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

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Abstract: Human trafficking is a complex transnational problem for society and the global economy. While researchers have studied this topic in a variety of contexts, including the criminology, sociology, and clinical domains, there has been little coverage in the operations research (OR) and analytics community. This paper highlights how techniques from OR and analytics can address the growing issue of human trafficking. We describe some of the unique concerns, problems, and challenges of human trafficking in relation to analytical techniques; subsequently, we demonstrate a variety of ways that OR and analytics can be applied in the human trafficking domain.

Keywords: OR in societal problem analysis, Data mining, OR in government, Analytics, Human trafficking

1. Introduction

Human trafficking is a complex societal issue that involves the commercial exchange and exploitation of humans for monetary gain or benefit. Human trafficking is a modern form of slavery that constitutes a human rights violation and a global public health crisis [56]. Prevalent in both impoverished and wealthy countries, trafficking undermines fundamental human rights, as well as a broader sense of global order [132]. Previous reports have estimated that between 27 and 45.8 million individuals worldwide are trapped in some form of modern-day slavery [13, 14]; this is undoubtedly as human trafficking is an extremely profitable enterprise. Forced labor and sexual exploitation generate an estimated $150 billion (U.S.) globally in illegal profits each year [7], making human trafficking one of the largest sources of profit for global organized crime, trailing only illicit drugs and the weapons trade [67]. While there may be uncertainty as to its extent, one thing is certain: human trafficking is an enormous global problem, and it is *rapidly increasing* [7].

While the exploitation of humans for gain has a long and infamous past; until recently, researchers mainly classified it as slavery with a history of endorsement and acceptance by a variety of

political groups and people in power. The year 2015 marked the fifteenth 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 enacted laws and policies to prosecute traffickers of humans, provide assistance and protection to survivors, and otherwise prevent this criminal activity. Owing in part to this recent momentum, such abuses of human rights have become much more secretive, and they are now mainly referred to under the designation of *human trafficking*.

At the same time, scholars have sought to enhance the understanding of the human trafficking phenomenon. They have undertaken research to explore both the nature and the extent of trafficking in persons at the local, national, and international levels, as well as to develop evidence-based research to support more effective public policy responses. Scholarly work on this phenomenon has mainly emerged rather recently, in the late 1990s [132], relating to the contexts of criminology [49, 82], sociological research [30, 78, 82], international studies [19], and more recently, clinical domains [70, 103, 109, 136].

Despite a growing awareness of human trafficking, scholars continue to struggle with formulating basic measures of its size and extent. Human trafficking is a difficult crime to detect and gather relative statistics on due to its clandestine nature; even data used to estimate the prevalence of human trafficking are deficient in scope and quality [64]. Furthermore, the coordination among multiple agencies and information systems typically required to identify victims and prosecute traffickers is generally lacking. To curb this invasive problem, accurate statistics, as well as effective agency coordination and cooperation, are essential.

There is a need for quantitative research that would provide an understanding of the operations of the trafficking phenomenon, develop methods of deterring its prevalence, and ultimately inform and transform policy. Recently, the executive director for the United Nations Office on Drugs and Crime (UNODC) 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 [12]. Given that services to trafficked persons are in their infancy [76] and evidence-based clinical and sociological research in the area is burgeoning, a profound opportunity exists to examine how operations research (OR) and analytics can be used to effectively combat human trafficking.

Operations research and related analytical tools can serve to identify better ways of allocating scarce resources, discover potentially useful patterns in data, and predict future trends and behaviors. Such techniques can help not only 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 of the aforementioned tools, the authors are aware of only a few isolated studies to date in which OR and analytics tools have effectively been applied to human trafficking. In particular, analytics-based methods have been applied to identify victims [81, 89, 90], identify trafficking circuits [75], and understand how trafficking networks operate [42, 47].

OR and analytics have significant potential to successfully combat human trafficking. This article provides a viewpoint on the challenges and opportunities that lay ahead for the OR and

analytics community in the field of human trafficking. Our objectives are as follows: 1) to illustrate the issues related to combatting human trafficking, 2) to survey existing OR and analytics literature in the area, 3) to suggest possible research avenues, and 4) to act as a guide for interested researchers. While quantitative models and case studies in human tracking are also lacking, the present paper does not serve to address this gap.

Section 2 provides the reader with some background on human trafficking. A discussion of expected challenges faced by the OR and analytics community is presented in Section 3. Section 4 suggests research directions that are classified according to the challenges presented, while Section 5 concludes the paper. A directs interested researchers to a sample of organizations and human trafficking-related resources.

2. Background on Human Trafficking

Developing effective OR and analytics models to support anti–human trafficking efforts depends acutely on understanding the decision-making context; such an understanding will allow appropriate and useable knowledge to be generated. In this section, we explore the context, meaning, and pervasiveness of human trafficking.

2.1 What Is Human Trafficking?

Human trafficking refers to the recruitment, transportation, or harboring of persons by means of force, coercion, abduction, or deception for the purpose of exploitation [1]. A victim of trafficking has not consented to exploitation [119, 120]. Human trafficking is frequently thought of as sex trafficking [12]; however, while the amount of sex trafficking as a proportion of human trafficking is significant, researchers have estimated that victims of labor and domestic trafficking make up more than 68% of the population of trafficked people worldwide [7, 50]. Worldwide, victims range from child soldiers and child brides to domestic workers (such as housekeepers and nannies), laborers (including commercial fishing, manufacturing, construction, mining, food service, and agricultural), sex work (including pornography, exotic dancing, etc.), and beggars [53, 95].

2.2 The Extent of Human Trafficking

Human trafficking has always existed; however, as evidenced by official discourse and media reporting, it has increasingly been considered a serious social problem in recent years [38, 65]. Human trafficking is a largely clandestine activity; as such, it is both difficult and complicated to measure its prevalence [11, 51, 79]. Sources estimate that between 27 and 45.8 million individuals are victims of human trafficking around the world [13, 14]; at the same time, it has been reported that less than 1% of the total estimated number of people trafficked have been identified [11]. We can observe tremendous gaps in estimations concerning the number of people trafficked, the number of victims identified, and the number of people arrested for actual human trafficking crimes [35].

