



Estimating the Prevalence of Child Sex Trafficking in Maharashtra, India

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Acronyms

CAPI	Computer Assisted Personal Interviewing
GFEMS	Global Fund to End Modern Slavery
IST	IST Research
CST	Child Sex Trafficking
IJM	International Justice Mission
Gol	Government of India
MCMC	Markov chain Monte Carlo
NGO	Nongovernmental Organization
NSUM	Network Scale-Up Method
POCSO	Protection of Children from Sexual Offences
RDD	Random Digit Dialing
RDS	Respondent-Driven Sampling
TIP Office	Office to Monitor and Combat Trafficking in Persons
TLS	Time-Location Sampling
UCLA	University of California, Los Angeles

Executive Summary

Estimating the prevalence of child sex trafficking (CST) is a critical first step for comprehensively addressing the problem. Information on the size of this key population provides national government agencies, non-profit organizations, and other key stakeholders with an estimate of the scale and scope of the problem to inform protective and preventive measures. Such estimates also allow leaders to advocate for resources for CST victims. However, reliably estimating the size of this population has historically been extraordinarily challenging because victims are hidden by design. Further, it is often impossible to survey this population through traditional enumeration methods due to ethical and legal guidelines for interviewing children who are victims of sexual exploitation.

In addition, the COVID-19 pandemic has severely constrained survey research operations for many organizations. It has reduced situational awareness and made field-based population engagements and program monitoring efforts extremely challenging and more costly, if not impossible. Amid the current environment—characterized by restrictions that reduce access to a traditional geographic sampling frame—standard survey approaches are at great risk of inducing unpredictable sampling error, coverage error, systematic non-response, and even measurement error.

In 2020, IST Research, in collaboration with the University of California, Los Angeles (UCLA), and with funding from the Global Fund to End Modern Slavery (GFEMS) via the U.S. Department of State’s Office to Monitor and Combat Trafficking in Persons, used a hybrid methodological approach to address the important challenge of estimating the number of CST victims in Maharashtra, India. This hybrid method, which uses the Network Scale-Up Method (NSUM) and Respondent-Driven Sampling (RDS), allowed researchers to obtain a point estimate of the size of the CST population using a general population survey and triangulate this estimate using targeted surveys of adult sex workers.¹ This approach enhanced the ability of the research team to validate the findings drawn from each method, identify potential biases that may have otherwise been challenging to review or discuss, and provide more substantive inferences and conclusions regarding the overall commercial sex environment in Maharashtra.

¹ The authors recognize that as part of what they refer to as sex work, there are situations in which people engaged in this industry are doing so against their will or are doing so for reasons related to personal or economic vulnerability. For the purposes of this study, sex trafficking is focused exclusively on individuals in the industry under 18 years of age, in alignment with the definition of sex trafficking outlined in the Trafficking Victims Protection Act (TVPA).

All population engagement in this study took place remotely via telephone or smartphone. IST Research's remote engagement experience, combined with pre-pandemic sampling frame data provided by local partners, proved vital in enabling rigorous and rapid data collection amid India's national lockdown. IST's findings indicate that there were approximately 29,000 sex workers in Maharashtra in early 2020 (95% Confidence Interval [CI]: 14,000, 52,000). Among this population, roughly 7,900 (approximately 27.2%) are under the age of 18 (95% CI: 2,600, 15,000). IST used data triangulation with response data collected via RDS surveys of adult sex workers in Maharashtra that indicate that roughly 30% of adult sex workers enter the commercial sex industry while underage. However, IST also found that fewer than 10% of adult sex workers admitted to knowing a CST victim, possibly out of fear of legal repercussions or due to the existence and expansion of separate, isolated communities within the commercial sex industry.

As part of the study, the research team also inquired on buyer behavior to further triangulate data. IST estimates indicate approximately 35,000 local buyers of the commercial sex industry in 2019 in Maharashtra (95% CI: 22,000, 54,000). Among these buyers, approximately 7,300 (21%) paid to have sex with children between the ages of 15 and 17 (95% CI: 3,700, 12,000) and approximately 1,700 (5%) paid to have sex with someone 14 years old or younger (95% CI: 500, 3,200).

It is important to note that point estimates may underestimate the overall size of the commercial sex industry in Maharashtra. Potential transmission bias—an individual's lack of awareness or reluctance to acknowledge their contact's affiliation with the sex industry—and response biases due to the stigma of sex commerce and the legal implications of being connected to CST may affect results. These limitations and associated mitigations are discussed at length within the body of this report.

As a result of the COVID-19 pandemic, statewide prevalence rates of both sex work and CST may be significantly different (and continue to evolve) from pre-COVID estimates. As part of this study, IST surveyed sex workers about the effects of the pandemic on the commercial sex trade. Five percent stated they knew someone who had entered the industry due to the COVID-19 pandemic compared to 41% who knew at least one individual who had exited the industry due to the pandemic.

The findings from this study will be remeasured in 2022 to assess trends over time in Maharashtra. This initiation of trend analysis is critical for the modern slavery field to

understand the trajectory of CST in specific geographies, enabling it to comment on the potential collective effect of anti-CST interventions in the state.

The results of the study use several data points and methods to quantitatively examine the scale of child involvement in the commercial sex industry in Maharashtra. Taken together, the results suggest the involvement of child sex trafficking victims in the industry is notable, indicating a need for multidimensional approaches to reduce the victimization of minors in the state.

Introduction

According to the US Department of State, India is a significant source, destination, and transit country for sex trafficking, and most victims are obtained from the most disadvantaged social strata.² While India's trafficking issue is mostly internal, its victims include women and children from Nepal, Bangladesh, and the broader Eurasian-African region.³

Sex trafficking in India may stem from multiple factors, including:

- poverty,
- sociocultural practices, and
- sex tourism.⁴

Poverty is a critical driver because it limits opportunities that would otherwise reduce an individual's vulnerability. Victims in search of options to escape their conditions often fall prey to the snares of traffickers under the promise of a better life. Increased commercial sex demand has also given traffickers reason to continue illicit activities with hopes of substantial profit. Civil strife, regional unrest, and health crises—including the COVID-19 pandemic—exacerbate trafficking factors while the most vulnerable individuals of a population search for means to escape their predicaments and/or obtain a stable income by whatever means are available.

How traffickers acquire their targets vary. The Government of India's (Gol's) Ministry of Women and Child Development notes that "most victims are trafficked through means like duping, luring, fake marriages, abduction, kidnapping and through manipulation of social and economic vulnerabilities."⁵ However, this manipulation is not limited to physical spaces. Digital solicitation has increased significantly over the last few years in tandem with internet and mobile technology in India's rural areas.⁶ According to Nirnay John Chettri, president of Mankind in Action for Rural Growth,

² US Department of State. (2019). *India: 2019 trafficking in persons report*. <https://www.state.gov/reports/2019-trafficking-in-persons-report-2/india/>

³ Ibid.

⁴ Deb, H. & Sanyal, T. (2017). Human trafficking: An overview with special emphasis on India and West Bengal. *Journal of Humanities and Social Science*, 22(9), 76–97. <https://doi.org/10.9790/0837-2209057697>

⁵ Ministry of Women and Child Development. (2017) *Annual report 2016–2017*. https://wcd.nic.in/sites/default/files/FINAL%20WCD_AR_English%202016-17.pdf

⁶ Shekhar, S. (2017, April 23). Sex traffickers using social media to prey on victims. *India Today*. <https://www.indiatoday.in/mail-today/story/human-trafficking-social-media-women-minors-modern-slaves-973008-2017-04-23>

With the increase in mobile connectivity, cases of human trafficking have shot up drastically in the hills [of India]. Earlier, these traffickers used to visit the villages and meet parents to convince them to take their kids to metro cities. But now with Facebook and WhatsApp, we don't know who we are chasing.⁷

In 2019, internet and social media use in India rose 23% and 48%, respectively,⁸ increasing opportunities for buyers to exploit digital spaces. The expanding options for buyers in these markets, along with the persistence of traditional venues, necessitate effective counter-trafficking methods, regardless of origin, and powerful legislation to prosecute offenders.

Developing a comprehensive counter-trafficking effort requires an understanding of the size or prevalence of the victimized populations. Multiple measurements help identify trends over time that can improve the targeting and implementation of interventions, comment on the potential effectiveness of counter-trafficking programs (where appropriate), and provide vital information to decision-makers seeking to best allocate resources to ensure that counter-trafficking programs have a significant and lasting positive impact. However, population-level prevalence estimates involving sex trafficking can be rife with issues. From a process perspective, lack of access and connectivity may limit the reach of some studies while legal and ethical elements can limit investigations into trafficking that includes minors. The clandestine nature of human trafficking further complicates estimation, as can victims' reluctance to participate.⁹ The associated stigma and penalties levied on victims who are coerced into committing illegal acts may seem to outweigh the benefits of self-identification.

While challenging, prevalence estimates of this nature are feasible using indirect estimation approaches such as the Network Scale-up Method (NSUM) and surveys over adjacent but "close" populations using Respondent-Driven Sampling (RDS). This study leverages both approaches to determine the prevalence of child sex trafficking (CST) in Maharashtra, India, in support of counter-trafficking initiatives.

⁷ Shekhar, S. (2017, April 23). Sex traffickers using social media to prey on victims. *India Today*.

⁸ We Are Social. (2020). *Digital in 2020: India*. <https://datareportal.com/reports/digital-2020-india>

⁹ US Department of State. (2019). *India: 2019 trafficking in persons report*. <https://www.state.gov/reports/2019-trafficking-in-persons-report-2/india/>; Ministry of Women and Child Development. (2017) *Annual report 2016–2017*. https://wcd.nic.in/sites/default/files/FINAL%20WCD_AR_English%202016-17.pdf

Review of Existing Research

Prevalence Studies of Sex Trafficking in India

Global Slavery Index data from 2018 ranks India 57th of 167 countries for overall modern slavery, estimating that 6 out of every 1,000 Indians allegedly live in modern slavery while over half the population (55%) is vulnerable to exploitation.¹⁰

Unfortunately, the Global Slavery Index does not define the scope of CST in these findings and limited CST prevalence estimation research exists in the literature.

However, several studies investigated India's commercial sex industry and adjacent topics such as child labor trafficking.

Das and Mishra investigated the prevalence of child labor trafficking using household surveys over two districts in Bihar,¹¹ finding that 7.7% of children in their sample had been trafficked. Bau, Rotemberg, Shah and Steinberg¹² showed that 9% of children aged 5-17 report work (instead of school) as their primary activity in rural India using household level data from the National Sample Survey.

Further, several studies exist concerning the prevalence of India's commercial sex industry. A 2001 study across Mumbai, Thane, Pune, and Sangli found prevalence rates of adult sex workers as a proportion of all adult women in these cities to be 0.5%, 0.4%, 0.4%, and 0.2%, respectively.¹³ Many have investigated the relationship between this industry and phenomena such as HIV, using RDS to estimate the size of these hidden populations as well as correlations with several public health issues.¹⁴ Earausquin, Reed, and Blankenship used RDS in 2009–2010 to examine the connections between

¹⁰ The Global Slavery Index. (2018). *India*. <https://www.globallslaveryindex.org/2018/data/country-data/india/>

¹¹ Das, M., & Mishra, S. (2011). *Stolen Childhoods: A Study of Child Trafficking in the Kosi Region of Bihar*. [eBook edition]. Save the Children India. <https://resourcecentre.savethechildren.net/node/5464/pdf/5464.pdf>

¹² Bau, N., Rotemberg, M., Shah, M., & Steinberg, B. (2020). Human Capital Investment in the Presence of Child Labor. NBER Working Paper 27241. <https://www.nber.org/papers/w27241>.

¹³ Family Health International. Mapping of commercial sex access points and relevant service outlets in Maharashtra, 2001.

https://childhub.org/system/tdf/library/attachments/fhi_2001_mapping_of_sex_access_in_maharashtra_may_04_1.pdf

¹⁴ Armstrong, G., Humtsoe, C., & Kermodé, M. (2011). HIV risk behaviours among injecting drug users in Northeast India following scale-up of a targeted HIV prevention programme. *BMC Public Health*, 11(6), S9.

<https://doi.org/10.1186/1471-2458-11-S6-S9>

specific policing behaviors and HIV prevalence among sex workers in Andhra Pradesh.¹⁵

Additionally, a number of studies exist concerning the rate of underage entry into the commercial sex industry in India. Erausquin, Reed, and Blankenship's study also investigated the age of entry among their respondents from Andhra Pradesh, with approximately 20% stating that they entered commercial sex under the age of 18. Gupta et al. also used RDS to survey sex workers in Andhra Pradesh, finding that roughly 15% of survey participants entered the industry under the age of 18 in 2006.¹⁶ Sampling from 27 different geographies, Mukherjee and Mukherjee found that 36% of surveyed sex workers entered commercial sex under the age of 18.¹⁷

IST was not able to find a prior statewide study of Maharashtra after 2001, but other studies within the state have produced a range of findings over time. Historical data from 1993–2002 in Pune indicated that 43% of sex workers screened for sexually transmitted diseases at participating clinics entered the industry under the age of 16.¹⁸ A study in Mumbai based on a convenience sample of HIV-positive sex workers in 2008–2009 found that 50% entered the industry under the age of 18.¹⁹ A study conducted using two-stage cluster sampling and TLS across Maharashtra, Andhra Pradesh, and Tamil Nadu in 2009–2010 found that 16% of sex workers entered the industry while under 20 years old.²⁰ Silverman et al. used survey data from 2008–2009 that targeted a subset of sex workers in Mumbai who were HIV positive, finding that 50% had entered the commercial sex industry under the age of 18.²¹ Perhaps most

¹⁵ Erausquin, J. T., Reed, E., & Blankenship, K. M. (2011). Police-related experiences and HIV risk among female sex workers in Andhra Pradesh, India. *Journal of Infectious Diseases*, 204(suppl 5): S1223–S1228.

<https://doi.org/10.1093/infdis/jir539>

¹⁶ Gupta, J., Reed, E., Kershaw, T., & Blankenship, K. M. (2011). History of sex trafficking, recent experiences of violence, and HIV vulnerability among female sex workers in coastal Andhra Pradesh, India. *International Journal of Gynecology and Obstetrics*, 114(2), 101–105. <https://doi.org/10.1016/j.ijgo.2011.03.005>

¹⁷ Mukherjee, K. K., & Mukherjee, S. S. (2004). *Girls/women in prostitution in India. A national study*. Gram Niyojan Kendra.

¹⁸ Brahme R, Mehta S, Sahay S, et al. (2006). Correlates and trend of HIV prevalence among female sex workers attending sexually transmitted disease clinics in Pune, India (1993–2002). *Journal of Acquired Immune Deficiency Syndromes*, 41(1):107–113.

