DYNAMICS OF THE HIV EPIDEMICS AMONG INJECTING DRUG USERS AND FEMALE SEX WORKERS IN VIETNAM

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By

THUY THI CAM LE

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OR

Dean

College of Graduate and Postdoctoral Studies

University of Saskatchewan

116 Thorvaldson Building, 110 Science Place

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ABSTRACT

Although injecting drug users (IDUs) and female sex workers (FSWs) carry a disproportionate burden of HIV in Vietnam, little is known about the dynamics of the HIV epidemic among these high-risk populations. This thesis involved a secondary data analysis of the '2009 HIV/STI Integrated Biological and Behavioral Surveillance' (IBBS) study to identify the correlates of HIV among IDUs and FSWs in Vietnam. It also involved the creation and simulation of an Agent-based model (ABM) to characterize the dynamics of the HIV epidemics among IDUs and FSWs, and to explore the effects of different intervention strategies.

Data collected from 3,038 male IDUs, 2,530 street-based sex workers (SSWs) and 2,768 venue-based sex workers (VSWs) from 10 provinces in Vietnam during 2009-2010 were analyzed using descriptive statistics, bivariate and multivariate logistic regression analyses. An ABM was constructed using key behavioral data from the IBBS study. Different intervention scenarios based upon different levels of behavioral change were then simulated and compared.

The aggregated prevalence of HIV infection was 30.6% (n=930) among male IDUs, 10.6% (n=267) among SSWs and 6.7% (n=186) among VSWs. Lifetime needle sharing, duration of drug injection $\geq$ 5 years, and having regular sexual partners who injected drugs were associated with increased risk of HIV among IDUs. Independent correlates of HIV infection in multivariate analysis, regardless of sex work types, included lifetime injecting drug use, high self-perceived HIV risk, and age $\geq$ 25 years. Intervention scenarios of lowering needle sharing levels among those who injected drugs resulted in the largest reductions in HIV infection in all simulated populations and across various intervention scenarios of behavioral change. The majority of the reductions occurred when needle sharing levels declined from 50% to 40% and to 30%, respectively.

The HIV epidemic in Vietnam requires targeted prevention interventions among populations at high-risk of HIV infection. Results from the thesis suggest drug injection-related risks play an important role in fueling the epidemic and thus underscore the need to strengthen HIV harm reduction services in Vietnam. The thesis demonstrates that the use of ABM well complements traditional epidemiologic regression-based analysis in providing important insights into the complex dynamics of the HIV epidemics among IDUs and FSWs.

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LIST OF ABBREVIATIONS

ABM	Agent Based Model
AEM	Asian Epidemic Model
AIDS	Acquired Immune Deficiency Syndrome
ART	Antiretroviral Therapy
ARV	Antiretroviral
ATS	Amphetamine Type Stimulants
BCC	Behavioral Change Communication
BSS	Behavioral Surveillance Survey
CDC	Centers for Disease Control and Prevention
DE	Differential Equation
DU	Drug User
ELISA	Enzyme-Linked Immune-Sorbent Assay
EPP	Estimation and Projection Package
FHI 360	Family Health International
FSW	Female Sex Worker
HAART	Highly Active Antiretroviral Therapy
HCMC	Ho Chi Minh City
HIV	Human Immunodeficiency Virus
HTC	HIV Testing and Counseling
HSS	HIV Sentinel Surveillance
IBBS	Integrated Biological and Behavioral Surveillance
IDU	Injecting Drug User
IEC	Information, Education, and Communication
iPrEx	Pre-exposure Prophylaxis Initiative
MMT	Methadone Maintenance Therapy

NEP	Needle Exchange Program
NIHE	National Institute of Hygiene and Epidemiology
Non-DU	Non-Drug User
N/S	Needle/Syringe
OAT	Opioid Agonist Therapy
OR	Odds Ratio
PEP	Post-Exposure Prophylaxis
PrEP	Pre-Exposure Prophylaxis
RDS	Respondent Driven Sampling
RPR	Rapid Plasma Reagin
SD	System Dynamics
SIR	Susceptible – Infected - Recovered
SSW	Street-based Sex Worker
STD	Sexually Transmitted Disease
STI	Sexually Transmitted Infection
SWEAT	Sex Workers Education and Advocacy Taskforce
TB	Tuberculosis
TLS	Time-Location Sampling
TPHA	Treponema Pallidum Hemagglutination Assay
TV	Trichomonas Vaginalis
UNAIDS	Joint United Nations Programme on HIV/AIDS
UNODC	United Nations Office on Drugs and Crime
VAAC	Vietnam Administration of AIDS Control
VCT	Voluntary Counseling and Testing
VSW	Venue-based Sex Worker
WHO	World Health Organization

1. CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Since the first HIV case was detected in the early 1980s, the HIV epidemic has been recognized as one of the most serious global health problems (1, 2). As the world enters the forth decade of the epidemic, the evidence of its impact is undeniable (1). According to the latest statistics from UNAIDS (2), there were an estimated 36.7 million people living with HIV globally in 2016, while 1.0 million people died of AIDS and about 1.8 million new infections were detected. Sub-Saharan Africa remains the most severely affected region, with nearly one in every 20 adults living with HIV, accounting for 70% of the people living with HIV worldwide (2). Though the regional prevalence of HIV infection is nearly 25 times higher in sub-Saharan Africa than in Asia, there were 5.1 million people living with HIV in Asia and the Pacific in 2016, making Asia one of the regions with the fastest growing HIV epidemic in the world (2).

Vietnam is a country in South-East Asia. Since the detection of the first HIV case in Vietnam in 1990, the HIV epidemic has spread rapidly and HIV cases have been detected in all 63 cities and provinces throughout the country. After reaching its peak in the early 2000s, Vietnam's HIV epidemic has stabilized, with the prevalence of HIV infection among adults (aged 15 - 49) staying at the level of 0.4% in 2016 (3). However, HIV remains a major public health threat in Vietnam, with an estimated 11,000 new HIV infections and 7,800 AIDS-related deaths in 2016 (3).

The HIV epidemic in Vietnam has been characterized by many sub-epidemics across the country. Infection remains concentrated primarily among high-risk populations such as injecting drug users (IDUs) and female sex workers (FSWs) (4, 5). Drug use has been recognized as a major social problem since the 1990s, following the expansion of a market-oriented economic policy known as the "Renovation Policy" (6). Vietnam has been an attractive drug transit route for heroin produced in the Golden Triangle, increasing heroin availability (4, 7, 8). Heroin injection replaced opium smoking as the primary method of drug administration (72%) due to the decreased availability of opium and easy access to injectable heroin at a relatively low price. The estimated number of IDUs increased from 101,000 in 2000 to 217,000 in 2011, meaning that a growing portion of the population is exposed to HIV infection (9). The

IDU population in Vietnam is predominantly composed of males, who account for up to 90% of the total IDU population (4). The explosive spread of HIV infection among IDUs was first recognized in 1993, especially in southern Vietnam (4). In that year alone, 945 new cases of HIV were reported, of which 87% were IDUs. During the period of peak HIV prevalence among IDUs, that prevalence varied widely across regions, ranging between zero percent and 89.4% (4). There is evidence that the HIV epidemic among IDUs has stabilized in recent years due in part to HIV prevention efforts, yet IDUs remain the predominant risk group driving the epidemic, accounting for up to 70% of all HIV cases reported in Vietnam (10).

Figure 1-1 presents the HIV prevalence among IDUs from 1994 to 2013 based on the results of the national HIV Sentinel Surveillance (HSS) survey conducted among IDUs in 29 provinces across Vietnam (10, 11). As shown, after reaching a peak of 29.3% in the early 2000s, HIV prevalence among IDUs gradually decreased to 10.3% in 2013. However, prevalence was highly variable across the country and remained high in some northern mountainous provinces (e.g., 32% in Thai Nguyen and 28% in Lai Chau) and in major metropolitan cities (e.g., 24% in Hanoi and 22% in Ho Chi Minh City) (10, 11).

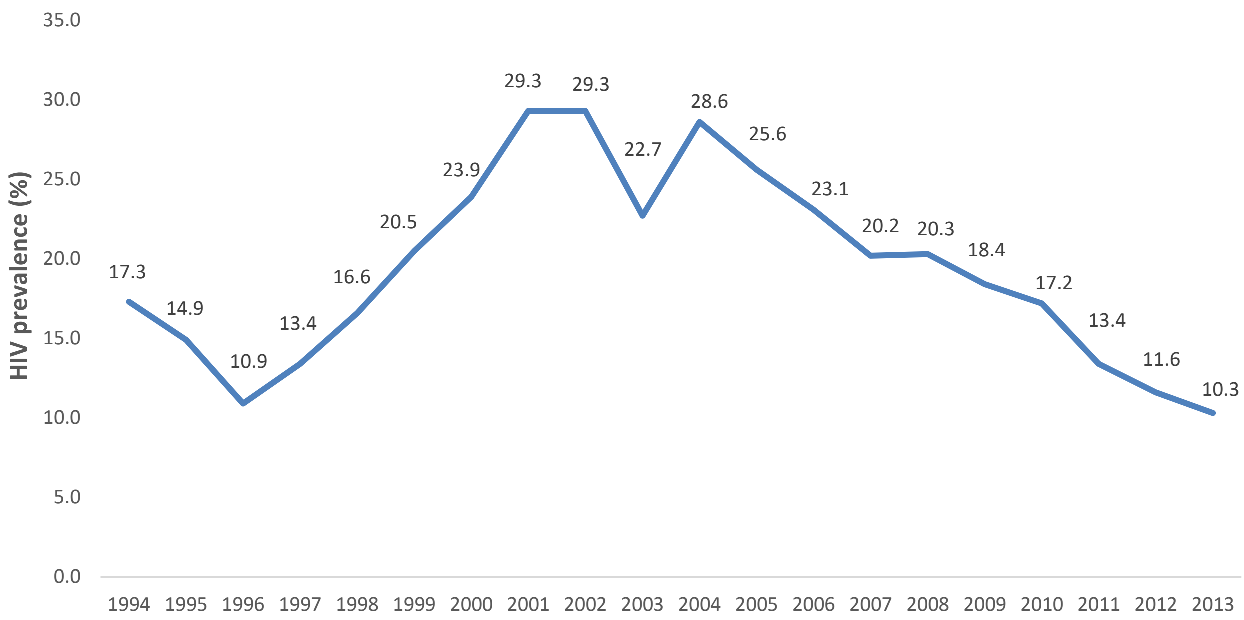


Figure 1-1. HIV prevalence among injecting drug users in Vietnam, 1994 – 2013.

The Vietnamese government's introduction of the Renovation Policy created great opportunities for economic development as well as tourism and international investment (12-14). However, it has also contributed to the rapid growth of the sex industry, which emerged from a number of structural and social problems, such as widespread unemployment in some sectors, a widening gap between rich and poor, increasing rural-urban immigration, and dramatic changes to rural family life (12-14). Although sex work is illegal and labeled as a "social evil" under the government's anti-prostitution law, it is widely practiced, particularly in urban areas (13, 14). According to the most recent HIV/AIDS estimates and projections in Vietnam, there were an estimated 68,000 FSWs throughout the country (15).

Following IDUs, FSWs are the population most affected by HIV (15). Similar to the HIV situation among IDUs, results from the national HSS system also show evidence of epidemic stabilization among FSWs in Vietnam in the past decade (Figure 1-2) (10, 11). Nationally, HIV prevalence among FSWs reached a peak of 5.9% in 2002 then started decreasing, dropping to 2.6% in 2013. Despite such a decline at the national level, the prevalence of HIV infection varied significantly across the country and surpassed 10% in major cities such as Hanoi (22.5%) and Can Tho (12%) (10, 11).

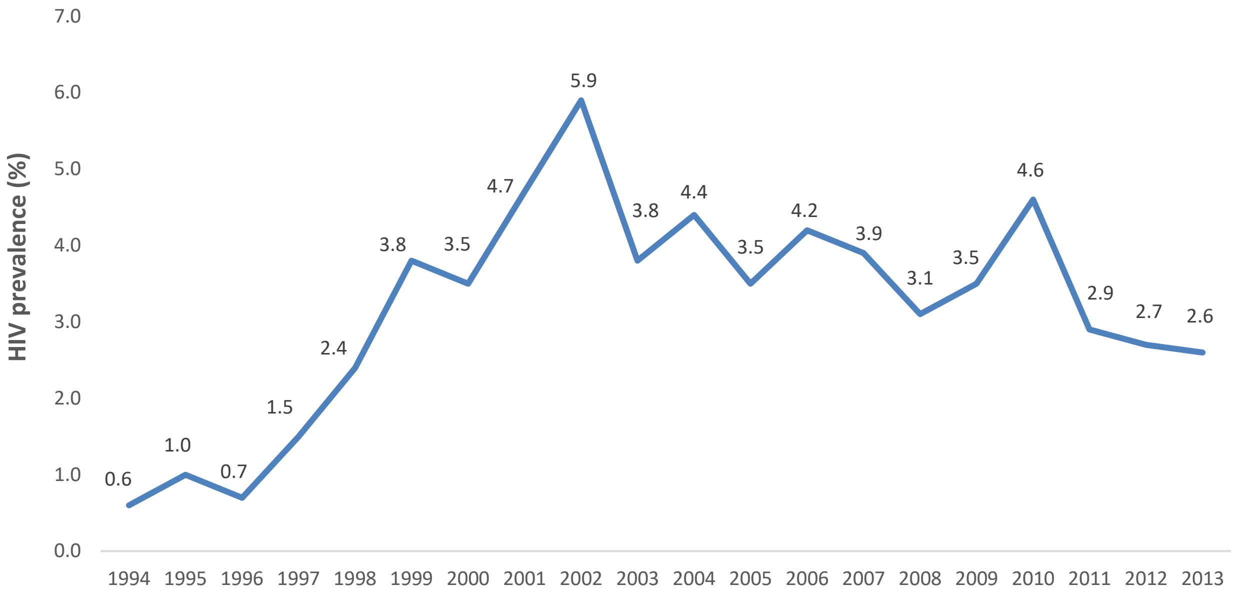


Figure 1-2. HIV prevalence among female sex workers in Vietnam, 1994 – 2013.

FSWs in Vietnam are generally divided into two main sub-populations for epidemiological purposes: street-based sex workers (SSWs) and venue-based sex workers (VSWs) (16-20). SSWs are women who work on streets and in other public places, such as parks, bus/railway stations, alleys, construction sites, and football stadiums (16-20). Usually, SSWs support themselves through sex work and do not have any other sources of income. VSWs, on the other hand, often work in entertainment establishments such as cafes, beer bars, karaoke bars, pubs, hair salons, massage parlors, clubs, and hotels (16-20). These sex workers provide sexual services in addition to their officially registered occupation as waitresses, bar maids, karaoke hostesses, and massage attendants, and earn much of their income through sex work with clients they meet at the workplace (16-21). About 70% of FSWs in Vietnam are estimated to be working in these kinds of entertainment establishments (22). However, this figure varies across different parts of the country. Studies from a variety of global contexts indicate significant variation in HIV risk across different FSW sub-populations, with SSWs being more likely to get infected than those working in entertainment establishments (5, 23-33).

Despite the apparent HIV epidemic among IDUs and FSWs in Vietnam, the epidemiology of HIV in these two populations has not been well studied. The national HSS system, in operation since 1994, serves as a rich source of HIV prevalence and risk behavior data for IDUs and FSWs (10, 11). The major limitation of the HSS system, however, is its unstable sampling frame over time and a lack of sampling representativeness given that a large proportion of the samples were taken at government-run rehabilitation centers (34).

Since 2005, the Vietnam Ministry of Health, in collaboration with Family Health International, has conducted a series of cross-sectional surveys among populations at high-risk of HIV infection, including male IDUs and FSWs. This is known as the HIV/STI Integrated Biological and Behavioral Surveillance (IBBS) study (18, 19). The IBBS study is the first systematic community-based surveillance survey that provides estimates of HIV and STI prevalence and risk behaviors among male IDUs and FSWs over time. It is a useful tool to supplement the existing HSS system. The first IBBS round was conducted in 2005 - 2006 in seven provinces in Vietnam (Hanoi, Hai Phong, Quang Ninh, Da Nang, Ho Chi Minh City, Can Tho, and An Giang). The second round was conducted in 2009 - 2010 in 10 provinces, including the initial seven provinces and an additional three provinces (Yen Bai, Nghe An, and Dong Nai). Figure 1-3 shows the locations of the IBBS study provinces in 2005 and 2009.

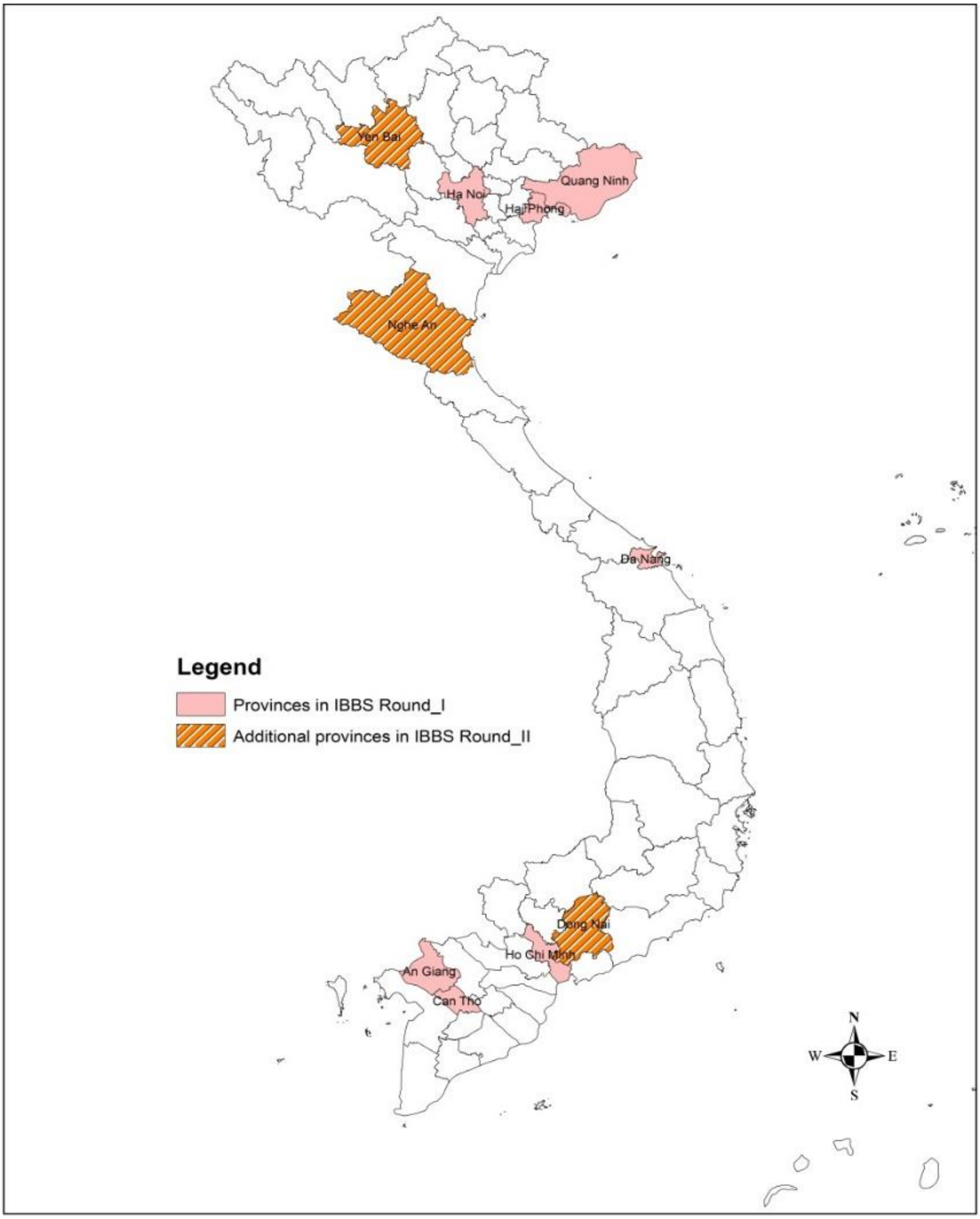


Figure 1-3. Locations of study provinces in IBBS study, 2005 and 2009.

While an analysis of the IBBS data would contribute significantly to understanding the factors associated with HIV infection among HIV high-risk populations in Vietnam, such an analysis relies on statistical regression-based models, as does the vast majority of HIV research in Vietnam. The key motivation for the use of a regression-based approach has been the desire to estimate the independent effect of different risk factors on a particular outcome, after statistically controlling for individual-level attributes which could simultaneously be related to both the risk factors and the outcome (35). However, the regression modeling approach has the tendency to simplify complex relationships between various factors because of its focus on the decomposition of variability and the estimation of independent effects, which isolates elements from each other (35). With attempts to isolate the effect of changing a single factor while holding constant all other factors in the model, the regression modeling approach might be ill-equipped to investigate the processes embedded in complex systems characterized by dynamic interactions among heterogeneous individuals, and between individuals and their environment (35). Regression-based models can be problematic since they are associated with an inability to examine the dynamic processes from which the HIV epidemic emerges. Such limitations prevent research from informing intervention policies because of its incapacity to draw inferences on the plausible impact of interventions in the context of dynamic systems (35, 36).

Since the first HIV cases appeared in the early 1980s, various mathematical models representing the dynamics of HIV transmission have been developed with increasing complexity (37). These models are acknowledged in the HIV literature as powerful tools to inform policies and intervention designs (38). However, the complex dynamics of HIV transmission makes the use of traditional mathematical modeling techniques problematic (39). There is increasing recognition that advanced computational modeling, which simulates the real-world as it might be in a variety of circumstances, may help address some of the challenges faced not only by traditional statistical regression-based methods but also by mathematical modeling techniques (35, 40). Agent Based-Modeling is a computational simulation method that defines the behavior of a population of heterogeneous individuals within an environment in which the characteristics of the population are the sum of individuals' interactions (37). Compared with other types of HIV models that are built using mathematical or statistical equations, an agent-based modeling approach has the advantage of allowing for understandings of heterogeneous individuals' behaviors, interactions between individuals, correspondence to real life situations, and a representation of the environment with which individuals interact (40, 41).

Agent-based Model (ABM) simulation also allows experimentation with a model by answering “what-if” questions such as, what if the parameters change their values? Does the model reflect the real system that it represents? How will the model behave after a certain period of time? (41) Through experimentation with the model, ABMs can provide insights into the impact of behavioral feedbacks that may occur during the epidemic (37, 41). They allow researchers to build theoretical models of social and sexual networks that may describe the context in which the epidemic may spread (37). They also allow policy makers to understand multi-level determinants of HIV infection and to design and assess the effectiveness of HIV intervention policies (42).

Given that different sub-epidemics reoccur among different sub-populations, the HIV epidemic in Vietnam is complicated. Vietnam has also witnessed the intertwining of the drug injection-related epidemic and the heterosexual epidemic (10, 11). This situation suggests that Vietnam could constitute a good case study for the application of the agent-based modeling approach to HIV epidemic modeling. To the best of the author’s knowledge, this modeling approach has never been employed in any HIV research in Vietnam.

