge. Knowledge about the structure of a human trafficking network, from beginning of the supply chain to the end, is extremely important for protecting victims, yet all too often is missing. Further complicating the effective development of strategies to identify and dismantle networks, at least on the global scale, is the great deal of diversity amongst network structures. Culture, local customs, access points, competing activities, and efficacy of local law enforcement are all key factors which influence the manner in which networks are created. For example, in a country like Costa Rica where adult prostitution is legal and there is a large market for these services, human traffickers work within existing criminal networks that control casinos, clubs, and brothels. Trafficked minors are blended into this larger "legal" network. In other jurisdictions such as Nepal, there is no apparent single large criminal network. Instead there are smaller networks that control perhaps one or two brothels and a few dozen victims. Networks could also be constructed around local tribal control, such as those observed in countries like Afghanistan and Pakistan.

Network analysis focuses on the structure of relationships and interactions between all actors in a network. Network analysis can be used to measure relationships in trafficking networks, and to identify structures (individuals, groups, paths, etc.) that facilitate or block flow (monetary, communication, trafficking, etc.). Furthermore, network analysis enables the study of how the network may change as nodes or the connections between nodes are severed (Arquilla & Ronfeldt, 2001).

Not only can the structure of trafficking networks be studied, but network interdiction strategies as well. In the classical network interdiction setup, an evader operates on the network to optimize some objective such as moving through the network as fast as possible (shortest path interdiction), with as little probability of being detected as possible (most reliable path interdiction), or to maximize the amount of goods transported through the network (network flow interdiction). At the same time, the interdictor has the ability to change certain structural parameters of the network, such as node or arc removal, improving detection probabilities, and/or altering arc capacities, so as to optimally disrupt the evader's objective

function (Smith, Prince, & Geunes, 2013). Early work in network interdiction began with military applications such as the disruption of the flow of enemy troops (Ghare, Montgomery, & Turner, 1971; McMasters & Mustin, 1970). Since that time, it has been applied in areas such as infectious disease control (Assimakopoulos, 1987), counter-terrorism, interception of contraband and illegal items such as drugs (Caulkins, Crawford, & Reuter, 1993; Malaviya, Rainwater, & Sharkey, 2012), weapons, or nuclear material (Morton, Pan, & Saeger, 2007).

While the fundamental ideas of network interdiction research are applicable to human trafficking, it is important to note several key differences that distinguish human trafficking from other forms of interdiction of illegal "items". First, unlike network interdiction research based on drugs or weapons, trafficked humans are a "renewable commodity" (Jayson, 2013). That is, trafficked humans have an "advantage" that a person can be sold over and over, which is not the case for illicit consumables such as drugs or weapons (Dougherty & Burke, 2008; Logan et al., 2009). Second, trafficking of humans may yield high profits with less risk than drugs and weapons trafficking (Winterdyk et al., 2011). This is partly due to the fact that trafficked humans are routinely manipulated, intimidated, and threatened, so that valuable information is suppressed, altered, and even falsified. Third, human trafficking is an undercover commercial enterprise frequently hidden under the guise of private employment or legitimate businesses such as agriculture and the hospitality industry (Wilson, Walsh, & Kleuber, 2006). Yet, the interconnection of human trafficking with the narcotic drug trade is one of enormous intricacy (L. Shelley, 2012). Drug and human trafficking routes do overlap (L. Shelley, 2012), and drugs play a prominent role in the recruitment, retention and exploitation of human trafficking victims.

There may be room for collaboration and development between researchers working in network analysis and interdiction, on the one hand, and anti-trafficking advocates, on the other. As noted in the conclusion of (Smith et al., 2013) three main shortcomings exist in modern network interdiction theory, namely existing models remain somewhat limited in their abilities to handle dynamic changes in data; limited action sets and information symmetry assumptions limit their practical application, and that multiple interdictors with varying interdiction mechanisms serve to compound problem complexity. To begin to address some of the challenges in quantifying interdiction efforts in human trafficking requires theoretical advancement in network interdiction theory.

4.2.3 Shelter Location

Both emergency shelters and long-term transitional housing are among the most pressing needs for the protection of rescued victims of human trafficking. Shelters and transitional housing serve as a safe haven for victims, providing critical services such as legal advocacy, support, and therapy.

There has been a great deal of work in operations research and analytics in the general area of facility location, a few of which investigate shelter location with respect to natural disasters (Kongsomsaksakul, Yang, & Chen, 2005; Li, Nozick, Xu, & Davidson, 2012; Li, Xu, Nozick, & Davidson, 2011). We refer the interested reader to (Owen & Daskin, 1998).

Some unique facets come in to play when selecting shelters. Apart from the obvious factors of costs and capacities, it is important to consider the geographic proximities of potential locations to human trafficking victims. The locations of shelters should be undisclosed and private in order to aid, to the extent possible, the victim's peace of mind against retribution by the trafficker. Thus, the proximity of the shelter to the expected future victims should be balanced with the need for victim protection.