¹⁹ Silverman, J. G., N. Saggurti, Cheng, D. M., Decker, M. R., Coleman, S. M., Bridden, C., Pardeshi, M., Dasgupta, A., Samet, J. & Raj, A. (2013). Associations of sex trafficking history with recent sexual risk among HIV Infected FSWs in India. *AIDS and Behavior*, 18(3), 555–561. <http://doi.org/10.1007/s10461-013-0564-3>

²⁰ Yadav, D., S. Ramanathan, P. Goswami, P., Ramakrishnan, L., Saggurti, N., Sen, S., George, B., & Paranjape, R. (2013). Role of community group exposure in reducing sexually transmitted infection related risk among female sex workers in India. *PloS one*, 8(10). <https://doi.org/10.1371/journal.pone.0078361>

²¹ Silverman, J. G., N. Saggurti, Cheng, D. M., Decker, M. R., Coleman, S. M., Bridden, C., Pardeshi, M., Dasgupta, A., Samet, J. & Raj, A. (2013). Associations of sex trafficking history with recent sexual risk among HIV Infected FSWs in India. *AIDS and Behavior*, 18(3), 555–561. <http://doi.org/10.1007/s10461-013-0564-3>

recently and most closely related to this study is International Justice Mission’s (IJM’s) commercial sexual exploitation of children study in Mumbai,²² which relied on venue-based approaches for collecting and engaging with these victims.

IJM found that 15% of surveyed public establishments in Mumbai had CST victims available. They found that the prevalence rate of CST victims as a proportion of all sex workers in these public establishments was approximately 5.5%. They also conducted visits of 43 meeting locations for “private networks,” finding that approximately 12% of sex workers (25 of 214 observed) in these networks were CST victims. The authors warned that private networks pose a new and sophisticated threat to counter-trafficking organizations and law enforcement, as the perpetrators are often technologically savvy and use sophisticated tactics, techniques, and procedures to facilitate exploitation and evade arrest. They noted that private network-driven commercial sex and CST is difficult to investigate and measure via field study, as they leveraged years of relationships to survey just 214 sex workers in this hidden side of the market.

This study aimed to estimate the population size of CST victims in Maharashtra at a state level across both the public and the private sides of the commercial sex trade. While the prior research indicates that Maharashtra hosts a significant commercial sex industry, few or no studies have investigated characteristics of the populations of sex workers and CST victims in Maharashtra at a statewide level. Furthermore, few studies of either sex work or CST in India or elsewhere also include investigations into the behaviors of buyers, which may offer valuable insights to organizations seeking to develop, implement, and measure the effectiveness of counter-trafficking programming.

Prevalence Estimation Methodologies

Network Scale-Up Method

Overview of the Network Scale-Up Method

NSUM is an approach to estimating population sizes—in particular, hidden or hard-to-reach populations—using indirect measures based on the network structures of the

²² Parks, A. C., Macwan, S., Rusk, A. G., Fernandes, C., Walavalkar, M., Alfonso, S., Nanda, L., Newgigging, S., Morley, S., Mane, P., Symon, K., Blagg, K., Lacey, V., Pyke, K., West, L., & Sumitra, H. (2017). Commercial sexual exploitation of children in Mumbai: Findings in public establishments, private networks and survivor perspectives. *International Justice Mission*.

<https://www.ijmindia.org/files/library/CSES%20Study%20Report%20Rev%20%28Final%20Prevalence%20Study%29.pdf>

general population. For example, if a respondent knows 100 people, two of which are survivors of trafficking, it may be surmised that 2% of the total population are survivors of trafficking. NSUM uses a similar approach but expands this logic to a larger sample pool, accounts for individual variations in network structure, and enables pooling to reduce the effects of outliers to produce a more accurate estimate for the size of the hidden population.

Through NSUM, participants are asked a series of “how many X do you know” questions, where X corresponds to several subpopulations of known and unknown size.²³ Groups of known size (“known populations”) are used as reference groups whose size and scope have been measured; unknown groups correspond to the target hidden populations of interest (e.g., sex workers or CST victims). A statistical model adjusts for differences between polled groups in the NSUM survey instrument (i.e., reference groups and hidden populations) and “scales up” the network data from all respondents to build and calibrate an accurate estimation of the sizes of the hidden populations. Of note, NSUM does not require respondents to indicate who in the person’s network belongs to a particular group (to include respondents themselves), allowing respondents to answer truthfully without repercussion or counting for variance in the size and structure of individual networks.

NSUM bases its estimates on three assumptions:

1. Social ties are random.
2. Respondents are aware of their alters’ characteristics and conditions (i.e., members of their social network).
3. Respondents can provide accurate information concerning members within their networks.

The feasibility of NSUM to provide valid size estimates for hidden populations has been shown to credibly estimate the number of intravenous drug users, men who have NSUM has also been used in the public health literature to estimate the prevalence of HIV positivity and other regional or national epidemics in various countries and within

²³ For more information on this “game of contacts,” see McCarty, C., Killworth, P. D., Bernard, H. R., Johnsen, E. C., & Shelley, G. A. (2001). Comparing two methods for estimating network size. *Human Organization*, 60, 28–39. <http://doi.org/10.17730/humo.60.1.efx5t9qjtgmg73y>

specific subpopulations.²⁴ ²⁵ Other previous applications of NSUM for hidden sex with men (MSM), and sex workers.²⁶ ²⁷ ²⁸ ²⁹ ³⁰ Population size estimation include measuring the number of Americans directly and indirectly affected by the September 11, 2001 terrorist attacks³¹ and estimating the prevalence of homelessness and sexual assault in the United States.³²

The NSUM estimator has unique benefits in the case of estimating the current number of sex workers and CST victims in Maharashtra because recent research and reports from partnered field organizations suggests that the commercial sex industry in India is increasingly moving toward private networks and technology-enabled commerce. For instance, IJM's 2017 study of Mumbai notes that many traffickers are remotely organizing encounters using over-the-top messaging services such as WhatsApp.³³ If this represents a more substantial supply-side reorganization, then investigations that rely solely on surveys of venue-based sex workers will miss a growing component of the sex trade in the state. By contrast, NSUM estimates that are obtained from general

²⁴ Shokoohi, M., Baneshi, M. R., & Haghdoost, A. A. (2012). Size Estimation of Groups at High Risk of HIV/AIDS using Network Scale Up in Kerman, Iran. *International Journal of Preventative Medicine*, 3(7), pp. 471–476.

²⁵ Guo, W., Bao, S., Lin, W., Wu, G., Zhang, W., Hladik, W., Abdul-Quader, A., Bulterys, M., Fuller, S., & Wang, L. (2013). Estimating the size of HIV key affected populations in Chongqing, China, using the Network Scale Up Method. *PLoS one*, 8(8), p.e71796. <https://doi.org/10.1371/journal.pone.0071796>

²⁶ Salganik, M. J., Fazito, D., Bertoni, N., Abdo, A. H., Mello, M. B., & Bastos, F. I. (2011). Assessing network scale-up estimates for groups most at risk of HIV/AIDS: Evidence from a multiple-method study of heavy drug users in Curitiba, Brazil. *American Journal of Epidemiology*, 174(10), 1190–1196. <https://doi.org/10.1093/aje/kwr246>

²⁷ Kadushin, C., Killworth, P. D., Bernard, H. R., & Beveridge, A. A. (2006). Scale-up methods as applied to estimates of heroin use. *Journal of Drug Issues*, 6, pp. 417-440. <https://doi.org/10.1177/002204260603600209>

²⁸ Teo, A. K. J., Prem, K., Chen, M. I., Roellin, A., Wong, M. L., La, H. H., & Cook, A. R., 2019. Estimating the size of key populations for HIV in Singapore using the Network Scale Up Method. *Sexually Transmitted Infections*, 95(8), 602–607. <http://doi.org/10.1136/sextrans-2018-053747>

²⁹ Ezoe S., Morooka T., Noda T., Sabin M.L., & Koike S. (2012). Population size estimation of men who have sex with men through the network scale-up method in Japan. *PLoS One*, 7(1). <https://doi.org/10.1371/journal.pone.0031184>

³⁰ Sulaberidze, L., Mirzazadeh, A., Chikovani, I., Shengelia, N., Tsereteli, N., & Gotsadze, G. (2016). Population size estimation of men who have sex with men in Tbilisi, Georgia: Multiple methods and triangulation of findings. *PLoS One*, 11(2). <https://doi.org/10.1371/journal.pone.0147413>

³¹ Bernard, H. R., Killworth, P. D., Johnsen, E. C., Shelley, G. A., & McCarty, C. (2001). Estimating the ripple effect of a disaster. *Connections*, 24(2), pp. 18–22.

³² Killworth, P. D., McCarty, C., Bernard, H. R., Shelley, G. A., & Johnsen, E. C. (1998). Estimation of seroprevalence, rape, and homelessness in the United States using a social network approach. *Evaluation review*, 22(2), 289–308. <https://doi.org/10.1177/0193841X9802200205>

³³ Parks, A. C., Macwan, S., Rusk, A. G., Fernandes, C., Walavalkar, M., Alfonso, S., Nanda, L., Newgigging, S., Morley, S., Mane, P., Symon, K., Blagg, K., Lacey, V., Pyke, K., West, L., & Sumitra, H. (2017). Commercial sexual exploitation of children in Mumbai: Findings in public establishments, private networks and survivor perspectives. *International Justice Mission*. <https://www.ijmindia.org/files/library/CSES%20Study%20Report%20Rev%20%28Final%20Prevalence%20Study%29.pdf>

population survey response data will provide overall estimates, regardless of the modalities used or underlying structural changes in the industry.

Potential Biases and Limitations of the Network Scale-Up Method

As with any assumptions and generalizations, several forms of bias may affect the quality of the data set. For instance, the theoretical respondent of an NSUM study would have a heterogeneous network, composed of an array of groups; however, this is rarely the case in reality, subjecting NSUM to barrier effects. In addition, respondents may be unaware of or unwilling to identify alters in their networks that are part of a hidden population, making NSUM prone to transmission bias and response bias, respectively. Further, NSUM may suffer from recall bias as respondents may overestimate or underestimate the size of subpopulations in their networks. According to Maltiel, Rafferty, McCormick, and Baraff, respondents tend to “underestimate the number of people they know in larger groups because they forget some of these contacts, and to overestimate the number of people they know in small or unusual groups.”³⁴ The below details the various limitations of the NSUM method in detail. The Study Design section (p. 25) details mitigation techniques employed within this study to address those limitations.

Transmission Bias. Transmission bias occurs when respondents may know people who are sex workers but not realize they are sex workers.^{35 36 37} Because the populations under study are often stigmatized, failure to account for this lack of knowledge may lead to an underestimate of unknown size.

Several approaches exist that explicitly account for transmission bias. Some implementations of NSUM parameterize this bias explicitly, treating it as the result of an underlying distribution that may be quantified. For example, Maltiel, Rafferty, McCormick, and Baraff introduced a Bayesian model that assumes all known

³⁴ Maltiel, R., Rafferty, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3): 1247–1277. <https://doi.org/10.1214/15-AOAS827>

³⁵ Shelley, G. A., Bernard, H. R., Killworth, P., Johnsen, E., & McCarty, C.. (1995). Who knows your HIV status? What HIV+ patients and their network members know about each other. *Social Networks*, 17(3–4), 189–217. [https://doi.org/10.1016/0378-8733\(95\)00262-M](https://doi.org/10.1016/0378-8733(95)00262-M)

³⁶ Shelley, G. A., Killworth, P. D., Bernard, H. R., McCarty, C., Johnsen, E. C., & Rice, R.E. (2006) Who knows your HIV status II? Information propagation within social networks of seropositive people. *Human Organization*, 65(4), 430–444. <https://doi.org/10.17730/humo.65.4.08mwwg9d3nfy8w9th>

³⁷ Salganik, M. J., Fazito, D., Bertoni, N., Abdo, A. H., Mello, M. B., & Bastos, F. I. (2011). Assessing network scale-up estimates for groups most at risk of HIV/AIDS: Evidence from a multiple-method study of heavy drug users in Curitiba, Brazil. *American Journal of Epidemiology*, 174(10), 1190–1196. <https://doi.org/10.1093/aje/kwr246>

populations have no transmission bias.³⁸ Then, when performing hidden population size estimation, each hidden population k has a transmission bias coefficient T_k between 0 and 1, indicated by the prior $T_k \sim \text{Beta}(\eta k, V k)$. The transmission bias modifies the probability distribution of the binomial model for the estimation for the number of people in any given group k that respondent i knows, $Y_{ik} \sim (d_i, T_k \frac{Nk}{N})$.

Others, such as the generalized scale-up estimator of Feehan and Salganik, require direct engagement with the hidden population in order to determine their “visibility.”³⁹ As a caveat, these responses may be difficult for many researchers to collect in practice and may also introduce new biases related to the subjective perception of visibility. However, their conceptualization of the topic reframes it as a problem that can be solved through sampling and survey design.

Response Bias. Respondents may know people who are sex workers but be unwilling to provide this information because of the possible stigma involved. This phenomenon, called response bias, could result in an underestimate of that population’s size.

Barrier Effects. While NSUM relies on heterogeneous personal networks, individual personal networks tend to be homogeneous (i.e., people tend to know other people similar to themselves).⁴⁰ Additionally, sex workers and CST victims are often not randomly distributed in the general population, meaning some respondents have a higher propensity to know people who are sex workers or CST victims.^{41,42} If the sample systematically excludes those more likely to know members of the hidden population, an underestimate would result. However, if the sampling frame systematically excludes those less likely to know members of the hidden populations, an overestimate would result. The likely magnitudes of these problems are unknown. Thus, it is critical to obtain a “representative sample of personal networks” from the study geography. In practice, this is commonly treated as equivalent to obtaining a representative sample of respondents.