2.3 Classification of Activities to Combat Human Trafficking

The United Nations Palermo Protocol and the United States' Trafficking Victims Protection Act classified activities to fight human trafficking into three broad categories: *prevention, protection, and prosecution* - the 3P paradigm [5]. In 2009, a fourth category, *partnership*, was proposed as a critical element in the fight against human trafficking [3].

Prevention involves fostering public awareness and carrying out educational campaigns aimed at conveying the nature and gravity of human trafficking, as well as providing alternative vocational opportunities for at-risk persons, particularly women and girls [5]. *Protection* includes the rescue, rehabilitation, and reintegration of victims into society. Activities may include establishing training to recognize possible human trafficking victims and providing short-term and long-term crisis care for rescued victims [5]. *Prosecution* refers to the just creation and enforcement of anti–trafficking laws and punishment of those convicted of trafficking [5]. For the interested reader an overview and review of the 3Ps is provided in [34]. 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 [3]. We revisit this paradigm toward the end of this paper by classifying the proposed applications of OR and analytics to human trafficking into the four categories.

3. Some Key Challenges in Human Trafficking Relevant to OR and Analytics

To develop, implement, and analyze effective counter–trafficking strategies, knowledge about the dynamics and structure of human trafficking is essential. In this section, we outline four key challenges that OR and analytics practitioners face in applying their skills to the realm of human trafficking.

3.1 Victims are *Hidden*: Limited Societal Interfaces

One of the primary problems in human trafficking research is that the population is "hidden" [38, 71, 104]. The UNODC Trafficking in Persons report presents basic descriptive statistics on trafficking in persons, including profile information, such as the age and gender of victims and traffickers, and forms of exploitation used [12]. While these statistics differ by region, they have in common that victims are almost exclusively from vulnerable and marginalized populations [4]. This vulnerability makes them susceptible to traffickers. The fraudulent recruitment that characterizes a victim's trail often begins with promises of a better life, but quickly takes a turn for the worse, for example, in the confiscation of identity documents. These practices render a person vulnerable to servitude and worsens in situations when the victim is in a foreign country or in a place where labor rights and laws are not respected.

After recruitment, the traffickers leverage their power over the victims to force them to carry out certain tasks in conditions that they would not accept if they were free to decide. As these tasks and conditions are typically considered immoral and illegal, traffickers need to hide their victims to continue their operations. Traffickers use a variety of techniques to accomplish this, including

violence, threats, restraint, coercion, and physiological stress. The act of trafficking can be "hidden in plain sight" [71, 107]. It can involve the person at a nail salon, the teenager busing tables at a restaurant, the live-in nanny, or cleaning staff in an office [95]. Moreover, traffickers often hide their victims by concealing their operations. For example, traffickers will use transit lodging, such as motels and hotels, to set up operations for sexual exploitation. These mobile operations are difficult to identify or subject to law enforcement, as they commonly operate for only a few days before relocating to another destination [41].

Trafficking victims have limited societal interaction; most have little to no contact with professionals such as health care workers, police, or social services. However, any contact with society, particularly health and social care or law enforcement, presents an opportunity for data collection and potential victim identification. Such professionals are in a unique position to identify and assist trafficking victims, but active awareness is also needed to ensure that they are adequately prepared for encountering these individuals [24, 44, 60]. Any lack of awareness impedes their ability to accurately collect data and subsequently use them in analytical techniques; this problem is further compounded by the relatively infrequent interaction with the local community and society at large. This lack of access to "subjects" can present a challenge for OR and analytics practitioners, where an accurate understanding of the situation at hand is necessary to develop a realistic model.

3.2 Traffickers are *Covert*: Dynamic Adaptation to Avoid Detection

Trafficking networks are configured defensively to mitigate the overall damage that any one intrusion could generate [41]. Connections are consciously hidden because of the need for covertness, leaving law enforcement and analysts with incomplete information. Knowledge about the structure of a human trafficking network, from the beginning of the supply chain to its end, is extremely important when it comes to protecting victims; however, all too often, this information is missing.

Traffickers have shown great flexibility and ingenuity in eluding law enforcement, quickly changing transportation and distribution routes or moving operations further underground [93]. As a simple example consider a sexual trafficking ring that advertises a victim on a particular website, but frequently changes some small details associated with the advertised name or phone number to evade police. Such subtle changes would make it difficult for basic pattern matching tools to track repeated advertisements. In a more complex example, although many traffickers have a circuit consisting of cities or locations within a city, transportation routes between the revolving locations (transit lodging) within the circuit change to evade detection [41].

Mobile devices and connectivity are of central importance to trafficking activities around the world [85, 89]. These technologies' capacity to facilitate communication and coordination, as well as to provide a (perhaps illusory) sense of anonymity, all unbounded by physical location, are leveraged by traffickers to extend their activities. Their increasing presence and affordability has led to most traffickers, and even victims, being in possession of such devices. Traffickers are able

to recruit, advertise, sell, organize, and communicate primarily – or even exclusively – via mobile phone [89] or the Internet [129].

While some human trafficking activity leaves traces in the public areas of the Internet [15, 81, 89] and presents a valuable source of data to identify victims, their locations, and methods of engagement with perpetrators [129], only a small subset of the traffic on most adult content sites may be related to human trafficking. A study of 1.5 million escort advertisements estimates a likely trafficking prevalence rate of only 5.5% of the volume of processed ads [47]. In addition, posts that advertise minors often use deceptive and clandestine language to avoid detection by law enforcement, commonly using false images to portray subjects as older [89]. The difficulty in discerning whether the victim is in any capacity a willing participant rather than a victim of fraud, threat, or coercion through posted advertisements and personal interaction further adds to the challenge.

Even when a human trafficking crime has been identified, traffickers are frequently able to avoid prosecution [124]. Often, traffickers are not present when a victim is intercepted. Even if traffickers can readily be identified, they frequently pressure victims and their families not to file a case using threats and bribes, and most victims face rejection due to social stigmatization. These factors result in a lack of evidence and witnesses. As recently as 2012, a total of 46,570 victims of human trafficking were officially identified on a global scale. However, out of these cases, there were only 7,705 prosecutions and 4,746 convictions recorded [11].