Therefore it is worth investigating how and which factors should be included in modeling shelter locations of rescued trafficking victims. How can constraint tradeoffs and conflicting objective functions be ethically resolved in these models?

4.3 Prosecution

Prosecution refers to the just enforcement of anti-trafficking laws, and punishment of those convicted of trafficking. We also consider in this section the evaluation of such policies to help curb the advance of human trafficking efforts.

4.3.1 Providing Evidence for Prosecution
Unfortunately while most forms of trafficking are illegal all over the world, existing information suggests these laws are rarely used and enforced. The 2013 US Trafficking in Persons Report notes that while 46,570 victims of human trafficking were officially identified in 2012, there were only 7,705 prosecutions, and 4,750 convictions recorded globally.

There are a number of reasons for such low levels of convictions. Often traffickers are not present at the time a victim is intercepted. Even if a trafficker is present or can be located, victims and their families are often pressured against filing a case by threats and bribes and most victims face societal rejection due to social stigmatization. For these reasons, victims or their families may be unwilling to file a case against their traffickers (International). These factors result in a lack of evidence and witnesses. For these reasons, prosecutors are trying to biometric data to obtain the desperately needed evidence. Biometric data includes fingerprints, DNA profiles, IRIS scans, and other physical markers or features of an individual. Similarly ''soft'' forensic evidence (e.g. a trafficker's modus operandi) can also provide the basis of crime matching(Oatley, Ewart, & Zeleznikow, 2006) . For instance, law enforcement has linked unusual records of petty thief to trafficked victims. Linking both biometric and "soft" forensic evidence presents an enormous opportunity to support prosecution efforts. Clustering and link analysis algorithms can be used as a means to discover meaningful underlying dimensions in data and to explain observed similarities between investigated data points. As these datasets have large feature sets, dimensionality reduction using multidimensional scaling and principal components analysis are required. To support crime matching and profiling tools from artificial intelligence (neural networks, case-based reasoning and feature selection, logic programming) could be used.

4.3.2 Reducing Undue Processing Delays

One of the challenges of effectively prosecuting alleged traffickers is to have a reasonable processing timeframe between alleged acts of human trafficking and their trials. Given the depth of physical and psychological trauma associated with trafficked victims, coupled with threats of harm to victims, family, etc., lengthy delays in due process can lead victims to misremember or suppress key testimony that can help convict guilty traffickers.

The study and application of queueing models can serve to alleviate some of these associated challenges. Outside of the context of human trafficking crimes, there are a few studies in the literature that consider the waiting times of defendants in judicial court contexts (Goodwin, Smith, & Verhage, 1991; Schwartz, 1974). To the extent that queueing model insights can be leveraged in the processing of human trafficking cases, for example proposing additional judges (servers), queues, etc., there is great potential to positively impact the prosecution of human trafficking cases. Similarly system dynamics models can be used to understand the influence that case flows and resource constraints have on prosecution's capacity for deterring crime (Hovmand, 2003; MacDonald & Mojtahedzadeh, 2007; Rouwette, van Hooff, Vennix, & Jongebreur, 2007).

4.3.3 Policy Effectiveness and Evaluation

"To date, the global monitoring and evaluation of counter-trafficking projects has generally been non-standardized and output (not impact) focused." (Crime, 2012) The availability of comparative measures to assess the severity of human trafficking or the responses to it are lagging (Kangaspunta, 2010). This information gap has led to a situation in which the effectiveness and impact of anti-trafficking policies and measures are difficult to evaluate (Kangaspunta, 2010). The United States and other countries are increasingly seeking to invest in evidence-based programs that demonstrate an impact on trafficking in persons (Crime, 2012). Although there has been a recent increase in the number of studies on human trafficking as well as an increasing number of initiatives to respond to trafficking in persons, unfortunately, there is still relatively little knowledge of the effectiveness of these efforts since their impact has seldom been evaluated (Crime, 2012). Further, program evaluation should not be limited to law enforcement interventions but include regulatory approaches, prosecutorial techniques, collaborative approaches to investigating and prosecuting these crimes, and the provision of services to victims of trafficking.

Operations research and analytics researchers and practitioners have modeled the implications and effectiveness of policy interventions in illicit markets. Using production functions (Rydell, Caulkins, & Everingham, 1996) consider whether drug enforcement ("supply side") or drug treatment ("demand side") policies are more likely to reduce cocaine consumption. Optimization is used to determine if "zero tolerance" sentencing policies are effective in reducing illicit drug consumption (Caulkins et al., 1993), and optimal control is used to examine how the portfolio of drug prevention and treatment programs should be balanced over time (Behrens, Caulkins, Tragler, & Feichtinger, 2000). A system dynamics model of national cocaine prevalence examined the potential impact of a relaxation of drug law enforcement (Homer, 1993), and agent-based simulations examine how street-level drug markets adapt to difference law enforcement strategies (Dray, Mazerolle, Perez, & Ritter, 2008). In regards to evaluating anti-human

trafficking policies, the only study we are aware of is a System Dynamics simulation model used to provide insights related to the effects of proposed policies to combat human trafficking in Holland (Kovari & Pruyt, 2012). The authors conclude that the topic is so complex and uncertain that simple (combinations of) basic policies will not hold in all circumstances, are requires further exploration and policy testing under deep uncertainty.