³⁸ Maltiel, R., Raftery, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3): 1247–1277. <https://doi.org/10.1214/15-AOAS827>

³⁹ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/2F0081175016665425>

⁴⁰ Lewis, K., Gonzalez, M., & Kaufman, J. (2012). Social selection and peer influence in an online social network. *Proceedings of the National Academy of Sciences*, 109(1), 68–72. <https://doi.org/10.1073/pnas.1109739109>

⁴¹ Killworth, P. D., McCarty, C., Bernard, H. R., Shelley, G. A., & Johnsen, E. C. (1998). Estimation of seroprevalence, rape, and homelessness in the United States using a social network approach. *Evaluation Review*, 22(2), 289–308. <https://doi.org/10.1177/0193841X9802200205>

⁴² Zheng, T. Z., Salganik, M. J., & Gelman, A. (2006). How many people do you know in prison? Estimating overdispersion in count data to estimate social structure in networks. *Journal of the American Statistical Association*, 101(474), 409–423. <https://doi.org/10.1198/016214505000001168>

An NSUM model that treats the estimated personal network sizes of respondents as fixed can lead to an underestimate.⁴³ Maltiel et al. developed a binomial distribution to account for barrier effects that considers the individual's network size (d_i) and the probability of membership in a subpopulation (q_{ik}) for respondent i and group k was used. q_{ik} is derived from a Beta distribution. The nonstandard parameterization of the Beta function identifies m_k as the prior mean and τ_k as its dispersion (i.e., $m = \frac{\alpha}{\alpha + \beta}$ and $\rho = \frac{1}{1 + \alpha + \beta}$ where $f(x) \propto x^{\alpha-1}(1-x)^{\beta-1}$).⁴⁴ Drawing from priors from each reference/hidden population group, dispersion varies randomly across respondents. Other respondent-specific weighting approaches exist, including incorporating sampling weights to apply an overall adjustment to response data based on external data sources.⁴⁵

Recall Bias. Recall bias may be avoided through systematically defining network ties and reference groups so respondents are less likely to forget or inaccurately estimate connections to a particular group and can accurately recall information about their connections with ease. In most studies, this is achieved by targeting relatively small reference groups and hidden populations. For example, if a respondent knows between 15 and 20 members of a group, they may struggle to remember all of these connections; however, if a respondent is likely to only know 1 or 2 members of a group, they can more easily count their connections. For this reason, it is recommended that researchers performing NSUM evaluate whether the hidden populations under study are likely to be appropriately sized to minimize recall bias. If so, the researchers should also select reference groups that are generally within an order of magnitude of the anticipated size range of the hidden population(s).

Confidence Interval Calculation. The implementation and interpretation of confidence intervals in NSUM studies have been subject to criticism in the research literature, particularly for providing anti-conservative coverage rates.⁴⁶ Some NSUM methods leveraging Markov chain Monte Carlo (MCMC) processes, such as Metropolis-Hastings or Gibbs samplers, have instead enabled examination of the convergence of the

⁴³ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/2F0081175016665425>

⁴⁴ Maltiel, R., Raftery, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3), 1247–1277. <https://doi.org/10.1214/15-AOAS827>

⁴⁵ Feehan, D. M., & Salganik, M. J. (2014). networkreporting package (Version 0.1.1). *R Foundation for Statistical Computing*. <https://cran.r-project.org/web/packages/networkreporting/index.html>

⁴⁶ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/2F0081175016665425>

estimate corresponding to the hidden population(s) under study as a measure of confidence. This is possible in Maltiel and Baraff's NSUM model package, for example.⁴⁷ However, this approach is conceptually different from confidence intervals derived based on standard error calculations and may be better described in some cases as an evaluation of model fit. Recently, Feehan and Salganik have proposed a bootstrap approach to confidence interval estimation to replace the original Killworth method.⁴⁸

Definition of Network Ties. "Knowing" an individual can be understood in many ways. For instance, an NSUM survey may ask respondents to examine their next-door neighbors or Facebook friends. In practice, a stricter or looser definition does not affect the estimate; instead, it will merely result in upward or downward adjustments to the scale-up factor that determines the relationship between the personal network and full population sizes. However, certain definitions may induce unnecessary bias by systematically omitting categories of alters. For example, many individuals in Maharashtra do not have Facebook accounts and would be excluded from estimates that ask respondents specifically about their Facebook friends. Moreover, a study that asks respondents about their neighbors may produce biased results, owing to significantly different responses between respondents who live in cities (e.g., respondents who live in housing complexes with many neighbors) versus those who do not. The key considerations in selecting a definition are that the definition must be consistently applied by all respondents and should minimize the addition of external biases such as barrier effects.

Other Factors. IST notes other potential considerations when modeling and estimating based on social network data. If the sex worker population is extremely sparse, scale-up estimates may be susceptible to false positives from a small fraction of respondents, resulting in an overestimate. More generally, this is sometimes referred to as the "needle in a haystack" problem and is common in questionnaire approaches to estimating rare events.⁴⁹ The sparsity of network ties to hidden populations may also lead to greater estimator variance. However, this second issue arises from collected data, not from the estimator itself. Because the NSUM estimator is calibrated using the relationships between network reports and known population data, if the known

⁴⁷ Maltiel, R. and Baraff, A. J. (2015), NSUM: Network Scale Up Method, R package (Version 1.0).

<https://rdrr.io/cran/NSUM/>

⁴⁸ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/2F0081175016665425>

⁴⁹ Hemenway, D. (1997) Survey research and self-defense gun use: An explanation of extreme overestimates. *The Journal of Criminal Law and Criminology*, 87(4), 1430–1445.

<https://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=6936&context=jclc>

populations used as reference groups contain similarly sparse responses (i.e., comparable numbers of network ties), then the effects of data sparsity inform the model and the effect is reduced.

Respondent-Driven Sampling

Overview of Respondent-Driven Sampling

RDS is a network-based sampling method that studies hidden populations by identifying seeds, or initial respondents, in the population of interest and then recruiting them to participate in the study. It is a useful supplementary sampling technique that increases the number of respondents without sacrificing the rigor of the initial sampling strategy. For hidden population estimates in particular, RDS “assumes that those best able to access members of hidden populations are their own peers.”⁵⁰

Initial participants in an RDS study (i.e., “seeds”) are typically recruited through convenience sampling methods. Seeds recruit peers by referral, allowing researchers to access—in a systematic way—members of typically hard-to-reach populations who may not otherwise be accessible. Still, each seed is limited in the number of participants it can recruit, minimizing the influence of highly connected individual seeds on subsequent waves (i.e., individuals recruited by an initial seed = wave 1; individuals recruited by wave 1 participants = wave 2). As waves recruit subsequent waves and the sample population grows, the effects of the original seeds attenuate. According to Volz and Heckathorn, as an RDS sample expands across waves, the overall sample diverges from the initial sample as long as the number of respondents is sufficiently large.⁵¹ This point has been used to address criticisms of RDS based on the use of an initial convenience sample, reasoning that the overall sample eventually becomes independent from the initial sample as the sample population grows. As a result, it is possible to obtain an approximate probability sample via RDS when researchers collect social network information that enables them to measure the selection probabilities of referrals from within each respondent’s network (i.e., to determine equilibrium).⁵²

Referrals are tracked to permit researchers to assess and adjust for recruitment biases in the analysis; however, this approach does not require subjects to identify their peers.

⁵⁰ Heckathorn, D. D. (1997). Respondent-Driven Sampling: A new approach to the study of hidden populations. *Social Problems*, 44(1), 174–199. <https://doi.org/10.2307/3096941>

⁵¹ Volz, E., and Heckathorn, D. 2008. Probability based estimation theory for respondent driven sampling. *Journal of Official Statistics*, 24(1):79–97.

⁵² Heckathorn, D. D. (1997). Respondent-Driven Sampling: A new approach to the study of hidden populations. *Social Problems*, 44(1), 174–199. <https://doi.org/10.2307/3096941>

In this manner, RDS offers a mechanism for rapid recruitment while preserving the identities of participants in hidden populations and accounts for the influence of specific seeds on the overall estimate. This weighting for network size separates RDS from other referral-based sampling methods that lack the rigor necessary to be considered probabilistic.

In a variety of studies, RDS has been shown to enable researchers to reach an “equilibrium,” wherein respondents are selected with proportion to network degree. Volz and Heckathorn state that this must also be a unique attracting equilibrium.⁵³ A unique equilibrium is a singular equilibrium for the entirety of a Markov process (i.e., a global selection probability distribution), and an attracting equilibrium indicates that the system will eventually approach this equilibrium, regardless of its starting state (for practical explanations of unique attracting equilibria, see Salganik and Heckathorn.⁵⁴

Potential Biases and Limitations of Respondent-Driven Sampling

Hidden population estimates using RDS rely on five primary assumptions:

1. Respondents can accurately report their network size (i.e., the number of relatives, friends, and acquaintances who are members of the hidden population).
2. Referrals are based on reciprocity; that is, the respondent and the referred individual know one another as members of the hidden population.
3. Sufficient cross-over and networking exist between members of the population to sustain the referral process.
4. Eligible participants are recruited from a respondent’s network at random.
5. Sampling occurs with replacement; therefore, the sample size must be small in relation to the population size.

These assumptions require a hidden population with a large enough network capable of sustaining the study, but they also require networks with sufficient diversity over successive waves. Several bootstrap methods have been developed to reduce

⁵³ Volz, E., & Heckathorn, D. 2008. Probability based estimation theory for respondent driven sampling. *Journal of Official Statistics*, 24(1), 79–97.

<http://www.sverigeisiffror.scb.se/contentassets/ff271eeeca694f47ae99b942de61df83/probability-based-estimation-theory-for-respondent-driven-sampling.pdf>

⁵⁴ Salganik, M. J., & Heckathorn, D. D. (2004). Sampling and estimation in hidden populations using respondent-driven sampling. *Sociological Methodology*, 34(1), 193–240. <https://doi.org/10.1111/j.0081-1750.2004.00152.x>

uncertainty not accounted for in current methods to address some of these limitations.⁵⁵

In addition, RDS methods have faced criticism in cases where initial samples are not probabilistically selected. This poses a challenge for many researchers seeking to use RDS because it is most commonly used in situations where access to a rigorous and large sample is not possible. Furthermore, determining whether an RDS sample has become “independent” from the initial seeds, as postulated by Heckathorn, may be difficult.⁵⁶ As methodological research and discussion continue, a best practice for researchers who seek to use RDS in as rigorous a manner as possible is to sample initial seeds probabilistically. By doing so, they avoid the risk of inducing and amplifying any potential sampling biases caused by non-probabilistic initial sample selection.

⁵⁵ Baraff, McCormick, and Raftery provide an overview of various bootstraps developed for RDS their paper, “Estimating uncertainty in Respondent-Driven Sampling using a tree bootstrap method.” Baraff, A. J., McCormick, T. H., & Raftery, A. E. (2016). Estimating uncertainty in Respondent-Driven Sampling using a tree bootstrap method. *Proceedings of the National Academy of Sciences*, 113(51), 14668–14673. <https://doi.org/10.1073/pnas.1617258113>

⁵⁶ Heckathorn, D. D. (1997). Respondent-Driven Sampling: A new approach to the study of hidden populations. *Social Problems*, 44(1), 174–199. <https://doi.org/10.2307/3096941>

Study Design

To estimate the prevalence of CST in Maharashtra, IST Research—with data collection support provided by Kantar—designed and executed a hybrid approach, leveraging two different samples in support of parallel estimation efforts using NSUM and RDS. NSUM was used for estimations across the general population of Maharashtra, whereas RDS focused on the adjacent hidden population of adults in the sex industry in Maharashtra. The following section introduces these methods and draws from the existing research literature to provide context and rationales for their use.

The design of the study enabled measuring the prevalence of CST in two distinct ways. NSUM was used to directly survey for point estimates of both sex workers and CST victims. Then, using RDS over the population of adult sex workers in Maharashtra, the proportion of surveyed sex workers who began working in the industry under the age of 18 was estimated. This result was compared with the NSUM estimate of the total number of sex workers and the number of CST victims. Comparing the results from both methods, the potential for biases inherent to a single method to affect overall findings was minimized.

IST selected these modalities, sampling strategies, and estimation techniques based on a variety of factors. A 2018 report from the Telecom Regulatory Authority of India states that Maharashtra has 108 mobile phone connections per every 100 citizens of the state, suggesting that nearly every adult living in Maharashtra may be reached via phone.⁵⁷ Owing to the need to perform the general population survey via phone as a result of the COVID-19 pandemic, as well as to reduce the logistical burden and cost of performing in-person enumeration, random digit dialing (RDD) was identified as an ideal sampling strategy for the general population NSUM survey. This strategy is inexpensive, probabilistic, and has a strong track record in survey research literature. Although the initial RDS survey was planned to be executed in-person, owing to the COVID-19 pandemic, the RDS survey was conducted entirely remotely via computer-assisted telephone interviews (CATI).

By law, CST victims in Maharashtra cannot be surveyed.⁵⁸ Therefore, IST determined that the most reliable means of indirectly studying this population would be via the

⁵⁷ Thakar, M. R., (2018, March 27). Maharashtra: Cell phone connections increase by 1.50 crore in 3 years. *DNA India*. <https://www.dnaindia.com/mumbai/report-maharashtra-cell-phone-connections-increase-by-150-crore-in-3-years-2597808>

⁵⁸ Ministry of Law and Justice. (2012). The Protection of Children from Sexual Offences Act, 2012. <https://wcd.nic.in/sites/default/files/POCSO%20Act%2C%202012.pdf>

adjacent population of adult sex workers. Because sex workers are themselves a hidden population in Maharashtra, and because prior literature and feedback from subject matter experts suggests that the sex worker population is too sparsely distributed to be efficiently discovered via random sampling of the general population, traditional sampling strategies were not considered feasible for surveying sex workers for CST prevalence. IST leveraged time-location sampling (TLS), an established method for performing probability sampling of populations of unknown size given access to and prior knowledge of the locations of such populations.⁵⁹ IST, Kantar, and Kantar's network of nongovernmental organizations (NGOs) that support sex workers in Maharashtra developed and sampled from a time-location frame drawn from rosters, field observations, and subject matter expertise of sex workers to make initial selections. To ensure a large enough sample size to produce a reliable prevalence estimate, RDS was used to propagate the survey across sex worker networks from the initially selected "seeds." Due to the COVID-19 pandemic and resultant restrictions on public gatherings, all RDS surveys were conducted via CATI.

Use of the Network Scale-Up Method

NSUM was used to estimate how many sex workers and CST victims the respondents know among all the people that they know in Maharashtra. The data needed for this hidden population size estimation was collected through a standard survey administered to the general population via a probabilistic sampling approach. Using an RDD methodology, IST and partners surveyed 1,036 adult members of the general population about their demographics and the people they know in various groups of known and unknown sizes.

In this study, respondents were asked about their alters who live in Maharashtra and are members of populations of known size (e.g., teachers in public secondary educational institutions) or unknown size (e.g., sex workers or CST victims). The known population approach was also used to estimate the number of alters in a person's network, which required several populations of known size—a minimum of 15—to assist with estimation.⁶⁰ When aggregated over all respondents, this information provides the numerator for the maximum likelihood estimator.

⁵⁹ Leon, L., Jauffret-Roustide, M., & Le Strat, Y. (2015). Design-based inference in time-location sampling. *Biostatistics*, 16(3), 565–579. <https://doi.org/10.1093/biostatistics/kxu061>

⁶⁰ McCarty, C., Killworth, P. D., Bernard, H. R., Johnsen, E. C., & Shelley, G. A. (2001). Comparing two methods for estimating network size. *Human organization*, 60(1), 28–39. <http://doi.org/10.17730/humo.60.1.efx5t9gjtgmga73y>

IST used the most current and rigorous procedures available to both account for sample-based biases and produce confidence intervals. The method for producing confidence intervals is based on Feehan and Salganik's bootstrap approach to standard error measurement, first recommended as an alternative to Killworth et al. in 2016.⁶¹

The NSUM study results include point estimates, a proportion of the total population in the sex worker and CST victim subpopulations, and the proportion of sex workers estimated to be CST victims. Where needed, the proportions of the general population are multiplied by the entire population of Maharashtra, not just the adult population, to accurately estimate the size of both populations.