1.2. RATIONALE

Knowledge of HIV epidemiology and its associated risk factors is of utmost importance for the development of appropriate intervention measures and to determine the best allocation of medical and public health resources. This thesis used data drawn from the 2009 IBBS study to describe the extent of HIV infection and to identify correlates of HIV infection among male IDUs and FSWs in Vietnam. By utilizing IBBS data, with its large sample size and wide geographic coverage, this thesis is expected to obtain more reliable estimates than previous studies conducted in Vietnam that suffered from large variance in the measures of association.

The ABM for this thesis was constructed using key behavioral data results from the 2009 IBBS study as inputs to examine the relevance of an agent-based approach to studying the dynamics of the HIV epidemic in Vietnam. The key motivation for the application of agent-based modeling in this thesis is the need to represent reciprocal causal interactions between a variety of risk factors, most notably both among risk factors and outcomes, which are difficult or even impossible to capture in traditional regression-based analyses. In addition, since the ABM approach uses prospective simulations, it can also anticipate future HIV trends and thus help policy makers evaluate the effectiveness of HIV prevention intervention strategies by performing various “what-if” intervention scenarios within the model.

Results from this thesis are expected to fill in part of the deficiencies of current research knowledge and enable the development of relevant intervention strategies targeting populations at high-risk of HIV infection, which will in turn relieve the burden of the HIV epidemic in the Vietnamese community as a whole.

1.3. AIMS AND SPECIFIC OBJECTIVES

This thesis involved (i) a secondary data analysis of the 2009 IBBS study to identify correlates of HIV infection among male IDUs and FSWs in Vietnam and (ii) a construction of an ABM to characterize the dynamics of the HIV epidemic in Vietnam and to explore the effects of various intervention strategies.

The specific objectives of this thesis were:

Study objective 1:

To describe the extent of HIV infection among male IDUs and FSWs in Vietnam.

Study objective 2:

To identify independent correlates of HIV infection among male IDUs and FSWs in Vietnam.

Study objective 3:

To construct an ABM that characterizes the dynamics of the HIV epidemic in Vietnam.

Study objective 4:

To simulate HIV trends among both HIV high-risk populations and the overall population in Vietnam based on different intervention scenarios of behavioral changes among HIV high-risk populations, in order to:

(i) Project and compare the HIV situations in different HIV high-risk populations and among the overall population across various intervention scenarios;

(ii) Identify intervention scenario(s) that help reduce HIV infection the most in both HIV high-risk populations and among the overall population.

1.4. THESIS STRUCTURE

This thesis is structured as follows. Chapter 2 provides a literature review of the epidemiology of HIV and its correlates among IDUs and FSWs, as well as an overview of HIV transmission models since the start of the HIV epidemic. Chapter 3 describes the methods used for the secondary analysis of the 2009 IBBS data and for the construction of the ABM. Results from the analysis of IBBS data and from various intervention scenarios experimented from the ABM are presented in Chapter 4. Public health and policy implications from the thesis results are discussed in Chapter 5 and some concluding thoughts are provided in Chapter 6.

2. CHAPTER 2: LITERATURE REVIEW

This chapter provides an epidemiological view of the HIV epidemic among IDUs and FSWs. An overview of HIV transmission models developed over the years, including the rationale for the application of an agent-based approach to HIV epidemic modeling is also described in this chapter. With these aims, the chapter is divided into seven main parts, as follows: 2.1. Global situation of the HIV epidemic; 2.2. Conceptual framework for factors associated with HIV infection; 2.3. Correlates of HIV infection among IDUs; 2.4. Correlates of HIV infection among FSWs; 2.5. Differences in the correlates of HIV infection across different FSW sub-populations; 2.6. Overview of HIV prevention interventions targeting IDUs and FSWs; and 2.7. Overview of HIV transmission models over time.

2.1. GLOBAL SITUATION OF THE HIV EPIDEMIC

2.1.1. Global HIV epidemic

Since the appearance of the first HIV case in 1981, the cumulative number of HIV infected individuals reached an estimated 78 million worldwide in 2016 (2). Despite successful HIV prevention programs and improvement in access to antiretroviral treatment and care in a number of countries, 35 million people had died of AIDS-related illnesses up to 2016, and around two million people are newly infected with the virus annually (2).

Table 2-1 summarizes the global and regional HIV/AIDS statistics in 2016 according to the latest estimates from UNAIDS (2). There were approximately 36.7 million people living with HIV in 2016, representing for an increase of 3.5 million from 2010. This increase is a result of new infections, people with Anti-Retroviral Therapy (ART) treatment living longer with HIV, and general population growth (2). One million people died of AIDS in 2016, accounting for a 48% decrease since its peak in 2005. Although HIV-related deaths have declined due in part to ART scale-up, HIV/AIDS remains a leading cause of death worldwide and the leading cause of death among women of reproductive age globally. There were about 1.8 million new infections in 2016, equivalent to about 5,000 new infections per day. While new HIV cases have been reported in all regions of the world, approximately two-thirds are in sub-Saharan Africa, with 43% of new cases in Eastern and Southern Africa. Among all geographic regions in the world, sub-Saharan Africa bears the greatest burden of the epidemic, with nearly 1 in every 20 adults living with HIV. An estimated 25.5 million people live with HIV in Sub-Saharan Africa, which accounts for 70% of the people living with HIV worldwide. Though the regional prevalence of HIV infection is nearly 25 times higher in sub-Saharan Africa than in Asia, the fact that 5.1 million people were living with HIV in Asia and the Pacific in 2016 makes Asia one of the regions with the fastest growing HIV epidemic in the world (2).

Table 2-1. 2016 global and regional HIV/AIDS statistics by UNAIDS.

Region	People living with HIV (total)	New HIV infections			AIDS-related deaths (total)
		Total	Aged 15+	Aged 0-14	
Easter and Southern Africa	**19.4 million** [17.8 million– 21.1 million]	**790 000** [710 000– 870 000]	**710 000** [630 000– 790 000]	**77 000** [52 000– 110 000]	**420 000** [350 000– 510 000]
Asia and the Pacific	**5.1 million** [3.9 million– 7.2 million]	**270 000** [190 000– 370 000]	**250 000** [180 000– 380 000]	**15 000** [7700– 26 000]	**170 000** [130 000– 220 000]
Western and central Africa	**6.1 million** [4.9 million– 7.6 million]	**370 000** [270 000– 490 000]	**310 000** [220 000– 410 000]	**60 000** [35 000– 89 000]	**310 000** [220 000– 400 000]
Latin America	**1.8 million** [1.4 million– 2.1 million]	**97 000** [79 000– 120 000]	**96 000** [78 000– 120 000]	**1800** [1300– 2400]	**36 000** [28 000– 45 000]
The Caribbean	**310 000** [280 000– 350 000]	**18 000** [15 000– 22 000]	**17 000** [14 000– 21 000]	**<1000** [<1000, 1000]	**9400** [7300– 12 000]
Middle East and North Africa	**230 000** [160 000– 380 000]	**18 000** [11 000– 39 000]	**17 000** [10 000– 36 000]	**1400** [<1000, 3300]	**11 000** [7700– 19 000]
Eastern Europe and central Asia	**1.6 million** [1.4 million– 1.7 million]	**190 000** [160 000– 220 000]	**190 000** [160 000– 220 000]	*Estimates were unavailable from the time of publication*	**40 000** [32 000– 49 000]
Western and central Europe and North America	**2.1 million** [2 million– 2.3 million]	**73 000** [68 000– 78 000]	**72 000** [67 000– 78 000]	*Estimates were unavailable from the time of publication*	**18 000** [15 000– 20 000]
Global	**36.7 million** [30.8 million– 42.9 million]	**1.8 million** [1.6 million– 2.1 million]	**1.7 million** [1.4 million– 1.9 million]	**160 000** [100 000– 220 000]	**1.0 million** [830 000– 1.2 million]

2.1.2. Epidemiology of HIV among injecting drug users

Injecting drug use has made a substantial contribution to the HIV epidemics globally (43). As estimated by the United Nations Office on Drugs and Crime (UNODC), the regional prevalence of injecting drug use ranges from less than 0.2% in sub-Saharan Africa to approximately 1.3% of adults in Eastern Europe and Central Asia (44). Extrapolated estimates from 148 countries with available data suggest that 15.9 million people might inject drugs worldwide, nearly three-quarters of whom are from low- and middle-income countries (45, 46). The largest numbers of IDUs are in South East and East Asia, with approximately 4.5 million IDUs, followed by Eastern Europe with an estimated 3 million IDUs (45, 47). In the former region, China is estimated to represent a majority of the IDUs (2.3-2.9 million), followed by Japan and Indonesia (45, 47). In Eastern Europe, Russia, and Ukraine represent the bulk of IDUs. North America has over 2.2 million IDUs while Latin America and Western Europe each have approximately one million estimated IDUs (45, 47). The total number of IDUs across the Middle East, sub-Saharan Africa, and in South Asia is not well understood. However, it is estimated that just in Kenya, Mauritius, and South Africa combined there may be about 300-350,000 IDUs (45, 47).

In many countries throughout Eastern Europe, the Commonwealth of Independent States, North Africa, North America, the Middle East, and different parts of Asia, the direct sharing of needles, syringes, and other injection equipment among IDUs has driven HIV epidemics (45-47). According to UNAIDS' global report on HIV/AIDS in 2013, the world was not on track to reduce HIV transmission among IDUs given the lack of significant change in the HIV burden in this population (44). Although IDUs account for an estimated 0.2-0.5% of the world's population, they make up approximately 5-10% of people living with HIV globally (44). This figure increases to 30% when sub-Saharan Africa, where injecting drug use has made a negligible contribution to the epidemic, is excluded (43, 44, 46). There were an estimated three million IDUs living with HIV globally in 2008 (46-48). Of them, China, the United States, and Russia reported the largest numbers of HIV-infected IDUs (46-48).

All regions report high HIV prevalence among the IDU population, although the severity of prevalence varies (45). HIV prevalence among IDUs ranged from 5% in Eastern Europe to 28% in Asia (45). High HIV prevalence estimates were found in Southeast Asia, Eastern Europe, and Latin America, where the prevalence of HIV infection among some sub-populations of people who inject drugs has been reported to be over 40% (45). HIV prevalence among IDUs ranged from 20% to 40% in Russia (37.2%), Spain (39.7%), Cambodia (22.8%), and Libya (22.0%) (45). HIV prevalence was over 40% in nine countries: Estonia (72.1%), Ukraine

(41.8%), Burma (42.6%), Indonesia (42.5%), Thailand (42.5%), Nepal (41.4%), Argentina (49.7%), Brazil (48.0%), and Kenya (42.9%) (45).

Injecting drug use is also responsible for an increasing proportion of new HIV infections in many parts of the world, including countries in Eastern Europe, South America, and East and Southeast Asia (44, 45). Results from recent modes of transmission analysis suggest that IDUs and their sexual partners accounted for 68% of new HIV infections in Iran, 40% in Eastern European countries where such studies were conducted, and 36% in the Philippines (44).

2.1.3. Epidemiology of HIV among female sex workers

In addition to IDUs, FSWs have been an important contributor to the HIV epidemic worldwide since it began. Estimates of the proportion of FSWs among women in different regions around the world range from 0.2% to 2.6% in Asia, 0.4% to 4.3% in sub-Saharan Africa, and 0.2% to 7.4% in Latin America (49).

According to a meta-analysis based upon data from approximately 100,000 FSWs in 111 studies across 50 low- and middle-income countries in 2013, the overall estimated global HIV prevalence among FSWs was 11.8% (50). On average, FSWs are 14 times more likely to be infected with HIV than adult women in the general population (50-52). However, HIV prevalence among FSWs varied significantly by region, reflective of background rates of HIV (50). The highest HIV prevalence was found in Sub-Saharan Africa with a pooled prevalence of 36.9%, followed by Eastern Europe (10.9%), Latin America and the Caribbean (6.1%), and Asia (5.2%). The lowest HIV prevalence rate was found in the Middle East and North Africa, with a pooled prevalence of 1.7% (50). There was significant variation in HIV prevalence among 14 countries reported in Asia in the same study (50). While relatively low HIV prevalence of less than 1.0% was reported in countries like Mongolia, Pakistan, Afghanistan, Bangladesh, and Lao PDR, the prevalence exceeds 10% in Malaysia, Thailand, India, Papua New Guinea, and Cambodia, which has the highest prevalence, at 23.1%. The estimated HIV prevalence among FSWs in Vietnam was 6.5%, which was pooled from samples of 3,381 FSWs in three studies (50).

A systematic review conducted by Platt et al. among FSWs in 40 European countries further revealed that HIV prevalence among FSWs in Western Europe is generally low, at 1.0% or less (53). Prevalence was higher in Italy and Spain among street samples that included migrants and transgender SWs (53). Prevalence of HIV is low in countries in Central Europe (1.0%-2.0%) and higher in Eastern Europe (2.5%-8.0%) (53). In the Netherlands, HIV prevalence was reported at 3.8% among FSWs overall, but is far higher among women with a history of injecting drug use (13.6%) compared with those without (1.5%) (53). In Spain, Portugal, and the UK, small samples of FSWs suggested higher HIV prevalence ranging between 4% and 24% among heroin or crack users (53). In other high-income countries such as Canada and the US, epidemics that initially escalated in people who injected drugs in the mid-1990s shifted to FSWs (54). Available data also suggest emerging or established epidemics among FSWs who inject drugs (54).

2.1.4. Differences in HIV risks across female sex worker sub-populations

Sex work is defined as the provision of sexual services for money or its equivalent, though it varies enormously in its forms and social contexts (55). According to Harcourt and Donovan, the boundaries of sex work are difficult to defined; they range from erotic displays without physical contact with the client to high risk unprotected sexual intercourse with clients (55). Individuals may occasionally exact a fee or gift for a sexual favor without perceiving themselves to be sex workers or officially engaging in the sex work industry in the form of the explicitly commercial provision of sex services (55). The behavioral risk profile of FSWs therefore depends to a considerable degree on the context and location of their transactions and the intensity of their working life (55). Given the heterogeneity of the FSW population, differences in HIV risks across different sub-populations of FSWs have been the subject of research over the last several decades.

2.1.4.1. Typologies of female sex workers

As the role of sex work in driving and sustaining the HIV epidemic has become apparent, there is an increasing recognition of the importance of properly understanding the context of FSWs as well as the drivers and organization of the sex work industry (56). Attempts have been made to document the variety of sex work arrangements and to develop typologies of sex work into which these arrangements fit (49, 55-58).

A distinction regarding the typologies of FSWs has been made in many studies (22, 49, 55-60). The most narrow categorization of FSWs is based on place of work, mode of soliciting clients, type of sexual services provided, and type and number of clients (22, 55, 56). The broad categorization of FSWs, which covers a number of narrow categories, is also in general usage (55). For example, FSWs could be categorized into low, middle and high-class FSWs based on their levels of income. FSWs could also be grouped into direct and indirect categories to reflect their primary occupation. “Direct” FSWs are women who typically do not have any occupation other than sex work (55, 58). "Indirect" FSWs often have a primary occupation and sex work is only a means for them to earn additional income (55, 58).

The focus of this thesis is on two FSW sub-populations frequently studied in the context of HIV/AIDS, namely street-based sex workers (SSWs) and venue-based sex workers (VSWs). In many studies, SSWs are interchangeably referred to as low-class or direct FSWs while VSWs are referred to as middle-class or indirect FSWs (55, 58).

2.1.4.2. Discrepancies in HIV risks between street-based and venue-based sex workers

Street-based sex workers have long been considered most vulnerable to HIV infection (24, 25, 31, 32, 61, 62). Even in European and North American countries where the prevalence rates of HIV infection among FSWs are generally much lower than in other parts of the world, the risk of HIV appears to be highest among SSWs compared with that of other sub-populations of FSWs (53, 61, 63). Different studies in Asia, Africa, and Europe have consistently found that SSWs were at least several times more likely to acquire HIV infection than their venue-based counterparts (5, 26, 29-33, 64-69).

2.2. CONCEPTUAL FRAMEWORK FOR FACTORS ASSOCIATED WITH HIV INFECTION

In order to develop effective HIV prevention intervention strategies, an understanding of who is at risk and why they are at risk is of critical importance. Studies suggest that individual characteristics, the environment people live in, and the infection itself could all contribute to determine the risk of HIV exposure and acquisition (70). Thus, there should be causal pathways linking socio-demographic, economic, cultural, biological, and behavioral factors (70). Epidemiological studies have explored various factors associated with HIV risks and examined how these factors vary across populations and over time (70). However, much is still unknown about why different populations have experienced different epidemics, what the drivers of high risk are as compared to factors that simply correlate with risk, what is amenable to change, and what the appropriate targets for interventions are (70). In order to improve our understanding of the factors that are driving the HIV epidemic and to identify the multiple inter-relationships responsible for HIV infection, a coherent conceptual framework is needed (70, 71). The HIV conceptual framework used in this thesis is adapted from Mosley and Chen's conceptual framework (72) for child survival research and, more recently, Kembo's conceptual framework for determinants of HIV infection (71). According to the Mosley and Chen framework, socio-economic characteristics operate through proximate factors to influence the health outcome

(72). HIV research has increasingly used the Mosley and Chen framework to examine the determinants of HIV infection (71). The adapted conceptual framework for factors affecting the risk of HIV infection among IDUs and FSWs that shapes this thesis is presented in Figure 2-1.

According to this conceptual framework, demographic characteristics (*e.g., age, sex, marital status, religion, mobility*) and socio-economic factors (*e.g., education, occupation, income, place of residence*) fall under the umbrella of underlying factors. They operate through proximate factors, which include behavioral factors (*e.g., age at first sex, age at commencement of sex work, duration of involvement in sex work, age at first drug use/injection, number of sexual partners, condom use practice, needle sharing practice, frequency of needle sharing, place of drug injection*) and biological factors (*e.g., sexually transmitted infections*) to influence the risk of HIV acquisition among IDUs and FSWs (71, 72). In agreement with Kembo's point of view (71), this conceptual framework could be expanded with the addition of other variables depending on the availability of data. The 2009 IBBS study, from which data for this thesis were drawn, permits the analysis of all variables presented in this conceptual framework.

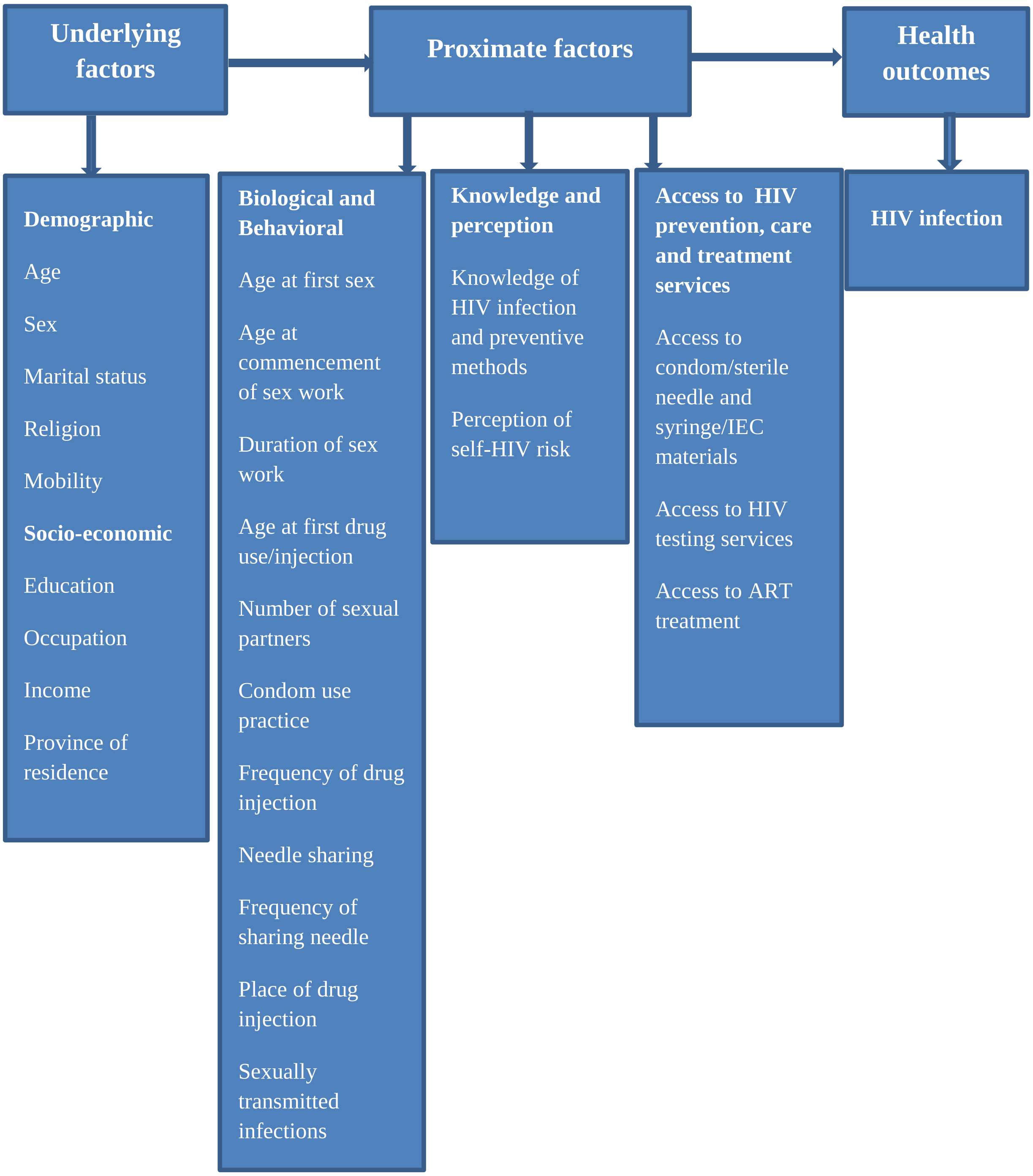


Figure 2-1. Adapted conceptual framework of the factors associated with HIV infection risk among injecting drug users and female sex workers.

2.3.CORRELATES OF HIV INFECTION AMONG INJECTING DRUG USERS

From the outset, injecting drug users have been the predominant risk group driving the HIV epidemic (4). Understanding IDUs' risk behaviors is critical for the design of effective prevention interventions to curtail the spread of HIV among IDUs, as well as from IDUs to their sexual partners and to the general population (73). Epidemiological studies have identified a range of factors associated with HIV infection among IDUs. The next section focuses on factors that have been extensively studied in the literature. Such factors are broadly classified into socio-demographic factors, drug injection-related behaviors, sexual behaviors, sexually transmitted infections, and HIV/AIDS knowledge and perception.