Quantitative approaches are lagging in the area of trafficking prosecution and policy evaluation. On the other hand, over the past decade there has been an explosion of theoretical and algorithmic advancement in data analytics. It is worth investigating if existing machine learning and data mining approaches can be adapted to collect relevant, affordable, evidence for trafficking prosecution cases. We ask the community if comprehensive models could be developed to evaluate coordinated anti-trafficking policy responses. While optimization models have been used for policy evaluate in illicit markers, generally speaking optimization has been accused of being "highly stylized representations of problems that achieve robust results while sacrificing contextual information" (Besiou, Pedraza Martinez, & Van Wassenhove, 2012; Van Wassenhove & Besiou, 2013). On the other hand, simulation, particularly system dynamics is a powerful methodology for obtaining insights into problems of dynamic complexity and policy resistance. It is possible to link optimization and system dynamics approaches to produce relevant anti-trafficking policy evaluations.

4.4 Partnership

Collaboration amongst various organizations and government agencies is crucial to combat and prevent human trafficking. We examine two types of partnership: interagency information sharing and interoperability

Effective interdiction requires the fusion of data from many sources to detect and track human trafficking activities. However, human trafficking criminal data tends to be collected by authorities and institutions while data on victims is collected by non-governmental organizations (NGOs) and service providers (such as hospitals and shelters). Each agency collects data for its own local purpose resulting in data dispersion and fragmentation. Interagency information sharing is impeded by the lack of standards and organizational cultures. There are no conventions or standard methodologies amongst various agencies, thus data sets vary so greatly that they are not easily combined or cross-analyzed. Currently, only law enforcement agencies have protocols for the collection, analysis and dissemination of data internally and to other law enforcement agencies. This issue is further compounded by governmental restrictions on data sharing. Law enforcement is unable, and in some cases unwilling, to share data with non-law enforcement organizations and researchers due to the sensitivity of the information, privacy concerns and possibly jeopardizing ongoing investigations. Likewise organizations working in anti-human trafficking, specifically those providing direct victim services have access to relevant and pertinent data that is of extreme value to the overall efforts to combat human trafficking. However, these organizations

are generally unwilling to share the data or are not collecting the data pertinent to the needs of others including law enforcement. Some of this unwillingness to share data stems from privacy concerns.

For this data to be collected and analyzed there needs to be an international effort among all stakeholders to collaborate on data collection and sharing. Best practices, standards, and protocols for collection and storage would need to be drafted and adopted as well as developing a central "fusion center" where the data would be stored for analysis. Victim privacy concerns and data dissemination procedures would need to be established along with standardized data collection forms. Issues surrounding the veracity and validity of the information as well as the source of the data can be overcome by having the sourcing organization code the data according to standardized procedures and by referring source requests to that organization.

In recent years we are beginning to see positive developments with respect to analytics initiatives in information sharing to support anti-trafficking initiatives. The Polaris Project runs the Global Human Trafficking Hotline Network (Polaris, 2013), an effort that is beginning to connect disparate data sources across the world. This network enables information sharing between human trafficking advocacy groups, so that internationally-trafficked victims have a greater chance of being found and rescued. Their data-driven approach uses software from Palantir and Salesforce.com to aggregate disparate data from existing anti-trafficking hotlines worldwide, enabling victim mapping and empowering identification.

Through data envelopment analysis and cooperative game theory, (Lozano, 2012) explores the positive effects of including different organizations in a data. The authors estimate the cost reductions that can be derived from this information-sharing and determine a fair allocation of the benefits of the collaboration between the organizations. We believe that this type of approach can be very illustrative to the larger anti-trafficking community of the benefits partnering to share information.

Interagency cooperation among different responding entities (such as border patrol and victim services) is a critical component of effective victim response operations. As mentioned in Section 3.4, anti-human trafficking initiatives suffer from a lack of resources which contributes to interagency competition. Although competition exists between various organizations, the altruistic nature of humanitarian relief draws personnel who share common goals (Jie, 2008) and optimization has been used in the past to illustrate the impact of interagency cooperation. Cooperative game theory models identify methods for partnering agencies to achieve greater impact than what is possible when operating independently, and guide agencies on how to select and develop relationships to improve resource utilization and project outcomes. Game theoretic approaches have been very illustrative in the humanitarian logistics literature (J. Coles & Zhuang, 2011; J. B. Coles, Zhuang, & Yates, 2012; Moore & Heier Stamm, 2012). We also point out a parallel between the competitive funding atmosphere of anti-trafficking initiatives and vaccine pricing models for developing countries.(Proano, Jacobson, & Zhang, 2012) suggest that a third player, such as the World Health Organization use their model to negotiate fair prices with vaccine producers. In such a case, vaccine manufacturers may experience a lower net profit, but if they share the objective to

maximize vaccination coverage, cooperation may produce beneficial solutions for all. Similarly NGOs working in the same region (though not necessarily on the same counter-trafficking initiative) could cooperate to obtain funding.