Traffickers avoid detection of their illicit activities through deception and other adaptive actions that serve to mask their identities, as well as those of their victims. The covertness of traffickers presents a challenge for data collection to support OR and analytics model development.

3.3 Data Are *Fragmented*: Lack of Comprehensive Data, Reluctance to Share Data

To this point, we have clarified that human trafficking victims are hidden and traffickers are secretive. Thus, it should come as no surprise that human trafficking, like other illicit activities, is difficult to measure directly. Nevertheless, doing so is critical for basic decision analysis and effective mitigation strategies. The available quantitative estimates of trafficking activity carry substantial uncertainties as to the true extent of trafficking activity [61, 63, 135]. There are few reliable data on the distribution of victims, traffickers, buyers, and exploiters [79]. The data that do exist can be inaccurate, missing or – worse – false, and simply enhancing data collection techniques and methodologies is often insufficient [8]. As such, the difficulty in accessing *representative* data presents a barrier to conducting quantitative studies [100].

Data analysis of both trafficked persons and traffickers typically involves data from multiple sources and jurisdictions; thus, data ownership, privacy, unwillingness to share, or a simple lack of knowledge concerning what data are available often hamper data collection. That said, many organizations are beginning to see the value in collecting various data from trafficking victims and traffickers, and some have started to conduct basic analytics for their own internal uses. A major difficulty in this process is organizations' reluctance or even refusal to cooperate and share data.

The reasons for this often involve concerns about data privacy, how the data will be used, and who will receive credit.

Data sets are disconnected. Criminal data are collected by authorities and institutions, whereas data on victims are collected by non governmental organizations (NGOs) and service providers. Because each organization collects data for its own purposes, the information gathered is fragmented, scattered, and not always 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 at a hospital in Spain. This person could have originated in Nepal, been trafficked through a hub in India, and been brought to Spain on a work visa. Her trafficker could be operating a legally registered business in one location, while the victim has been arrested for prostitution in another jurisdiction. It is likely that agencies at various levels (e.g., local, federal) have collected some data about the individual [16], but her situation may have been alleviated only if information has been judiciously shared.

Collecting, sharing, and disseminating data related to human trafficking activity involves challenges. At the same time, there are techniques to circumvent poor or missing data (estimation, removal, stochastic, and robust approaches, etc.). The current state of human trafficking data presents an opportunity for the application and the advancement of OR and analytics tools, which can enable more productive and effective analyses in anti–trafficking efforts.

3.4 Resources Are *Limited*: Lack of Sufficient Resources to Combat the Problem

Despite the pervasiveness of human trafficking, resources to combat the problem are severely lacking. For instance, it is estimated that the leading 12 Organisation for Economic Co-operation and Development (OECD) countries contribute a combined annual average of $124 million (U.S.) to international development projects combating modern slavery, predominantly funding projects in Southeast Asia, Eastern Europe, and Sub-Saharan Africa [128]. For these 12 countries, spending on modern slavery represents only a tiny proportion of their total development assistance; the largest spender is Norway by percentage, which spends 0.36% of its Overseas Development Assistance contributes to combat slavery, followed by the United States (0.27%) and Australia (0.26%) [128]. There is a similar dearth of funding for domestic anti–trafficking initiatives.

The relatively modest scale of governmental spending suggests that private sector spending on anti–trafficking may represent a considerable proportion of the total funding [128]. In recent years, corporations and foundations have made several large private contributions; Humanity United has contributed $17.5 million (U.S.) towards modern slavery projects since 2011, and Google Innovation Awards provided $11.5 million (U.S.) to be used to counter trafficking in 2011.

While few resources are allocated to combat human trafficking, virtually no analysis has been carried out regarding the actual allocation of funds: how many tiers there are in the sub-contracting hierarchy before funding is put to use; which organizations are the main beneficiaries; and what

proportion of the money is allocated to administrative charges of the various organizations involved [43]. To date, the global monitoring and evaluation of counter trafficking projects has generally been nonstandardized and output (not impact) focused [6]. In contrast, comparative measures are needed to assess the severity of human trafficking and evaluate associated responses [79]. The information gap has led to a situation in which the effectiveness of anti–trafficking policies and measures is difficult to determine effectively [79]. Countries are increasingly seeking to invest in evidence-based programs that demonstrate the ability to mitigate human trafficking [6]. Although there has been a recent increase in the number of human trafficking studies and initiatives to respond to trafficking in persons, unfortunately, there is still relatively little knowledge concerning the effectiveness of these efforts because their results have seldom been evaluated [6]. Program evaluation should cover not only law enforcement interventions but also regulatory approaches, prosecutorial techniques, collaborative approaches to crime investigation and prosecution, and the provision of services to victims.

The present lack of sufficient resources inhibits the development and deployment of initiatives that can inform and potentially transform the human trafficking landscape. Even so, the OR and analytics community is uniquely situated to succeed in such conditions, offering methods to most efficiently allocate scarce resources, or alternatively, to achieve desired outcomes with minimal expenditures. Moreover, such methods allow for follow-up analysis to better understand how changes to the model input affect the resulting output. In the next section, we illustrate ways in which OR and analytics can be leveraged in anti–human trafficking efforts.

4. Opportunities for OR and Analytics in Human Trafficking

While it stands to reason that OR and analytics can play a unique and effective role in counter-trafficking efforts, a number of practical challenges exist for OR and analytics practitioners in applying their techniques: the extent of the problem is unknown, traffickers dynamically adapt their deceptive techniques, data is fragmented and resources are limited. At the same time, these challenges present opportunities to advance OR and analytical methodologies and there are many possibilities for members of this community to apply their skills to counter human trafficking. In what follows, we suggest a number of open opportunities to do so.