2.3.1. Socio-demographic factors

The association between age and HIV infection among IDUs remains inconsistent in the literature. The majority of the evidence documented indicates that younger age is associated with increased HIV risk among IDUs (30, 74-88). Young injectors often lack injecting skills, which may lead them to inject drugs and share needles and syringes with other older, more skillful, and more experienced IDUs who might already be infected with HIV but not be aware of their HIV status and still appear healthy (88). Also, youth is generally related to a lower socio-economic status (76, 89-92), which may predispose young IDUs to high levels of risky behaviors, such as unprotected sex or the sharing of needles, syringes, and other injecting equipment (86), placing them at higher risk of acquiring HIV (75, 79, 80, 82-84, 93-96). However, several studies among IDUs in China suggested that being over 27 years old was associated with a higher risk of HIV infection compared with the younger age group (97-99). Another study conducted among 275 IDUs in Edmonton, Canada, also found older age to be an independent correlate of HIV infection (100). Given that being a young age at first injection (99) and the long duration of injecting drug use (101, 102) are both associated with HIV, being older may reflect a cumulative risk for HIV infection (75, 77, 103-107).

Marital status is also found to be associated with HIV risk among IDUs. While being divorced is associated with a higher likelihood of HIV infection (88), being married is suggested to have a protective effect on the acquisition of HIV (84, 92, 108, 109).

Several variables representing socio-economic status are also found to be associated with HIV infection among IDUs. For example, studies have consistently shown that IDUs with low a level of education were significantly more likely to acquire HIV than those with higher educational achievements (86, 102, 110-113). HIV infection was also more likely among those who are unemployed (102, 114), are homeless (73, 103), have unstable housing (82, 88), and who do not live with family (109).

Mobility is also an important factor that contributes to the spread of HIV infection among IDUs. A study by Tran et al. suggests that the experience of injecting drug use in different cities was associated with an increased chance of HIV infection (86). According to the authors, it could be that those mobile IDUs had spread HIV infection from city to city (86). On a related topic, evidence has also shown that migrants are vulnerable to HIV (115) and that high levels of sexual risk behaviors were frequent among mobile individuals with HIV (116). Migration usually accompanies a situation with limited access to appropriate information on HIV and also low levels of social support (117, 118). Moreover, mobile IDUs are likely to visit shooting galleries, which are defined as places IDUs often congregate for injecting drug use (86, 119). Syringes are often borrowed, rented, or purchased at these venues while other drug injection equipment such as drug containers, cookers, and cotton are commonly shared among both friends and strangers (119-123). The risk of HIV transmission would be high in such places due to the fact that an IDU has more chance to find other IDUs for needle sharing and also due to the unavailability of sterile needles and syringes (86, 119, 121).

A history of being detained in a drug rehabilitation center appeared to be associated with HIV infection in the sense that an increased number of incarcerations in such centers was associated with heightened risk of HIV (73, 88, 124). Prior studies found that this IDU subgroup more often participated in injecting behaviors associated with HIV infection than other sub-groups of IDUs (125, 126).

2.3.2. Drug injection-related behaviors

HIV infection among IDUs has shown a capacity to spread rapidly through unsafe injecting practices (4, 73, 76, 82, 86, 106). The sharing of contaminated needles, syringes, and other injection equipment among IDUs led to explosive HIV outbreaks in North America and Western Europe in the 1980s and then in Asia in the late 1990s in countries such as Thailand, Myanmar, India, Nepal, Malaysia, and China (78). In many countries, unsafe drug injecting practices have been recognized not only as a direct factor for HIV spread, but also as a facilitating factor for heterosexual transmission of HIV from IDUs to their sexual partners (78). The sharing of needles, syringes, and other drug injecting equipment among IDUs has also fueled the HIV epidemics in many other parts of the world, such as eastern Europe, Southeast and Central Asia, Northern Africa, and South America (46, 127).

Research from various settings, of different designs, and conducted among different samples of IDUs have consistently found that the direct sharing of contaminated needles and syringes is associated with an elevated risk of HIV infection among IDUs from several to several-hundred-fold (4, 9, 73, 76, 77, 82, 84, 86, 96, 102, 106, 107, 124, 128-142).

Paraphernalia sharing, defined as the indirect sharing of injecting equipment and materials such as drug solution, rinse water, cotton, cookers, drug containers, and other drug preparation items, involves less risk than direct needle and syringe sharing, but does also contribute to HIV transmission among IDUs (4, 9, 77, 84, 86, 102, 134, 143-145). A study conducted among a large cohort of 3,711 IDUs in 16 cities across Ukraine also identified the frequency of sharing drug preparation equipment as a significant correlate of HIV risk (102). Results from this study suggested that IDUs who consistently shared drug preparation equipment in the past month were 50% more likely to be HIV positive compared with those who never reported this behavior (102).

Recent studies of HIV-infected IDUs in Taiwan indicated that needle and syringe sharing followed by the sharing of solvents (i.e., heroin diluents) were the two major risky behaviors associated with HIV infection among Taiwanese IDUs (140, 146). Peng et al. also found that sharing dilutes and sharing dilutes concurrently with needles significantly predicted HIV seroconversion (124).

Apart from unsafe injecting practices, several drug injection-related factors, such as frequency of drug injection, drug injection duration, and places of injection, were also found to have influences on the risk of HIV acquisition. No matter how the frequency of injecting drug use was measured, existing evidence suggests that frequent injecting drug use is significantly associated with HIV seropositivity (82, 99, 101, 103, 112, 147-150). Along this line, a study looking at HIV incidence and behavioral correlates of HIV among a cohort of 717 IDUs in St. Petersburg, Russia, found that the high frequency (i.e., defined as frequent or always) of drug injection in groups with other people, rather than injecting alone, was a significant predictor of HIV incidence during the 12-month follow up period of the study (151). This study provides supportive evidence for an earlier study conducted among a sample of male IDUs in Karachi, Pakistan, which found that injecting drugs in groups was associated with an elevated risk of HIV positive serostatus (109).

Early studies on the correlates of HIV seropositivity among IDUs already identified the duration of drug injection as a significant associated factor for HIV (101). More recently, a strong dose-response relationship between the duration of drug injection and HIV infection was found in

Taran et al.'s study (102). According to this study, IDUs who injected from 1 - 3 years were two times more likely to be infected with HIV compared with those who injected drugs for less than one year. In addition, those who injected for 4 - 10 years were five times more likely to be HIV infected compared to IDUs who injected drugs for 1 - 3 years; those who injected for 10 or more years were seven more likely to be infected (102).

Research has also identified places of injection as an important factor contributing to HIV infection risk among IDUs. Injecting drugs in places other than homes magnifies the level of risk behaviors in HIV acquisition, such as injecting drugs in groups or needle sharing (4). It has been found that there is a higher likelihood of needle sharing for IDUs who inject on the streets, in other public places, or at a shooting gallery in comparison to those who inject at private homes or friends' houses (4). Given that both needle sharing and drug injection in groups heighten the risk of HIV acquisition (109, 151), injecting drugs on the street (77) and even more so at shooting galleries where high risk behaviors are common practice, significantly increases the chance of infection (4, 77, 119-123, 148, 149, 152-155). These findings are supported by a large body of research that suggests that shooting gallery use is a risk factor for HIV infection and plays an important role in the rapid spread of HIV (78, 121, 130, 150, 152, 156-161).

2.3.3. Sexual behaviors

Injecting drug users are at dual risk for HIV acquisition and transmission (79). In the early stages of the epidemic, studies among IDUs attributed most HIV infections to injection risks (162). Although there were several studies suggesting the existence of sexual risks among IDUs, such risks were overshadowed by injection risks (162). However, as the epidemic progresses, there is increasing evidence on the important role of sexual transmission among IDUs, even after accounting for drug injection risks (75, 105, 162-165). Among various sexual risk behaviors, unprotected sex, defined as the lack of condom use or infrequent use of condom during sexual intercourse, is considered the major risk factor for HIV infection (114, 166).

Visiting commercial sex workers has also been found to be associated with an increased risk of HIV acquisition among IDUs (86, 102, 164, 167). A review on HIV risk behaviors among IDUs in Vietnam suggested that IDUs commonly perceive the risk of virus transmission to be less through sexual practice than sharing injection items and, hence, are less likely to adopt safe sex practices than they are safe injection practices (4). As a result, condomless sex with FSWs is widespread among IDUs. For example, only 50% of IDUs in Ho Chi Minh City used condoms when having sex with FSWs in the past month (4). Around 15% of IDUs in Bac Ninh, a northern province in Vietnam, used condoms inconsistently and another 15% did not like to use condoms at all while having sex with FSWs (4).

The association between HIV risk and the number of sexual partners remains inconsistent in the literature. While Shapatava et al. suggested a positive association between a larger number of sexual partners and HIV infection (164), Bruneau et al. found that IDUs who reported more than one sexual partner in the previous six months were less likely to be HIV sero-positive than those reporting no sexual partners (103). According to the authors, loss of libido with the heavy use of injection drugs and poor general health related directly or indirectly to HIV status could explain this finding (103).

2.3.4. Sexually transmitted infections

Sexually transmitted infections (STIs) have also posed a risk for HIV infection among IDUs. Early studies identified the presence of a sexually transmitted disease (STD) in the previous year as a predictive factor for HIV incidence (129, 168-171). Although the exact temporal order between STIs and HIV seroconversion has not been determined in these studies, the presence of a STD in the year prior to seroconversion suggests a temporal order between risk and the onset of infection (129, 168-171). Findings from earlier studies have been supported by more recent studies that find syphilis infection to be a risk factor for HIV infection (142, 164, 172). A syphilis infection is considered to be a marker for high risk sexual behavior (173) and is also an ulcerative disease that facilitates the transmission of HIV (174).

2.4. CORRELATES OF HIV INFECTION AMONG FEMALE SEX WORKERS

While the relative burden of HIV varies by geographic and epidemic context, FSWs are often found to be at significantly increased vulnerability to HIV (50). There is a strong need to identify determinants of HIV infection among FSWs in order to develop effective strategies and targeted interventions. Research has identified a wide range of risk factors for HIV infection among FSWs. This section focuses on factors that have been extensively studied in the literature. Such factors are broadly classified into socio-demographic factors, sexual behaviors, drug use-related behaviors, STIs, and HIV/AIDS knowledge and perception.

2.4.1. Socio-demographic factors

Among various socio-demographic factors, age is an important biological factor that influences HIV risk among FSWs. That said, the nature of the association between age and risk of HIV is unclear. Some evidence suggests that HIV prevalence rates were significantly higher among younger FSWs than among older individuals (26, 66, 85, 175-179). According to Sarka and colleagues, the reasons why younger FSWs are at higher risk of HIV infection could be explained by either the professional immaturity of young FSWs, which might increase the likelihood of practicing unsafe sex with their clients, or the higher rate of injury of the cervico-vaginal epithelium that results from young FSWs' immature genital track anatomy (177, 178). These explanations corroborate the results of other FSW studies that show a greater occurrence of high-risk sexual behaviors among younger FSWs compared with older FSWs (32). For example, adolescent FSWs had a greater number of clients per week, had less knowledge of HIV, reported fewer condom negotiation skills and less condom use, and also engaged in more anal sex than their older counterparts (32).

Another body of evidence indicates that advancing age increased the likelihood of HIV acquisition (32, 68, 180-187). The common arguments across these studies were that older age may reflect cumulative HIV risk because of the long duration of sex work and a higher number of sexual partners, and thus a higher probability of having had an HIV-infected partner (68, 182). Older age was also identified as an independent risk factor for unprotected sex, injection drug use, and a self-reported history of an STI infection (32). In the sex work industry, older FSWs are considered as a disadvantaged group compared with those who are younger (32). They are more likely to go on the street or other public places to get clients, accept HIV high-risk clients such as those who inject drugs, or be willing to have condomless sex for more money (32).

Studies have found a negative association between the level of educational attainment of FSWs and HIV infection. Studies in different settings and across different regions worldwide have consistently shown that FSWs with low educational attainment were significantly more likely to acquire HIV than those with higher educational achievement (32, 65, 179, 187-194). Although education levels varied across studies, FSWs with limited education are extremely vulnerable to unsafe sex and drug involvement (32) and were found to be several to over 20 times more likely to be infected with HIV compared with those with higher levels of education (32, 65, 179, 187-194).

Income level is equal important determining HIV risk among FSWs. Different studies among FSWs have consistently reported that lower income levels are associated with an elevated risk of HIV infection (186, 191, 195). There have also been several studies suggesting that low cost sexual services were related to a higher risk of HIV infection (180, 196-198). Available evidence suggests that FSWs who have few sources of income are often under increased financial pressure to support themselves and their family. This situation makes those women less able to refuse clients who refuse to use a condom, putting them at high risk of HIV infection

(32, 195, 199).

Age at the commencement of sex work also influences the likelihood of getting HIV in the sense that FSWs who begin at a younger age have an elevated risk of HIV seroconversion (179, 190, 193). Studies among FSWs in Thailand consistently found that women who started selling sex before the age of 15 were at least twice as likely to be infected as those who initiated sex work at an older age, after controlling for potential confounders such as duration of sex work and number of sexual partners (190, 193). A similar association was observed in a study of SSWs in Hanoi, Vietnam, although sex workers commenced sex work at an older age compared with those in the Thai studies. This study found that beginning sex work at aged 20 or younger is associated with a threefold increase in the likelihood of getting infected with HIV (179).

In a similar vein, the duration of engagement in sex work has also frequently been identified as a correlate of HIV infection among FSWs. However, the association between HIV risk and the duration of sex work is inconsistent in the literature. Various studies from Africa, Europe, Asia, and South America have shown that FSWs involved in sex work for an extended period of time were more likely to be infected with HIV compared with those who were not (32, 66, 180, 200-203). Such findings are in line with the theory that long-term involvement in sex work tends to elevate HIV risk due to increased exposure to HIV over time (32, 66, 68, 200-202, 204). As Kakchapati and colleagues argued, the longer FSWs are involved in sex work, the more likely they are to be exposed to large numbers of sexual partners, to have high concurrency of these partners, to use condoms less and/or inconsistently, and to use alcohol or drugs, all of which increase their chance of contracting HIV (32). However, other studies suggest that the duration of sex work was negatively associated with HIV infection, with a shorter time involved in sex work being associated with a greater HIV risk (33, 175, 205). According to Dunkle et al., women involved in sex work for a longer period of time might adopt protective sexual or occupational strategies that can help them reduce the risk of HIV acquisition (175). In contrast, the higher prevalence of HIV infection among those involved in sex work for a shorter time may be attributed to the low perception of personal HIV risk, which might result in a higher number of clients with less motivation to use condoms or a lack of experience in and the skills necessary to negotiate condom use (196).

Since the early years of the HIV epidemic, male mobility has been highlighted as one of the key factors for the spread of HIV among men involved in commercial sex services (16, 17, 206-212). However, the mobility of FSWs has largely been ignored (212). Research across continents has shown that FSWs are highly mobile (212-215), and that mobility and migration are an inherent part of sex work in most settings (185, 216-218). FSWs often move between places of work, both within and between towns and/or countries, to improve their working conditions, to access a wider or different client base, to look for new adventures, or to conceal HIV-related illnesses that might prevent them from work (212, 213, 219, 220). As a consequence of this mobility, FSWs may be vulnerable in their new environments, including unfavorable workplaces, a lack of familiarity with the legal system and health regulations, and limited access to HIV prevention and care services (51, 55, 212, 213, 216, 219, 220). Findings from a multi-center study among 1,845 FSWs in various countries in South America revealed that immigrant FSWs were more likely to be involved in high-risk sexual behaviors, such as unprotected sex, and drug use practices compared with local FSWs (219). Along this line, Shannon and colleagues argued that migration and mobility have particularly complex and non-linear effects on HIV risk among FSWs (221). They provide evidence that, while internal domestic and circular migration and mobility (e.g., intra-urban or intra-district mobility, and short-term travel to sex-work hotspots), have been associated with increased HIV vulnerability, long-distance mobility and international migration from non-endemic settings have been linked to high rates of condom use and thus low HIV prevalence. In addition, geographical features and epidemic structures (e.g., immigration or emigration to higher-prevalence settings and rural vs. urban migration), language skills, and access to health care services add further complexity to the association between migration and HIV risk among FSWs (54, 65, 221). Most recently, Coetzee and colleagues' study among FSWs in South Africa found a link between migration and HIV risk; FSWs born outside of the study province had 2.3 times the likelihood of being HIV infected compared with those who were born in the same province (187).

2.4.2. Sexual behaviors

There is a large body of research documenting the association between condom use and HIV infection among FSWs. This association is often examined from two opposite angles, either the protective effect of condom use against HIV infection, or the detrimental effects of inconsistent condom use. Despite variations in the definition of consistent condom use and in recall periods used in different studies, most of the existing evidence suggests that consistent condom use reduced the risk of HIV (175, 185, 188, 195, 203, 222) while condomless sex or infrequent use of condom increased this risk (5, 53, 85, 141, 204). In this connection, research has also suggested that non-use of condoms with steady sexual partners such as spouses or lovers, especially in the case where spouses/lovers are at high risk of infection, represents a great risk for HIV (223-226).

Unlike the majority of the evidence that exists about the protective effect of consistent condom use, a recent study conducted by Mutagoma et al. among a sample of FSWs in Rwanda found that consistent condom use with clients in the 30 days prior to the survey was linked to a higher prevalence of HIV infection (182). According to the authors, due to the cross-sectional nature of the study, the result observed does not infer a causal relationship between condom use and HIV risk (182). Instead, it may reflect a reverse causality, where HIV-positive FSWs were previously aware of their HIV-positive status and possibly already linked to HIV prevention, care, and treatment services (182). As a result, they received greater education and counseling regarding the prevention of spreading HIV to commercial clients and had easy access to condoms and other HIV prevention commodities (182).

It has generally been suggested that a larger number of sexual partners among FSWs is a potential risk factor for HIV infection. To date, however, conflicting findings have been documented regarding the true association between the number of sexual partners and HIV infection among FSWs. Various studies of FSWs and HIV conducted since the start of the epidemic have found a positive association between a larger number of sexual partners and increased risk of HIV acquisition (175, 186, 189, 194, 200, 201, 222, 227, 228). A similar association was also reported between the number of commercial clients and HIV infection (5, 53, 187, 188, 204). In a study of 1,633 FSWs in Spain by Estebanez et al., however, a U-shape association (i.e., a frequency distribution shaped more or less like the letter U, with its greatest frequencies at the two extremes of the range of the variable) was found between the number of sexual partners and HIV seropositivity (66). This association was relatively similar to the one observed in a previous study of FSWs in Amsterdam, the Netherlands (229). According to Estebanez and colleagues, the negative association between the number of sexual partners and HIV infection may reflect an increased professionalism with respect to HIV prevention among FSWs who have a large number of sexual partners (66). However, an African study and a multi-centers study by the Centers for Disease Control and Prevention (CDC) observed none of the above associations (230, 231). As Estebanez et al., suggested, this lack of association could be attributed to differences in HIV prevalence among sexual partners of FSWs (232). The number of sexual partners is considered as less important in the acquisition of HIV in a community where the HIV prevalence is low, or the practice of safer sex is high (232).

Having sexual partners, especially steady non-commercial partners who inject drugs, has also emerged as a major risk factor for acquiring HIV among FSWs. Despite variations in the types of FSWs studied and the methodologies used across different studies, the likelihood of getting

HIV has ranked from several to over 60 times higher among FSWs whose regular and/or non-paying sexual partners inject drugs than among FSWs whose partners do not engage in this behavior (66, 79, 179, 194, 233-235). Such practices are considered to be one of the major routes for the introduction of HIV in FSWs in a number of Western countries, especially those in Europe and North America (53, 233, 236).

2.4.3. Drug use-related behaviors

In addition to the risk of acquiring HIV through unsafe sexual practices, FSWs who use or inject drugs are at higher risk of HIV infection through the sharing of contaminated needles, syringes, and other injecting equipment, and through the increased likelihood of high-risk sexual behaviors while under the influence of drugs or experiencing withdrawal (237). Various studies have also suggested that the use of non-injecting recreational drugs may contribute to the acquisition of HIV among FSWs (200, 203, 238-243). In a large-scale study of 13,600 FSWs from nine South American countries, Bautista and colleagues found that the use of non-injecting illicit drugs in general was associated with a three-fold increase in the risk of HIV acquisition among FSWs and that the risk was even higher for marijuana and cocaine use (200). The link between cocaine use and HIV infection is widely documented and some studies also report a link between the use of stimulants such as ecstasy with higher HIV prevalence (238-241). Patterson et al.'s study on correlates of HIV infection among FSWs in two Mexico-U.S. border cities identified methamphetamine use, either smoked, inhaled, or snorted, as one of the associated factors for HIV seroconversion among FSWs (244). Although no significant association was found between unprotected sex and HIV in Patterson et al.'s study, the authors considered methamphetamine use as a proxy of high-risk sexual behaviors through sensation-seeking behaviors, increased libido, uninhibitedness, and other personal attributes that are associated with methamphetamine use (242, 244). Methamphetamine use could also serve as a marker for the engagement in high-risk sexual behaviors such as exchanging sex for drugs that can adversely affect women's ability to negotiate safe sex (242, 244). Such arguments are in line with and provide further support for prior studies that indicate that the disinhibiting effects of alcohol and drugs may decrease the likelihood of using condoms and increase the tendency to engage in high-risk sexual practices (166, 215, 228, 245-248). Most recently, a study among a large cohort of 1,058 Vietnamese FSWs at Hekou, a China-Vietnam border area, found that the use of amphetamine type stimulants (ATS) was associated with a 10-time increase in the likelihood of HIV infection (243).

Injecting drug use represents an efficient mode of HIV transmission among FSWs, noticeably in countries where heterosexual contact tends to play a minor role in the acquisition of HIV infection (179, 232-234, 249-255). There is also growing evidence linking injecting drug use to HIV infection among FSWs globally (27, 32, 141, 179, 203, 256-265). Regardless of the types of FSWs studied and the methodologies used across different studies, injecting drug use has consistently been found to be associated with an elevated risk of HIV infection among FSWs, from several to several-hundred fold (5, 27, 29, 30, 53, 67, 68, 87, 141, 179, 192, 194, 200, 203, 204, 233, 250, 256-267). In most cases, infections among injecting FSWs are probably attributed to the double risk-behaviors of sharing contaminated needles and syringes and having unprotected sex (16, 226, 232, 234, 253). However, according to Estebanez et al., these two risk behaviors are often concurrent and thus difficult to evaluate separately (232).

2.4.4. Sexually transmitted infections

Sexually transmitted infections also pose a major risk for HIV infection among FSWs. Researchers have explored a number of STIs in relation to HIV infection among FSWs, such as syphilis (26, 32, 180, 186, 190, 194, 196, 205, 227, 233, 242, 268, 269), gonorrhea (26, 196, 233, 268, 270), chlamydia (26, 196, 231, 233, 271), genital ulcers (85, 190, 196, 231, 233, 250, 270, 272-274), virginal trichomoniasis and candidiasis (68, 275-278), and herpes simplex virus type 2 (203, 243). Regardless of the types of STIs, the presence or history of STIs has consistently been found to be associated with a higher likelihood of HIV infection among FSWs. Kim et al.'s study of a sample of Cambodian FSWs also revealed that even the self-reporting of STI symptoms such as abnormal vaginal discharge and genital rash was associated with a three-fold increase in the prevalence of HIV infection (189). Most recently, a study conducted among FSWs in Rwanda found a higher prevalence of HIV infection among FSWs experiencing at least one STI symptom in the 12 months preceding the study (182). Despite the strong association between STIs and HIV, the exact nature of this association is still unclear. STIs could increase the risk of HIV infection, given that such infections can cause vaginal inflammations that disrupt the vaginal mucosa and increase vulnerability to HIV (68, 236, 275-281). On the other hand, HIV infection may increase the risk of STIs, which could be explained by a higher susceptibility to genital tract infections due to immunosuppression in persons infected with HIV (182, 282).