The interdisciplinary and multifaceted natures of anti-trafficking efforts require interagency information sharing and interoperability for initiatives to be successful. The operations research and analytics community is well equipped to illustrate the positive (or potentially negative) impact of partnerships to the larger anti-trafficking community.

4.5 Where to start

Measures to counter human trafficking are significantly cross-functional. Consequently, the data and modeling efforts to support research in this area appears in a wide variety of academic journals, media outlets and government reports. Readers who would like more information on human trafficking in general should consult Appendix A, which provides a selected list of organizations and information resources on the worldwide web. For example, the Global Slavery Index can be obtained via internet. These reports are an excellent source of information about the size and nature of the human trafficking problem, risk factors, and to some degree the effectiveness of responses. Therefore, even though the main focus of this article is OR journals, to encourage interdisciplinary research we list a variety of outlets.

5. CONCLUSIONS AND PERSPECTIVES

Over the past two decades, human trafficking has generated a tremendous amount of public attention throughout the world (Weitzer, 2014). The problem has received growing coverage in the media, anti-trafficking activism has grown, and a majority of countries have created new policies, laws, and enforcement mechanisms to tackle the problem (Weitzer, 2014). Despite this recognition, there remains a lack of technical solutions to analyze, make impact assessments and assess decisions related to human trafficking. Operations Research and analytics techniques have the potential to make a powerful impact in the war against human trafficking. Given the growth of modeling in humanitarian research and big data analytics, we believe human trafficking is an excellent and compelling opportunity to make a profound difference in humanity, and should be of interest to both practitioners and academic researchers.

In this paper we brought forth several important issues that researchers need to address when considering operations research and analytical approaches to combat human trafficking. From the challenges perspective, there is a plethora of research opportunities for both operations research and analytics to confront the challenges of asymmetric and fragmented data from hidden populations. In search for new directions for operations research and analytics research, human trafficking contains enormous potential. Particularly in discovering interdisciplinary approaches …. As knowledge about human trafficking continues to develop, multidisciplinary and multi-stakeholder partnerships in this area hold some promise.

In the spirit of "Doing Good with Good OR", we believe that not only can the operations research and analytics community advance their theoretical portfolio, but truly make a significant impact on a horrendous crime against humanity.   Our hope is that this paper will offer insights into the current range of applications of operations research and analytics to anti- human trafficking efforts, and provide ideas about where methods may be further developed and applied to benefit this sector. We listed several ideas, but believe there are many more. We call to the Operations Research and Analytics community to make an impact in this area.

Appendix A. Human Trafficking groups/ organizations/web links

The following list is in no way is a complete list of resources regarding human trafficking. Our intention is not to promote any one entity, but merely supply some starting points for interested researchers.

A.1. Journals and meta-sites

- Journal of Human Trafficking
- SlaveryToday: A Multidisciplinary Journal of Human Trafficking Solutions

A.2. Research centers

- Center for Forensic Investigations of Trafficking in Persons
  http://www.newhaven.edu/lee-college/institutes/center-for-forensic-investigations-of-trafficking-in-persons/

- HEAL Trafficking
Group of health professionals and advocates passionate about ending human trafficking
https://healtrafficking.wordpress.com/

A.3. Organizations and agencies

- Global Sentry Group
  http://www.globalsentrygroup.org/

- Countering Trafficking in Persons
  http://www.usaid.gov/trafficking/

- Coalition to Abolish Slavery & Trafficking (CAST)
- United Nations Office on Drugs and Crime (UNODC)
- International Organization for Migration
- US Department of State, Office to Monitor and Combat Trafficking in Persons
  http://www.state.gov/j/tip/index.htm

- Polaris
  http://www.polarisproject.org/

- DHS Human Trafficking website

- Immigration and Customs Enforcement Human Trafficking website

- Department of Justice

- Florida Coalition Against Human Trafficking

A.4. Databases

- Human Trafficking Law Project (HTLP) database
  http://www.law.umich.edu/clinical/HuTrafficCases/Pages/searchdatabase.aspx

Trafficking in Persons (TIP) Report is the U.S. Government's principal diplomatic tool to engage foreign governments on human trafficking. It is also the world's most comprehensive resource of governmental anti-human trafficking efforts

A.5. Guides & directories

Shelley, Louise. *Human trafficking: A global perspective*. Cambridge University Press, 2010.