4.1 Opportunities for OR and Analytics to Address *Hidden Victims*

Human trafficking victims typically belong to vulnerable populations. A number of anti–trafficking initiatives aim to prevent trafficking through public awareness and educational campaigns designed to convey the gravity of human trafficking to potential victims. 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 analytical technique used to achieve exposure and awareness while conserving limited resources. The goal of this activity is to determine the right amounts of investment in various media to ensure that specific exposure targets are hit while minimizing cost outlays. Trafficking awareness initiatives often contend with this very problem. Various platforms are used for public awareness campaigns, including radio, television, billboards, and social media[1]. An important concern can be wearout, where the effectiveness of an advertisement generally decreases with increasing exposure to the same subjects [98, 127]. Furthermore, human trafficking often begins with fraudulent labor recruitment methods that traffickers are adept at adjusting; thus, a key question in media planning for anti–trafficking campaigns is how and when to change to remain effective.

There is potential for analytics practitioners to leverage the structures and information embedded in social networks in media campaigns targeting human trafficking prevention. Analyzing the social networks of at-risk persons, such as Facebook and Twitter, can help to determine which contacts have a critical influence over others [80]. Such an analysis enables the prediction of those network nodes and paths that may enable early identification of victims, or those that are expected to have the highest likelihood of propagating critical information flow, for example, messages that can serve to reduce vulnerability.

Effectively prosecuting alleged traffickers in a reasonable timeframe is also important for anti–trafficking initiatives. Given the depth of physical and psychological trauma associated with trafficked victims, coupled with threats against victims and their families, lengthy delays in due process can lead victims to lose interest, misremember, or otherwise suppress key testimony that could help to convict guilty traffickers. Outside of the context of human trafficking crimes, a few studies have considered the waiting times of defendants in judicial court contexts [62, 116]. To the extent that insights from queuing can be leveraged in the processing of human trafficking cases (for example, proposing additional judges [servers]), there is an opportunity to positively affect the prosecution of human trafficking cases. System dynamics models can similarly be used to understand the influence of case flows and resource constraints on the prosecution's capacity to deter crime [74, 96, 114].

Quantitative approaches are lacking in the area of victim protection in terms of the effective detection and prosecution of traffickers. In contrast, over the past decade there has been an explosion of theoretical and algorithmic advancements in data analytics. There is potential for machine-learning and data-mining approaches to be applied for the collection of relevant and affordable evidence against traffickers.

4.2 Opportunities for OR and Analytics to Address *Covert Traffickers*

Traffickers' operations can be modeled as networks. For example, two of our authors collected information from intercepted trafficking victims in Nepal and analyzed data to identify high-risk recruitment districts, recruitment methods, routes, transportation methods, and safe houses used

[1]For the interested reader, the US Office to Monitor and Combat Trafficking in Persons provides examples of funded anti–trafficking public awareness campaigns at: http://www.state.gov/j/tip/rls/tiprpt/index.htm

along the routes. This information – along with phone records and online social media – were successfully used to identify trafficking networks and traffickers. Moreover, this information was used to intercept and recover other victims of trafficking, as well as to assist in trafficker prosecution. While traffickers want to conceal these network structures, they present an opportunity for OR and analytics practitioners to draw from a rich field of network-based analytical techniques.

Network analysis can be used to measure relationships in trafficking networks, as well as to identify means (individuals, groups, paths, etc.) to facilitate or block flow (monetary, communication, trafficking, etc.). Furthermore, network analysis enables the study of network behavior as nodes or the connections between them are severed [20]. In a network interdiction model, an evader typically operates on a network to optimize some objectives such as moving through the network as rapidly as possible (shortest path interdiction) [25], with as little probability of being detected as possible (most reliable path interdiction) [110], or to maximize the amount of goods transported through the network (network flow interdiction) [18]. At the same time, the interdictor has the ability to change certain structural parameters of the network, such as node or arc removal, thereby improving detection probabilities or altering arc capacities and optimally disrupting the evaders objective function [121]. Early work in network interdiction began with military applications, such as the disruption of the flow of enemy troops [59, 102]. Since then, it has been applied in areas like infectious disease control [21] and the interception of illegal contraband and narcotics [33, 97] and nuclear material [106]. In addition, recent advancements in the area of search games where a "mobile hider" may flee a search region, also can be applied to find traffickers [17].

While the fundamental ideas of network interdiction are applicable to human trafficking, it is important to note there are unique challenges. Unlike interdiction of drugs or weapons, trafficked humans are a "renewable commodity" [76]. That is, humans have an "advantage" to traffickers in that a person can be sold repeatedly, which is not the case for illicit consumables like drugs or ammunition [95]. Moreover, while in drug or weapons interdiction, there is little dispute as to whether the commodity is illicit, human "commodities" may not be able or willing to identify themselves as a victim of trafficking. Hence, human trafficking evidence may be more ambiguous, and interdictors are faced with the additional decision of whether to pursue prosecution, and if they decide to do so, they take on the burden of collecting evidence. An emerging idea in anti–trafficking research is to use biometric features, which are unique to individual victims (or traffickers) and difficult if not impossible to alter or fabricate, to identify trafficking network patterns.

It will be necessary to overcome some existing limitations of modern network interdiction theory for use in anti human trafficking. These include the ability to accommodate dynamic changes in data, a more robust handling of action sets and information symmetry assumptions, and allowance for multiple interdictors with varying interdiction mechanisms [121]. In light of these challenges, there appears to be ample room for cooperation between researchers in network analysis and interdiction together with anti–trafficking advocates to counter human trafficking. Another area that merits development is that not only are traffickers strategic agents, but victims could also be

considered strategic agents interacting with traffickers in an attempt to improve their economic situation. As such, techniques that typically treat events as chance will need to be re-visited and perhaps made more sophisticated.

The prevalence of social media for communicating trafficking activities naturally leads to applications of social media mining, a rapidly growing field at the intersection of computer and social sciences [134]. It attempts to elucidate the relationships between individuals embedded in social media networks by drawing on knowledge from the fields of information retrieval, machine learning, data and text mining, graph theory, and social network analysis. Data visualization tools can further depict the results of the analysis [58]. For instance, maps of trafficking hot spot locations or high-activity areas could help to identify trafficking patterns and recurrences of trafficking-related activities. Social media mining is one of the few areas for which concrete quantitative anti–trafficking studies have emerged [31, 47, 89]. The advent of big data analytics has provided many opportunities for OR and analytics practitioners to apply their skills to identify illicit trafficking activities. Currently there are a few software applications that have been developed extensively for law enforcement that mine and analyze escort ads on a few major web sites, such as Backpage. While these software applications are not substantively analytical, they are effective in providing investigators with real-time investigative leads.