Definition of Network Ties

In defining personal network ties for this study, IST seeks to obtain personal network data that is unbiased and as systematically derived as possible. For this study, "knowing" a person means the individual meets the three following criteria:

1. The respondent knows the person by face and name.
2. The person they know also knows the respondent by face and name.
3. The respondent has communicated with the individual in the last 12 months (for example, in-person, phone call, text, or social media).

These criteria are also included in the questionnaire provided in Appendix A.

In selecting the above definition, IST Research accounts for both of these key considerations. IST developed and tested this definition in collaboration with GFEMS and researchers from the National University of Singapore and has used it in multiple previous NSUM studies in both Asia and Europe. NSUM researchers from other institutions additionally reviewed this definition.

Managing NSUM Biases and Limitations

Responses to questions such as "How many people do you know who are individuals engaged in the commercial sex industry?" are critical for size estimates. However, as outlined in the methodological review, these responses may be inaccurate due to the

⁶¹ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/0081175016665425>

existence of several biases and effects. In this study, IST Research’s approach to bias management was to draw from both the data selection and design recommendations and the estimator adjustments of recent literature such as the work by Maltiel et al.⁶² and Feehan and Salganik.⁶³

First, to help account for population-specific biases including response bias and transmission bias, IST carefully selected and pre-tested the set of known populations included in the survey, including both large and small groups as well as groups that may be similarly disenfranchised or vulnerable, such as children in foster care, individuals receiving aid under the Slum Rehabilitation Scheme, members of specific castes or ethnic groups, and people suffering from a number of ailments including leprosy. In practice, because the NSUM estimator learns from relationships between personal network data and populations of known size to develop an estimate for a population of unknown size, the simplest way to account for these biases is to provide data that enables the estimator to model biased responses. When possible, including known populations that are similarly vulnerable or stigmatized will benefit estimation by enabling the estimator to fit to similarly biased response data.

This ensured that the NSUM estimator, which is first fit to known population data to accurately extrapolate to the hidden population(s), was exposed to a diverse distribution of groups during calibration, including groups that may exhibit similar network tie patterns due to stigma, social desirability, or lack of knowledge (i.e., transmission bias). Although IST’s measurement of the potential lack of knowledge or awareness among respondents does not extend to surveying sex workers on their perceived visibility to alters, this approach follows the conceptual recommendations set forth by Feehan and Salganik, who frame transmission bias as a design consideration rather than an issue of latent parameter modeling.⁶⁴

In practice, NSUM models that can account for respondent-specific underreporting or overreporting (for instance, models that apply a respondent-level random effect) may also be able to account for this bias as the motivations for underreporting are typically irrelevant to quantitative formulations of underreporting in NSUM algorithms. Whether a respondent willingly underreports their connections to stigmatized groups or

⁶² Maltiel, R., Raftery, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3): 1247–1277. <https://doi.org/10.1214/15-AOAS827>

⁶³ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/0081175016665425>

⁶⁴ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/0081175016665425>

underreports due to a lack of full knowledge of their alters (transmission bias), the effect is a respondent-specific effect.

Feehan and Salganik provide several additional simple guidelines for adjusting for both transmission bias and barrier effects as well as a suite of additional sample- and survey design-based weighting and adjustment capabilities for NSUM estimation.⁶⁵ IST leveraged these capabilities in constructing its NSUM estimates. Moreover, to account for respondent-specific biases, IST used an estimator that leverages sample and respondent weighting as well as variations in personal network reports at the respondent level. This practice has been previously identified as useful in controlling for transmission bias and barrier effects.⁶⁶

Prior to estimation, IST weighted responses according to publicly available information from the Indian Census and Government of Maharashtra statistics.⁶⁷ This accounted for sample-based biases, and provided estimates based on the most accurate and representative data possible. These adjustments were used to provide representation in terms of region, gender, education, and age, in order to minimize barrier effects. During pre-processing, IST also used the resampled bootstrap process, which reduces sampling variance when performing survey-driven estimation.⁶⁸ The confidence intervals were derived from this bootstrap process as well, which is based on earlier work by Rust and Rao.⁶⁹

When any particular results are uncertain, IST believes that conservative estimates have greater value than overestimates. The ability to control for factors such as transmission bias, barrier effects, and recall bias when performing NSUM estimation is still limited, and some new attempts to adjust for these factors may risk overparameterization, yielding unpredictable and volatile predictions as a result of overfitting to known population data. For this reason, further testing and evaluation are necessary to validate whether (and which) methodological improvements are reliable and effective. However, IST argues that if these biases are both systematic and static, they can be

⁶⁵ Feehan, D. M., & Salganik, M. J. (2014). networkreporting package (Version 0.1.1). *R Foundation for Statistical Computing*. <https://cran.r-project.org/web/packages/networkreporting/index.html>

⁶⁶ Maltiel, R., Raftery, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3): 1247–1277. <https://doi.org/10.1214/15-AOAS827>

⁶⁷ Data were drawn from: <https://mahades.maharashtra.gov.in/> (Accessed 10 July 2020); <https://www.censusindia.gov.in/> (Accessed 1 May 2020)

⁶⁸ Feehan, D. M., & Salganik, M. J. (2016). Generalizing the Network Scale-Up Method: a new estimator for the size of hidden populations. *Sociological Methodology*, 46(1), 153–186. <https://doi.org/10.1177/0081175016665425>

⁶⁹ Rust, K., Rao, J. (1996). Variance Estimation for Complex Surveys Using Replication Techniques." *Statistical Methods in Medical Research* 5(3): 283–310. <https://doi.org/10.1177/096228029600500305>

acknowledged at both baseline and endline estimates and reported accordingly during trend analysis.

Use of Respondent-Driven Sampling

In this study, adult sex workers were selected as initial RDS seed participants using TLS. This was performed to nullify the potential risks of network or sample bias induced by selecting seeds via non-probability sampling. Individuals who completed the initial wave of the survey were asked to recruit others in the same target population—that is, sex workers—and were provided an additional incentive for successfully recruiting new participants. Participants were allowed to recruit a maximum of five participants, and those who completed the survey after being recruited were invited to recruit additional participants.

The RDS component of this prevalence estimation effort will provide meaningful prevalence information via two different response data points. First, a subset of respondents is asked several demographic questions, including their age and how long they have worked in the commercial sex industry. This information enables us to determine their age of entry into this industry, which in turn identifies whether they became sex workers while underage. Although this does not provide a *current* prevalence estimate, it provides valuable information with which findings produced via other methods may be triangulated (e.g., NSUM). Second, prevalence was measured using a new experimental mechanism where respondents are asked how many other sex workers they know, and of those, how many are underage CST victims. Based on the proportion of CST victims to overall sex workers within respondents' networks, a new form of prevalence estimate of CST victims as a proportion of all sex workers can be produced.

Managing RDS Biases and Limitations

Whether an RDS sample derived from an initial convenience sample can eventually become entirely “independent” from the convenience sample—and therefore, whether it can ever be treated as equivalent to a probabilistic sample—remains subject to debate in the research literature. However, RDS was used solely to augment a sample based on TLS (itself, a probability sampling approach). As such, this study does not face the same methodological risks as researchers who perform RDS using seeds drawn initially from convenience samples.

Although the TLS-RDS sampling approach for sex workers is methodologically sound, even rigorous samples may require weighting. Further, current, adequate data may not exist to granularly weigh the collected responses. This is unavoidable in any study seeking to sample from a hidden population directly. IST used Gile's SS (Sequential Sampler) to weight response data for any population estimates. Gile's SS is a weighting technique for RDS samples based on the inclusion probabilities of members of the sample. The inclusion probabilities are based on the reported network sizes, or how many people a respondent knows within the target population. This approach is the best possible solution given the challenges of normalizing data from a hidden and stigmatized population.

Another hazard faced by the RDS survey as a means of supporting prevalence estimation is that respondents may face considerable personal and legal risk if they reveal their knowledge of, or connections to, CST victims. To alleviate this hazard, IST and Kantar worked collaboratively in designing the RDS engagements to ensure respondent personal data was kept fully confidential and that respondents would be fully informed of the data protections put in place. Furthermore, respondents were informed that their responses would not be shared with local police. Nonetheless, the potential risk may affect the estimate drawn from sex worker personal network data.

Lastly, this approach relies on network data from the RDS respondents. Due to privacy considerations, respondents and their networks are completely anonymized. Therefore, "double counting" is unavoidable in terms of both sex worker network data and CST victim data provided by this approach. Thus, the network-based findings from this study should be used as a means for contextualizing other results from this study and possibly assisting in identifying or evaluating response biases among the sex worker respondent pool.

Survey Organization and Implementation

This survey was commissioned by GFEMS. The design and execution were carried out and overseen by IST Research. UCLA provided logistical advice on fielding surveys concerning sex workers and a methodological review of the protocols and research design. Kantar performed field data collection across Maharashtra. Funding for the study came from the US Department of State's Office to Monitor and Combat Trafficking in Persons (TIP Office).

NSUM data collection was conducted from March 19, 2020, to April 10, 2020, on a geographically representative sample of 1,036 adults in Maharashtra. Each of these respondents was contacted via a geographically stratified RDD approach to participate in a telephone questionnaire. All adults aged 18 years and older were eligible to be interviewed, as long as they were current residents in the state of Maharashtra.

RDS data collection began on May 15, 2020, with 51 sex worker seeds identified using a random selection process over previously gathered time-location data provided by local NGOs. Seeds and referrals were both surveyed via telephone. The RDS survey ultimately propagated across nine different districts in Maharashtra. IST was able to examine the respondents' demographic information compared with limited quantitative data available on sex workers in Maharashtra to weigh responses to obtain full representativeness of sex workers across the entire state. RDS data collection was completed on June 25, 2020.

IST Research's initial design for this study included in-person registration of seeds for the RDS survey; however, in consultation with Kantar, IST modified this approach in light of the COVID-19 pandemic and resulting quarantine across Maharashtra, which excluded the possibility of in-person enumeration. Fortunately, both time-location data and sex worker telephone numbers had already been collected in consultation with Maharashtrian NGOs prior to the spread of COVID-19; as a result, IST Research was able to rapidly adapt to fully remote engagement modalities.

Sampling Design

The NSUM component used an RDD sample design, implemented in a regionally representative sample of 1,036 adults in Maharashtra in which all individuals aged 18 years or above were eligible to participate. RDD is a means of probability sampling individual households from a frame of available telephone numbers; it is distinct from

other telephone-based sampling approaches because it does not rely on a roster.⁷⁰ Specifically, to enable the RDD approach, the first five digits of the mobile number were required to belong to the state of Maharashtra. Upon reaching a potential respondent, a set of screening questions first confirmed that they currently lived in any part of Maharashtra state and were willing to continue the interview. This determined the eligibility of potential respondents to participate in and complete the survey.

The RDS study used TLS to identify the “seeds” for the RDS referral process and was executed via CATI. The TLS process was confidentially managed to protect the private and identifiable information of sex workers rostered by multiple NGOs in Maharashtra and was overseen by Kantar. Participants' private information was only accessed by the research team to distribute incentives, and only those who needed to distribute incentives had access to their information. To be eligible for participation, a respondent was required to be an active sex worker, to live in Maharashtra, and to be 18 or older. Referrals in subsequent RDS waves were also asked these screening questions and were additionally asked for unique identification codes that provided researchers with information about who referred them. As part of the RDS surveys, mobile financial incentives of Rs. 300 were provided to each individual who successfully referred another participant into the stud. An incentive of Rs. 300 was also provided to all respondents who completed the survey.

Questionnaires

Network Scale-Up Method

To effectively respond to multiple concerns among field organizations associated with international organizations performing surveys about the Indian commercial sex industry, IST Research collaborated with several subject matter experts over a significant period of time, including all of 2019 and January and February of 2020, to design and develop the NSUM questionnaire. Individuals from UCLA, GFEMS, Kantar, and other organizations that work with sex workers in Maharashtra (i.e., IJM and local NGOs) reviewed the NSUM questionnaire and provided feedback prior to finalization. The draft questionnaire was initially reviewed by Kantar in December 2019 and was refined during the following three months. The final modifications were made during a field site visit by IST personnel in February 2020, which included a full review of the instrument and protocols with local partners assisting with the study's data collection

⁷⁰ Waksberg, J. (1978). Sampling methods for Random Digit Dialing, *Journal of the American Statistical Association*, 73(361), 40–46. <https://doi.org/10.2307/2286513>

component. The draft questionnaire was first developed in English, then translated into Marathi and Hindi. The entire survey protocol, including the questionnaire and consent forms, were reviewed and approved by the Social Research Institute Institutional Review Board in India and the Western Institutional Review Board in the United States.

To derive an estimate, NSUM requires identifying the number of people in the target hidden population(s) known by each survey respondent, the number of people in various non-hidden population groups known by each respondent, and the size of the respondent's overall personal network. Personal network size is estimated indirectly by aggregating the respondent's connections to known populations and hidden populations. The questionnaire was organized into the following four sections:

- Respondent's background;
- Personal views and stigmas;
- Known population; and
- Target population.

Respondent's background. This section collected information on the socio-demographic characteristics of the respondent, including age, sex, state of residence, district of residence, and highest level of education.

Known population. Estimating the size of the respondent's network requires collecting data on a number of populations of which the size is already known. During the first draft of the questionnaire in December 2019, an initial list of 16 populations was chosen (e.g., number of teachers, number of doctors.). However, reviews with external partners revealed that some of the populations were too difficult for respondents to provide a reliable answer. Therefore, some of the original categories were dropped from the list of known populations and replaced with questions deemed easier for respondents to reliably answer. The final set included 16 populations whose sizes were available from official census documents and other public records.

Target populations. This section collects the number of persons known by the respondent in each key population of interest, namely the number of sex workers and the number of CST victims.

Stigma toward sex workers. An attempt was made to estimate response bias by measuring the stigma towards sex workers. This measurement helped researchers determine how respondents might adjust their responses due to social desirability bias

or whether or not the number of ties between a respondent and a known or hidden population may be the explainable result of underlying personal beliefs.

Respondent-Driven Sampling

The RDS arm had two questionnaires. The first questionnaire was written for seeds. The first question asked for the age of the seed to ensure they were 18 years old or older. Those who were at least 18 years old could proceed through the questionnaire. Respondents were then asked demographic questions, including gender, highest level of education, and district of residence. These questions were asked to develop a level of comfort with participants and a profile of adults engaged in the commercial sex industry. Next, respondents were asked whether they were engaged in the commercial sex industry to ensure they met the eligibility requirements of the personal network section.