REFERENCES

Allen, D. K., Karanasios, S., & Norman, A. (2013). Information sharing and interoperability: the case of major incident management. *European Journal of Information Systems*.

America, D. o. S. U. S. o. (2014). Trafficking in Persons Report June 2014. Washington, D.C.

Amin, S. (2010). *A Step Towards Modeling and Destabilizing Human Trafficking Networks Using Machine Learning Methods.* Paper presented at the AAAI Spring Symposium: Artificial Intelligence for Development.

Aradau, C. (2004). The perverse politics of four-letter words: risk and pity in the securitisation of human trafficking. *Millennium-Journal of International Studies, 33*(2), 251-277.

Arquilla, J., & Ronfeldt, D. (2001). *Networks and netwars: The future of terror, crime, and militancy*: Rand Corporation.

Assimakopoulos, N. (1987). A network interdiction model for hospital infection control. *Computers in biology and medicine, 17*(6), 413-422.

Austin, L. (2011). 2012 Games and human trafficking research: London Councils.

Baron, D. P. (2001). Private politics, corporate social responsibility, and integrated strategy. *Journal of Economics & Management Strategy, 10*(1), 7-45.

Batsyukova, S. (2007). Prostitution and human trafficking for sexual exploitation. *Gender Issues, 24*(2), 46-50.

Behrens, D. A., Caulkins, J. P., Tragler, G., & Feichtinger, G. (2000). Optimal control of drug epidemics: prevent and treat—but not at the same time? *Management Science, 46*(3), 333-347.

Berry, J. W., Fleischer, L., Hart, W. E., Phillips, C. A., & Watson, J.-P. (2005). Sensor placement in municipal water networks. *Journal of Water Resources Planning and Management, 131*(3), 237-243.

Besiou, M., Pedraza Martinez, A., & Van Wassenhove, L. N. (2012). The effect of earmarked funding on fleet management for relief and development.

Bespalova, N., Morgan, J., & Coverdale, J. (2014). A Pathway to Freedom: An Evaluation of Screening Tools for the Identification of Trafficking Victims. *Academic Psychiatry*, 1-5.

Bilger, V., Hofmann, M., & Jandl, M. (2006). Human smuggling as a transnational service industry: Evidence from Austria. *International Migration, 44*(4), 59-93.

Blackburn, V., Brennan, S., & Ruggiero, J. (2014). Measuring efficiency in Australian Schools: A preliminary analysis. *Socio-Economic Planning Sciences, 48*(1), 4-9.

Capous Desyllas, M. (2007). Critique of the Global Trafficking Discourse and US Policy, A. *J. Soc. & Soc. Welfare, 34*, 57.

Castle, T., & Lee, J. (2008). Ordering sex in cyberspace: a content analysis of escort websites. *International Journal of Cultural Studies, 11*(1), 107-121.

Caulkins, J. P., Crawford, G., & Reuter, P. (1993). Simulation of adaptive response: a model of drug interdiction. *Mathematical and Computer Modelling, 17*(2), 37-52.

Chandler, A. (2015). Human Traffickers Are Abandoning Ships Full of Migrants.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444.

Clawson, H. J., Dutch, N., Solomon, A., & Grace, L. G. (2009). Human trafficking into and within the United States: A review of the literature. *US Department of Health and Human Services, Office of the Assistant Secretary for Planning and Evaluation*.

Coles, J., & Zhuang, J. (2011). Decisions in disaster recovery operations: a game theoretic perspective on organization cooperation. *Journal of Homeland Security and Emergency Management, 8*(1).

Coles, J. B., Zhuang, J., & Yates, J. (2012). Case study in disaster relief: A descriptive analysis of agency partnerships in the aftermath of the January 12th, 2010 Haitian earthquake. *Socio-Economic Planning Sciences, 46*(1), 67-77.

Crime, U. N. O. o. D. a. (2012). Global Report on Trafficking in Persons.

Crime, U. N. O. o. D. a. (2014). Global Report on Trafficking in Persons 2014. Vienna:

United Nations Publication.

Crime), U. U. N. O. o. D. a. (2014). Global Report on Trafficking in Persons 2014 *United Nations publication*. Vienna.

Cwikel, J., & Hoban, E. (2005). Contentious issues in research on trafficked women working in the sex industry: Study design, ethics, and methodology. *Journal of Sex Research, 42*(4), 306-316.

Dean, A. W. (2011). *Fighting networks the defining challenge of irregular warfare.* Monterey, California. Naval Postgraduate School.

Development, U. S. A. f. I. (2013). Countering Trafficking in Persons - Field Guide: Center of Excellence on Democracy, Human Rights and Governance in the Bureau for Democracy, Conflict and Humanitarian Assistance within the United States Agency for International Development.

Dougherty, M., & Burke, J. (2008). Exploitation and immigration policy: human bondage. *America, 198*(12).