Public areas of the Internet contain traces of human trafficking activity that can be found, for example, in publicly available escort service ads [123]. Advertisers use social networking, chat, dating, and community websites like Facebook, Twitter, Tinder, Instagram, or Humaniplex.com [47]. For researchers, these sites provide an affordable, abundant, and arguably underutilized source of valuable information. They can be leveraged to both quantify the prevalence of trafficking and to characterize the populations involved and their modes of operation. Beyond law enforcement's use of these sites identify and monitor suspicious activity and build evidence for prosecution, victim services organizations could employ them to identify, track, and recover victims in cooperation with local law enforcement.

The uncertainty of whether certain activities are in fact human trafficking is another difficulty in apprehending traffickers. Traffickers are aware that they are vulnerable to law enforcement as a result of online postings, and so adapt their tactics accordingly. With increased observation, the true dynamics of an online trafficking presence may become clearer; however, it may be challenging to determine when to act given the secretive nature of such illicit operations; the shifting, deceptive actions typically employed by traffickers; and the risk to health and life of the victims. The point at which an investigator may then intervene when tracking a potential victim or trafficker could be modeled as a variant of the secretary or stopping problem [55]. Here, the idea is to consecutively observe a sequence of possible choices with the aim of stopping at the right time. Advances in this direction will be of assistance in transitioning from the prevalent reactive law enforcement methods towards proactive strategies.

The rapid evolution of trafficking activities required to avoid detection presents yet another opportunity for OR and analytics practitioners. Tools such as spatial autocorrelation and space-time clustering analysis can help by enabling the prediction of temporal and spatial aspects of dynamic problems. These techniques have been successfully used to study epidemics [86], crime [48, 77], and terrorist activities [57], and may likewise be applicable to human trafficking. Traffickers take advantage of increased demand for commercial sexual exploitation during major sporting events and conventions [22, 133]. The transportation of victims surrounding such events presents an opportunity to conduct spatio-temporal analyses of online classified ads. The results could benefit law enforcement and policymakers to build a consensus as to where and when they should focus collective intervention efforts.

While 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 identifying trafficking activities. As the authors found, other data sources, such as mobile phone data, law enforcement records, and medical records, also hold promise.

4.3 Opportunities for OR and Analytics to Address *Fragmented Data*

The dispersion and fragmentation of data is perhaps one of the most challenging aspects of understanding and modeling human trafficking activities; missing, inaccurate, and false data only compound the complexity. Even so, analytics techniques may be able to help in addressing this challenge. Techniques like matrix completion [29, 83] have recently been developed to accurately predict missing entries in data matrices in applications such as recommender systems, text clustering, and Internet tomography. In the context of human trafficking, where the possibility of falsified data is all too real, such techniques may well be adapted to help identify where anomalies exist [94].

Effective intervention requires the integration of data from many sources to detect and track illicit activities. Technologies like neural networks, decision trees and other machine learning algorithms can be used to help uncover potential trafficking activities and related events across different distributed databases [122]. These data fusion techniques may serve to detect crimes and activities such as kidnapping, abuse, runaway minors, drug arrests, prostitution, petty theft, and pornography that are commonly associated with human trafficking [52].

A number of technologies are able to automatically compile and correlate data automatically from disconnected (yet open) Internet sources (for example, link analysis, information retrieval and integration, and natural language processing). Rules can be extracted from structured, semi-structured, or unstructured data to uncover new patterns that may assist in victim protection. For example, it is possible to begin linking specific online postings to individuals and different locations through the analysis of their syntax and semantics. As traffickers move victims from city to city, the routes and locations can be mapped, possibly revealing an organized network or trafficking ring; in [75] in authors used network analysis to examine online classified ads for adult services to identify

trafficking circuits. Advertisements containing photos may contain geocoded data or other information that could assist in identifying the location. Such information can be very valuable to law enforcement in uncovering and investigating an organized trafficking network. In another example, the authors in [47] highlighted the classification methods that use these rich, publicly available data sources to gain valuable information concerning trafficker behavior, prevalence, and trends.

Given the limited and disjointed data associated with traffickers and victims alike, prosecutors are trying to use biometric data to obtain desperately needed evidence. These data include individuals' fingerprints, DNA profiles, iris scans, and other "hard" physical markers and features. Similarly, "soft" forensic evidence, which refers to the modus operandi and the temporal and geographical features of the crime, can also provide the basis of crime matching [108]. For instance, law enforcement has linked unusual records related to petty theft of basic necessities (toiletries, etc.) to trafficked victims. Linking biometric and "soft" forensic evidence presents an excellent opportunity to strengthen 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 may be required to obtain key salient attributes.

Interagency cooperation among different responding entities, such as border patrols and victim services, represents a critical component in effective anti–trafficking operations. Cooperative game theory models identify methods for partnering agencies to achieve greater effectiveness than what is possible when operating independently; such models also guide agencies on how to select and develop relationships to improve resource utilization and project outcomes. Game theoretical approaches for interagency operations have been illustrative in the humanitarian logistics literature [36, 37, 68, 105]. We also think it noteworthy that there is a parallel between the competitive funding atmosphere of anti–trafficking initiatives and vaccine-pricing models for developing countries. The authors of [111] suggest that a third player, such as the World Health Organization, can 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 of maximizing 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 OR and analytics community is well equipped to illustrate the positive (or potentially negative) effect of partnerships to the larger anti–trafficking community.

Some positive developments have occurred with respect to information sharing to support anti–trafficking initiatives via analytics. One noteworthy example involves the Polaris Project, which seeks to connect disparate data sources across the world through the Global Human Trafficking Hotline Network [10]. This network enables information sharing between human trafficking advocacy groups so that internationally trafficked victims have a greater chance of being identified

and assisted. A winner of a Google Impact Award, the Polaris Project's data-driven approach uses software from Palantir and Salesforce.com to aggregate disparate data from existing anti–trafficking hotlines worldwide, thereby enabling victim mapping and empowering identification [9].