2.4.5. HIV/AIDS knowledge and perception

Existing research has suggested that FSWs with poor and inaccurate knowledge of HIV risk factors and prevention methods are a vulnerable group for HIV infection (30, 31, 182, 215, 268, 283). A study by Wong and colleagues among FSWs in Singapore showed that there were widespread misconceptions about HIV transmission, something that may be true because FSWs imagined as many modes of transmission as possible (283). According to the authors, this might result in feelings of powerlessness over the disease, which in turn leads FSWs to disregard protective behaviors and thus increases their chance of HIV acquisition. Lankoande et al. also suggested that a lack of knowledge about HIV transmission indirectly contributed to increased risk of HIV infection given that FSWs without knowledge of HIV/AIDS may take no precautions to protect themselves (268). In contrast, Mutagoma et al. found that FSWs who possessed comprehensive HIV knowledge had a lower HIV prevalence compared with those who did not (182). This is probably because FSWs with a greater awareness of HIV prevention methods and knowledge regarding the transmission of HIV may have taken more appropriate measures to protect themselves against infection (182, 284, 285).

The perception of personal HIV risk is also considered a potential factor associated with HIV infection among FSWs (30, 31, 215, 268). It has been suggested that a FSW's perception that she has little or no risk of being infected with HIV may put FSWs at an increased risk of being infected given that a poor understanding of their own HIV risk may foster risk-taking behaviors such as drug use and unsafe sex practices (30, 31, 215, 268).

2.5. DIFFERENCES IN THE CORRELATES OF HIV INFECTION BETWEEN STREET-BASED AND VENUE-BASED SEX WORKERS

As reviewed in the previous section, various factors have been found to be associated with HIV infection among FSWs. However, given the heterogeneity of the FSW population, as well as the substantial variation in HIV risks in this population, we could expect to find that the distribution of factors associated with HIV infection is different across different sub-populations of FSWs. To date, however, a limited number of studies examine these differences. Most existing research has come from Asian countries, noticeably from Vietnam. The differences in the distribution of factors associated with HIV infection between SSWs and VSWs are discussed in the next section. However, since comparisons are not available for all factors identified in the previous section, only those most frequently compared in the literature are included.

2.5.1. Socio-demographic factors

Studies of FSWs in Vietnam have consistently found that FSWs working on the streets are older than those working in entertainment establishments such as karaoke bars, bathing centers, etc. (16, 17, 62, 68, 286, 287). The mean age difference between these two sub-populations ranged between four and 10 years across different studies (16, 17, 62, 68, 286, 287).

Compared with FSWs who worked in entertainment establishments, those working on the streets tend to be less educated, with a majority of them having primary schooling or less (16, 17, 24, 32, 59, 68). The latter were also more likely to charge lower prices for sexual services (32), and thus had lower incomes (59, 62, 68, 215, 253, 286, 288).

Available evidence suggests that SSWs had their first sexual experience at a younger age (i.e., before or at the age of 15 years old) (68) but initiated sex work at later age than their venue-based counterparts (17). Results from the Behavioral Surveillance Survey (BSS) study among 3,602 FSWs in five sentinel provinces in Vietnam revealed that the median age at which SSWs began sex work was higher than among VSWs in a majority of the provinces surveyed, with the age difference ranging between one and five years (17). A subsequent study among FSWs in Nha Trang, Vietnam, also found that, while about three quarters of VSWs began sex work before the age of 25 years, more than two thirds of SSWs entered sex work after that age (287).

In terms of the duration of sex work, available evidence has also suggested that SSWs engage in sex work for a significantly longer period of time than VSWs (17, 32, 59, 287). Results from the BSS study in Vietnam indicated that the mean duration of sex work among SSWs ranged from 6 - 7 years compared with only 1-2 years among VSWs (17). In line with this finding, Minh and colleagues found that 37% of SSWs, compared to over 50% of VSWs, had engaged in sex work for less than one year (287). In addition, while 14% of SSWs had worked in the profession for at least five years, less than 5% of those working in entertainment establishments had done so (287). Similar findings were also observed among Chinese FSWs (59) and most recently among FSWs in Nepal (32).

2.5.2. Sexual behaviors

Studies on condom use across the two sub-populations of FSWs have conflicting results. Several studies among Vietnamese FSWs have shown that SSWs were more likely to report frequent condom use with their sexual partners, especially irregular clients, than their venue-based counterparts (68, 226, 286). Findings from a qualitative study by Trung Nam et al. suggested that SSWs had a high awareness of the dangers of contracting HIV from clients if condoms were not used (226). In addition, given that SSWs often have sex with their clients in public places with few facilities to clean up after sex, they tended to use condoms to avoid infection (226). However, there have also been studies suggesting that SSWs are less likely than VSWs to consistently use condoms with their sexual partners, including both clients and regular sexual partners (17, 24, 32, 59, 253, 287-290). As Tung and colleagues suggested, poor educational level of SSWs might result in a lack of understanding about the risks of having sex without a condom, which in turn leads to low levels of condom use (253, 288). Researchers also suggested that the rate of condom use among SSWs is low because the majority of their clients belong to lower socio-economic groups who tend to be poorer and less educated, and thus may not be aware of the consequences of unprotected sex (21, 253, 288). According to Hoque et al., the working conditions in public places also make SSWs vulnerable to unprotected sex (290). While VSWs enjoy immunity from police round-ups through protection from establishment owners (21, 22), SSWs are visible and are the subject of police and other law enforcing authorities (290). SSWs are also more vulnerable to assault or gang rape, and the fear of violence may make it difficult for them to insist on safe sex (21, 291). It is also clear that, in many cases, clients refuse to pay for sex with a condom and even offer more money to have sex without a condom (21). Given that SSWs often come from poor economic backgrounds and have few sources of income, they are less able to refuse a client who is unwilling to use a condom and will engage in unsafe sex to avoid losing that client (21, 195, 291).

Studies have suggested that SSWs have a larger number of sexual partners than VSWs, despite variations in how the number of sexual partners is evaluated (24, 30, 31, 68, 215, 226, 292). Tran and colleagues found that, on average, SSWs reported having at least twice as many sexual partners per day as VSWs did (30, 31, 226). Similarly, the number of sexual partners per week was found to be almost three times higher among SSWs than among those working in entertainment establishments (24, 215). In line with these findings, results from a study conducted among 406 FSWs in Soc Trang, a southern province in Vietnam indicated that the median number of clients per month was more than twice as high among SSWs as among VSWs (68).

To date, there is limited research on the sexual practice of FSWs with at-risk sexual partners. However, available research has suggested that SSWs received lower payments for each sexual encounter and so possibly have clients who are poorer, have lower levels of education, and have a higher risk of HIV (287). Existing evidence has also indicated that SSWs are more likely to have sexual partners who injected drugs compared with VSWs (30, 226, 287, 292). Qualitative research to identify the underlying mechanisms behind such high-risk practices revealed that, although most FSWs are not willing to serve injecting drug use clients, poor FSWs, especially SSWs, are more likely to accept them to earn money (30).

2.5.3. Drug use-related behaviors

The extent of drug use among FSWs varies significantly across different countries and different sub-populations of FSWs. However, most existing studies have consistently reported a much higher rate of drug use and/or injecting drug use among SSWs than among other sub-populations of FSWs. In the early years of the HIV epidemic, various studies among SSWs in Glasgow found an extremely high prevalence rates of injecting drug use, ranging from 60% - 70% among those studied (30, 252, 293, 294). As documented in a review by Estebanez et al., a study of over 1,500 FSWs from various parts of Spain indicated that more than half of FSWs working on the streets reported injecting drugs, while less than a quarter of those working in places such as roadside bars reported doing so (232). Similarly, studies among FSWs in Vietnam and Nepal also found that SSWs were more likely to use and/or inject illicit drugs than VSWs (17, 32, 68, 69, 226, 292). The only exception is Yi et al.'s study of a sample of 348 FSWs from three sex work environments: entertainment establishments, personal service sectors, and street-based venues in Beijing, China (62). The researchers found that 30% of the sampled FSWs reported using drugs, 71% of whom were establishment-based FSWs (62).

2.5.4. Sexually transmitted infections

Although limited research has been done to examine the extent of STI prevalence across different sub-populations of FSWs, available evidence suggests that STIs are more prevalent among SSWs than among VSWs (17, 59, 68, 69, 287, 295). Results from the BSS study in Vietnam revealed that the prevalence of self-reported STI symptoms in the 12 months prior to the study was significantly higher among SSWs than among VSWs in the majority of the cities studied, notably in Hanoi (46% among SSWs vs. 31% among VSWs) and Da Nang (35% among SSWs vs. 3% among VSWs) (17). A study by Thuong et al. indicated that SSWs more frequently reported having had an STI in the past and having more selected STIs than VSWs did (68). Studies of various settings found that the prevalence rates of syphilis, gonorrhea, chlamydia, genital discharge, and genital ulcers was higher among those working on the streets than among those working in venue-based establishments (59, 69, 287, 295).

2.5.5. HIV/AIDS knowledge and perception

A study looking at the profile of HIV risk factors in the context of sex work environments among FSWs in Beijing, China, revealed that overall, FSWs were relatively knowledgeable about HIV, yet there were significant differences in HIV knowledge across FSW sub-populations, with SSWs having a lower level of HIV knowledge compared to those working in entertainment establishments and in personal service sectors (62). SSWs were also more likely to be concerned about their HIV risk than VSWs (36% of SSWs vs. 26% of VSWs were very worried about being infected with HIV), though SSWs (12%) were less likely than VSWs (18%) to be tested for HIV (59).

2.6. AN OVERVIEW OF HIV PREVENTION INTERVENTIONS TARGETING INJECTING DRUG USERS AND FEMALE SEX WORKERS

2.6.1. HIV prevention interventions targeting injecting drug users

It did not take long after the appearance of the first HIV case in 1981 for public health practitioners and policy makers to recognize that sharing contaminated needles, syringes, and other injection equipment among IDUs was the major driver of the HIV epidemic in many parts of the world (46). They also quickly recognized the need to develop measures that could control HIV and change the course of the epidemic (43). Several prevention interventions to reduce HIV transmission among IDUs have been found to be successful in various settings, though uptake has been slow and coverage has been uneven within as well as across countries (46). This section provides an overview of key HIV prevention interventions targeting IDUs, including needle exchange programs (NEPs), community-based HIV prevention outreach programs, opioid agonist therapy (OAT), HIV testing and counseling, and biomedical interventions to prevent HIV infection.

2.6.1.1. Needle exchange programs

Since the start of the epidemic, the main focus of HIV prevention efforts targeting IDUs has been on sharing contaminated needles, syringes, and other drug injection equipment (46). The key strategy underlying needle exchange programs (NEPs) is to provide sterile needles and syringes to IDUs who cannot stop their use of drugs (46). A typical NEP also offers IDUs health information, counseling, and referrals to other health services (46). NEPs are more favorable than bleach disinfection given that the latter, though it effectively inactivates HIV in vivo, has shown little or no effectiveness in reducing the incidence of HIV infection (46). After the establishment of the first NEP in Amsterdam, the Netherlands, in early 1980s, NEPs expanded rapidly throughout 1990s in developed countries such as the United Kingdom, Australia, and North America, and achieved success in some resource-poor countries such as Nepal, Malaysia, Brazil, and, more recently, parts of Vietnam (46).

A large body of evidence suggests that NEPs are associated with the reduction of drug injection-related risk behaviors as well as the incidence of HIV and other blood-borne infections (43, 46).

In a review summarizing major international findings on the effectiveness of NEPs in reducing the spread of HIV infection among IDUs, Wodak and Cooney assessed published data based on the nine Bradford Hill criteria on causal inference from epidemiological studies and concluded that existing evidence met five of the nine assessed Hill criteria, including strength of association, replication of findings, temporal sequence, biological plausibility, and analogy (43). There is also no convincing evidence that NEPs are accompanied by serious negative consequences such as increased illicit drug use, injection frequency, syringe sharing, inciting of drug use, recruiting of new IDUs, social network formation, or the discarding of needles in public places (43, 46). Instead, NEPs have been found to be associated with reductions in and the cessation of injection drug use, and increased enrollment in drug treatment programs (43, 46).

Despite the well-established evidence on the effectiveness of NEPs and the successful implementation of NEPs in various settings, even in resource-constrained areas (46, 296), political opponents of NEPs are often misled by the findings that the prevalence of HIV infection is higher among NEP attendees than among non-attendees without recognizing that NEPs attract high-risk IDUs who may have a higher risk of HIV seroconversion (43, 46). In many countries, particularly those that rely on foreign donor assistance that comes with conditions against harm reduction, restrictive drug-control policies and local law enforcement often deter the implementation and scale-up of NEPs by challenging their legality, threatening staff, and arresting NEP attendees (46). In such settings, improving access to sterile needles and syringes at pharmacies is recommended as an effective alternative to reducing the circulation of contaminated needles, syringes and other injection equipment among IDUs (46). Documented benefits of pharmacy access include reductions in needle and syringe sharing among IDUs, high cost-effectiveness, and no increase in the number of discarded needles and syringes in public areas, violent crime, or other negative consequences (46).

2.6.1.2. Community-based outreach programs

Community-based outreach is among the most frequently implemented interventions among IDUs (297, 298). According to the WHO, community-based outreach is designed to reach hidden or partly hidden populations of IDUs in their natural surroundings and provide them with the knowledge and means to enable them to reduce their drug injecting and sexual risk behaviors, especially the multi-person reuse of contaminated needles, syringes, and other drug injection equipment, and to reduce their exposure to HIV (298). Community-based outreach programs have been widely implemented over the past four decades and are particularly relevant in the settings where needle sharing practices are prevalent but where NEPs are not a politically viable public health option (298). Community-based outreach has also been applied in conjunction with NEPs and other HIV prevention, care, and treatment services where outreach workers are trained to provide information and counseling on protective health behaviors, HIV risk reduction methods, and/or drug injection equipment, as well as to refer IDUs to proper health services (298). Since the early 1980s, various models of community-based outreach have been developed and adapted for use in different regions of the world, including Europe, North America, Latin America, Africa, the Eastern Mediterranean, Asia, and the Pacific (298). In Asia, community-based outreach programs are often used as a substitute for NEPs, which are politically or legally prohibited (298).

Accumulated evidence from various studies in different settings and with different study designs strongly indicates that community-based outreach is an effective strategy for reaching out-of-treatment IDU populations and providing them the means for effective behavior change and for reducing their risk of HIV infection (297, 298). Country-level reports from Western Europe, the United States, Latin America, Central and Eastern Europe, and South and Southeast Asia reveal that a large number of IDUs were provided with condoms, needles and syringes, risk reduction education, and referrals to drug treatment services (297). In a comprehensive review of published evidence from over 40 studies, mostly in the United States, on the effectiveness of outreach interventions on post-intervention behavior change, Coyle at al. found that IDUs in a variety of places, circumstances, and time periods consistently changed their drug injection and sexual risk behaviors following participation in outreach-based programs (299). IDUs regularly reported follow-up reductions in major risk behaviors, including quitting injecting drug use; reducing the frequency of drug injection; reducing the multiple-person reuse of needles, syringes and other drug injection equipment (e.g., cookers, cotton, rinse water); and reducing crack use (299). The studies under review also showed promising changes in health protective behaviors, including more frequent needle disinfection and increased condom use (297, 299). Outreach interventions are designed to bridge the gap between out-of-treatment IDUs and health services and evidence has shown that participation in outreach programs contributed to the increased and continued use of other health services, especially voluntary counselling and testing (VCT) and drug treatment services (297, 299). Such promising results lend support to the inference that outreach-based interventions promoted behavior changes among IDUs (297, 299). Following Coyle et al.'s review (299), a number of studies have provided further support that community-based outreach programs are associated with reductions in HIV risk behavior as well as the increase in protective health behaviors (298).

One example of a successful program is the outreach program in Denpasar, Bali, which was designed with two main components: outreach activities and a drop-in center to provide information on HIV/AIDS, STDs, hepatitis B and C; promote safer injecting and safer sex; and provide referrals to health services and counselling (298). Despite the small sample size, post-intervention assessments indicated the cessation of injecting drug use and increases in awareness of HIV/AIDS, knowledge about how to clean needles and syringes, the actual prevalence of cleaning drug injecting equipment, the use of sterile needles and syringes, and condom use (298).

Evidence about whether reductions in risk behavior and HIV transmission are the result of outreach programs was also promising (297, 299). Results from a prospective study of intensive street-based outreach interventions in Chicago, US, indicated that interventions resulted in reductions in the multi-person reuse of syringes among IDUs and reductions in the incidence of HIV infection (298). However, caution must be used with this interpretation given the difficulties in disentangling the relative contributions of the multiple components of HIV prevention strategies such as NEPs, voluntary HIV counseling and testing, and drug treatment. In that respect, the outreach component should be seen as a tool that can be implemented in combination with other initiatives rather than as a stand-alone program (297, 299). Des Jarlais and colleagues also demonstrated that the introduction of a range of prevention activities before HIV prevalence reaches 5% among IDUs could help maintain low HIV prevalence (297, 299). The authors linked HIV serostatus and risk behavior data with local reports to test the hypothesis that introducing a comprehensive HIV prevention program where community outreach programs disseminate AIDS information as well as HIV prevention commodities to IDUs is key in lowering seroprevalence (297, 299). They concluded that the evidence available indicated that an HIV epidemic could be prevented among IDUs (297, 299).

2.6.1.3. Opioid Agonist Therapy

Opioid Agonist Therapy (OAT) was developed decades before the HIV epidemic emerged to treat opioid dependence (46). The main goal of OAT is to reduce the consumption of illicit opioids and, in a context where treatment for substance use is considered to be a strategy for preventing HIV infection among IDUs, to limit exposure to needle and syringe sharing (46).

Unlike detoxification or abstinence programs where the use of any illicit drugs is prohibited, OAT administers regular, controlled doses of opioid agonists to retain patients for extended period of time, allowing IDUs to stabilize and reduce their injecting risk behaviors (46). Methadone Maintenance Therapy (MMT) is the most widely applied OAT. Methadone was first developed in the late 1930s for medical use and subsequently adopted in the management of opioid addiction. With the use of an appropriate dose, methadone blocks the euphoric effects of other opioids to help IDUs reduce illicit drug use (46). Apart from methadone, buprenorphine was recognized decades ago as an OAT, though its application was initiated later than MMT (46). Compared with methadone, buprenorphine is safer for HIV-infected patients receiving Highly Active Antiretroviral Therapy (HAART) because it has fewer medication interactions. MMT and buprenorphine were found to be approximately three times more effective than non-pharmacological therapies in treatment adherence (46).

A large body of both observational and experimental research worldwide has identified compelling benefits associated with MMT and buprenorphine use, including reductions in illicit drug use and overdose; decreases in the sharing of needles, syringes, and other drug injection equipment; a decrease in the frequency of drug injection; a reduction in unprotected sex acts and overall safer sexual practices; and reductions in the prevalence of HIV and other blood-borne infections (46, 300). Administering OAT is also associated with reduced crime and increases in well-being and social functioning of IDUs (46, 300). OAT further benefits HIV-infected IDUs by improving their adherence to HAART, thus slowing down the progression of HIV (46). Evidence has shown that OAT is highly cost-effective and feasible in culturally diverse settings, including middle- and low-income countries such as Lithuania, Poland, Ukraine, China, Thailand, Indonesia, and Vietnam (46, 300).

Despite abundant scientific evidence on the effectiveness of OAT in HIV prevention among IDUs (46, 300), policies on drug control and HIV/AIDS prevention and treatment strategies are not yet harmonized to maximize the advantages of the program (300). For example, the national drug-control policies in the US were criticized for ignoring scientific evidence on OAT and hindering global expansion by their restrictions on foreign aid (46). In Russia and many other countries, the administration of methadone and buprenorphine remain illegal despite the high level of HIV prevalence among IDUs (46). There are still controversies among policy makers around the misconceptions that OAT is just replacing one drug with another; thus, addressing this kind of political barrier is critical in expanding OAT to prevent the spread of HIV (46, 300). In settings where opposition to OAT persists, the initiation of small-scale OAT to demonstrate efficacy in local contexts, educational efforts to destigmatize addiction, coherent national leadership regarding the appropriate role of OAT in the prevention of HIV infection, and the promotion of global coordination and financial commitments are recommended (46).

2.6.1.4. HIV testing and counseling

HIV testing and counseling (HTC) is recognized as an effective preventive measure and an entry point to care and support services, and thus underlies the implantation of nearly all other prevention and treatment approaches (5, 301-303). Knowledge of HIV serostatus is essential not only to tailor services to individual needs but also to prevent the further spread of HIV (302, 303). Despite its significant benefits, HIV testing is not a common practice in various settings, even in developed countries (302). Uptake of HIV testing is a major challenge within the population of drug users due to the stigma and discrimination associated with their illegal drug use behaviors (302). Results from a large WHO review of 26 low- and middle-income countries in 2010 revealed that the median percentage of IDUs who had tested for HIV and knew their test results in the last 12 months was 23%, with wide variations across countries (304). The rate of HIV testing uptake was lowest in the Philippines; only 1% of IDUs surveyed in 2009 had ever tested for HIV and knew their results. In Thailand, on the other hand, 89% of IDUs surveyed in 2010 reported this practice (304).

There are different approaches to improve HIV testing uptake among the IDU population, though the efficacy of these approaches has not been fully reported. Examples of such approaches include peer-led outreach to address HIV testing barriers and to refer and/or accompany IDUs to the proper health care facilities, counselling to promote HIV testing (e.g., increasing awareness of personal HIV risk, the benefits of regular HIV screening and early HIV diagnosis and treatment, the efficacy of ART treatment, and the availability of government-supported treatment services), and integrating HIV testing at the primary healthcare level (305, 306). The last approach is considered a highly cost-effective strategy for increasing HIV screening, providing links to HIV treatment services, and reducing the stigma associated with HIV testing (305). For example, voluntary drug treatment facilities could be used to promote HIV testing given that they provide IDUs an important point of contact with the health system and can engage individuals in HIV testing by linking them to testing services (305). Integrative MMT-VCT clinics also help improve the uptake of HIV testing in some settings because the provision of VCT at MMT clinics may eliminate barriers for uptake, such as distance and lack of transport (306). In remote areas where issues of accessibility serve as a barrier for HIV testing, mobile HIV testing clinics could be a solution to improve HIV testing uptake (306).

The model of youth clubs, which have widely been applied in India and in many Asian countries, could be engaged to reach young IDUs and create awareness about injection risk behaviors as well as promote HIV testing (305).