Dovydaitis, T. (2010). Human trafficking: the role of the health care provider. *Journal of Midwifery & Women's Health, 55*(5), 462-467.

Dray, A., Mazerolle, L., Perez, P., & Ritter, A. (2008). Policing Australia's 'heroin drought': using an agent-based model to simulate alternative outcomes. *Journal of Experimental Criminology, 4*(3), 267-287.

Du, J., Wang, J., Chen, Y., Chou, S.-Y., & Zhu, J. (2014). Incorporating health outcomes in Pennsylvania hospital efficiency: an additive super-efficiency DEA approach. *Annals of Operations Research, 221*(1), 161-172.

Dubrawski, A., Miller, K., Barnes, M., Boecking, B., & Kennedy, E. (2015). Leveraging Publicly Available Data to Discern Patterns of Human-Trafficking Activity. *Journal of Human Trafficking, 1*(1), 65-85.

Eck, J. E., Chainey, S., Cameron, J. G., Leitner, M., & Wilson, R. E. (2005). Mapping crime: Understanding hot spots: National Institute of Justice Special Report.

Farrell, A. (2009). State and local law enforcement responses to human trafficking: Explaining why so few trafficking cases are identified in the United States. *Sociology of Crime Law and Deviance, 13*, 243-259.

Farrell, A., & Fahy, S. (2009). The problem of human trafficking in the US: Public frames and policy responses. *Journal of Criminal Justice, 37*(6), 617-626.

Farrell, A., McDevitt, J., & Fahy, S. (2010). Where are all the victims? *Criminology & Public Policy, 9*(2), 201-233.

Feingold, D. A. (2005). Human trafficking. *Foreign Policy*, 26-32.

Freeman, P. (1983). The secretary problem and its extensions: A review. *International Statistical Review/Revue Internationale de Statistique*, 189-206.

Friebel, G., & Guriev, S. (2006). SMUGGLING HUMANS: A THEORY OF DEBT‐FINANCED MIGRATION. *Journal of the European Economic Association, 4*(6), 1085-1111.

Gajic-Veljanoski, O., & Stewart, D. E. (2007). Women trafficked into prostitution: determinants, human rights and health needs. *Transcultural Psychiatry, 44*(3), 338-358.

Galeotti, M. (2014). *Global crime today: the changing face of organised crime*: Routledge.

Gao, P., Guo, D., Liao, K., Webb, J. J., & Cutter, S. L. (2013). Early Detection of Terrorism Outbreaks Using Prospective Space–Time Scan Statistics. *The Professional Geographer, 65*(4), 676-691.

Ghali, N., Panda, M., Hassanien, A. E., Abraham, A., & Snasel, V. (2012). Social networks analysis: Tools, measures and visualization *Computational Social Networks* (pp. 3-23): Springer.

Ghare, P., Montgomery, D., & Turner, W. (1971). Optimal interdiction policy for a flow network. *Naval Research Logistics Quarterly, 18*(1), 37-45.

Goodwin, C., Smith, K. L., & Verhage, B. J. (1991). An equity model of consumer response to waiting time. *Journal of Consumer Satisfaction, Dissatisfaction, and Complaining Behavior, 4*, 129-138.

Gozdiak, E. M. (2011). *Data and research on human trafficking: Bibliography of research-based literature*: DIANE Publishing.

Gulati, G. J. (2011). News frames and story triggers in the media's coverage of human trafficking. *Human Rights Review, 12*(3), 363-379.

Haken, J. (2011). Transnational crime in the developing world. *Global financial integrity*.

Hepburn, S., & Simon, R. J. (2010). Hidden in plain sight: Human trafficking in the United States. *Gender Issues, 27*(1-2), 1-26.

Homer, J. B. (1993). Projecting the impact of law enforcement on cocaine prevalence: a system dynamics approach. *Journal of Drug Issues, 23*, 281-281.

Hovmand, P. S. (2003). *MANAGING A PROSECUTOR'S OFFICE DOMESTIC VIOLENCE CASELOAD TO INCREASE ASSAILANT ACCOUNTABILITY: A SYSTEM DYNAMICS APPROACH.* Michigan State University.

Ibanez, M., & Suthers, D. D. (2014). *Detection of Domestic Human Trafficking Indicators and Movement Trends Using Content Available on Open Internet Sources.* Paper presented at the System Sciences (HICSS), 2014 47th Hawaii International Conference on.

International, T. H. Prosecutions.   Retrieved June 6, 2015, from https://www.tinyhands.org/

Jayson, K. G. (2013). Human Trafficking in North Carolina: Human Beings as a Commodity: N.C. Governor's Crime Commission Criminal Justice Analysis Center.

Jie, W. (2008). *Exploration of Dual Organization in Internal Management of NGO.* Paper presented at the Information Management, Innovation Management and Industrial Engineering, 2008. ICIII'08. International Conference on.

Johnson, S. D., & Bowers, K. J. (2004). The stability of space-time clusters of burglary. *British Journal of Criminology, 44*(1), 55-65.