The personal network section, which was the second section of the seeds questionnaire, asked respondents how many people they currently knew who were engaged in the commercial sex industry. If they responded with one or more individuals, they were asked how many of them were under the age of 18. The next section asked questions about the commercial sex industry overall. Specifically, it asked respondents how long they had been working in the commercial sex industry and what they thought they would be doing for work in the next five years.

The last section in the seeds questionnaire asked respondents for a mobile phone number so they could receive their incentive. Respondents who provided a phone number were also asked if they wanted to be notified about future survey opportunities. This contact information was held securely and confidentially with local partners and was used strictly to administer incentives. There was no link between the contact information and the actual responses.

The second questionnaire was written for the subsequent responders from the seeds. It asked all of the questions the seeds received except for the additional commercial sex industry questions (including, for example, what they planned to do for work in the next five years). These questions were not asked due to questionnaire limitations for the subsequent respondents.

Mid-way through the execution of this study, quarantines were enacted as a result of the COVID-19 pandemic that significantly impacted the lives of billions of people (including sex workers and CST victims in Maharashtra). At this point, the RDS

instrument was modified to include several questions about the impact of the COVID-19 pandemic on sex workers. Specifically, respondents were asked how many individuals they knew who began engaging in the commercial sex industry and how many quit due to COVID-19. If a respondent answered one or more to either of these questions, they were also asked how many of these individuals were 17 years old or younger.

Training

Training was conducted in March 2020 by local partners, with assistance from IST Research. Ten individuals attended the training to work as either team supervisors or interviewers.

Training provided the team with an opportunity to become familiar with the overall purpose of the survey, the survey questions, and conduct mock interview sessions. The training covered the ethical norms to be followed, including maintaining the confidentiality of the respondents who provided interviews, the questions and administration procedures, and how to record responses in the software developed for the survey. Team members were also allowed to ask any questions that emerged during training.

Trainees were assigned to two data collection teams; each team consisted of a team supervisor and interviewers. Senior staff from Kantar coordinated and supervised the fieldwork activities. The eight teams began NSUM data collection on March 19, 2020, and completed fieldwork on April 10, 2020. RDS data collection began on May 15, 2020, and was completed on June 25, 2020.

Data Processing

The study data processing began shortly after the fieldwork commenced. Completed survey data was sent periodically from local partners to IST Research, where it was checked for consistency by research staff trained in conducting human subjects research. The concurrent processing of the data was a distinct advantage for data quality because IST Research had the opportunity to review incoming data during the field period and make modifications as needed. The data entry and editing phase was completed in July 2020.

Participation and Completion Rates

A total of 1,249 participants started the NSUM survey. The number of individuals who completed the entire survey was 1,036, yielding a survey completion rate of 83%. Because the RDS referral process is opaque to the research team, IST Research cannot provide comparable statistics for the RDS surveys. However, IST Research was able to report that the study used 51 seeds and achieved a total sample size of 301 over 41 days. This sample size was in line with the overall research design.

Participant Characteristics

Table 1 displays the unweighted characteristics of the NSUM sample by region. The unweighted sample was geographically representative of the state of Maharashtra. IST conducted a chi-square test to confirm, $\chi^2(5) = 8.07, p = 0.15$. Table 2 displays the unweighted characteristics of the participants in the NSUM sample by age, gender, and education. The average age was 37 years old. The sample was 92% male.⁷¹ Additionally, 97% of the sample completed primary school and 95% completed middle school. The sample was weighted to improve representation in terms of age, gender, and education. IST used the raking procedure for weighting. Further, IST trimmed the weights so no one particular respondent would be overly represented. IST set the range for the trim at a minimum of 0.3 and a maximum of 3.

Table 1 – NSUM Respondent Characteristics by Region

The NSUM population were adults, 18+ who reside in the state of Maharashtra.

Region	Population of Maharashtra		NSUM Sample (Unweighted)	
	Percent		Percent	N
Amravati	10%		9%	95
Aurangabad	16%		22%	224
Konkan	29%		31%	323
Nagpur	11%		13%	132
Nashik	16%		16%	163
Pune	21%		10%	99

⁷¹ Field managers at Kantar explained that the sensitivity of the subject matter was the major reason for low female representation. Most of the women who talked to a phone interviewer said “I don’t know” and/or ended the survey once they were asked about sex workers. Additionally, for those women who did stay on the call, many of them passed the phone to their male household members so they could continue with the survey instead.

Table 2 – NSUM Respondent Characteristics by Age, Gender, and Education

The NSUM population were adults, 18+ who reside in the state of Maharashtra.

NSUM Sample (Unweighted)		
Variable	Mean (Std. Dev.) or percent	N
Age	37.1 (11.3)	1,126
Male	92%	1,121
Proportion Completed Primary School	97%	1,093
Proportion Completed Middle School	95%	1,093

Table 3.1 displays the unweighted characteristics of the RDS sample for the quantitative variables. The mean age was approximately 36, and the mean number of years worked in the commercial sex industry was approximately 15. On average, the respondents knew 32 individuals who worked in the commercial sex industry. Additionally, the standard deviation was approximately 14, which indicates that some respondents' networks of sex workers exceeded 50. To be exact, 14% of participants had networks of sex workers above 50.

Table 3.1 – RDS Respondent Characteristics (Quantitative)

The RDS population were sex workers, 18+ who reside in the state of Maharashtra.

RDS Sample (Unweighted)			
Variable	Mean	Standard Deviation	N
Age	35.5	7.6	301
Number of individuals known	31.4	13.8	301

who engage in
commercial sex
industry

Years Worked in Commercial Sex Industry	14.5	7.8	51
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Table 3.2 displays the unweighted characteristics of the RDS sample for the categorical variables. Almost 30% of the sample was below primary school, and 70% were primary school or above. For those who attended primary school or above, most participants' highest education level was middle (33%), primary (19%), or matric/secondary (17%). Further, among the seeds, 31% started sex work at age 17 or younger.

Table 3.2 – RDS Respondent Characteristics (Categorical)

The RDS population were sex workers, 18+ who reside in the state of Maharashtra.

RDS Sample (Unweighted)		
Variable	Percent	N
Education		
Below primary	29%	88
Primary	19%	57
Middle	33%	98
Matric/Secondary	17%	50
Higher Secondary/Undergraduate	< 1%	1
Graduate and above	2%	7
Started sex work age 17 or younger		

Yes	31%	16
No	69%	35

Findings

The findings are broken into two sections, wherein the results obtained from each prevalence estimation are described and discussed. Wherever possible, IST attempts to provide methodological notes and caveats related to each finding. IST also notes that, owing to the period of data collection, these results may significantly differ from those collected prior to the COVID-19 pandemic, as the effects of the pandemic on the commercial sex industry are still poorly understood.⁷²

Network Scale-Up Method

Findings from the NSUM component of the baseline prevalence estimation research effort are described below.

Stigma and Personal Beliefs

When the general population was asked how acceptable it is for an individual to engage in commercial sex, 58% responded that it was not acceptable at all; 22% responded that it was acceptable, with their responses ranging from slightly acceptable to extremely acceptable; and 20% of participants refused to answer the question.

Personal Network Size

Weighted and unweighted estimates for NSUM findings are provided for this study. Unweighted results are presented when describing the sample, and weighted results are presented when making estimates about the population of Maharashtra. Weights were used for population estimates so the estimates would reflect the demographic composition of Maharashtra.

Known Population Approach

The groups that were used and their sizes are presented in Table 4. Mean responses (unweighted) for all groups are also presented in Table 4.

⁷² The researchers also note that they surveyed a majority of adult sex workers contacted for this study about the effects of COVID-19 pandemic on their peer networks, and include survey findings related to the COVID-19 pandemic in the Respondent-Driven Sampling section.

Table 4 – Known populations used in the study

Description, size, and data source for the known populations used in the known population approach to network size estimation			
Category of population	Size	Source	Mean number of connections
Teachers in public secondary and higher (Std IX to XII) educational institutions	213,000	Economic Survey of Maharashtra, 2018 – 2019	2.408
Ayurveda doctors who are officially registered with the Maharashtra Council of Indian Medicine	79,623	Economic Survey of Maharashtra, 2018 – 2019	1.079
Blind women between ages 50–59	26,115	Socio-Economic Caste Census, 2011 (Regression)	0.444
Men who are members of Scheduled Castes and also 90 years old or older	7,134	Socio-Economic Caste Census, 2011 (Regression)	0.4122
People who passed away due to a car accident in the past year	13,089	Ministry of Road Transport and Highways, 2018	0.6834
Members of a spinning mill co-operative society	345,000	Economic Survey of Maharashtra, 2018 – 2019	0.4537

Students at Sainiki schools	18,924	Economic Survey of Maharashtra, 2018 – 2019	0.7442
People who reported suffering from leprosy (i.e., to Gol) in the past year	24,899	Economic Survey of Maharashtra, 2018 – 2019	0.3041
Women between ages 40–49 who are deaf	25,609	Socio-Economic Caste Census, 2011 (Regression)	0.4373
People who were diagnosed with Dengue fever by a doctor in 2019	6,583	Economic Survey of Maharashtra, 2018 – 2019	0.5618
Members of families that received rehabilitation under the Slum Rehabilitation Scheme last year	11,438	Economic Survey of Maharashtra, 2018 – 2019	0.3842
Children receiving foster care in 2019	13,863	Economic Survey of Maharashtra, 2018 – 2019	0.2664
People who suffered from burns that required them to ride in an ambulance in 2019	3,606	Economic Survey of Maharashtra, 2018 – 2019	0.3301
People who reported suffering from a case of malaria to the State (i.e., Gol) in 2019	21,859	Economic Survey of Maharashtra, 2018 – 2019	0.5338
Mothers who lost their baby within	39,907	Economic Survey of Maharashtra, 2018 – 2019	0.2597

their first year of life in 2019

Teachers in public primary (Std I to VIII) educational institutions

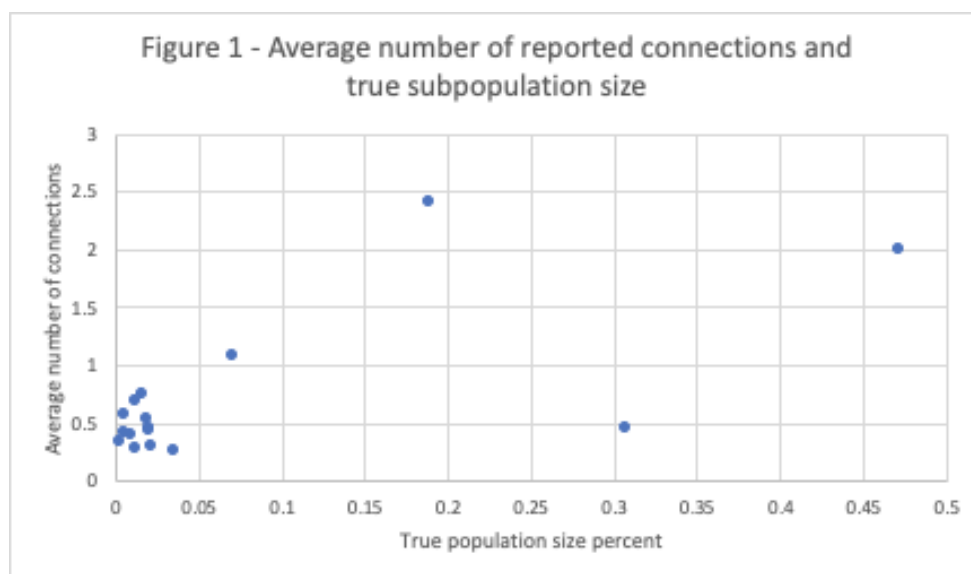
530,000

Economic Survey of Maharashtra, 2018 – 2019

1.992

The median estimated personal network size in Maharashtra based on known population connections is 571.

The data suggest that responses to questions such as “How many individuals engaged in the commercial sex industry do you know?” are reasonable. As the size of the group increases, the mean number of people that respondents know in the group increases. (Figure 1). For the most part, the average number of reported connections has a strong positive relationship with the true subpopulation size. These results are unweighted.



Validation Test

The known population sizes were estimated for cross-validation. The known percentage of the population was then compared to the estimated percentage of the population for the known groups. The results are presented in Table 5. The average difference between the known percentage of the population and the estimated percentage of the population was less than 0.085 in 87% of the known population

cases. In cases with a larger deviation, transmission bias could be a possible explanation. For example, respondents may not have known that their contacts were members of a spinning mill co-operative society, leading to an underestimate of the known percentage of this population.

Table 5: Comparing the known percentage of the population to the estimated percentage of the population

Category of population	Known percentage of the population	Estimated percentage of the population	Percentage difference
Teachers in public secondary and higher (Std IX to XII) educational institutions	0.172	0.255	0.083
Ayurveda doctors who are officially registered with the Maharashtra Council of Indian Medicine	0.064	0.111	0.046
Blind women between ages 50–59	0.019	0.045	0.026
Men who are members of Scheduled Castes and also 90 years old or older	0.005	0.042	0.037
People who passed away due to a car	0.011	0.071	0.060

accident in the past year			
Members of a spinning mill co-operative society	0.279	0.035	0.244
Students at Sainiki schools	0.015	0.077	0.062
People who reported suffering from leprosy (i.e., to Gol) in the past year	0.020	0.030	0.010
Women between ages 40–49 who are deaf	0.019	0.044	0.025
People who were diagnosed with Dengue fever by a doctor in 2019	0.005	0.058	0.053
Members of families that received rehabilitation under the Slum Rehabilitation Scheme last year	0.009	0.039	0.030
Children receiving foster care in 2019	0.011	0.027	0.015
People who suffered from burns that required them	0.003	0.033	0.031

to ride in an ambulance in 2019

People who reported suffering from a case of malaria to the State (i.e., GoI) in 2019

0.018

0.054

0.037

Mothers who lost their baby within their first year of life in 2019

0.032

0.025

0.007

Teachers in public primary (Std I to VIII) educational institutions

0.429

0.147

0.283

Prevalence Estimation Findings

The previous section described how the personal network size was calculated. In this section, the personal network size is used as a denominator to estimate the proportion of that network that is composed of persons who are sex workers or CST victims. This proportion is then “scaled up” to estimate the size of the sex worker and CST victim populations.

Respondents were asked how many sex workers they know (see Appendix A for the actual wording). Those who responded that they knew one or more individuals were then asked, “among the sex workers that you know, how many are 17 or younger?”