2.6.1.5. Biomedical interventions

Biomedical interventions that use antiretroviral (ARV) drugs to protect uninfected individuals from acquiring HIV, and can reduce infectiousness of infected partners, have become increasingly important in the 2000s (46, 303). Post-exposure prophylaxis (PEP) was originally developed to address occupational injuries related to HIV-infected patients. However, its effectiveness remains an open question and virtually no studies have been reported to formally examine the PEP approach to addressing the risk of HIV infection (46). Vlahov et al. suggested a scenario for PEP use by IDUs that involves a population of former drugs users whose use has been stabilized with OAT but who experience a transient relapse (46). In this case, PEP should serve as a means to support treatment retention rather than expel the drug user from treatment (46).

Another approach to HIV prevention using ARV drugs is pre-exposure prophylaxis (PrEP), though discussion of its possible applications to IDUs is virtually absent from the literature (46). According to Vlahov and colleagues, the implementation of either a PEP or PrEP prophylaxis program for drug users faces several major challenges, including drug use policy that equates preventing HIV infection with being soft on drug use and considerations that some drug users will be noncompliant with treatment, thus implying a potential for treatment diversion (46). For these reasons, there is a strong need for studies to examine the issue of feasibility in developing and testing programs for at-risk populations other than IDUs (46).

2.6.2. HIV prevention interventions targeting female sex workers

Along with IDUs, FSWs have been considered a key affected population since the early years of the HIV epidemic (303, 307). Thus, reducing HIV transmissions associated with sex work, and making sex work services safer for FSWs and clients, are crucial in achieving universal HIV prevention (308). The following section provides an overview of key HIV prevention interventions to address the five levels of risk among sex workers as defined by Bekker et al. (303). These five levels are individual behavioral and biomedical interventions (level 1), network level factors (level 2), community engagement (level 3), environmental factors that define how sex is bought and sold (level 4), and the epidemic context (level 5) (303, 309). Existing HIV preventions among FSWs are broadly categorized into condom provision, community empowerment, STI management and control, HIV testing and counseling, and biomedical interventions (303).

2.6.2.1. Condom provision

The provision of condoms is inherent in almost all HIV prevention interventions targeting FSWs (309). HIV prevention interventions targeting FSWs worldwide, including low- and middle-income countries, have shown the feasibility of promoting condom use to reduce the acquisition and transmission of HIV and other STIs (303, 307, 310). Countries in Africa have experienced increased levels of protected sex among FSWs and their clients as a result of peer-mediated condom promotion activities, with increased effects observed among those with greater peer exposure (311). In Santo Domingo, Dominican Republic, intervention efforts in the form of workshops and meetings with FSWs and owners of sex establishments to strengthen the collective commitment to prevention, and particularly to support FSWs to use condoms with their partners, resulted in the increase of condom use and the rejection of condomless sex among FSWs. Motivational interview interventions have also been shown to improve condom use and harm reduction among FSWs who injected drugs (303). In the Democratic Republic of the Congo (DR Congo), the "moonlight" (i.e., night time) distribution program, where peer educators used Facebook messaging, short message services, and email platforms as a medium to encourage safe sex practices, was adopted and increased reported consistent condom use among FSWs (309). Similarly, the 100% condom campaign in Thailand, and subsequently similar programs in Cambodia and other countries in Asia, have resulted in interventions focused on safer sex practices in sex venues, including increased condom use among FSWs and clients and reduced STIs among STI clinic attendees (303). Although HIV incidence was not directly measured, ecological data in Thailand and Cambodia indicates the significant effects of such programs on the trajectories of the countries' respective HIV epidemics (303).

2.6.2.2.Community empowerment

HIV prevention interventions that address individual level factors associated with HIV risk among FSWs has been shown to have modest effects in many settings (307). Schebe et al. concluded that creating a supportive and enabling environment for the provision of sex work services and addressing the structural and policy barriers to recognizing an individual's human rights, especially the right to a safe working environments and the access to justice, are of critical importance if HIV response efforts are to have an impact (307). Community empowerment via peer-led and self-help activities, including education, health services, and advocacy on issues such as violence and work conditions, reduces the vulnerability of FSWs

(303, 309). Evidence across various settings around the world has shown the impact the meaningful involvement of FSW communities in the design and implementation of HIV prevention programs has on HIV prevention (303).

The best documented examples of the success of FSW-led HIV prevention comes from India, most notably the Sonagachi and Avahan projects (303, 307). The Sonagachi Project in Northern Kolkata made substantial efforts to define the problem of HIV prevention as a community issue and showed that FSW health outcomes can be enhanced when programs encourage a sense of shared identity in FSWs and address concerns beyond HIV and sexual health, including violence, stigma, and discrimination (303). Gender responsive economic strengthening activities within empowerment programs, including vocational training, education, and micro-financing, could also give FSWs control over vital economic resources and reduce FSWs' vulnerability to HIV (303). The Sonagachi Project has documented increased condom use and decreased HIV prevalence not only in FSWs but also in bridge populations (303). Similarly, the Avahan project reached coverage of nearly 80% where implemented and resulted in increased condom use, decreasing syphilis prevalence, and the stabilization of HIV prevalence (307, 312).

Intervention efforts with FSW participation and leadership have been successful in many other settings, including in sub-Saharan Africa, southeast Asia, the Dominican Republic, and South America (303, 308, 309). For example, the "champion community" group program for FSWs in DR Congo, whereby peer educators participated in the mapping of sex work venues, the identification of clinics to provide health services to FSWs, and led HIV sensitization campaigns within communities, led to the significant increase in coverage of Behavioral Change Communication (BCC) within one year of program implementation and in clinic utilization among FSWs (309). In Burkina Faso, SWs were represented on the community advisory board of HIV prevention interventions and participated in consultations related to the design and implementation of the interventions (309). Sex worker empowerment interventions in Benin and South Africa reported police collaboration between FSWs and sex work venue owners and venue managers to reduce harassment of FSWs (309). An intervention in Kenya that incorporated skills building in small businesses, provided small loans, and organized SWs in credit groups reported that 45% of the FSWs quit sex work (309). Interventions such as Empower Thailand include sustained engagement with local FSWs to raise awareness about sex-worker rights, the establishment of safe spaces, the formation of collectives that define the services to be provided, outreach, and advocacy (303). These are associated with a reduction in HIV and STI prevalence and increased condom use among FSWs (303).

Community empowerment interventions such as education sex-workers about their rights, community mobilization to respond to violence and discrimination, practical warning systems in sex work networks, sensitization workshops with police and law enforcement authorities, and advocacy at the community and policy levels to promote FSWs' human rights have also helped reduce violence against FSWs (303, 309). Such interventions, however, are proven to undermine HIV prevention efforts and increase the vulnerability of sex workers to HIV transmission (303, 309). Examples of several successful violence reduction interventions targeting FSWs include the sex-worker education program devised by the Sex Workers Education and Advocacy Taskforce (SWEAT) in South Africa and the venue-level interventions identified by sex workers in Vancouver, Canada, including in-room buzzers and corridor video surveillance (303).

2.6.2.3. Sexually transmitted infection management and control

Sexually transmitted infections have posed as a major risk for HIV infection given that bacterial and viral STIs can increase the efficiency of HIV transmission (303). Screening and treating FSWs for STIs were almost a universal component of HIV interventions targeting FSWs, though efficacy in reducing HIV infection has been difficult to demonstrate (303, 309). STI treatment could include active case finding, individual case management, or periodic mass STI treatment regardless of diagnosis (303). A community-based trial in Mwanza, Tanzania, which included the participation of more than 12,500 individuals in the region (1,200 of whom were probably FSWs or bar workers), showed efficacy in the individualized syndromic management of STIs against sexual transmission of HIV with a reduction of 38% in HIV incidence (303). Interventions using monthly antibiotic prophylaxis to control STIs in different countries in sub-Saharan Africa had different results (309). The monthly periodic presumptive oral treatment of metronidazole 2 g combined with fluconazole 150 mg showed increased vaginal colonization by lactobacilli, but had no significant effect on reducing STI prevalence (309). Monthly azithromycin treatment was found to have a significant effect on reducing chlamydia, gonorrhea, and Trichomonas vaginalis (TV) infections (309). An intensive STI diagnosis and treatment intervention among a cohort of FSWs in Cote d'Ivoire demonstrated a decrease in HIV incidence and a reduction in gonorrhea and TV (309). Alternative monthly periodic azithromycin or ciprofloxacin was associated with a decrease in gonorrhea prevalence but had no significant impact on chlamydia and HIV incidence (309). As mentioned in Bekker's review, the periodic presumptive treatment of curable STIs has been effective at reducing STIs but not HIV incidence among FSWs in places where the burden of STIs is high (303). While screening for asymptomatic STIs in FSWs can reduce STIs, this is often not feasible, especially in resource-constrained settings (303). Furthermore, most STIs are asymptomatic, making syndromic management to reduce STIs in FSW networks problematic (303). However, this situation could change once point-of-care STI diagnostics become more available and affordable (303).

2.6.2.4. HIV testing and counseling

Similar to the case of IDUs, despite the fact that HIV testing is an effective intervention for reducing HIV risk (302), uptake of HIV testing presents a major challenge in the FSW population due to the stigma and discrimination associated with their dual risks from both sexual and drug use behaviors (304). In a WHO review of 52 low- and middle-income countries in 2010, the median percentage of FSWs who had tested for HIV in the last 12 months and knew their test results was 49%, with significant variation across countries (304). Rates of HIV testing among FSWs throughout Africa are suboptimal, and only 4% of those surveyed in Somalia in 2008 had ever tested for HIV (304). In Zimbabwe where HIV prevalence among FSWs was about 50% in 2011, one half of HIV-positive FSWs were aware of their status, only 30% – 40% of those eligible were accessing ART, and fewer than a quarter of HIV negative FSWs reported HIV testing in the past six months (304). Key barriers to HIV testing include a lack of awareness of the services offered, distance to facilities, transportation costs, opportunity costs, time constraints, and a fear of a positive result as well as the consequent discrimination and loss of income (304). FSWs, however, face additional barriers associated with their work, including fear of authorities and concerns about confidentiality, particularly regarding status disclosure to others FSWs or potential clients (304).

Various intervention efforts in sub-Saharan Africa to help increase HTC uptake in FSWs have been documented, though the efficacy of such approaches on the uptake of HIV testing were not fully assessed (309). Examples of such intervention efforts include peer-led outreach to increase access to HIV testing, mobile HIV testing provided around sex work settings, night time testing, and police assistance in bringing FSWs who do not have an updated health card to the facility to be tested for HIV (309). In a review of existing HIV prevention strategies among FSWs, Bekker et al. also documented several successful interventions that have increased the uptake of HIV testing among FSWs (303). They pointed out that strengthened peer support and a supportive network are associated with the willingness of FSWs to engage in HIV testing, care, treatment initiation, and adherence (303). Also, even when FSWs have access to health facilities, prejudice and quality of care services are crucial determinants of their willingness to be tested and retain such services, indicating the importance of affordable, sex worker-friendly clinics, and their ability to attract and retain FSWs (303).

2.6.2.5. Biomedical interventions

Similar to the case of IDUs, the application of antiretroviral drugs for HIV prevention among the FSW population remains to be proven (303). The use of PEP is most frequently applied for needle-stick incidents and increasingly for sexual assault, rather than for prevention associated with sex work (303). The reasons for this include user reluctance (in relation to the need to access care within 72 hours and continue treatment for 28 days and connected to the side-effects associated with PEP use) and inadequate services (i.e., the scarcity of on demand PEP starter packs) (303). As Bekker et al. pointed out, PEP may not be scalable, practical, or sustainable as a sole intervention for FSWs, though it has a role in sexual assault and other episodes of unanticipated, condomless sex (303). A study among FSWs in Kenya revealed that PEP was well accepted by urban FSWs with greater than 10% requesting PEP at least once during the year after its introduction, though no association between PEP use and reduced HIV acquisition was found (303).

Bekker et al. documented four clinical trials including women from diverse geographical and risk settings where PrEP was shown to reduce HIV acquisition by 39% – 75% (303). However, there has not been any randomized, controlled trial specifically undertaken to examine the efficacy of PrEP in FSWs. In this context, any application to FSWs is based on an extrapolation from a general female population; thus, product safety and the effect of the conditions associated with the nature of sex work on PrEP effectiveness are still unknown (303). In all trials reviewed, no HIV protection was reported in trials with the lowest level of adherence to PrEP (303). However, in the Partners PrEP and Pre-exposure Prophylaxis Initiative (iPrEx) studies among homosexual men, case-control analyses suggested that those using PrEP consistently had a greater than 90% reduction in HIV risk (303). Bekker et al. also documented a clinical trial of PrEP that included 2,413 drug users in Thailand, about 20% of whom were female and 38% of whom reported having sexual intercourse with people other than their live-in partner, including casual sex or sex work (303). The HIV incidence reduction of 49% for those on PrEP is an important finding given that FSWs who inject drugs are often the most vulnerable and marginalized sub-population of FSWs. The authors suggested that PrEP could work synergistically with other prevention approaches given that condom usage increased and

STI diagnoses decreased during the study period in all clinical trials (303). However, as PrEP is introduced in the FSW population, community engagement, further behavioral and social science research, and careful program monitoring and assessment will be needed (303).

2.7. AN OVERVIEW OF HIV TRANSMISSION MODELS

The exploration of the HIV cases in the 1980s gave rise to the proliferation of HIV models. The following section provides an overview of the key HIV models developed over time, with the focus on HIV transmission within heterosexual populations. This overview was mainly based on the work of Rhee published in 2006 (37). Detailed descriptions of models presented in this section were documented elsewhere (37). A summary of these models is presented in Table 2-2.

2.7.1. Extrapolation models

Extrapolation or back calculation models are the simplest HIV models developed since the mid-1980s that project HIV future trends in a country by extrapolating from current prevalence data on different populations (37). These models were frequently used by UNAIDS and the WHO to estimate the number of people who would be infected with HIV at a given date in the future. Despite their simplicity, these early HIV models served as a useful tool for informing policy and response (37).

The epi model is also an extrapolation tool. It was initially developed for the United Nations (37). This model uses HIV prevalence and the reproduction rate to estimate the date the outbreak began and predict future prevalence (37). The reproduction rate is the product of the per-partnership probability of the transmission of the virus, the number of partnerships per time period that could result in transmission, and the duration of the infectious period (37). The reproduction rate refers to the number of secondary infections resulting from an infected individual. If the reproduction rate is above 1.0, the epidemic will persist, if it is below 1.0, it will eventually end (37). However, given the over-generalization of this type of model, it was replaced with the UNAIDS Estimation and Projection Package (EPP) in 2003 (37, 313). EPP model uses four key parameters: (i) the year the epidemic started; (ii) the size of the initial population at risk; (iii) the force of infection (i.e., the rate at which susceptible individuals as an aggregate become infected); and (iv) the rate in which individuals enter an HIV high-risk population group (37, 313).

In 2004, the Asian Epidemic Model (AEM) was first introduced by Brown and Peerapatanapokin to reflect the primary populations and transmission modes that drove HIV transmission in Asia (314). Though AEM is also an extrapolation model, it is more advanced than the EPP given its ability to take risk behaviors of different at-risk populations into account in the model. The user adjusts AEM parameters until HIV prevalence outputs from the model agree with observed epidemiological trends (314). By varying input behaviors and STI trends, the impact of different prevention interventions on the future course of the epidemic could also be assessed (314). The AEM model has been adopted as a tool for policy and program analysis in Thailand, Cambodia, and, more recently, in several provinces in Vietnam (314).

2.7.2. Differential Equations models

Differential Equations (DE) have been widely used to simulate HIV epidemics. DE models define the number of infected individuals within a population and the rate at which individuals become infected and progress (37). Susceptible-Infected-Recovered (SIR) models serve as the basis for most DE models of epidemics (37). An example is represented in Figure 2-2, below.

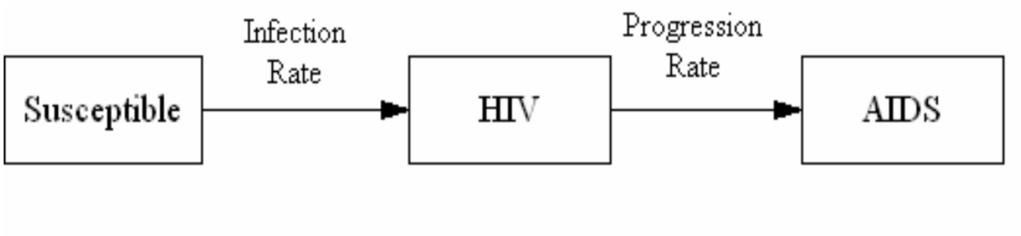


Figure 2-2. Typical Susceptible-Infected-Recovered (SIR) compartments.

DE models assume individuals within each compartment in this system are homogenous and have an equal probability of interacting with others in specified compartments (37). DE models involve the use of several key parameters, including: (i) the probability of HIV infection within a sero-discordant partnership; (ii) the rate at which partnerships are formed; (iii) the progression rate from HIV to AIDS; (iv) the mortality rate due to AIDS; and (v) the reproduction rate (37). Models allow for experimentation with different intervention scenarios by varying different parameters in the system, for example, by decreasing the contact rate and transmission probability or increasing the duration of infection (37).

2.7.3. HIV transmission models

More complex and realistic models that incorporate possible risk factors of HIV infection have been developed from the original DE models (37). Anderson and colleagues were considered pioneers in the development of HIV transmission models (37, 315). They extended the idea of a core group of HIV transmitters (i.e., individuals that are highly connected to others and have circular social patterns) in which the disease persists and spreads rapidly (37, 315) from STD models (316). Anderson et al. also extended the SIR model to describe unique aspects of HIV, providing the foundation for future deterministic HIV models (37, 315).

As HIV epidemics progressed, witnesses noted a significant heterogeneity in the characteristics of the epidemics within and between countries, and models have been adapted to incorporate factors that could be responsible for such differences (37). The heterosexual spread of HIV has been found to have a significant social aspect in transmission (37). Garnett and Anderson explored the effect of inter-mixing between high- and low-risk populations in the heterosexual spread of HIV (37, 317) and extended Anderson et al.'s model (37, 315) to incorporate probabilities of mixing between populations (37, 317). Work by Jacquez and colleagues also assumed that there could be several high-risk sub-populations within a low-risk population and that these sub-populations would exhibit preferred mixing (37, 318). Jacquez et al. examined the impact of varying the proportion of intra- and inter-group mixing between high- and low-risk populations (37, 318). They found that while increased inter-group mixing decelerates the epidemic among high-risk HIV populations, the rate of infection in low-risk populations is highly sensitive to increased mixing with high-risk ones (37, 318).

2.7.4. System Dynamics

Though traditional DE models are capable of capturing the dynamics of the spread of HIV within a population, they typically assume that an individual's behavior does not change in response to the spread of the disease (37). As a consequence, such models do not define explicit behavioral feedbacks (e.g., increased awareness of HIV risk, consistent condom use) in the system (37). In other words, these behavioral feedbacks are incorporated into models not by explicit equations but by the manual increase or decrease of the contact rate or transmission efficiency (37).

Though System Dynamics models use the same underlying mathematics, they are often more advanced than the traditional DE models when considering feedback mechanisms (37). In addition to two components also routine in DE models (i.e., aggregate characteristics and variables), System Dynamics models also incorporate behavioral feedback into the system (37). This allows parameters (e.g., infectivity and contact rate) to change over time, making the linkages between these parameters and other variables in the system explicit (37). The drag-and-drop feature in most System Dynamics models allow the visualization and incorporation of important underlying variables in the system (37). Figure 2-3 illustrates a typical System

Dynamics approach that employs the stock-and-flow diagramming technique to depict the impact of behavioral feedbacks on infection rate (37, 319).

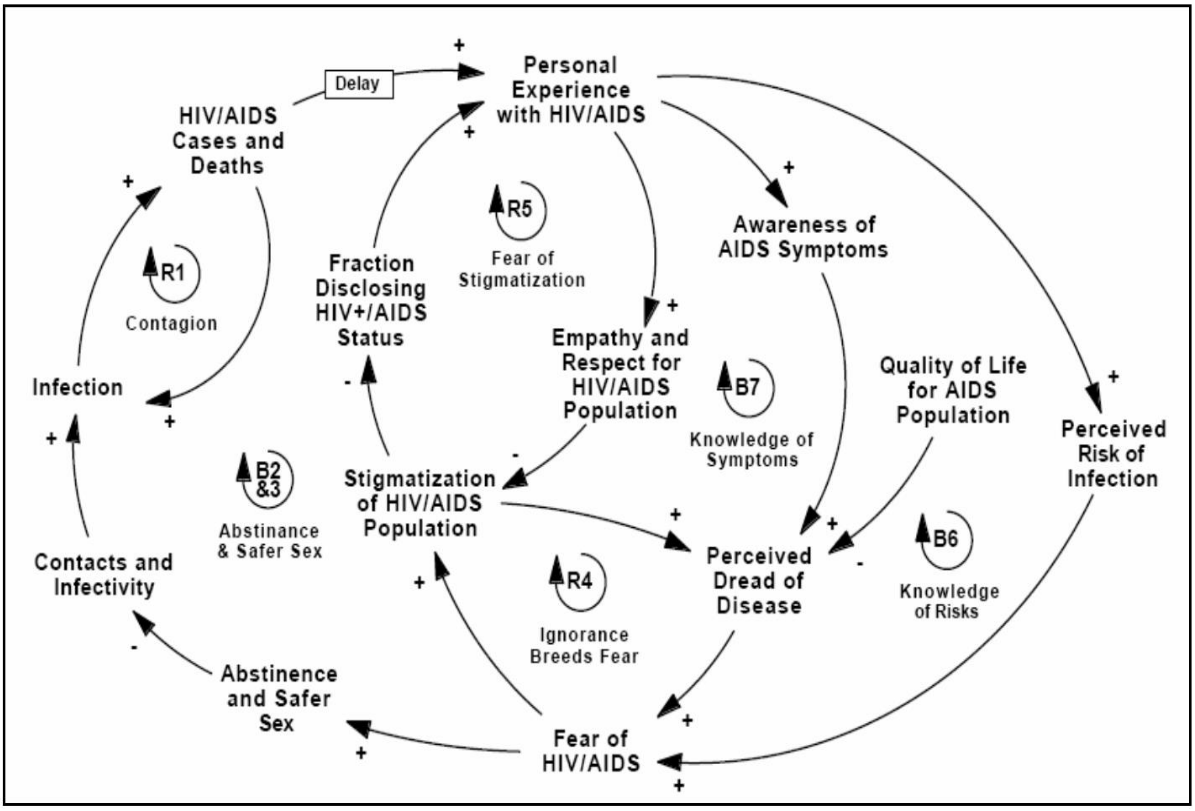


Figure 2-3. Impact of behavioral feedbacks on HIV infection rate.

System Dynamics is considered a relevant approach to HIV modeling given its emphasis on the identification of reinforcing mechanisms that sustain the dynamics of the system (37). Although HIV/AIDS is a viral disease, the heterosexual transmission of HIV epidemics is ultimately driven by behavior patterns of sexual practices, which could be addressed via a System Dynamics approach (37).