4.4 Opportunities for OR and Analytics to Address *Limited Resources*

The heart of many problems in the OR and analytics community is the need to effectively allocate scarce resources appropriately. There is no shortage of human trafficking challenges that require analysis and understanding to answer questions surrounding how to best allocate limited resources.

The deployment of scarce manpower resources is directly illustrated in the problem of inspection scheduling. The apparel, food, and other manufacturing industries are known to exploit child and sweatshop labor [23, 112]. An effective method to curb exploitation is through inspection and certification programs, whether via governmental or more organic movements, such as GoodWeave and Fair Trade. All of these programs all require inspections to ensure that suppliers and manufacturers adhere to certain standards [112]; however, the availability of the human resources required to conduct in-person inspections is frequently insufficient. For example, Bangladesh, a country with numerous reports of exploitative labor practices, has just over 100 labor inspectors for 75 million workers. Scheduling these inspections presents an opportunity for the OR and analytics community. Thus, the question arises of how to optimally deploy scarce inspection resources, which bears similarities to existing problems in the literature such as the sensor location problem [27, 101] and the generalized assignment problem (e.g., assigning workers to suspected sites) [32, 113]. The inspection problem could also be examined through profiling methods to select high-risk workers or locations for inspection as in [73]. In a similar vein, Seidl et al. (2016) consider how a government should optimally employ undercover agents to fight terror [117] . This work could be extended to account for how manufacturers and suppliers may adapt their behavior in response to increased – or more efficient – labor inspection. Wang and Zhuang (2011) make a similar observation in stating that future development is required to account for potential threats employing deception techniques to evade screening [130].

The inspector deployment and similar assignment problems can be modeled as a (possibly mixed) 0–1 integer program, and for such problems, there are opportunities to extend existing approaches (see, e.g., [126]) to present a decision maker with attractive alternative solutions. Moreover, in many cases, an optimal solution cannot be implemented immediately, as it represents too much organizational disruption from the status quo or is cost-prohibitive - for example, inspectors may need to learn a new regional language or culture or may confront temporary barriers to travel to a particular region. Conventional optimization approaches are not designed to illustrate feasible paths toward a global optimum. Thus, there is an opportunity to address the inspection deployment and related human trafficking problems by further developing techniques that generate an improving succession of solutions that progressively optimize change from the status quo [125].

Techniques used in disaster preparedness could also be adapted to assist governments and agencies to allocate limited funds for anti–trafficking. On the surface, balancing an organization's budget among prevention and protection efforts, has some parallels to balancing pre-and postdisaster preparedness, as described in [69]. Like those related to human trafficking, disaster-preparedness approaches need to manage the uncertainty in disaster management data, as well as assessing intangible costs [69]. However, as trafficking is an ongoing event and disaster-management modeling approaches typically consider a single event, techniques developed for this application area will likely have to be extended to the case over time. Similarly, models addressing fund allocation for terrorism defense could be used to allocate human trafficking prevention funds or interdiction funds against an unknown adversary. In [118], a game-theoretic hybrid model is used to allocate defensive resources among multiple potential terrorist targets to minimize expected loss caused by an unknown adversary, who could be either strategic or non-strategic.

In the area of victim services, 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 like legal advocacy, mental health support, and skills training. There has been a great deal of work in OR and analytics in the general area of facility location; a few of which have investigated shelter location with respect to natural disasters, although we are not aware of any shelter location studies in relation to trafficking victims [84, 91, 92]. For general coverage on the topic of facility location, we refer the interested reader to [40].

Some unique facets come into play when selecting shelters for survivors of human trafficking. Apart from the obvious factors of costs and capacities, it is important to consider the geographic proximities of potential locations to victims. The locations of shelters should be undisclosed and private to offer survivors tranquility and protection from retribution by the trafficker as well as follow-up recruitment. Thus, the proximity of the shelter to the expected future victims should be balanced with the need for victim protection. There are rich ethical and security considerations in this context, for example, in terms of how tradeoffs among constraints and conflicting objective functions should be handled in these models.

Even in light of the extremely limited economic resources allocated to anti–human trafficking worldwide, a critical challenge for agencies and governments that do acquire such funding is the evaluation of its effectiveness. However, the anti–trafficking community largely lacks the techniques to do this [12]. Given the scarce resources, many programs and donors are not in a position to divert resources away from direct services for victims of trafficking to conduct formal program evaluation [8]. The 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; those that can justify their performance form the best-practice frontier. DEA has

been used in a wide variety of applications, including public sector areas such as schools [28, 66], transportation [39], and healthcare [46].

DEA can be used to benchmark efficient and best-practice organizations. Moreover, it may be possible to consider various sub-affiliates of NGOs or other governmental offices as DMUs. Such program evaluation should include not only law enforcement interventions but also regulatory approaches, prosecutorial techniques, collaborative approaches to crime investigation and prosecution, and the provision of services to victims. While the evaluation of such affiliates may be both revealing and potentially challenging, it could pave the way for improvement of those DMUs falling outside of the best-practice frontier and potentially even their reform.

One area in which OR and analytics have made inroads is in the analysis of policy and intervention effectiveness of illicit narcotics markets. Production functions have been used to consider whether drug enforcement ("supply side") or drug treatment ("demand side") policies are more likely to reduce cocaine consumption [115]. Likewise, optimization has been used to determine whether "zero tolerance" sentencing policies are effective in reducing illicit drug consumption [33], and optimal control has been used to examine how the portfolio of drug prevention and treatment programs should be balanced over time [26]. A system dynamics model of national cocaine prevalence examined the potential impact of a relaxation of drug law enforcement [72], while agent-based simulations have examined how street-level drug markets adapt to differences in law enforcement strategies [45]. Such approaches would have to be extended to consider that ambiguous evidence of the " illicit commodity", and that the commodity (a human being) is renewable (as discussed in Section 4.2). With respect to evaluating anti human trafficking policies, we are aware of only one study, namely a system dynamics simulation model used to provide insights related to the effects of proposed policies to combat human trafficking in Holland [87]. In this work, the authors conclude that the topic is so complex and uncertain that simple (combinations of) basic policies will not hold in all circumstances, and it requires further exploration and policy testing under deep uncertainty.