Point Estimates of Hidden Populations

The census estimates that the total population of Maharashtra in 2011 was 112,374,333. Based on the projected growth in the census from 2001 to 2011, Maharashtra’s 2019 population is projected at 123,522,214.⁷³ As described earlier, in producing hidden population size estimates, NSUM estimates the average number of

⁷³ <https://www.census2011.co.in/census/state/maharashtra.html>

people known in each target population. In addition, the method estimates how many people in Maharashtra the respondent knows (i.e., their personal network size, or total out-degree). Thus, the result is the proportion of all people in Maharashtra who are in the target populations. Since the reported proportions relate to all people in Maharashtra, old and young, the full state population is applied to each of the proportions to determine the estimated sizes of the target populations.

Using the personal network size data drawn from the responses to “known population” questions, the estimated number of sex workers in Maharashtra is approximately 29,000 (95% CI: 14,000, 52,000), and the estimated number of CST victims is 7,900 (95% CI: 2,600, 15,000) (Table 6). The UNAIDS estimates that there are approximately 650,000 sex workers across India.⁷⁴ Since Maharashtra has 9% of the Indian population, researchers might estimate based on UNAIDS data that there are approximately 59,000 sex workers in the state of Maharashtra, which is near the upper confidence interval.

Table 6 – Estimated percentages of the target populations among the total population of Maharashtra and estimated sizes of the target populations

	Estimated percentage of the key populations among the total population of Maharashtra			Estimated size of the key populations		
	Lower 95% CI	Estimate	Upper 95% CI	Lower 95% CI	Estimate	Upper 95% CI
Sex workers	0.011%	0.023%	0.042%	14,000	29,000	52,000
Victims of child sex trafficking ⁷⁵	0.002%	0.006%	0.012%	2,600	7,900	15,000

Overall, the estimated prevalence of sex workers is roughly 0.02% of the population of Maharashtra. Though there is little prior research on the prevalence of sex workers at

⁷⁴ https://www.unaids.org/sites/default/files/media_asset/20170720_Data_book_2017_en.pdf

⁷⁵ Minors (individuals under the age of 18) are not able to legally provide consent and thus should not be referred to as “sex workers.” For this data point, involvement in the sex industry refers to exchanging sexual services for monetary or in-kind remuneration (to oneself or a third party).

the state level, Family Health International's 2001 study indicates the prevalence of female sex workers in hotspots across Maharashtra is 0.4% of all adult women.⁷⁶ This is not directly comparable geographically or demographically to this study; however, if IST were to interpret its results as a proportion of all adult women in the state, the statewide prevalence rate amongst women would be roughly 0.11% (with a 95% confidence interval of 0.05% to 0.19%).⁷⁷ Considering the different geographic targets, the difference between these two rates may be used to inform how tightly clustered the commercial sex trade is in these hotspots. If these 2001 findings hold true today, then hotspots in Maharashtra would have an average prevalence of sex workers that is two to eight times greater than for the overall state.

Between the lower and upper confidence intervals of each estimate, the CST prevalence estimate resulting from NSUM is between 18.6% and 28.8% that of the sex worker population estimate, which aligns with some previous research findings in India.⁷⁸ The 95% confidence interval of the point estimate range is significantly greater than the number of Protection of Children from Sexual Offences (POCSO) Act cases in Maharashtra involving a penetrative sexual act against a minor (2,832 in 2018, the most recent available year⁷⁹) as well as the 450 child sexual abuse complaints from Maharashtra in 2018–2019 as fielded by Childline, a phone emergency outreach service for child exploitation in India.⁸⁰

In providing this point estimate, IST acknowledges the potential for underreporting due to response bias among respondents, but also notes that any response bias that may exist would likely correlate between both groups, reducing its impact on the prevalence estimate.

⁷⁶ Family Health International. Mapping of commercial sex access points and relevant service outlets in Maharashtra, 2001.

https://childhub.org/system/tdf/library/attachments/fhi_2001_mapping_of_sex_access_in_maharashtra_may_04_1.pdf

⁷⁷ While sex workers are not required to be female, conversations with local NGOs and field data collectors indicated a widespread characterization that sex workers in Maharashtra are overwhelmingly majority-female. Furthermore, all respondents to this RDS survey of sex workers were female.

⁷⁸ Akula, S. L. (2006). Situational analysis report on prostitution of boys in India. *ECPAT International*. http://childhub.org/en/system/tdf/library/attachments/ecpat_06_sarop_of_boys_in_india_250806.pdf?file=1&type=node&id=17624

⁷⁹ National Crime Records Bureau. (2018). *Table 4A: IPC crimes against children (crime head-wise & state/UT-wise) - 2018*. [Infographic.]

https://ncrb.gov.in/sites/default/files/crime_in_india_table_additional_table_chapter_reports/Table%204A.2_0.pdf

⁸⁰ Natu, N. (2019, December 26). Maharashtra ranks third in child sexual abuse complaints to Childline. *Times of India*. <https://timesofindia.indiatimes.com/city/pune/maharashtra-ranks-third-in-child-sexual-abuse-complaints-to-childline/articleshow/72973159.cms>

Buyers of Commercial Sex

Respondents were also asked about individuals who are buyers of sex workers to help better understand the commercial sex trade. They were particularly asked how many individuals purchased sex from someone between 15 and 17 years old and how many individuals purchased sex from someone 14 years or younger. They were also asked among those who purchased sex from someone under the age of 18, how many completed the transaction digitally.

IST estimates indicate that there were approximately 35,000 local buyers of the commercial sex industry in 2019 in Maharashtra (95% CI: 22,000, 54,000). Among these buyers, approximately 7,300 (21%) paid to have sex with children between the ages of 15 and 17 (95% CI: 3,700, 12,000) and approximately 1,700 (5%) paid to have sex with someone 14 years old or younger (95% CI: 500, 3,200), in clear violation of the law. IST also found that among the 9,000 buyers who paid to have sex with someone aged 17 or younger, more than 3,200 (36%) arranged the transaction digitally (for example, using web sites, Facebook or WhatsApp; 95% CI: 1,700, 5,400).

The point and prevalence estimates for buyers of the commercial sex trade are slightly lower than expected across all buyer subgroups and lower than previous research suggests.⁸¹ IST surmises this is because the estimate is primarily a reflection of the number of local and socially acknowledged buyers, rather than the number of buyers of sex workers overall. First, IST's estimate only covers residents in Maharashtra who are buyers of the commercial sex trade. It excludes buyers from out of state or abroad, such as migrants, travelers, and other non-state residents.⁸² These individuals would not qualify as people that the respondents "know." Second, the transmission error for buyers is greater than the transmission error for sex workers, which means that many people do not know which of their ties are buyers. For buyers, participation in commercial sex is often a secret, private, and discreet activity. Many buyers can easily conceal their commercial sexual encounters, which may be brief. In contrast, people are more likely to know which of their ties are sex workers. For sex workers, it is likely harder to mask such activities from friends and contacts because sex work tends to be a full-time obligation, whether by choice or not.

⁸¹ Heckathorn, D. D. (1997). Respondent-Driven Sampling: A new approach to the study of hidden populations. *Social Problems*, 44(1), 174–199. <https://doi.org/10.2307/3096941>

⁸² One potential approach to estimate the number of buyers across India who purchase sex in Maharashtra is to perform a country-wide NSUM survey in which researchers specifically ask respondents about the number of individuals they know who have recently purchased sex in Maharashtra. However, respondents may not always be aware of where their alters make such purchases. Furthermore, this does not resolve the aforementioned issues related to transmission bias.

Percentage of Respondents Who Know Any Groups of Interest

Nine percent of the 1,036 respondents reported knowing at least one person in one of the target populations (Table 7). Six percent knew at least one sex worker, and two percent knew at least sex worker under the age of 17. Seven percent knew at least one buyer of a sex worker, three percent knew at least one buyer of a child sex trafficking victim who was between the ages of 17 and 15, one percent knew at least one buyer of a child sex trafficking victim under the age of 14 and two percent knew at least one buyer of a child sex trafficking victim under the age of 18 who organized the transaction digitally.

Table 7 – Percentage of respondents reporting that they know at least one person in the target populations

Target populations	Percentage who know at least one member
Sex workers	6
Child sex trafficking victims under the age of 17	2
Buyers of commercial sex	7
Buyers of child sex trafficking victims between the age of 17 and 15	3
Buyers of child sex trafficking victims under the age of 14	1
Buyers of child sex trafficking victims under the age of 18 who organized the transaction digitally	2
Any of the above	9

Respondent-Driven Sampling

The findings from the RDS component of the CST prevalence estimation research effort are summarized below.

Summary

IST and partners executed an RDS survey that targeted adult sex workers, aged 18 and older, in Maharashtra to provide triangulation data for the NSUM estimate and to better understand the sex worker profile in Maharashtra. The RDS study covered nine districts within Maharashtra: Jalgaon, Jalna, Kolhapur, Mumbai City, Nashik, Pune, Raigad, Thane, and Yavatmal. Data collection for the RDS study began on May 13, 2020, and concluded on June 18, 2020.

The target group for the RDS study was adult sex workers, including both those who consented to be seeds for the study and the referred individuals who contacted the research team by phone to complete a short interview about their demographics and personal networks. A total of 301 sex workers were recruited for the study, 51 of whom were seeds, and 250 of whom were subsequent referrals. The breakdown of the respondents by district is in Table 8.

Table 8 – RDS respondents by district

Location of Respondents		
	n	%
Jalgaon	63	21%
Jalna	1	< 1%
Kolhapur	32	11%
Mumbai City	50	17%
Nashik	31	10%
Pune	40	13%
Raigad	16	5%
Thane	31	10%
Yavatmal	37	12%

To identify initial RDS seeds, IST worked with local partners to randomly select 51 hotspots for sex commerce in Maharashtra from a list of hotspots developed via secondary research by field organizations in Maharashtra. The 51 hotspots covered the seven districts in Maharashtra mentioned earlier in this section. In each of the 51 locations, IST recruited one sex worker who consented to serving as a seed and introducing others to the study. These individuals, or seeds, shared a telephone number with the subsequent sex workers that they could use to complete the short telephone survey. The interviewers who received a phone call from referred respondents kept their phone numbers confidential throughout the engagement process.

Sex Worker Network Profile

Using the RDS data, IST was able to develop a sex worker network profile, which assisted in triangulating the findings from NSUM and validating the prevalence estimate. The analysis was performed using RDS Analyst, which is a well-known analysis software tool for RDS samples.⁸³ The population estimates for sex workers are listed below.

Table 9 – Age and Network Size of Sex Workers

Population Estimates ⁸⁴					
	Mean	Standard Deviation	Median	25th Percentile	75th Percentile
Age	34	7	33	29	40
sex worker network size	31	14	20	10	35

Using Gile’s SS estimator,⁸⁵ it is estimated that the mean age of adult sex workers in Maharashtra is 34 years old. The mean network size is 23, with the lower 25th

⁸³ Handcock, M. S., Fellows, I. E., & Gile, K. J. (2014). RDS Analyst: Software for the analysis of Respondent-Driven Sampling data (Version 0.42). *Hard to Reach Population Methods Research Group*. <http://hpmrg.org>

⁸⁴ Gile's SS weights are used. These weights are based on the inclusion probabilities of members of the sample, which are based on reported network sizes (how many people a respondent knows within the target population).

⁸⁵ Gile, K. J. (2011). Improved inference for Respondent-Driven Sampling data with application to HIV prevalence estimation. *Journal of the American Statistical Association*, 106(493), 135–146. <https://doi.org/10.1198/jasa.2011.ap09475>

percentile having network sizes of 10 or below and the upper 75th percentile having network sizes of 35 and above (Table 9).

Table 10 – Education of Sex Workers

Population Estimates ⁸⁶						
	Below primary	Primary	Middle	Matric/ Secondary	Higher Secondary/ Undergraduate	Graduate and above
Education	30%	19%	34%	16%	< 1%	1%

It is estimated that a third of adult sex workers’ highest attained education level is below primary, and more than 75% of the sample’s highest attained education level is middle school or below (Table 10). This demonstrates that adult sex workers generally have a middle school education level or lower.

Prevalence of Child Sex Trafficking

Child Sex trafficking Among Respondent Peer Networks

Of the 301 sex worker respondents who completed an RDS survey, only 17 stated that they knew a peer sex worker under the age of 18. The proportion of CST victims to all sex workers among respondents’ networks ranged from 0% (most common) to 100% (n=1), with only four respondents reporting a proportion of 20% or higher. Overall, the average prevalence of reported CST from within respondents’ networks of peer sex workers is approximately 1% (95% CI: 0% to 30%). This survey finding may disagree with previous research as well as with the NSUM findings, but it is difficult to tell owing to the large confidence interval.

Although IST and its collaborators were not able to immediately follow-up with the RDS respondents to determine the reason(s) for this result, IST proposes three potential explanations. First, it is possible that adult sex workers and CST victims are not occupationally connected to one another and that CST takes place nearly entirely

⁸⁶ Gile's SS weights are used. These weights are based on the inclusion probabilities of members of the sample, which are based on reported network sizes (how many people a respondent knows within the target population).

separately and independently from adult commercial sex operations. As observed in IJM's 2017 field study,⁸⁷ a significant portion of CST in Mumbai is arranged digitally and follows different tactics, techniques, and practices than adult sex work, which may indicate that the commercial sexual exploitation of children is performed separately from adult sex workers. As described later, IST identified statistically significant differences between the peer networks of sex workers who entered the commercial sex trade under 18 versus those who did not. Although this finding does not conclusively support this explanation of the results, the two results would be consistent with divergent networks between adult sex workers and CST victims. If this is true, then future CST survey research would be better served by targeting a different adjacent population, as sex workers would be, in reality, "less adjacent" than previous research and NGO feedback would suggest.

Second, sex workers may not be aware of the ages of other sex workers in their network, or may choose not to report especially young sex workers as underage because they are unable to confirm them as such. Although possible, IST does not believe that this uncertainty factor related to peer age would produce as large a divergence as that found in the response data.

A third explanation originates from the limitations of the RDS approach and the laws and norms related to survey research of sex workers in India. Because (1) interviews of sex workers must be conducted by NGO representatives operating within and funded according to local and national legal statutes and (2) research interviewers are typically required to report crimes as a matter of organizational policy, human subject research protocol, and research ethics, sex workers may have feared that reporting knowledge of current or ongoing CST to interviewers would obligate the interviewers to report the details of this information and how they obtained it to law enforcement. (For example, as a matter of policy, IST Research personnel who conduct field interviews are required to report the observation of serious criminal activities while conducting interviews within 72 hours to internal organizational management, appropriate local/national authorities, and to research sponsors in some cases.) Given that penalties for CST-related offenses tend to be severe and can even include capital punishment according

⁸⁷ Parks, A. C., Macwan, S., Rusk, A. G., Fernandes, C., Walavalkar, M., Alfonso, S., Nanda, L., Newgigging, S., Morley, S., Mane, P., Symon, K., Blagg, K., Lacey, V., Pyke, K., West, L., & Sumitra, H. (2017). Commercial sexual exploitation of children in Mumbai: Findings in public establishments, private networks and survivor perspectives. International Justice Mission. <https://www.ijmindia.org/files/library/CSES%20Study%20Report%20Rev%20%28Final%20Prevalence%20Study%29.pdf>

to the POCSO Act,⁸⁸ sex worker respondents may have deliberately not reported or underreported their knowledge of or association with CST victims to avoid potentially grave legal repercussions. As a caveat, evidence of this pattern did not arise during the NSUM survey of the general population, or it was mitigated by the ability of the random coefficient implementation of NSUM to adjust for predictable respondent-specific reporting biases.⁸⁹ In such a case, NSUM survey reports and NSUM estimates of stigmatized groups including sex workers would be systematically and predictably different from those of non-stigmatized groups; however, no such differences were found to exist in either reports or model estimates.