2.7.5. Partner-based approach and the rationale for ABM simulation in HIV modeling

In all the models mentioned in sections 2.7.1 - 2.7.4, uninfected individuals are continually susceptible to infection until infected (37). However, according to Dietz and Hadeler, for the heterosexual transmission of HIV, the possibility of transmission only occurs within a partnership (37, 320). If a partnership is formed between two uninfected individuals, they are immune from infection for the duration of the partnership. Thus, the rate of partner change may be considered an independent risk factor for infection since the formation of a new partnership leads to another opportunity for virus transmission (37, 320). In the context of commercial sex work, the HIV epidemic may spread much faster if individuals engage in sexual activity over some period of time with more than one partner (37, 320). In heterosexual partnerships, Dietz and Hadeler define the contact rate as the number of sexual acts within a partnership that may result in infection while the probability of transmission is defined per sexual act. Pairs are formed and separate with certain rates. Pair formation describes the probability that an individual forms a partnership with another individual, and is modeled by a function. The function computes a compatibility formula where partnership formation is dependent on attributes of the two individuals (37, 320).

Taking Dietz and Hadeler's partner-based approach (37, 321) as a point of departure, Kretzschmar and Morris further underscore the importance of network structure given that HIV infection is passed between individuals (37, 321). According to these researchers, the spread of HIV through a concurrent network may be dramatically faster than through a network of serially monogamous individuals. Kretzschmar and Morris used the below graphs to demonstrate the importance of partnership and network structure in disease spread, with the nodes representing individuals and the lines representing a partnership (37, 321) (Figure 2-4).

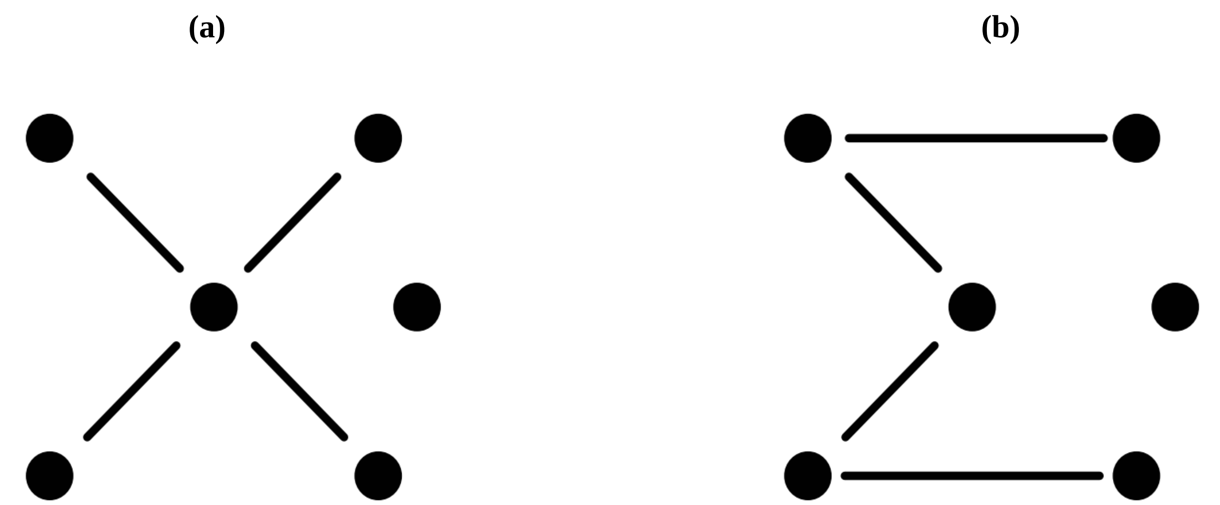


Figure 2-4. Partnership and network structure demonstration.

In Figure 2-4.a, four individuals who formed partnerships with the individual in the middle might be infected with HIV if the middle individual is infected. In Figure 2-4.b, however, the virus has to travel through each of the individuals to infect all of them. As a result, transmission may not spread through the entire network given the varying levels of infectiousness in the disease's lifespan (37, 321). Kretzschmar and Morris are also considered pioneers in using an agent-based approach to disease simulation. They used an ABM to test the impact of concurrent partnerships on the spread of HIV in their model (37, 321).

Agent Based-Modeling is a computational simulation method that defines the behavior of one or more populations of individuals within an environment where the characteristics of the population are the sum of the interactions between individuals in that population (37). While DE and System Dynamics models generally use aggregate variables for populations, ABM defines behaviors at the individual level. In ABM, partnerships are formed between discrete individuals and a dynamic sexual and social network is explicitly defined (37).

Given the advantages of the agent-based approach in HIV modeling, this approach has increasingly been employed in recent years (37, 41, 322-324). For example, Rhee used the ABM approach to examine the impact of social and sexual networks on HIV transmission in Papua New Guinea (37). The author constructed an ABM of HIV transmission and the diffusion of HIV/AIDS awareness by adapting elements from two models. Rhee used the Kretzschmar and Morris model (321) to develop a theoretical sexual network in which individuals exhibit preferential attachment and Axelrod's cultural diffusion model (325) to simulate the spread of HIV/AIDS risk awareness in the population (37). As Rhee pointed out, the unique ethnic heterogeneity and social network structure in Papua New Guinea provides a good case study for the application of agent-based modeling (37). Also, the biological determinants and individual risk factors of HIV infection make ABM a relevant approach to HIV epidemic modeling (37).

Teweldemedhin and colleagues also used agent-based modeling to conduct a case study of the HIV epidemic (41). This research used the agent-based approach to develop a simulation tool for estimating and predicting the spread of HIV in a population. According to the researchers, human beings are autonomous and have complex behaviors and interactions with each other. The environment they live in also changes frequently. Due to the interaction among individuals and between individuals and the environment in which they live, individuals tend to change their characteristics and behaviors, changes that are difficult to represent at the population level. With its advanced characteristics and features, ABM is thus considered relevant to modeling such a complex system comprised of heterogeneous individuals (41).

In another work by Alam et al., an agent-based simulation model was constructed to examine the social impacts of HIV/AIDS in selected villages in South Africa (322). The model focused on decisions made at the individual and household level based upon evidence from case studies and the different types of networks between these players that influence their decision making. Results suggest that ABM is a powerful tool for understanding this complex issue in South Africa and for policy development (322).

According to Tully et al., risk perception shapes an individual's behaviors; in turn, risk perception is shaped by the consequences of such behaviors (324). This dynamic was explored in the context of HIV spread via the construction of a simplified agent-based model based on a partner selection game where individuals were paired with others in the population and agreed to have unprotected sex, protected sex, or no sex via a decision tree. An individual's choice was conditioned by their HIV status, perceived population-level HIV prevalence, and the type of sex the individual with whom they were paired preferred. The model illustrated a potential mechanism by which distinct groups (i.e., defined by their sexual behavior), HIV status, and risk perceptions could emerge through the coevolution of HIV transmission and risk perception dynamics (324).

More recently, Huang used ABM to simulate social behaviors affecting HIV transmission among homosexual Taiwanese men (323). The author constructed an agent-based epidemic simulation model of a network of individuals who participated in high-risk sexual practices, using the number of partners, condom usage, and the length of the relationship to distinguish between high- and low-risk populations. In this model, in addition to attempting to reproduce epidemic curves of reported HIV cases among homosexual men in Taiwan, an ABM was used to determine the effects of various policies on epidemic dynamics. Results suggest that the model accurately simulates real-world behaviors as long as suitable adjustments are made based on available social survey statistics (323).

Table 2-2. A summary of key HIV transmission models.

Models	Model focus and application	Comments
Extrapolation models	Project HIV future trends by extrapolating from current prevalence data on different populations. Estimate the number of people infected with HIV.	Simple, easy to use. Little data needed.
Epi model	Estimate the date of outbreak began. Estimate future prevalence. Key parameters involved: HIV prevalence and reproduction rate.	Over-generalization.
UNAIDS Estimation and Projection Package (EPP)	Use in replacement for epi model. Estimate and project HIV future trend. Key parameters involved: Year of epidemic start, size of the initial population at risk, force of infection, and the rate at which an individual enters a HIV high-risk population.	Useful tool for policy in countries with paucity of data.
Asian Epidemic Model (AEM)	Reflect the primary populations and transmission modes that drive HIV transmission in Asia. Assess the impact of different prevention interventions on the future course of the epidemic. Key parameters involved: Risk behaviors of different at-risk populations, HIV prevalence, size of populations at risk, STI data. Adjust AEM parameters until HIV prevalence output from the model agree with observed epidemiological trends.	Useful tool for policy and program analysis. More advanced than the EPP given the capability to take into account risk behaviors in the model. Applicable in several Asian countries.
Differential equation (DE) models	Simulate HIV epidemics. Define the number of infected individuals and the rate at which individuals become infected and progress. Use Susceptible-Infected-Recovered (SIR) models as the basis. Use aggregated characteristics and variables for population. Assume that an individual's behavior does not change in response to the spread of disease. Key parameters involved: probability of HIV infection within a sero-discordant partnership, rate at which partnership are form, progression rate from HIV to AIDS, mortality rate due to AIDS, reproduction rate.	Capable of capturing the dynamics of the HIV spread. Allow experimentation with intervention scenarios by varying different parameters in the system. Individuals in the system are homogenous, thus incapable of taking into account the characteristics of individuals in the population. Do not define explicit behavioral feedbacks in the model.
Anderson et al.'s model	Use the idea of core group of HIV transmitters in which the disease persists and spread quickly. Extend the SIR model to describe unique aspects of HIV and provide foundation for future deterministic HIV models.	Advanced from original DE models. More complex and realistic than DE models given the incorporation of possible risk factors of HIV infection.
Garnett and Anderson's model	Incorporate probabilities of missing between populations. Explore the effect of inter-mixing between high- and low-risk populations in heterosexual spread of HIV.	Extended from Anderson et al.'s model. More complex and realistic than DE models.
Jacquez et al.'s model	Examine the impact of varying the proportion of intra- and inter-group mixing between the high- and low-risk populations.	More complex and realistic than DE models
System Dynamics	Leverage the same underlying mathematics as DE models Key components: feedback mechanism, aggregated characteristics and variables. Drag-and-drop feature allows the visualization and incorporation of important underlying variables in the system.	More advanced than DE models. Incorporate behavioral feedback into the system, allowing parameters in the system to change over time. Individuals in the system are homogenous, thus incapable of taking

Models	Model focus and application	Comments
	Emphasize the identification of reinforcing mechanisms that sustain the dynamics of the system.	into account the characteristics of individuals in the population.
Dietz and Hadeler's model	Emphasize the importance of partnership in HIV transmission. The rate of partner change considered as independent risk factor for infection since the formation of a new partnership leads to another opportunity for virus transmission.	More flexible than System Dynamics. More realistic than DE models in the context of heterosexual transmission of HIV epidemics.
Kretzschmar and Morris's model	Emphasize the importance of network structure. HIV spread through a concurrent network may be dramatically faster than infection spread through a network of serially monogamous individuals.	Extended from the Dietz and Hadeler's model. More flexible than System Dynamics. More realistic than DE models in the context of heterosexual transmission of HIV epidemics. Given way for the use of agent-based approach to disease simulation.
Agent-based model (ABM)	Simulate HIV epidemics. Define the behavior of a population of heterogeneous individuals within an environment Define behaviors at the individual level. Characteristics of the population are the sum of the interactions of the individuals. Partnership are formed between discrete individuals and a dynamic sexual and social network is explicitly defined.	Allow understandings of heterogeneous individuals' behaviors and interactions between individuals Correspond to real-life situations. Representation of the environment with which individuals interact. Facilitate understandings of multi-level determinants of HIV infection. Allow experimentation with the model and assess HIV intervention policies.

3. CHAPTER 3: METHODS

This thesis has two main parts. The first part involves a secondary data analysis of the 2009 IBBS study to describe the extent of HIV infection among male IDUs and FSWs in Vietnam and to identify independent correlates of HIV infection among these two populations. The second part involves the construction of an Agent-based Model (ABM) to characterize the dynamics of the HIV epidemic in Vietnam.

This method chapter provides a detailed description of (i) IBBS data collection methods, (ii) data analysis methods used in this thesis, and (iii) ABM simulation methods.

3.1. IBBS DATA COLLECTION METHODS

Full details on the IBBS data collection methods were reported elsewhere (18, 19). IBBS data collection methods were also documented in the author's earlier publications (20, 326).

3.1.1. IBBS study design

The IBBS study included two components: (i) Face-to-face interviews using a semi-structured questionnaire survey and (ii) Biological specimen collection for HIV and syphilis testing.

The IBBS questionnaire consisted of over 100 questions and covered information on socio-demographic characteristics, sexual behaviors, alcohol consumption and drug use behaviors, HIV knowledge and perception, and exposure to HIV prevention and care services (Appendices A and B).

Venous blood samples were also collected for anonymous HIV and syphilis testing.

- HIV serologic testing was performed using one rapid test and two enzyme-linked immune-sorbent assay (ELISA) tests for screening and confirmation of positive results.
- Syphilis serologic testing was performed on sera transported in a cool box and processed using a quantitative rapid plasma reagin (RPR) screening test with a qualitative Treponema pallidum hemagglutination assay (TPHA) confirmation test. Syphilis was diagnosed and treated with a qualitatively positive RPR and positive TPHA confirmation.

3.1.2. Study populations

3.1.2.1. Injecting drug users

The IBBS study recruited men aged 18 years and older who reported illicit injecting drug use at least once within 30 days prior to the survey, who were accessible at the time of the survey, who were willing to participate in the study, and who agreed to provide specimens for HIV/STI testing. Inclusion of IDUs in the IBBS study was limited to males given evidence that up to 90% of drug injectors in Vietnam are male (4).

3.1.2.2. Female sex workers

The IBBS study recruited women aged 18 years and older who reported providing sex in exchange for money or gifts in the 30 days prior to the survey, who worked on the street (i.e., SSWs) or in entertainment establishments such as karaoke or massage bars (i.e., VSWs), who were accessible at the time of the survey, who were willing to participate in the study, and who agreed to provide specimens for HIV/STI testing. Although some FSWs were sampled at entertainment venues, they were characterized as SSWs in IBBS study based on their most common means of meeting clients. For example, in Hai Phong, some sex workers who were sampled at entertainment establishments were characterized as SSWs because they had moved off the street temporarily to avoid government campaigns against "social evils" (18).

3.1.3. Sample sizes and sampling strategies

3.1.3.1. Sample sizes

The sample sizes in the IBBS study were calculated to detect 15% differences in key risk behaviors between IBBS round I and round II, with the sample size varying from 300 to 400 participants per study population per province. Table 3-1 represents the sample sizes successfully recruited in each province in the 2009 IBBS study. Figure 1-3 shows the locations of these provinces.

Table 3-1. Study sample sizes by provinces, IBBS 2009.

Province	Male injecting drug users	Female sex workers	
		Venue-based sex workers	Street-based sex workers
Ha Noi	300	300	300
Hai Phong	300	300	300
Quang Ninh	300	298	159
Nghe An	300	274	282
Yen Bai	360	123	151
Đa Nang	291	251	300
Đong Nai	300	300	300
Ho Chi Minh City	310	305	300
Can Tho	277	354	138
An Giang	300	263	300
Overall sample	**3,038**	**2,768**	**2,530**

3.1.3.2. Sampling strategies

The sampling methods used for the 2009 IBBS study were respondent-driven sampling (RDS) and time-location sampling (TLS) using two-stage cluster sampling. Take-all sampling (i.e., recruiting all eligible members of the study population) and systematic random sampling (i.e., recruiting every other eligible member of the study population) were used as alternatives to TLS wherever the estimated size of a population was small. These alternative methods were only used for SSWs in four provinces (Quang Ninh, Nghe An, Yen Bai, and Can Tho) and VSWs in four provinces (Hai Phong, Quang Ninh, Da Nang, and Yen Bai). Figure 3-1 shows the sampling method selection based on population characteristics, while Table 3-2 summarizes sampling methods actually used in the 2009 IBBS study.

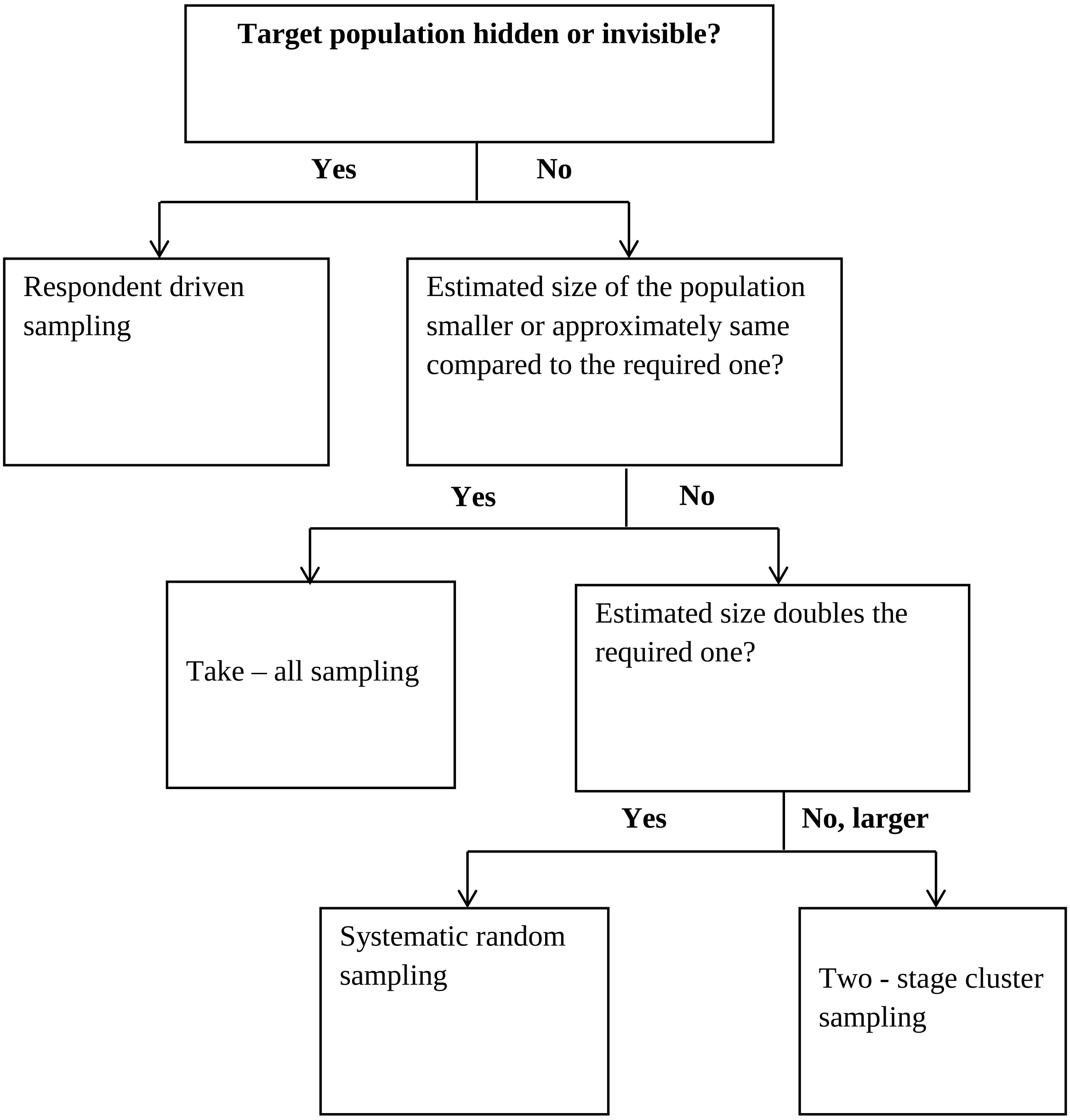


Figure 3-1. Determination of sampling method, IBBS 2009.

Table 3-2. Sampling methods, IBBS 2009.

Province	Male injecting drug users	Female sex workers	
		Venue-based sex workers	Street-based sex workers
Ha Noi	RDS	TLS	TLS
Hai Phong	TLS	TLS	TLS
Quang Ninh	TLS	Take-all	Take-all
Nghe An	TLS	Take-all	Take-all
Yen Bai	TLS	Take-all	Take-all
Đa Nang	RDS	TLS	Take-all
Đong Nai	TLS	TLS	TLS
Ho Chi Minh City	RDS	TLS	TLS
Can Tho	RDS	Take-all	TLS
An Giang	TLS	TLS	TLS

RDS: Respondent driven sampling

TLS: Time-location sampling

Time-location sampling

Time-location sampling using two-stage clustered sampling involved two stages: 1) Development of sampling frames and the selection of clusters and 2) Recruitment of study participants.

Stage 1: Development of sampling frames and the selection of clusters

Prior to recruitment, locations where IDUs congregated were mapped over two weeks. The primary sampling unit was a cluster of locations, defined as a group of 10 individuals from a target population, identified in the same area. Venues with low numbers of the target population (e.g., two or three FSWs at each venue) were combined to create a cluster before being included in the sampling frame. Thirty clusters were randomly selected from each sampling frame to achieve probability proportional to size.

Stage 2: Recruitment of study participants

Participant recruiters were given the addresses of venues and the specific number of individuals to be surveyed from clusters that were randomly selected. On a given survey visit, if there were more potential eligible subjects than the sample size required, participants were chosen at random. If not, all subjects present who satisfied the criteria were selected. All eligible participants were briefed on the study objectives and given invitation cards with information about the study, the address of data collection sites, and appointment dates.

Take-all sampling

After mapping, if the population size estimate was smaller than required, the take-all method was used where all members of the target population at all mapped locations were recruited. Participant recruiters visited designated sites, met eligible participants, explained the study's objectives, and distributed invitation cards (as above).

Systematic random sampling

After mapping, if the estimated population size was approximately twice the required sample size, systematic random sampling was applied. Participant recruiters visited all mapped locations and selected one in two eligible individuals. In cases where the sample size was not obtained after all sites were visited, this procedure was repeated until the sample size was obtained.

Respondent-driven sampling

Respondent-driven sampling (RDS) is a chain-referral method in which recruitment is achieved through participant referral. However, unlike the "snowball" method, it gives unbiased estimates of population parameters (327). RDS was initiated by recruiting participants identified as "seeds." Seeds were selectively chosen to guarantee diversity in the target population's characteristics, geographic area, and networks. Seeds were interviewed as participants, given a limited number of referral coupons (i.e., 2-3 coupons), and asked to invite peers from their social network to participate. Subsequent participants who completed the interviews were also given coupons to invite additional peers from their network. This process continued until the sample size was reached, which usually required five to eight waves, or rounds, of referrals.

3.1.4. IBBS data collection

Study centers were established for the collection of behavioral data and biological samples. At least one was created for each study population in each study province. Each study center had three separate areas, including a reception area, an interview room, and a room for the collection of biological samples with a space for individual counseling.

Potential participants were registered at the reception desk on arrival. The receptionist conducted a primary screening by asking questions according to the criteria for participant selection. Participants who did not meet the criteria were excluded from the study, as were those who had already participated. Verbal consent was then obtained for each participant to guarantee their anonymity, enabling all data to be de-identified.