The operations research and analytics community is in a unique position to increase the effectiveness of counter-trafficking initiatives by providing decision-support for resource allocation, policy evaluation and performance measurement.

4.5 Illustrative Examples

In this section, we provide two focused examples to give the reader a sense of how OR techniques can be adapted to address problems in human trafficking. These are illustrative in nature, and their detailed modeling is outside of the scope of the paper. We first demonstrate the applicability of optimization in a survivor shelter location problem and then outline how system dynamics could shed light on the implications of illegal fishing for labor trafficking.

Illustrative Example 1: Shelter location for intercepted victims

Although only a small percentage of trafficking survivors presently benefit from group rehabilitative shelters, these facilities are an important component of protection and prosecution efforts of anti-

trafficking organizations [2]. Facility location has a long and rich history in OR and analytics; however, several characteristics of rehabilitative facilities for trafficking survivors necessitate a different modeling perspective and the potential development of new techniques. Figure 1 supports our discussion. It contains data from trafficking victims intercepted by an anti–trafficking agency in Nepal in 2014; the circles represent the density of victim sourcing, indicating where the victims originated, while the straight lines link the points of intercept of the victims with their origins. For successful rehabilitation, shelters also need to be linked to a network of services such as education, psycho-social care, legal advocacy, medical treatment, and life-skills training. As it is impossible to anticipate all of the rehabilitative needs of survivors, as well as to determine in advance whether these services should be outsourced or provided within the shelter itself, locating a shelter in close proximity to services is important. However, this needs to be balanced with survivor security, threats of retaliation from traffickers, and the real possibility of survivor recidivism. A further consideration is survivors' reintegration with their community or family. Yet, as seen in Figure 1, the interception locations and urban areas offering access to rehabilitative services are located far from survivors' communities, thereby making transportation costs an important factor in the decision-making process. While approaches have been developed to model the discrete location problem with push-pull objectives [88], such techniques must accommodate more humane measures like family proximity considerations, service accessibility, uncertainty in demand for ancillary services, and demand for the facility itself.

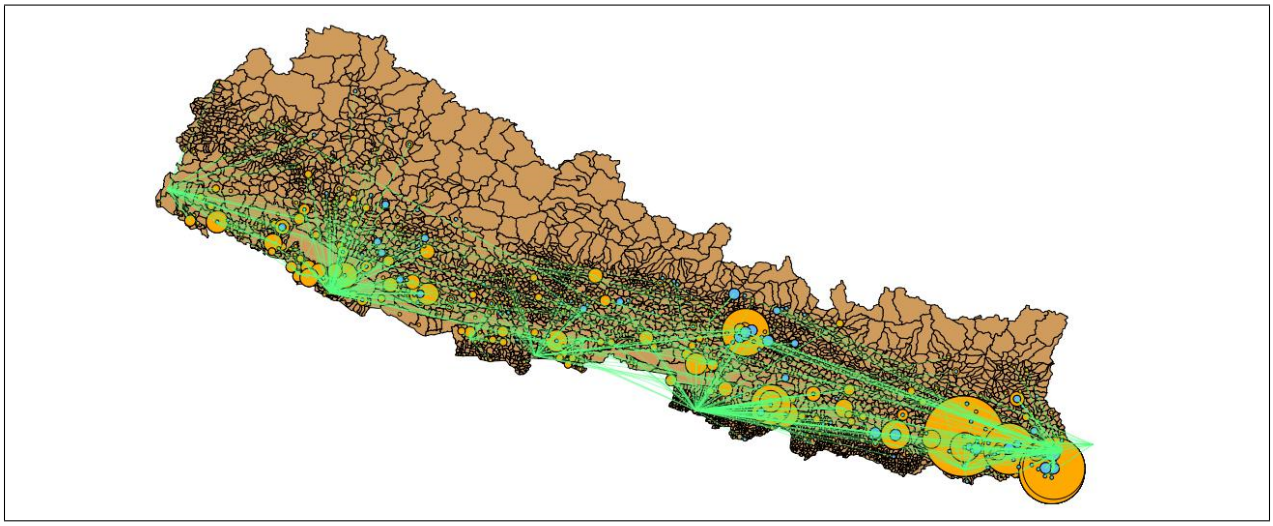

Figure 1: Interception victims of trafficking in Nepal 2014. Source: authors' data

Illustrative Example 2: Examination of the intersection between forced labor and illegal, unreported, and unregulated (IUU) fishing

A growing body of evidence has documented forced labor on deep sea fishing vessels occurring concurrently with illegal, unreported, and unregulated (IUU) fishing. As worldwide fish stocks deplete, fishing vessels push farther out to sea for longer periods of time. Such a situation heightens the vulnerabilities of the largely migrant crew members, as labor inspections rarely occur at sea,

the working conditions are dangerous, and the living conditions are frequently unsanitary [14]. Survivors of labor trafficking on fishing vessels have acknowledged that many of the vessels operate with illegal fishing practices that contribute to resource depletion and species endangerment [14]. Such evidence has prompted the international advocacy community to increase pressure on governments and private sector stakeholders to address labor trafficking in the commercial fishing sector, as well as illegal fishing practices [99]. For example, the Command Center for Combatting Illegal Fishing was established in Thailand in 2015 to coordinate interagency efforts to counter illegal, unreported and unregulated fishing, forced labor and trafficking in persons in the fishery sector.

Labor trafficking, environmental sustainability, aquaculture, and socio-economic development interact interdependently, and form a large system that has complex, dynamic, diverse and nonlinear characteristics. System dynamics (SD) provides a theory of system structure and an approach for representing complex systems and analyzing its dynamic behaviors [54].

4.6 Summary of the Opportunities for OR and Analytics to Counter Human Trafficking

Although human trafficking is among the top societal concerns globally [12, 14], and a wealth of OR and analytics techniques are available, little evidence exists to demonstrate that these techniques are being successfully applied to counter this type of crime. In Sections 3 and 4 we have highlighted challenges encountered in anti-trafficking efforts, as well as opportunities for the OR and analytics community to respond to such challenges. In Table 1, we summarize these ideas. For the sake of brevity, we note that the examples in this paper, while are illustrative, are not intended to be exhaustive.