Jordan, J., Patel, B., & Rapp, L. (2013). Domestic minor sex trafficking: A social work perspective on misidentification, victims, buyers, traffickers, treatment, and reform of current practice. *Journal of Human Behavior in the Social Environment, 23*(3), 356-369.

Kangaspunta, K. (2007). Collecting data on human trafficking: availability, reliability and comparability of trafficking data *Measuring Human Trafficking* (pp. 27-36): Springer.

Kangaspunta, K. (2010). Measuring the immeasurable. *Criminology & Public Policy, 9*(2), 257-265.

Kapur, R. (2014, August 23,204). Bacha Bazi: The tragedy of Afghanistan's Dancing Boys.

Kennedy, E. (2012). *Predictive Patterns of Sex Trafficking Online.* Carnegie Mellon University, Pittsburgh, USA.

Kenyon, S., & Schanz, Y. (2014). Sex Trafficking: Examining Links to Prostitution and the Routine Activity Theory. *International Journal of Criminology and Sociology, 3*, 61-76.

Kleemans, E. R. (2007). Organized crime, transit crime, and racketeering. *Crime and Justice, 35*(1), 163-215.

Knorr‑Held, L., & Richardson, S. (2003). A hierarchical model for space–time surveillance data on meningococcal disease incidence. *Journal of the Royal Statistical Society: Series C (Applied Statistics), 52*(2), 169-183.

Kongsomsaksakul, S., Yang, C., & Chen, A. (2005). Shelter location-allocation model for flood evacuation planning. *Journal of the Eastern Asia Society for Transportation Studies, 6*, 4237-4252.

Kovari, A., & Pruyt, E. (2012). *Prostitution and human trafficking: A model-based exploration and policy analysis.* Paper presented at the Proceedings of the 30th International Conference of the System Dynamics Society.

Latonero, M. (2011). Human trafficking online: The role of social networking sites and online classifieds. Technical Report. *Available at SSRN 2045851*: USC Annenberg School for Communication.

Lesniewski, M. J. (2014). *Monitoring Human Trafficking in Displaced Populations.* The Pennsylvania State University.

Li, A. C., Nozick, L., Xu, N., & Davidson, R. (2012). Shelter location and transportation planning under hurricane conditions. *Transportation Research Part E: Logistics and Transportation Review, 48*(4), 715-729.

Li, A. C., Xu, N., Nozick, L., & Davidson, R. (2011). Bilevel optimization for integrated shelter location analysis and transportation planning for hurricane events. *Journal of Infrastructure Systems, 17*(4), 184-192.

Logan, T., Walker, R., & Hunt, G. (2009). Understanding human trafficking in the United States. *Trauma, Violence, & Abuse, 10*(1), 3-30.

Lozano, S. (2012). Information sharing in DEA: A cooperative game theory approach. *European Journal of Operational Research, 222*(3), 558-565.

MacDonald, R., & Mojtahedzadeh, M. (2007). *Criminal justice simulation model (CJSIM).* Paper presented at the Proceedings of the International System Dynamics Conference. System Dynamics Society: Boston, MA.

Malaviya, A., Rainwater, C., & Sharkey, T. (2012). Multi-period network interdiction problems with applications to city-level drug enforcement. *IIE Transactions, 44*(5), 368-380.

Mantrala, M. K. (2002). Allocating marketing resources. *Handbook of marketing*, 409-435.

McDonagh, P. (2002). Communicative campaigns to effect anti-slavery and fair trade: The cases of Rugmark and Cafédirect. *European Journal of Marketing, 36*(5/6), 642-666.

McLay, L. A., & Dreiding, R. (2012). Multilevel, threshold-based policies for cargo container security screening systems. *European Journal of Operational Research, 220*(2), 522-529.

McMasters, A. W., & Mustin, T. M. (1970). Optimal interdiction of a supply network. *Naval Research Logistics Quarterly, 17*(3), 261-268.

Miller, C. L. (2013). Child sex trafficking in the emergency department: opportunities and challenges. *Journal of emergency nursing: JEN: official publication of the Emergency Department Nurses Association, 39*(5), 477-478.

Miller, J. R. (2008). Call it slavery. *The Wilson Quarterly*, 52-56.

Moore, B., & Heier Stamm, J. (2012). *Impact of Decentralized Decision-making on Access to Public Health Facilities.* Paper presented at the Industrial and Systems Engineering Research Conference, Orlando, FL,.

Morton, D. P., Pan, F., & Saeger, K. J. (2007). Models for nuclear smuggling interdiction. *IIE Transactions, 39*(1), 3-14.

Oatley, G., Ewart, B., & Zeleznikow, J. (2006). Decision support systems for police: Lessons from the application of data mining techniques to "soft" forensic evidence. *Artificial Intelligence and Law, 14*(1-2), 35-100.