As a final note, IST reiterates its earlier methodological caveat that these results are based on degree reports from sex workers. Responses from individuals within the same referral chain are, therefore, not independent from one another, and considerable network overlap is possible within referral chains. This increases the risk of overfitting to individual networks. Future RDS studies that can identify network overlap may be able to better disambiguate these results to provide more realistic estimates.

Historical CST Among Respondents

A subset of the RDS respondents was asked additional questions regarding their involvement in the commercial sex industry. One of the questions asked was how long the respondents had been sex workers. On average, the respondents had been in the commercial sex industry for 15 years, with the lower 25th percentile having been in the industry for 8 years or fewer (Table 11). Because participant ages were already captured, IST was able to use these responses to calculate the ages at which these respondents entered the industry.

Due to social desirability concerns, it was hypothesized that this data point would provide more reliable data than directly asking respondents how old they were when they entered the commercial sex trade. Furthermore, due to the legal repercussions of working alongside CST victims (described above), it was hypothesized that RDS respondents may not have been forthcoming with their peer network responses concerning CST victims that they know.

⁸⁸ Hindustan Times. (2019, July 10). Union Cabinet clears death penalty under POCSO Act. <https://www.hindustantimes.com/india-news/union-cabinet-clears-death-penalty-under-pocso-act/story-gmTselb9wSN4ssxeXdcHzM.html>

⁸⁹ Maltiel, R., Raftery, A. E., McCormick, T. H., & Baraff, A. J. (2015). Estimating population size using the Network Scale Up Method. *Annals of Applied Statistics*, 9(3): 1247–1277. <https://doi.org/10.1214/15-AOAS827>

Table 11 – Demographics of RDS Respondents

Demographics among a Subset of RDS Respondents ⁹⁰					
	Mean	Standard Deviation	Median	25th Percentile	75th Percentile
Years in the commercial sex industry	15	8	15	8	20
Age of entry	23	9	23	17	30

Using the calculations described above, the mean age at which the seeds entered the industry was 23, and the lower 25th percentile began at 17 years old or younger. In reviewing the total sample, 31% entered the industry while under the age of 18. This finding is relatively close to those of a number of historical studies of sex workers and underage entry into the commercial sex trade in India.

IST Research also found that among respondents who specified when they entered the commercial sex industry, the size of their personal networks and the age that they entered the industry was positively correlated, $r(49) = .29, p = .04$. This demonstrates that those who became sex workers at an older age have larger networks than those who entered the industry at a younger age. To delve further, IST investigated whether or not those who entered the industry under the age of 18 have a significantly different network size than those who entered it at age 18 or higher. The results suggest that those who entered the commercial sex industry under the age of 18 had a significantly lower network size ($M = 32$) compared to those who entered after the age of 18 ($M = 41$), $t(21) = 2.2, p = .04$. Although IST did not collect the qualitative data necessary to better understand the causes of this divergence, these findings demonstrate that, over time, CST victims maintain smaller networks of peers than those who enter the industry at age 18 or above.

IST’s findings regarding historical ages of entry among current sex workers contribute to the existing body of research, but provide important new implications when

⁹⁰ Since the seed sample was $n = 51$, IST used the arithmetic mean for these calculations, which means that all members of the sample are weighted equally.

considered alongside the NSUM findings. Although IST acknowledges that the NSUM estimates are not in fact single numbers but rather confidence intervals, the NSUM estimates could be interpreted to suggest that approximately 27% of current sex workers in Maharashtra are CST victims.

The researchers believe that a small number of possible explanations exist that account for both the NSUM findings and the RDS findings. First, adult sex workers may not be occupationally or personally connected to a majority of CST victims. This could be the case if a majority of CST takes place through different networks, organizations, and/or platforms (for example, via small private networks that do not operate or advertise within brothels).

Second, a large number of CST victims may not ultimately remain in the commercial sex industry, and/or a large number of adult sex workers may regularly exit the industry. One of these conditions is likely true, because for both the prevalence of CST among sex workers and the underage entry statistics to be roughly 30%, a large number of CST victims must exit the industry prior to adulthood or a large number of adult sex workers must regularly depart the industry to avoid shifting the prevalence of CST among sex workers lower over time. Otherwise, if one assumes that no individuals exit the industry, a sustained rate of 30% of individuals being underaged at the time of entry into the commercial sex trade will result in an overall CST prevalence rate of less than 15% within 10 years.

IST notes that these two explanations are not mutually exclusive. Turnover may be overwhelmingly higher at certain age ranges, and in particular between CST and adult sex work, while a majority of adult sex worker networks and CST victim networks remain siloed from one another. In fact, these conditions could be mutually supportive, in that child trafficking networks and adult commercial sex networks may intersect in particular circumstances (for instance, during points of transition from CST into primarily adult brothels) but otherwise do not typically operate in the same venues or following the same practices.

Impact of COVID-19 on the Commercial Sex Industry

IST also surveyed a subset of the sex workers regarding the impact of the COVID-19 pandemic on the commercial sex industry. Of 217 respondents who answered the question, 5% (n = 11) stated that they knew of new individuals who had entered the industry due to the pandemic. One of the 11 stated that they knew of an underage individual entering the industry. By comparison, 41% (n = 90) of the 217 respondents

stated that they knew at least one individual who had exited the industry as a result of the COVID-19 pandemic. One of these 90 stated that they knew a victim of child sex trafficking who had left the commercial sex trade.

In interpreting the results of the questions regarding entry into and exit from the commercial sex industry, IST notes the approximate proportion of individuals who have exited the industry relative to the total size of all sex worker networks from all RDS respondents. Summing the sizes of all sex worker networks for all sex workers, IST obtained a total of 9,444; summing the count of all sex workers who left the industry as a result of the pandemic from all respondents, a total of 355. As in the earlier findings concerning RDS respondents' personal network data, IST notes that in an RDS study, degree reports will include duplicate individuals; therefore, these results cannot provide a reliable estimate of the proportion of sex workers who have exited the industry versus all sex workers in Maharashtra. However, IST believes that the disparity between these two counts provides informative context to the finding that a majority of respondents indicated that they knew at least one individual who had exited the industry.

Conclusions

IST Research's chief objective in conducting this study was to produce a reliable estimate of the size of the CST victim population in Maharashtra, India, using a multi-method, hybridized approach leveraging two different rigorously designed and executed survey engagements. IST aims to use this baseline estimate as part of a trend analysis that evaluates the commercial sex industry and particularly CST over time. Owing to lack of access as well as legal and ethical sensitivities, IST designed this approach in consideration of (a) the limited number of methods available for estimating the size of the CST victim population in the target geography, and (b) the need, wherever possible, to triangulate the estimates obtained in order to minimize the effects of known and unknown biases. Although each of the methods IST used can provide a prevalence estimate, there is *no* method capable of approaching an exact count. In addition, as prevalence estimation continues to be a highly active subdiscipline of survey methodology research, there is currently no gold standard for hidden population prevalence or size estimation.

In this study, IST used NSUM and RDS to estimate the size of the CST victim population. To perform NSUM, IST asked the general population about individuals they knew who were currently engaged in the commercial sex industry, and among those individuals, how many were under the age of 18. IST also asked about the number of buyers participating in the commercial sex industry to validate the sex worker and CST victim NSUM estimates. In addition, RDS was used to examine the proportion of sex workers who are CST victims based on two different response data points: the peer networks of the respondents and the ages at which the respondents themselves entered the commercial sex industry. In aggregate, IST finds that two of the three CST victim estimates are in close agreement, and several reasonable rationales exist for understanding the third estimate's divergence from the first two as the result of biases associated with stigma, network structure, or respondents' concerns over the potential legal repercussions of responding honestly.

The results from this study are valuable because they provide a baseline estimate of the prevalence of CST in Maharashtra and also provide valuable context for these findings based on the hybrid methodological approach, which served as an effective tool for both prevalence estimation and data triangulation. Augmenting these findings with similarly targeted and constructed estimates at a later time will help establish trends in CST prevalence in Maharashtra, further evaluate whether (and the extent to which) the networks of adult sex workers and child sex trafficking victims are

independent from one another, and assist in further profiling sex workers in Maharashtra, especially those who are primarily engaged in online transactions and advertisement.

Future Studies

Implementing this study demonstrated that using both NSUM and RDS at once to develop prevalence estimates and evaluate their implications is an effective technique for researchers investigating hard-to-reach or hidden populations. However, researchers utilizing these methods should take special effort to measure and account for bias in multiple ways. The following list details recommendations for prevalence estimation using NSUM and RDS:

NSUM and RDS

- Larger sample sizes will enable both models to more readily show their effectiveness. IST previously reviewed the NSUM and RDS literature to determine appropriate sample sizes for this study. Based on the results obtained, IST recommends increasing both sample sizes, with particular attention paid to expanding the RDS sample to shrink confidence intervals by a factor of 2 or greater.

RDS

- Since former sex workers are more likely to be forthcoming than current sex workers about the commercial sex industry and their involvement in it, IST recommends that researchers consider interviewing former sex workers in addition to, or in lieu of, current sex workers.
- IST recommends continuing to ask all sex workers about the number of years they have been in the commercial sex industry, which may be used in combination with age to determine the sex worker's age of entry into the industry.

NSUM

- IST recommends additionally controlling for transmission bias by engaging with the target population (i.e., sex workers) concerning their perceived visibility. Drawing from previous studies, researchers interviewing sex workers in Maharashtra could ask: "For every 10 people who currently know you in Maharashtra, how many of them know that you are engaged in sex work?" Since this is a difficult concept to measure, additional variants of the aforementioned

question should be tested to determine the questionnaire with the least amount of measurement error.

- To improve the representation of gender when using RDD incorporate quota sampling requirements on the basis of gender into the sampling plan. Additionally, in addition to using an RDD methodology, it may be beneficial to implement a second phase of sampling to compensate for within household selection. Once a household member answers the phone, they will be asked to list the individuals in the household. A random selection procedure will then be used to select the household member who will complete the survey. This second level of sampling may alleviate the field work issue of the female household members passing the phone to male family members to complete the survey. Further research concerning local sensitivities and phone interviews may also be constructive.
- The known populations used as reference groups for NSUM represent the key connection between personal network data and real-world population numbers. As a result, they are one of the most important means of ensuring that the NSUM estimate is robust. IST recommends a large number of reference groups, and including a diversity in the types of known populations, specifically by size, to improve fit in the NSUM model. This also enables researchers to curate the reference groups used based on cross-validated model performance estimating the known populations, which allows analysts to test out multiple models in order to obtain highly accurate prevalence estimations.
- IST recommends continuing to ask stigma-related questions to understand the potential response bias better—specifically, questions about how people in the community respect unstigmatized groups (e.g., doctors, teachers), potentially stigmatized groups (e.g., sex workers, buyers or perpetrators), and a neutral group that is a known stigmatized group other than the population of interest so that a relative value can be obtained. These measurements can be used to create a respect index, which could then be used to make well-calibrated adjustments to prevalence estimations if needed.
- A more restrictive definition of “know” may be useful in some contexts because individuals who are members of stigmatized groups are more likely to confide this information in a small number of peers—for example, their family members, closest friends, or those with whom they have recently shared a meal. This may improve estimates of groups that otherwise may suffer from strong transmission bias effects.

Appendix A: NSUM Questionnaire

SECTION:1. PHONE SURVEY QUESTIONNAIRE				
MAHARASHTRA POPULATION SURVEY				
GENERAL INFORMATION				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
1.	What is your age in completed years? <i>TERMINATE IF LESS THAN 18 YEARS</i>	<input type="text"/> <input type="text"/>		
2.	What is your gender? <i>Single Coding Only</i>	Male	1	
		Female	2	
		Transgender	3	
3.	Which state do you currently live in? <i>CONTINUE ONLY IF 1 CODED</i> <i>Single Coding Only</i>	Maharashtra	1	
		Other state	2	
		Don't know	3	
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
4.	In which district do you live?	Ahmednagar	1	
		Akola	2	
		Amravati	3	
		Aurangabad	4	
		Beed	5	
		Bhandara	6	
		Buldana	7	
		Chandrapur	8	
		Dhule	9	
		Gadchiroli	10	
		Gondia	11	
		Hingoli	12	
		Jalgaon	13	
		Jalna	14	
		Kolhapur	15	
		Latur	16	
		Mumbai City	17	
		Mumbai Suburban	18	
		Nagpur	19	
		Nanded	20	
		Nandurbar	21	
		Nashik	22	
		Osmanabad	23	
		Palghar	24	
		Parbhani	25	
		Pune	26	
		Raigad	27	
		Ratnagiri	28	

SECTION:1. PHONE SURVEY QUESTIONNAIRE				
MAHARASHTRA POPULATION SURVEY				
GENERAL INFORMATION				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
		Sangli	29	
		Satara	30	
		Sindhudurg	31	
		Solapur	32	
		Thane	33	
		Wardha	34	
		Washim	35	
		Yavatmal	36	
6.	What is the highest level of education that you have completed? <i>Single Coding Only</i>	Below primary	1	
		Primary	2	
		Middle	3	
		Matric/Secondary	4	
		Higher Secondary/Undergraduate	5	
		Graduate and above	6	
<i>How much do you agree or disagree with the following statements?</i>				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
12.	In your opinion, how acceptable is it for a man or woman to engage in commercial sex (for example, prostitution)? <i>Single Coding Only</i>	Extremely acceptable	5	
		Very acceptable	4	
		Moderately acceptable	3	
		Slightly acceptable	2	
		Not acceptable at all	1	
		Refused	6	
	<p>People You Know</p> <p>In the questions below, you will be asked about how many people you <u>currently know</u> in specific groups of interest. When we say “currently know”, we mean the following:</p> <ol style="list-style-type: none"> 1. You know them by face and name 2. They know you by face and name 3. You have communicated with them in the <u>last 12 months (for example, in-person, by phone call, text, or social media).</u> 			

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
<p>How many people do you currently know in Maharashtra who are...</p> <p><i>Your answer must be between 0 and 99</i></p> <p><i>Only an integer value may be entered in this field.</i></p>				
13.	How many people do you currently know in Maharashtra who are teachers in public secondary and higher (Std IX to XII) educational institutions? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
14	How many people do you currently know in Maharashtra who are Ayurveda	<input type="text"/> <input type="text"/> In numbers		