Table 1: Highlighting Opportunities for the Operations Research (OR) and Analytics Community for Key Challenges in Anti–Human Trafficking; • (○) Indicate Primary (Secondary) Challenge that Opportunity Addresses.

	Key Human Trafficking Challenges			
OR and Analytics Opportunities	Hidden Victims	Covert Traffickers	Fragmented Data	Limited Resources
Criminal Profiling		•	○	
Interagency Information Sharing			•	
Interoperability				•
Judicial System	•			○
Media Planning	•			○
Network Interdiction		•		○
Performance Measurement (DEA)	○		○	•
Policy Evaluation			○	•
Predicting HT Locations or Activities		•		
Shelter Location	○			•
Social Media Analysis		•	○	
Supply Chain Inspection		○		•

This paper is also intended to raise awareness concerning the techniques OR and analytics practitioners can offer among anti–trafficking researchers. As such, in Table 2 we summarize how the techniques we presented address the 4P paradigm (see Section 2.3), a well-recognized classification within the anti–trafficking community.

Table 2: Relationship Between Operations Research (OR) and Analytics Opportunities and the 4P Classification System; • Indicate Which 4P Para Addresses.

	4P Paradigm			
OR and Analytics Opportunities	Prevention	Protection	Prosecution	Partnership
Criminal Profiling			•	
Interagency Information Sharing				•
Interoperability				•
Judicial System			•	
Media Planning	•			
Network Interdiction		•		
Performance Measurement (DEA)	•			
Policy Evaluation			•	
Predicting HT Locations or Activities	•	•		
Shelter Location		•		
Social Media Analysis	•	•		
Supply Chain Inspection	•			

4.7 Where to Start

Measures to counter human trafficking are present in many disciplines. Consequently, the data and modeling efforts to support research in this area appears in a wide variety of academic journals, media outlets, and governmental reports. Readers who would like more information on human trafficking in general should consult A, which provides a selected list of organizations and information resources on the Internet. For example, the Global Slavery Index [13] can be readily downloaded from the 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. Most of the sources listed, particularly those in Appendix A.4, provide data related to the scope, incidence and anti–trafficking efforts worldwide. We list a wide variety of outlets to encourage interdisciplinary research in this area.

5. Conclusions and Perspectives

Over the past two decades, human trafficking has generated an increasing amount of public attention throughout the world [131]. The problem has received growing coverage in the media, anti–trafficking activism has risen, and most countries have created new policies, laws, and enforcement mechanisms to counter the problem [131]. Despite this recognition, however, there is a shortage of the application of technical solutions related to analysis, making impact assessments,

and assessing decisions related to human trafficking. OR and similar analytical techniques have a unique potential to have a powerful effect in efforts against human trafficking.

Our intention in this paper was to shed light on issues to related to human trafficking for OR and analytics professionals. We summarize many of the key characteristics that are unique to the trafficking of humans and presented several particular challenges that quantitative researchers face. We then suggest a variety of ways in which techniques from the OR and analytics communities, broadly speaking, can be leveraged to counter human trafficking. An appendix is included to facilitate inroads for any interested parties.

In the spirit of "Doing Good with Good OR," we think that the opportunity exists for the OR and analytics community to support and strengthen existing anti-trafficking efforts. Our hope is that this paper offers key insights into the current range of applications of OR and analytics to anti–human trafficking efforts and provides ideas about where methods may be further developed and applied to benefit this sector. While we have presented a number of ideas, we think there are many more waiting to be discovered. We call on the OR and analytics community to make an impact in this area.

A. Appendix: Human Trafficking Resources

The following is a list of relevant resources concerning human trafficking. Our intention is not to promote any one entity or to be exhaustive in nature, but simply to supply some starting points for interested researchers.

A.1 Human Trafficking Journals

- Journal of Human Trafficking
- Slavery Today: A Multidisciplinary Journal of Human Trafficking Solutions
- Anti-Trafficking Review
- The International Journal of Children's Rights

A.2 Research Centers

- Center for Combating Human Trafficking
  `http://combatinghumantrafficking.org`
- Center for Forensic Investigations of Trafficking in Persons
  `http://www.newhaven.edu/lee-college/institutes/center-for-forensic-investigations-of-trafficking-in-persons`
- Fight Global Human Trafficking
  `http://www.fight-human-trafficking.org`
- The Technology and Human Trafficking Initiative
  `https://technologyandtrafficking.usc.edu`

A.3 Organizations and Agencies

- Awareness Against Human Trafficking (HAART)
  `http://haartkenya.org`
- Coalition to Abolish Slavery & Trafficking (CAST)
  `http://www.castla.org`
- End Child Prostitution, Child Pornography and Trafficking of Children for Sexual Purposes (ECPAT)
  `http://www.ecpat.net`
- European NGOs Platform Against Trafficking, Exploitation and Slavery
  `http://enpates.org`
- Free the Slaves
  `http://www.freetheslaves.net`
- Global Sentry Group
  `http://www.globalsentrygroup.org`
- HEAL Trafficking
  `https://healtrafficking.wordpress.com`
- International Justice Mission
  `www.ijm.org`
- International Labor Organization
  `http://www.ilo.org`
- International Organization for Migration, Counter-Trafficking
  `https://www.iom.int/counter-trafficking`
- La Strada International
  `http://www.lastradainternational.org`
- Liberty Asia
  `http://www.libertyasia.org`
- Office of The United Nations High Commissioner for Human Rights
  `http://www.ohchr.org`
- The Organization for Security and Co-operation in Europe
  `http://www.osce.org`
- The Polaris Project
  `http://www.polarisproject.org`
- United Nations Global Initiative to Fight Human Trafficking
  `http://www.ungift.org`

A.4 Reports, Guides & Directories

- Characteristics of Suspected Human Trafficking Incidents

- Global Report on Trafficking in Persons (issued annually)
- Global Slavery Index (issued annually)
- Report of the Task Force on Trafficking of Women and Girls
- Shelley, Louise. *Human trafficking: A global perspective.* Cambridge University Press, 2010
- The Trafficking in Persons (TIP) Report(issued annually)

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