Office, I. L. (2012). Profits and poverty: the economics of forced labour. Geneva.

Office to Monitor and Combat Trafficking in Persons, U. D. o. S. (2009). Four "Ps": Prevention, Protection, Prosecution, Partnerships.   Retrieved May 10, 2015, from http://www.state.gov/j/tip/4p/

Owen, S. H., & Daskin, M. S. (1998). Strategic facility location: A review. *European Journal of Operational Research, 111*(3), 423-447.

Persons, O. t. M. a. C. T. i. (2011). The 3Ps: Prevention, Protection, Prosecution. 3.

Polaris. (2013). "Polaris Project Launches Global Human Trafficking Hotline Network.".   Retrieved June 7, 2015, from http://www.polarisproject.org/media-center/news-and-press/press-releases/767-polaris-project-launches-global-human-trafficking-hotline-network

Proano, R. A., Jacobson, S. H., & Zhang, W. (2012). Making combination vaccines more accessible to low-income countries: The antigen bundle pricing problem. *Omega, 40*(1), 53-64.

. Protocol to prevent, suppress and punish trafficking in persons, especially women and children, supplementing the United Nations convention against transnational organized crime. (2002): UN General Assembly.

Rice, R. A. (2001). Noble goals and challenging terrain: organic and fair trade coffee movements in the global marketplace. *Journal of agricultural and environmental ethics, 14*(1), 39-66.

Rouwette, E., van Hooff, P., Vennix, J., & Jongebreur, W. (2007). *Modeling crime control in the Netherlands: insights on process.* Paper presented at the 25th International Conference of the System Dynamics Society, Boston, MA.

Rydell, C. P., Caulkins, J. P., & Everingham, S. S. (1996). Enforcement or treatment? Modeling the relative efficacy of alternatives for controlling cocaine. *Operations Research, 44*(5), 687-695.

Schwartz, B. (1974). Waiting, exchange, and power: The distribution of time in social systems. *American Journal of Sociology*, 841-870.

Senior Policy Operating Group, G. m. C. (2012). Promising Practices: A Review of U.S. Government-Funded Anti-Trafficking in Persons Programs: US Department of State.

Shelley, L. (2012). The Relationship of Drug and Human Trafficking: A Global Perspective. *European Journal on Criminal Policy and Research*, 1-13.

Shelley, L. I. (2003). Organized crime, terrorism and cybercrime (Vol. 302): Nomos Verlagsgesellschaft: Baden-Baden.

Sigmon, J. N. (2008). Combating modern-day slavery: Issues in identifying and assisting victims of human trafficking worldwide. *Victims and Offenders, 3*(2-3), 245-257.

Skinner, E. B. (2008). *A crime so monstrous: Face-to-face with modern-day slavery*: Simon and Schuster.

Smith, J. C., Prince, M., & Geunes, J. (2013). Modern network interdiction problems and algorithms *Handbook of Combinatorial Optimization* (pp. 1949-1987): Springer.

Spencer, G. M. (2012). *Approximation algorithms for stochastic combinatorial optimization, with applications in sustainability*: Cornell University.

State, U. S. D. o. (2013). Trafficking in Persons Report, 2013.

Tamura, Y. (2010). Migrant smuggling. *Journal of Public Economics, 94*(7), 540-548.

Territo, L., & Kirkham, G. (2009). *International sex trafficking of women & children: Understanding the global epidemic*: Looseleaf Law Publications.

Turner, J. (2010). *Ad slotting and pricing: New media planning models for new media.* CARNEGIE MELLON UNIVERSITY.

Van Wassenhove, L. N., & Besiou, M. (2013). Complex problems with multiple stakeholders: how to bridge the gap between reality and OR/MS? *Journal of Business Economics, 83*(1), 87-97.

Wang, H., Cai, C., Philpot, A., Latonero, M., Hovy, E. H., & Metzler, D. (2012). *Data integration from open internet sources to combat sex trafficking of minors.* Paper presented at the Proceedings of the 13th Annual International Conference on Digital Government Research.

Weitzer, R. (2014). New directions in research on human trafficking. *The ANNALS of the American Academy of Political and Social Science, 653*(1), 6-24.

Wilson, D. G., Walsh, W. F., & Kleuber, S. (2006). Trafficking in human beings: Training and services among US law enforcement agencies. *Police Practice and Research, 7*(02), 149-160.

Winterdyk, J., Perrin, B., & Reichel, P. (2011). *Human trafficking: Exploring the international nature, concerns, and complexities*: CRC Press.

Wright, A. L. (2013). Cleaning up the Blood, Sweat, and Tears of the Super Bowl [Sex Trade]: What Host Cities Must Do in Preparation for Major Sporting Events to Combat Sex Trafficking. *Va. Sports & Ent. LJ, 13*, 97.

Zafarani, R., Abbasi, M. A., & Liu, H. (2014). *Social Media Mining: An Introduction*: Cambridge University Press.