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
	doctors who are officially registered with the Maharashtra Council of Indian Medicine? <i>ACCEPT '0 to 99'</i>			
15	How many people do you currently know in Maharashtra who are blind women between ages 50-59? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
16	How many people do you currently know in Maharashtra that are men who are members of Scheduled Castes and also 90 years old or older? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
17	How many people do you currently know in Maharashtra who are people who passed away due to a car accident in the past year? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
How many people do you currently know in Maharashtra who are... <i>Your answer must be between 0 and 99</i> <i>Only an integer value may be entered in this field.</i>				
18	How many people do you currently know in Maharashtra who are Members of a spinning mill co-operative society? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
19	How many people do you currently know in Maharashtra who are Students at Sainiki schools? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
20	How many people do you currently know in Maharashtra who are People who reported suffering from leprosy (i.e., to Gol) in the past year? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
21	How many people do you currently know in Maharashtra who are Women between ages 40-49 who are deaf? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
22	How many people do you currently know in Maharashtra who are People who were diagnosed with Dengue fever by a doctor in 2019? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
23	How many people do you currently know in Maharashtra who are Members of families that received rehabilitation under the Slum Rehabilitation Scheme last year? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
24	How many people do you currently know in Maharashtra who are Children who are in foster care under the Bal Sangopan Yojana scheme? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
25	How many people do you currently know in Maharashtra who are People who suffered from burns that required them to ride in an ambulance in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
26	How many people do you currently know in Maharashtra who are People who reported suffering from a case of malaria to the State (i.e., GoI) in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
27	How many people do you currently know in Maharashtra who are People who purchased sex in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
Ask Qs 28 to Q 31 only if more than 0 recorded in 27				
28	Think about the people you know in Maharashtra who purchased sex in 2019. Among them, what is the highest number of individuals that someone has paid to have sex with in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
29	Think about the people you know in Maharashtra who purchased sex in 2019, how many do you know who only paid to have sex with someone who is age 18 or older in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
30	Think about the people you know in Maharashtra who purchased sex in 2019, how many do you know who paid to have sex with someone from age 15 to age 17 in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
31	Think about the people you know in Maharashtra who purchased sex in 2019, how many do you know who paid to have sex with someone age 14 or younger in 2019? ACCEPT '0 to 99'	<input type="text"/> <input type="text"/> In numbers		
Ask Q 32 only if more than 0 recorded in Q 31				
32	Of the people you know in Maharashtra who paid to have sex with someone age 14 or younger in 2019, what districts did they do it in? Purchased sex > 0 & under15 >			

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
	<i>(Programmer: For each district selected, follow up with the following question - How many individuals do you know that paid to have sex with someone age 14 or younger in the {enter district selected} district in 2019? Multiple districts can be selected.)</i>			
	District	How many individuals do you know that paid to have sex with someone age 14 or younger in the {enter district selected} district in 2019		
	Ahmednagar	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Akola	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Amravati	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Aurangabad	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Beed	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Bhandara	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Buldana	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Chandrapur	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Dhule	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Gadchiroli	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Gondia	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Hingoli	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Jalgaon	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Jalna	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Kolhapur	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Latur	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Mumbai City	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Mumbai Suburban	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Nagpur	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Nanded	<input type="checkbox"/> <input type="checkbox"/>	In numbers	
	Nandurbar	<input type="checkbox"/> <input type="checkbox"/>	In numbers	

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
	Nashik	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Osmanabad	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Palghar	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Parbhani	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Pune	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Raigad	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Ratnagiri	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Sangli	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Satara	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Sindhudurg	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Solapur	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Thane	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Wardha	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Washim	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Yavatmal	<input type="checkbox"/> <input type="checkbox"/> In numbers		
	Ask Qs 33 only if more than 0 recorded in Q 30 OR 31			
33	Of the people you know in Maharashtra who paid to have sex with individuals age less than 18 years in 2019, how many do you know who organized the transaction digitally (for example, using web sites, Facebook, or WhatsApp)? ACCEPT '0 to 99' Purchased sex > 0 & (under15 > 0 OR ages15to17 > 0)	<input type="checkbox"/> <input type="checkbox"/> In numbers		
How many people do you currently know in Maharashtra who are... Your answer must be between 0 and 99 Only an integer value may be entered in this field.				
34	How many people do you currently know in Maharashtra who are mothers who lost their baby within their first year of life in 2019? ACCEPT '0 to 99'	<input type="checkbox"/> <input type="checkbox"/> In numbers		

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
35	How many people do you currently know in Maharashtra who are Teachers in public primary (Std I to VIII) educational institutions? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
36	How many people do you currently know in Maharashtra who are People who are engaged in the commercial sex industry (i.e., people who are given money to perform sex acts)? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		
<i>Ask Qs 37 only if more than 0 recorded in Q 36</i>				
37	Of the people you currently know in Maharashtra who are of the people who are engaged in the commercial sex industry (i.e., people who are given money to perform sex acts), how many are less than 18 Years ? <i>ACCEPT '0 to 99'</i>	<input type="text"/> <input type="text"/> In numbers		

Thank you for your time. Have a great day!

Appendix B: RDS Seed Questionnaire

SECTION:1. F2F SURVEY INSTRUMENT FOR RDS SEEDS (CAPI)				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
101.	What is your age in completed years? <i>TERMINATE IF LESS THAN 18 YEARS</i>	<input type="text"/> <input type="text"/>		
102.	What is your gender? <i>SINGLE CODING</i>	Male	1	
		Female	2	
		Transgender	3	
103.	What is the highest level of education you have completed? <i>SINGLE CODING</i>	Below primary	1	
		Primary	2	
		Middle	3	
		Matric/Secondary	4	
		Higher Secondary/Undergraduate	5	
		Graduate and above	6	
104.	In which district do you live in? <i>SINGLE CODING</i>	Ahmednagar	1	
		Akola	2	
		Amravati	3	
		Aurangabad	4	
		Beed	5	
		Bhandara	6	
		Buldana	7	
		Chandrapur	8	
		Dhule	9	
		Gadchiroli	10	
		Gondia	11	
		Hingoli	12	
		Jalgaon	13	
		Jalna	14	
		Kolhapur	15	
		Latur	16	
		Mumbai City	17	
		Mumbai Suburban	18	
		Nagpur	19	
		Nanded	20	
		Nandurbar	21	
		Nashik	22	
		Osmanabad	23	
		Palghar	24	
		Parbhani	25	
		Pune	26	
		Raigad	27	
		Ratnagiri	28	
		Sangli	29	
		Satara	30	
		Sindhudurg	31	
		Solapur	32	
		Thane	33	
		Wardha	34	
		Washim	35	
		Yavatmal	36	

SECTION:1. F2F SURVEY INSTRUMENT FOR RDS SEEDS (CAPI)					
S. NO	QUESTIONS	CODING CATEGORIES		CODE	SKIP TO
105.	As stated earlier, for this study, we hope to reach adults who are engaged in the commercial sex industry – meaning people who are given money to perform sex acts. Are you currently someone who is engaged in the commercial sex industry in Maharashtra? <i>TERMINATE IF 'NO' CODED</i>	Yes		1	
		No		2	
Personal Network Size Questions The next two questions will ask you about how many people you currently know in specific groups of interest. Please remember that your responses are completely confidential.					
106.	How many people do you currently know in Maharashtra who are people who are engaged in the commercial sex industry? <i>ACCEPT NUMBER '0 TO 99'</i> <i>IF '0' CODED SKIP TO Q 108</i>	<input type="text"/> <input type="text"/> In numbers			
107.	Of the people who are engaged in the commercial sex industry who you know in Maharashtra, how many are less than 18 years old ? <i>ACCEPT NUMBER '0 TO 99'</i>	<input type="text"/> <input type="text"/> In numbers			
Additional Commercial Sex Industry Questions					
108.	How many years have you been working in the commercial sex industry? <i>(Programmer Note: Open-ended response up to 2 digits)</i>	<input type="text"/> <input type="text"/>			
109.	In the next five years, which work do you think you will be doing for earning? <i>(Programmer Note: If 2 coded, open for OE response recording)</i>	Sex Industry		1	
		Other work Specify _____		2	
Recontact Question					
208.	Thank you for completing this survey! In order for us to send you Rs. 300 of mobile airtime for taking this survey, we need your mobile phone number. What is your mobile phone number? <i>(Programmer Note: Open-ended response for mobile phone number)</i>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> Mobile Number			
209.	Would you like to be notified about future survey opportunities?	Yes		1	
		No		2	
		Refused to provide mobile number		3	

Chain Referral Display

Thank you again for completing this survey! With your help, we hope to reach additional adults who are engaged in the commercial sex industry to learn more about the commercial sex industry in Maharashtra. If you recruit other adults who are engaged in the commercial sex industry in Maharashtra to complete this survey, you will receive an additional Rs.200 in mobile airtime for each adult engaged in the commercial sex industry that you recruit to take the survey. You can recruit a max of three new participants to the survey. These participants will not be provided with your name or contact information.

To participate, please tell each person that you recruit to call XXX-XXX-XXX (call center number) and provide one of the three validation codes {{code 1}, {code 2}, {code 3}} and take a quick survey via phone. Each code can only be used once. Each time a survey is completed by one of your recruits, you will receive an airtime payment. If you have any questions or concerns, please contact Mr. Anadi Mishra at No: 011-4269-7800

Appendix C: RDS Non-Seed Questionnaire

SECTION:2. PHONE CHAIN REFERRAL/RDS INSTRUMENT FOR NON-SEEDS				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
Thank you for contacting {Digital Humanity}! This survey will take about 2 minutes to complete, and you will receive Rs.300 of mobile airtime for taking the survey. Your participation is completely voluntary, and you have the right to withdraw at any point, for any reason, and without any prejudice. Your responses and personal information will be kept completely confidential. By continuing with this survey, you acknowledge that you are 18 years of age or older.				
201.	What is your age in completed years? <i>TERMINATE IF LESS THAN 18 YEARS</i>	<input type="text"/> <input type="text"/>		
202.	In this study, we hope to reach adults who are engaged in the commercial sex industry – meaning people who are given money to perform sex acts – to learn more about the commercial sex industry in Maharashtra. Are you currently someone who is engaged in the commercial sex industry in Maharashtra? <i>TERMINATE IF 'NO' CODED</i>	Yes	1	
		No	2	
Personal Network Size Questions				
The next two questions will ask you about how many people you currently know in specific groups of interest. Please remember that your responses are completely confidential.				
203.	How many people do you currently know in Maharashtra who are engaged in the commercial sex industry? <i>ACCEPT NUMBER '0 TO 99' IF '0' CODED SKIP TO Q 205</i>	<input type="text"/> <input type="text"/> In numbers		
204.	Of the people who are engaged in the commercial sex industry who you know in Maharashtra, how many are age 17 or younger? <i>ACCEPT NUMBER '0 TO 99'</i>	<input type="text"/> <input type="text"/> In numbers		
205.	As a result of the COVID-19 pandemic and lockdown, how many people do you know who have started engaging in the commercial sex industry who were not involved in it before? <i>Response should be less than Q203.</i>	<input type="text"/> <input type="text"/> In numbers		
206.	Of the people you know who have started engaging in the commercial sex industry who were not involved in it before as a	<input type="text"/> <input type="text"/> In numbers		

SECTION:2. PHONE CHAIN REFERRAL/RDS INSTRUMENT FOR NON-SEEDS				
S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
	<p>result of COVID-19, how many are age 17 or younger?</p> <p><i>Response should be less than Q204 & Q205</i></p>			
207.	<p>As a result of the COVID-19 pandemic and lockdown, how many people do you know who have quit the commercial sex industry?</p> <p><i>Response should be less than Q203</i></p>	<p style="text-align: center;">□ □</p> <p style="text-align: center;">In numbers</p>		
208.	<p>Of the people you know who have quit the commercial sex industry as a result of COVID-19, how many are age 17 or younger?</p> <p><i>Response should be less than Q204</i></p>	<p style="text-align: center;">□ □</p> <p style="text-align: center;">In numbers</p>		

S. NO	QUESTIONS	CODING CATEGORIES	CODE	SKIP TO
Demographics Questions				
207.	In which district do you live in? SINGLE CODING	Ahmednagar	1	
		Akola	2	
		Amravati	3	
		Aurangabad	4	
		Beed	5	
		Bhandara	6	
		Buldana	7	
		Chandrapur	8	
		Dhule	9	
		Gadchiroli	10	
		Gondia	11	
		Hingoli	12	
		Jalgaon	13	
		Jalna	14	
		Kolhapur	15	
		Latur	16	
		Mumbai City	17	
		Mumbai Suburban	18	
		Nagpur	19	
		Nanded	20	
		Nandurbar	21	
		Nashik	22	
		Osmanabad	23	
		Palghar	24	
		Parbhani	25	
		Pune	26	
		Raigad	27	
		Ratnagiri	28	
		Sangli	29	
		Satara	30	
		Sindhudurg	31	
		Solapur	32	
		Thane	33	
		Wardha	34	
		Washim	35	
		Yavatmal	36	
208.	What is your gender? SINGLE CODING	Male	1	
		Female	2	
		Transgender	3	
209.	What is the highest level of education you have completed? SINGLE CODING	Below primary	1	
		Primary	2	
		Middle	3	
		Matric/Secondary	4	
		Higher Secondary/Undergraduate	5	
		Graduate and above	6	

Recontact Question				
210.	<p>Thank you for completing this survey! In order for us to send you Rs. 300 of mobile airtime for taking this survey, we need your mobile phone number. What is your mobile phone number?</p> <p><i>(Programmer Note: Open-ended response for mobile phone number)</i></p>	<div style="text-align: center;"> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> </div> <p>Mobile Number</p>		
211.	Would you like to be notified about future survey opportunities?		Yes	1
			No	2
			Refused to provide mobile number	3
Chain Referral Display				
<p>Thank you again for completing this survey! With your help, we hope to reach additional adults who are engaged in the commercial sex industry to learn more about the commercial sex industry in Maharashtra. If you recruit other adults who are engaged in the commercial sex industry in Maharashtra to complete this survey, you will receive an additional Rs.200 in mobile airtime for each adult engaged in the commercial sex industry that you recruit to take the survey. You can recruit a max of three new participants to the survey. These participants will not be provided with your name or contact information.</p> <p>To participate, please tell each person that you recruit to call XXX-XXX-XXX (call center number) and provide one of the three validation codes {{code 1}, {code 2}, {code 3}} and take a quick survey via phone. Each code can only be used once. Each time a survey is completed by one of your recruits, you will receive an airtime payment. If you have any questions or concerns, please contact Mr. Anadi Mishra at 011-4269-7800.</p>				