Each participant was provided with a unique ID number and brought to the interview room, where an individual face-to-face interview was conducted by a trained interviewer. The interview took approximately 30-45 minutes. When the interviews were completed, participants were guided to a private testing room where biological samples were collected. After pre-test counseling by a trained counselor, a lab technician took blood samples.

An individual's study ID number was regularly checked at each step to ensure that the numbered questionnaire and biological samples matched. By the end of the data collection procedure, receptionists ensured that participants had completed all the steps before they left the study center. Participants were remunerated 50,000-100,000 VND (equivalent to 2.7-5.4 USD) for their time depending on the location, travel expenses were also covered.

The IBBS protocol was approved by the National Institute of Hygiene and Epidemiology Ethics Review Board and an Institutional Review Board of the US Centers for Disease Control and Prevention (CDC).

3.2. ANALYSIS OF THE 2009 IBBS DATA

3.2.1. Key measures

3.2.1.1. Male injecting drug users

Key measures included data on socio-demographic characteristics; selected sexual, alcohol consumption, and drug injection-related behaviors; STIs; HIV knowledge and perception; access to HIV prevention and care services; and laboratory confirmed test results for HIV. Socio-demographic data included age, educational attainment, employment status, monthly income, and marital status. Alcohol consumption and drug-related risk behavior data included level of alcohol consumption, age at first injecting drug use, duration of injecting drug use, mobility, history of being detained in a drug rehabilitation center, frequency of injecting drug use in the past month, sharing of drugs or drug mixing equipment in the past six months, and place of last injection. Mobility was assessed by asking participants whether they had injected drugs in provinces other than the study province in the past 12 months. Sexual risk behavior data included: aggregated number of sexual partners in the past 12 months, condom use in the most recent sexual encounter, consistent condom use in the past 12 months with different types of sexual partners, and having any type of sexual partner who also injected drugs in the past 12 months. The total number of sexual partners in the past 12 months was calculated by adding up the number of different types of sexual partners, including regular sexual partners (i.e., wife/girlfriends), FSWs, casual sexual partners (i.e., any other sexual partners not including wife/girlfriends or FSWs), and male sexual partners. Consistent condom use was defined in the IBBS study as the use of a condom every time the participant had sexual intercourse with a sexual partner. STI data included the self-reported history of abnormal discharge, genital pain, or ulcers in the past 12 months and laboratory confirmed test results for syphilis. HIV knowledge and perception data included knowledge of HIV risk and prevention methods, and the self-perception of HIV risk. Knowledge of HIV risk and prevention methods was assessed by the ability of participants to accurately identify ways to prevent HIV infection and their rejection of misconception regarding HIV transmission. Exposure to HIV prevention intervention data included exposure to HIV testing and exposure and access to HIV prevention commodities (i.e., sterile needles and syringes, condoms, and Information-Education-Counseling (IEC) materials).

3.2.1.2. Female sex workers

Key measures included data on socio-demographic characteristics; selected sexual, alcohol consumption, and drug use-related risk behaviors; STIs; HIV knowledge and perception; access to HIV prevention and care services; and laboratory confirmed test results for HIV. Socio-demographic data included age, age initiating sex work, time of involvement in sex work, educational attainment, marital status, monthly income, price charged for sex work, mobility, a history of being detained in a rehabilitation center, and type of sex work. Sexual risk behavior data included the aggregated number of sexual partners in the past month, which was calculated by summing up the number of different types of sexual partners, including one-time clients, regular clients, and non-commercial regular sexual partners (i.e., husband/boyfriends); condom use during last sexual encounter; consistent condom use with clients in the past month; and having any type of sexual partner who injected drugs in the past month. Drug use risk behavior data included any lifetime drug use and any lifetime injecting drug use. These were determined by answering “Yes” to the question “Have you ever use any types of illicit drugs” and then

“Have you ever injected any type of illicit drugs.” STI data included a self-reported history of abnormal vaginal discharge, genital pain, or ulcers in the past 12 months and laboratory confirmed test results for syphilis. HIV knowledge and perception data included knowledge of HIV risk and prevention methods, assessed by the ability of participants to accurately identify ways to prevent HIV infection and their rejection of misconception regarding HIV transmission and their self-perception of HIV risk. Exposure to HIV prevention intervention data included exposure to HIV testing and exposure and access to HIV prevention commodities (i.e., condoms, sterile needles and syringes for injecting FSWs, and IEC materials).

3.2.2. Statistical analysis

Three separate analyses were undertaken for male IDUs and FSWs: descriptive statistics analysis, univariate and multivariate logistic regression analysis. Analyses in this thesis were performed using STATA version 10. Statistical tests were two-tailed with an α of 0.05.

3.2.2.1. Descriptive analysis

Descriptive analysis involved the calculation of the frequency of HIV infection, socio-demographic characteristics, sexual risk behaviors, alcohol consumption and drug use/injection-related risk behaviors, HIV knowledge and perception, and exposure and access to HIV prevention and care services. Contingency tables were formed for each variable. For continuous independent variables, the normality of data distribution was checked by the use of skew tests. Means and medians were then calculated for continuous symmetric variables and continuous asymmetrically distributed variables, respectively. Pearson’s chi-square test for categorical variables, the student t-test for continuous symmetric variables, and the Mann-Whitney test for continuous asymmetrically distributed variables were also conducted when necessary.

For the FSW population, data for SSWs and VSWs were examined separately. Comparisons between SSWs and VSWs for each of the indicators were performed using Pearson’s chi-square test (for categorical variables), the t-test (for continuous symmetric variables), and the Mann-Whitney test (for continuous asymmetrically distributed variables).

3.2.2.2. Univariate logistic regression analysis

One of the main aims of this thesis is to identify factors associated with HIV infection among study populations by estimating the effect of each of these factors on the outcome of interest. The greater the number of categories into which independent variables are divided, the fewer observations will remain in each strata, leading to a reduced chance of identifying significant and meaningful results. To deal with this problem, original independent variables were transformed to a series of binary variables to enable them to be used in univariate and multivariate logistic regression analyses. Therefore, a number of variables included in univariate and multivariate logistic regression analysis might have different categories from those presented in the contingency tables of the descriptive analysis. Crude odds ratios (OR) and 95% confidence intervals (95% CI) were estimated to identify variables for multivariate logistic regression analysis.

3.2.2.3. Multivariate logistic regression analysis

To determine which variables were independently associated with HIV infection, multivariate logistic regression analysis was performed. Variables significantly associated with HIV infection in univariate logistic regression analysis were included in the multivariate logistic regression analysis. However, the selection of variables into a multivariate model was also based on biological plausibility and prior knowledge, regardless of their p-values. To avoid the problem of multi-collinearity, only variables that were considered as logical risk factors for HIV infection were selected to be included in the model. For highly correlated variables (Pearson correlation coefficient > 0.9, p-value <0.05), only one representative variable was selected.

The initial logistic regression model included all variables that were significantly associated with HIV infection in univariate logistic regression analysis as well as variables considered to be potential factors associated with HIV infection. Only variables with p-value <0.05 were retained in the final multivariate model. Effect modification and confounding among variables were also examined. The validity of the final model was checked based on the magnitude of the adjusted ORs, 95% CIs, Wald chi-square statistics, and adjusted R squares.

For FSWs, the final multivariate model for the overall FSW population was stratified by the two FSW sub-populations to examine factors that were independently associated with HIV infection within each FSW sub-population. For behaviors and characteristics significantly associated with HIV infection among SSWs, additional multivariate analysis was performed to examine whether the distribution of these factors differed between SSWs and VSWs.

3.3. AGENT-BASED MODEL SIMULATION METHODS

After fitting traditional regression models to the 2009 IBBS dataset and obtaining estimates of all potential factors associated with HIV infection among male IDUs and FSWs, an ABM was constructed to characterize the dynamics of the HIV epidemic in Vietnam. The purpose of this study is to construct a simple but complete ABM to maximize learning regarding the origin of observed emergent behaviors from epidemiological data and to understand the implications of existing intervention theories. The model therefore used only selected socio-demographic factors which are of biological importance (i.e., sex and age), key sexual risk behaviors (i.e., condom use, number of sexual partners, and number of FSWs visited), and drug injection-related behaviors (i.e., prevalence of drug injection, frequency of drug injection, prevalence of needle sharing among IDUs, and size of IDU network) rather than matching the rich-information IBBS epidemiological data with hundreds of indicators.

While other factors such as educational attainment, occupation, income, mobility, location, STIs, Tuberculosis (TB) co-infections, Antiretroviral Therapy (ART), and knowledge of HIV/AIDS have been recognized as important contributors to the acquisition and transmission of HIV infection, these factors will be left for future research.

3.3.1. General features of a typical agent-based model

Within an agent-based modeling context, the PSARTE (i.e., Parameters, States, Actions, Rules, Time, Environment) framework is used to understand the key characteristics of an ABM (328). The next section describes each of these components.

In every ABM, at least one population exists that is composed of different agents. Agents are autonomous entities in the model that are defined by certain characteristics or attributes (37, 329). In disease modeling, the populations of greatest interest are generally those composed of individual persons (35). Typically, each agent is associated with:

- **Parameters**: Characteristics or attributes of an agent that often do not change or only rarely change, at least within a short period of time. A parameter could be discrete (e.g., sex, ethnicity, education attainment, risk groups) or continuous (e.g., age, birthweight, income) (328).
- **States**: Characterizations of the agent's status that vary over time. Example of states are drug injection status (e.g., non-drug use, drug use but not injecting, injecting drug use) and HIV status (e.g., susceptible, primary infection, acute infection, latent infection, AIDS, death from AIDS) (328).
- **Actions**: Agents have the ability to adapt and modify behaviors based on certain conditions (329). Agents can also interact with other agents. Many types of such interactions are possible, including the transfer and reception of data, and acting upon

data received between agents, typically between agents located close by in the simulated environment (328).

- **Rules**: The behavior of agents is defined by rules (328). Examples of rules that may define an HIV epidemic are:
    - Agents form partnerships with other agents based on their risk groups (e.g., IDUs, FSWs) (37).
    - The probability of HIV transmission through vaginal sex (i.e., per heterosexual contact) is 0.001-0.002 (330).
    - The probability of HIV transmission via single needle stick is 0.002-0.008 (330).
    - Average time length is 17 days for acute HIV, 9 years for latent HIV, 1-3 years from AIDS diagnosis to death (330-334).
- **Time**: ABM has a temporal time horizon, sometimes defined in discrete time space or discrete time (328).
- **Environment**: The environment is the virtual world in which the agents live (328, 335). Environments could represent geographical spaces or spaces characterized by some other features or network (328, 335). The environment can change based on the emergence of changes caused by the interaction of different agents (335)
- **Statechart:** Statecharts specifically specify the "State," "Action," and Rules" components of the PSARTE framework (328, 336). An illustration of a statechart is presented in Figure 3-2 (328, 336, 337).

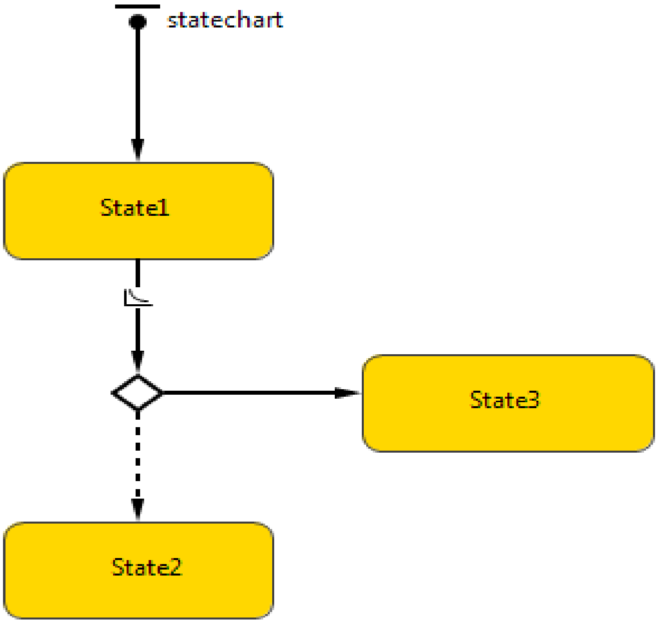
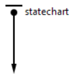
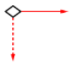


Figure 3-2. Illustration of a statechart.

A statechart is typically made of an entry point, states, transitions and branches, and relates to some particular concern of interest. A statechart entry point  is used to indicate the initial state of the statechart; there should be only one statechart entry point defined for each statechart. States and transitions are two major parts of a state chart. States  represent the possible current status of an agent. A transition  denotes an action consisting of a switch from one state to another and encodes the rules under which that change in status is triggered. A branch  represents a transition branching point. Two or more conditional transitions , represented as the solid and the dashed line from the branch to possible destination states, are associated with each branch. The solid transitions are associated with defined conditions, while the dashed line indicates the default branch if others do not apply (328, 336, 337).

3.3.2. Model description

3.3.2.1. Population

The ABM constructed in this thesis did not have isolated populations for IDUs and FSWs. Instead, it was set so that an agent was drawn from a common population. Depending on risk behaviors, an agent could be an IDU, a FSW, a client of FSW, or a HIV low-risk male/female in the general population. It is noted that an agent can change status over the course of the model; for example, an agent could be a female in the general population when the model started, she then got involved in sex work industry and became a FSW for 10 years before retiring at the time the model completed. To correspond with real statistics in Vietnam, it was assumed in the model that male IDUs account for 2.0% of the adult male population while FSWs account for 1.0% of the adult female population, with SSWs accounting for 30% and VSWs accounting for 70% of the overall FSW population.

The Male: Female (M:F) ratio set in this model closely reflected the actual M:F ratio in Vietnam of 0.51: 0.49, meaning that males account for 51% and females account for 49% of the overall population of the country. The age structure of the population in the model also followed Vietnam's age structure.

In this model, the population was set at 100,000 individuals. This decision was made based on a number of factors, including:

- Sufficiency of the size of population for HIV to spread (i.e., assuming the same number of initial HIV infections, HIV may spread more quickly in a larger population than in a smaller one);
- The sophistication of the model (i.e., a model with greater detail will take more processor time to execute);
- The run time of the model (i.e., a model with a larger population will take more processor time to execute).

A simulated population size which was close to the real country population size would be most ideal to examine the extent of the HIV epidemic. However, there is always a trade-off between the size of the population and/or the sophistication of the model and the run time of the model (37). In some cases, it could take a few hours to a few days for the model to complete just one run. It is important to point out that a hundred to a thousand of runs had to be made to get the model's final outputs. Given the level of detail of this model, 100,000 individuals were considered a reasonable population size and required a feasible amount of processor time to execute.

To best correspond the real world, the population represented in this model is not static but open. The birth rate and death rate are integrated into the model to capture population inflow and outflow. However, given the small size of the population simulated, it was assumed in this model that the growth rate for the population in 50 years was close to zero.

3.3.2.2. Parameters

A number of parameters related to HIV transmission and risk behaviors were created in this model. Their values were set based on the IBBS key behavioral data, past epidemiological research, and prior knowledge. The list of key parameters used, their associated values, and the sources where these values were taken are summarized in Table 3-3.

Table 3-3. List of key parameters used in the agent-based model.

Parameters	Values	Sources
Percentage of drug injection among SSWs	7.3%	2009 IBBS data
Percentage of drug injection among VSWs	2.4%	2009 IBBS data
Percentage of lifetime needle sharing among IDUs	46%	2009 IBBS data
Percentage of consistent condom use with FSWs by male IDUs	61%	2009 IBBS data
Percentage of consistent condom use with clients by SSWs	61%	2009 IBBS data
Percentage of consistent condom use with clients by SSWs	63%	2009 IBBS data
Number of sexual partners of SSWs per month: mean (min, max)	27.0 (18.0, 300.0)	2009 IBBS data
Number of sexual partners of VSWs per month: mean (min, max)	19.0 (14.0, 221.0)	2009 IBBS data
Number of sexual partners of male IDUs per month: mean (min, max)	2.0 (0.0, 92.0)	2009 IBBS data
Number of FSWs that male IDUs visited per month: mean (min, max)	1.0 (0.0, 92.0)	2009 IBBS data
IDU network size (i.e., number of other IDUs who an IDU had known and met in the past month): mean (min, max)	9.0 (6.0, 600.0)	2009 IBBS data
Frequency of drug injection among IDUs	52% of IDU population injected at least twice per day	2009 IBBS data
Probability of HIV transmission through injecting drug use	0.002 - 0.004	Public Health Agency of Canada, 2012
Probability of HIV transmission through single needle stick	0.007 – 0.008	Public Health Agency of Canada, 2012
Probability of HIV transmission via receptive vaginal intercourse (i.e., male to female)	0.001 – 0.002	Public Health Agency of Canada, 2012
Probability of HIV transmission via insertive vaginal intercourse (i.e., female to male)	0.0005 - 0.001	Public Health Agency of Canada, 2012
Time to progress from primary HIV infection to acute HIV infection: mean (min, max)	21 days (14, 28)	U.S. Department of Health and Human Services, 2017
Time to progress from acute HIV infection to latent HIV infection: mean (min, max)	21 days (7, 28)	Canadian Foundation for AIDS Research, 2017
Time to progress from latent HIV infection to AIDS: mean (min, max)	9 years (1, 20)	Nadler, 2005 O'Brien, 2004 U.S Department of Health and Human Services, 2017
Time to progress from AIDS to death: mean (min, max)	3 years (1, 10)	Nadler, 2005 O'Brien, 2004 U.S Department of Health and Human Services, 2017

3.3.2.3. Statecharts

Key elements of the dynamics of the HIV epidemics among IDUs and FSWs in Vietnam were captured via the construction of four statecharts: HIV_Infection_StateChart, Mortality_StateChart, Drug_Use_StateChart, and Sex_Work_StateChart. These four statecharts performed separate duties but interlinked with each other in many different ways to represent the overlap between and intertwining of IDUs and FSWs, as well as between these two high-risk populations and other low-risk populations.

3.3.2.3.1. HIV_Infection_StateChart

The HIV_Infection_StateChart was constructed to capture the natural progression of HIV infection and is presented in Figure 3-3.

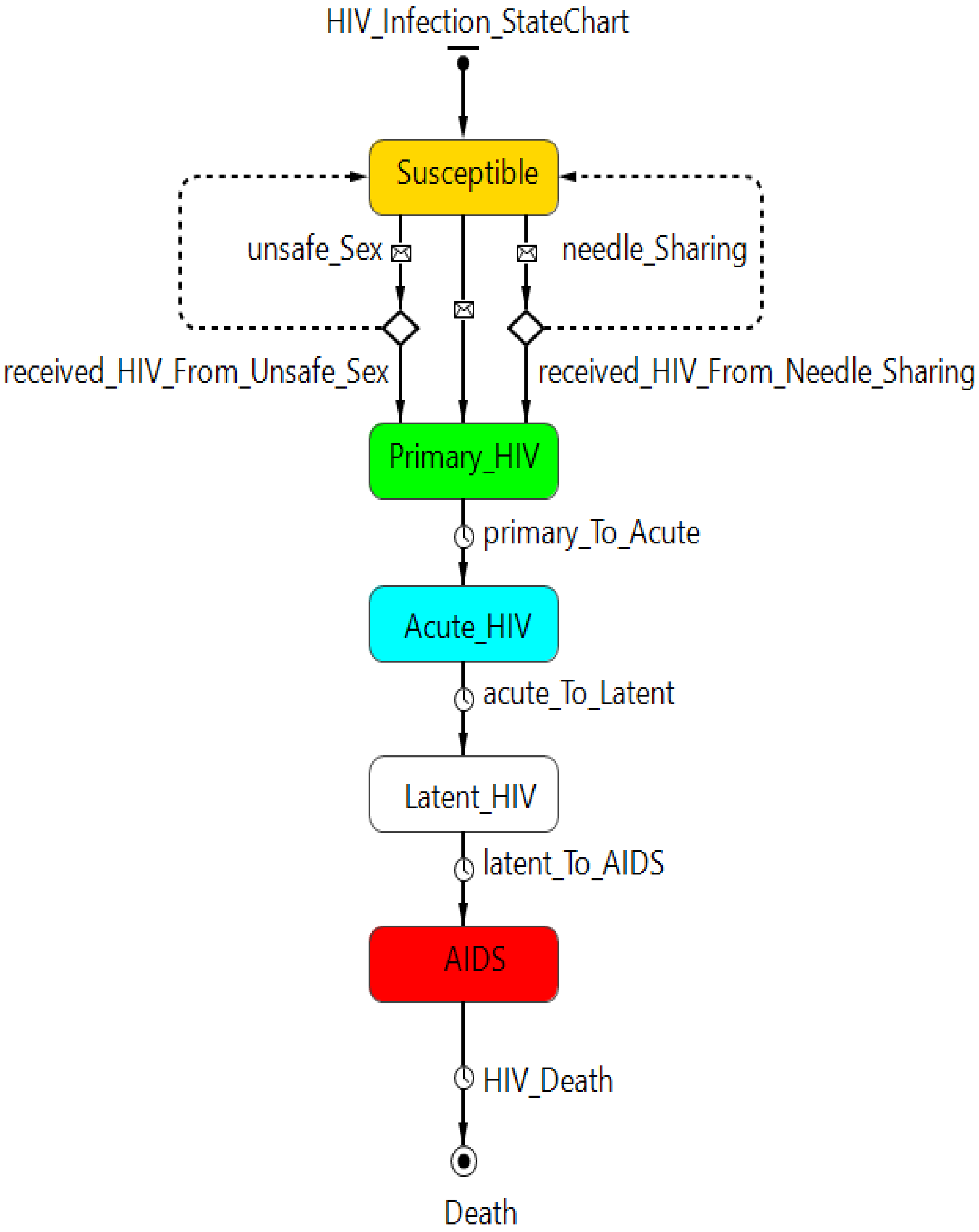


Figure 3-3. HIV_Infection_StateChart.

When the chart was created, the agent started in the "Susceptible" state, meaning that the agent was free of HIV. For HIV to spread in the population, at least one agent in the population has to be infected initially. In this model, two agents (i.e., one male IDU and one FSW) were forced to be infected as the model started via a transition linking the "Susceptible" and "Primary_HIV" states to make sure that HIV infection could spread at least within the IDU and FSW populations.

Among various risk behaviors, needle sharing and unsafe sex are identified as major risk factors for HIV acquisition among IDUs and FSWs. For this reason, these two risk behaviors were the main focus within the scope of this model. These behaviors are represented via the two transitions, "needle_Sharing" and "unsafe_Sex," that link the "Susceptible" to the "Primary_HIV" state, indicating that an agent could get HIV either via the sharing of contaminated needles or via the inconsistent use of condoms. When one of these two risk behaviors occurred, the not-yet-infected agent from the "Susceptible" state would either get infected and progress to the "Primary_HIV" state or remain uninfected in the "Susceptible" state, depending on a pre-specified probability. This phenomenon was captured via the two parallel branches linking the "Susceptible" state and "Primary_HIV" state. The solid transition from each branch represented pre-specified probabilities that an agent could get infected (i.e., either via needle sharing or via unsafe sex). The dash transition represented the probability that an agent would remain uninfected. Such probabilities were drawn from past epidemiological research (Table 3-3).

Once an agent had been in the "Primary_HIV" state, the agent subsequently progressed between successive states representing HIV progression (i.e., "Primary_HIV" to "Acute_HIV," "Acute_HIV" to "Latent_HIV," "Latent_HIV" to "AIDS," and "AIDS" to "Death"). An agent was removed from the population when it reached the terminal "Death" state. There were different time lengths for an agent's progression across different HIV states. The values for these time lengths were drawn from past epidemiological studies, as presented in Table 3-3.

In brief, acute HIV infection is the earliest stage of HIV infection after the HIV virus has entered the body. Most individuals experience acute infection within two to four weeks after initial infection (332, 334). During this stage, those who get infected may have no symptoms or may experience flu-like symptoms such as fever, headache, and rash. HIV multiplies rapidly and spreads throughout the body, and at the same time attacks and destroys the infection-fighting CD4 cells of the immune system (332, 334). There are dual dangers associated with this stage. First, the infected individual often does not know that he or she is infected, and thus is not aware of the need to take extra precautions against transmission. Second, the high viral loads that are often present raise the risk of HIV transmission to others (332, 334).

Once the immune system responds to the attack of the HIV virus, CD4 cells increase, the viral load declines, and the individual enters the latent stage of the disease (334). During this stage, HIV continues to multiply in the body but at very low levels. People with chronic HIV infections may not have any HIV-related symptoms but they can still spread HIV to others, though with much lower per-contact probability of transmission than during the acute phase (334).

For the majority of HIV cases, the immune system eventually fails, CD4+ cell counts decrease, the viral load rebounds, and individuals progress to AIDS. On average, the progression from initial infection to AIDS is nine to ten years without treatment (331, 334). However, AIDS may be diagnosed in as short as one year after the initial infection among rapid progressors and as long as 20 years among long-term non-progressors (333). Without treatment, people with AIDS typically survive one to three years after diagnosis (331, 334).

3.3.2.3.2. Mortality_StateChart

The Mortality_StateChart is presented in Figure 3-4. It was constructed to specify the mortality rates for different agents in the model. It was also linked with the HIV_Infection_StateChart to capture HIV/AIDS related-mortality.

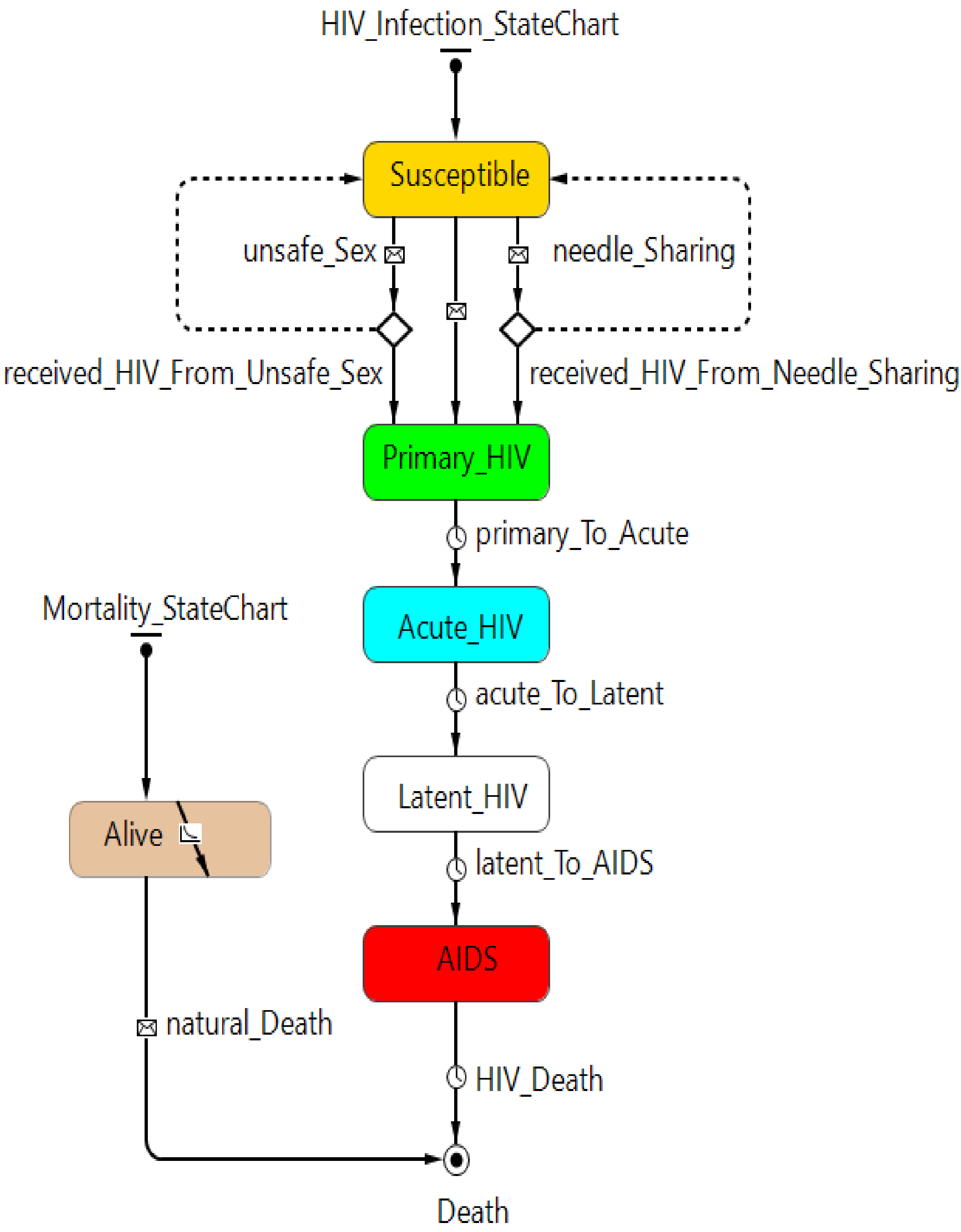


Figure 3-4. Mortality_StateChart and HIV_Infection_StateChart.

The calculation of a mortality rate for a specific agent took into account various characteristics of an agent, including age, sex, current HIV infection status, and risk behaviors. More specifically, an overall mortality rate for any single agent was calculated based on the mortality rate considering age, the mortality rate considering sex, the mortality rate considering drug use/injection, the mortality rate considering sex work, and the mortality rate considering the HIV status of that agent. For example, an active 30 year-old SSW has a different hazard rate of dying due to AIDS compared to a 50 year-old ex-IDU male who already quit drug injection and returned back to the general male population.

3.3.2.3.3. Drug_Use_StateChart

The Drug_Use_StateChart was constructed to capture drug injection-related behaviors of IDUs and is presented in Figure 3-5.

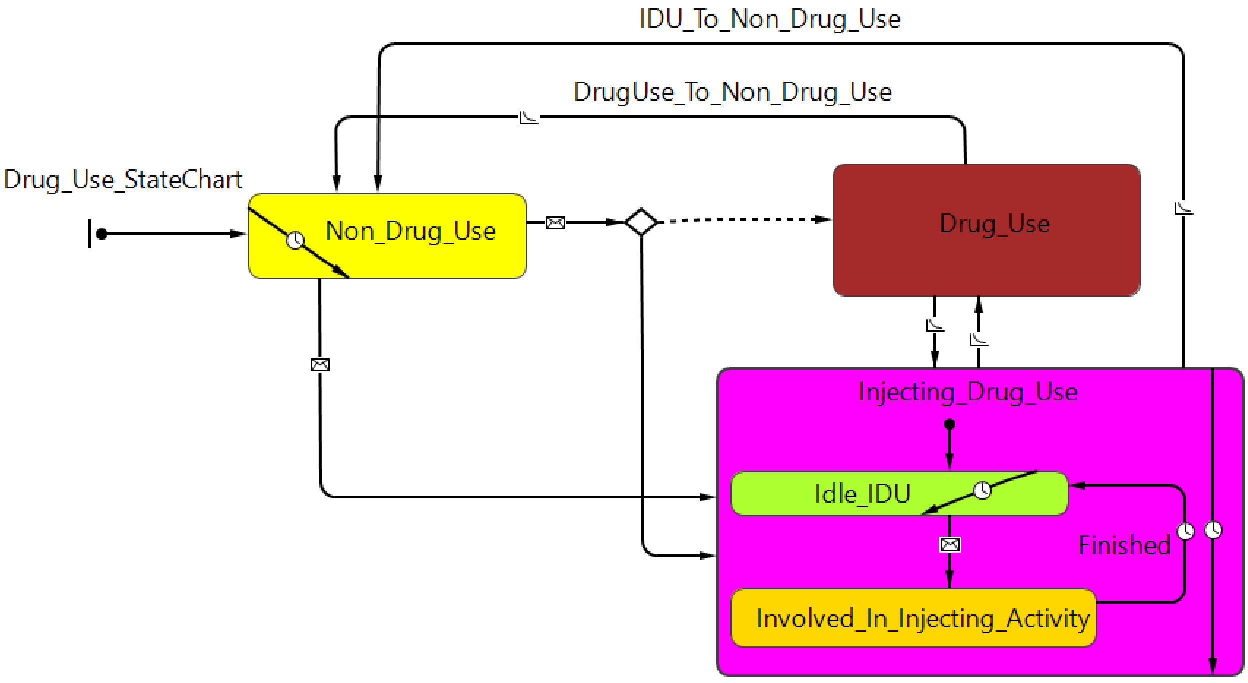


Figure 3-5. Drug_Use_StateChart.

The Drug_Use_StateChart was comprised of three main states (or compartments): "Non_Drug_Use," "Drug_Use," and "Injecting_Drug_Use."

As depicted in the statechart in Figure 3-5, every agent started in the "Non_Drug_Use" state, meaning that they initially are non-drug users in the general population. At a pre-specified rate per year, a proportion of the general population became involved in drug use and became either drug users (DUs) (i.e., captured in the "Drug_Use" state) or injecting drug users (IDUs) (i.e., captured in the "Injecting_Drug_Use" state). The Drug_Use_StateChart captured all individuals who injected drugs, no matter if they were male IDUs, female IDUs, or FSWs who injected drugs. To approximate Vietnam's actual statistics, the model was set so that up to 90% of the IDU population was male. The model also took into consideration the higher prevalence of drug injection among SSWs than that among VSWs. These values were based on 2009 IBBS data.

In this statechart, an agent could become an IDU via two routes. If they chose to inject immediately upon initiating drug use, they would transit directly from the "Non_Drug_Use' state (i.e., as a non-drug user) to "Injecting_Drug_Use" state (i.e., as an IDU). Otherwise, they became a DU first and then subsequently switched from DU to an IDU. For the latter, an agent would transit from the "Non_Drug_Use" to the "Drug_Use" state, and subsequently to the "Injecting_Drug_Use" state. Once an agent was in the "Drug_Use" state, he or she could move back and forth between the "Drug_Use" and "Injecting_Drug_Use" states. However, the likelihood of transiting from the "Drug_Use" state to the "Injecting_Drug_Use" state was set at a higher value than the transition from "Injecting_Drug_Use" to "Drug_Use" state. This is to capture the real situation in Vietnam where the majority of DUs switched to become IDUs after a period of time. However, once they have injected drugs, there is only a small chance that IDUs abandon it for recreational (non-injecting) drug use.

Similarly, there are two transitions from the "Drug_Use" state to the "Non_Drug_Use" state, and from the "Injecting_Drug_Use" state to "Non_Drug_Use" state. These respectively capture the probability that a proportion of the DU and/or IDU population quits drug use and moves back to the non-drug use population, either by their own decision or via HIV prevention intervention programs (e.g., Methadone Maintenance Therapy, Drug Rehabilitation programs, Behavioral Change interventions). Given the plausibility of quitting recreational drug use over quitting drug injection, the rate to transit from the "Drug_Use" to "Non_Drug_Use" state was often higher than the one from the "Injecting_Drug_Use" to the "Non_Drug_Use" state.

Key drug injection-related behaviors, including frequency of drug injection and needle sharing, as well as the IDU's network size, were also captured in the "Injecting_Drug_Use" state of the statechart. An IDU's network size refers to the number of other IDUs who an IDU knew and met in the last month from when IBBS data was collected. Results from the 2009 IBBS study suggested that more than half of the IDU population injected drugs at least twice per day. This phenomenon was captured in a nested statechart within the "Injecting_Drug_Use" state, which was comprised of two states: the "Idle_IDU" and "Involved_In_Injecting_Activity" states.

In the "Idle_IDU" state, an agent was assumed to stay away from drug injection (i.e., they might work, sleep, or be involved in non-drug use activities). They only injected at a specific time of the day, in which case they would move to the "Involved_In_Injecting_Activity" state via the transition linking the two states together. The "Involved_In_Injecting_Activity" state is where most drug injection-related behaviors occurred (e.g., organizing "parties" for drug injection, meeting other drug injecting partners in a "drug party," needle sharing, etc.). Any IDU agent in a drug party could share needles and syringes with IDUs of their choice. As long as one needle/syringe was infected, HIV would have a chance to spread within the specific network of those who shared that infected needle/syringe. The model was set so that drug parties took place where there was needle sharing among IDUs members and also where there was no needle sharing. An IDU agent could randomly go to one type of drug party or the other. It is worth mentioning that the percentage of drug parties with needle sharing attributes (i.e., those where needle sharing activities occurred) could be varied in the model to chart the impact of behavioral changes on the level of HIV infection. This kind of experimentation with the model will be further discussed in the following section of this thesis, titled "Experimentation of different intervention scenarios." Once the injecting activity was completed, the agent moved back from the "Involved_In_Injecting_Activity" to the "Idle_IDU" state and a new cycle started again at a different point in time.

The rationale for creating a nested statechart within the "Injecting_Drug_Use" state was to reflect the need to represent drug injection-related behavior. Since needle sharing is by definition an activity involving at least two people (often concurrently), capturing the interaction between these people is important in understanding how HIV spreads among the IDU population, taking IDU networks into account.

3.3.2.3.4. Sex_Work_StateChart

The Sex_Work_StateChart, presented in Figure 3-6, was constructed to capture sexual risk behaviors of FSWs.

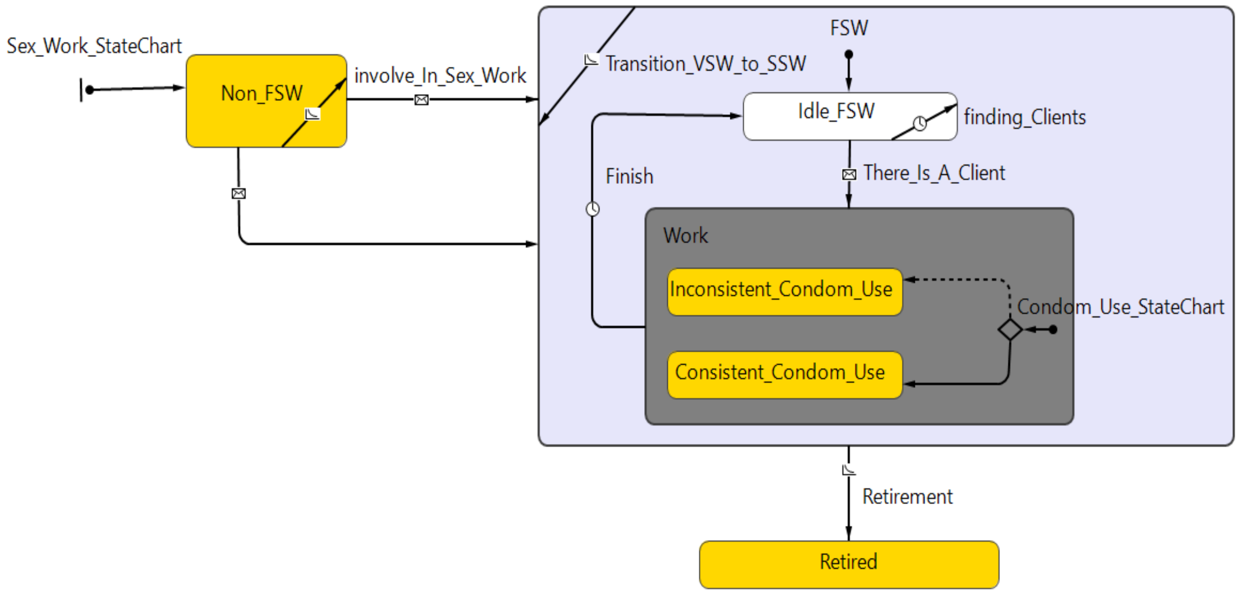


Figure 3-6. Sex_Work_StateChart.

The Sex_Work_StateChart was structured in a relatively similar way as the Drug_Use_StateChart and is comprised of three states: "Non_FSW," "FSW," and "Retired" states. Every agent departing from the "Non-FSW" state was considered a woman in the general population. At a pre-specified rate per year, a proportion of the general female population initiated involvement in the sex work industry and became FSWs (i.e., entered the "FSW" state). A FSW remained in the sex industry for a certain period of time before they retired from sex work, as captured by a transition from the "FSW" to the "Retired" state. The retirement rate depended on the current age of the FSWs (i.e., the older the FSWs, the higher rate for transiting from "FSW" to "Retired").

In the Sex_Work_StateChart, the type of sex work was also captured in the "FSW" state. The model was set to reflect the real situation in Vietnam, where VSWs are younger and account for a larger proportion (i.e., up to 70%) of the FSW population compared with SSWs. Young FSWs often start as VSWs and, generally speaking, only switch to SSW once they get older and initiate involvement in drug injection. This transitional phenomenon was captured via the transition rate "Transition_VSW_to_SSW" in the statechart.

Sexual behaviors of FSWs were represented via two nested statecharts within the "FSW" state. If frequency of drug injection and needle sharing are predominant risk factors among IDUs, the number of male clients and condom use practices of FSWs play a key role in the transmission of HIV infection among FSWs. These two factors were both captured in the "FSW" state. In brief, if an FSW agent did not have any clients, no sexual transaction occurred and so she was in the "Idle_FSW" state. She would seek male clients around her, a pattern that only stopped once she found a client. The FSW at this point moved from the "Idle_FSW" to the "Work," at which point the sexual transaction occurred. Once the transaction completed, she went back to the "Idle_FSW" state and a new cycle of client seeking started. Taking into account the differences in the risk profile between SSWs and VSWs, the model was set so that SSWs had more clients than VSWs, with the number of clients being set based on 2009 IBBS data.

In the Condom_Use_StateChart nested within the "Work" state, each FSW had a specific probability of either using condom consistently or inconsistently. This probability was represented as the branch with two conditional transitions: the solid transition to "Consistent_Condom_Use" represented the prevalence of consistent condom use with male clients, taking into account the differences in prevalence of condom use between SSWs and VSWs, while the dashed transition to "Inconsistent_Condom_Use" represented the prevalence of inconsistent condom use with male clients for these separate sub-populations. All data were drawn from the 2009 IBBS data.

3.3.2.3.5. Interlink across statecharts

As identified from secondary analysis of the IBBS data, there was an intersection between injecting drug use and sex work when male IDUs visited FSWs and FSWs also injected drugs. This facilitated the spread of HIV in Vietnam not only between these two high-risk populations but also from these populations to the general population. This phenomenon was captured via the linkage between the Drug_Use_StateChart and Sex_Work_StateChart.

As detailed in the previous section, the Drug_Use_StateChart was not only confined to male IDUs, but also captured injecting risk behaviors among FSWs. Although not visually depicted in the Drug_Use_StateChart, a male IDU's pattern of seeking FSWs, and the number of FSWs a male IDU could visit in one month were also captured in the model. It was assumed in the model that there was an equal chance that a male IDU sought out a regular FSW (i.e., a previously-visited FSW) versus a one-time FSW (i.e., new FSW who a male IDU had never visited before). That said, a male IDU was assumed to prefer a regular FSW over a one-time

FSW. He would prefer to seek out a regular FSW first and would only turn to a one-time FSW when the search was unsuccessful.

A FSW's pattern for seeking out male clients was also captured in the Sex_Work_StateChart, as described in the previous section. When the FSW sought out a client, he could be randomly picked up from any male in the population and was not necessary a male IDU. If the client served is a one-time client (i.e., new client who the FSW had never served before), that client would be added to the sexual network of the FSW, which the model would use later on to calculate the number of distinct clients a FSW would have in a specific period of time. If the client served was a regular client (i.e., a client whom the FSW has previously served), the client would not be added to the sexual network of the FSW. Instead, the model would use the transaction to calculate the number of times a FSW had sex with the client in a specific amount of time.

Although not visually depicted, male IDUs' condom use with FSWs was also captured in the Condom_Use_StateChart by applying a condition on condom use. Specifically, if a male agent was an IDU, his condom use level was derived from the IBBS data applied for IDUs (i.e., prevalence of condom use with FSWs among IDUs). Otherwise, his condom use level was derived from the IBBS data applied for FSWs (i.e., prevalence of condom use with male clients among FSWs).

3.3.2.4. Time horizon

The time unit for this model was a year. The time horizon specified was 50 years and the model was continuous in time, meaning that the model continuously ran for 50 years from its start, rather than dividing the time into discrete steps. There are several reasons to choose this 50-year time frame. First, the model run time should be long enough to ensure the stability of the model, otherwise results could vary due to the stochastics characteristics of the model (see Section 3.3.3). In addition, given the small size of the simulated population, the longer run time of the model will help create more HIV cases since HIV is circulated in the population for a longer time. This would facilitate the interpretation of and comparisons between different intervention scenarios experimented in the model (see Section 3.3.4).

3.3.3. Monte Carlo sensitive analysis

An ABM is typically stochastic in the occurrence of certain events and transitions between states. As a result, different simulations may show different results for the same model with the same parameters (337). It is important to examine the effects of this kind of stochastic variability on model outputs (e.g., the prevalence of HIV infection) since this might shed light on the degree to which the model explains the variability seen in the empirical IBBS data. Monte Carlo sensitivity analysis, with each simulation run for 100 realizations (i.e., 100 times), was performed to examine the effects of such variability.

3.3.4. Experimentation of different intervention scenarios

Once the logic of the ABM was confirmed, different "what if" intervention scenarios were simulated based on different levels of risk behavior.

- Baseline scenario: Reference scenario with the level of risk behaviors drawn from the 2009 IBBS study, though with some modifications when necessary:
    - 61% consistent condom use with FSWs among male IDUs.
    - 61% consistent condom use with clients among SSWs.
    - 63% consistent condom use with clients among VSWs.
    - 50% needle sharing among IDUs, regardless of their sex.

      For needle sharing behavior, IBBS data were only available to estimate indicators related to the level of needle sharing among the surveyed IDU population, such as lifetime needle sharing, needle sharing in the past six months, and needle sharing in the last injection. The survey statistics were unable to reveal any information related to the per-episode chance of needle sharing at an individual level. To match with the regression-based analysis in the first part of this thesis, the 46% lifetime needle sharing indicator obtained from the IBBS study continued to be used in the ABM simulation, though with modifications to operationalize the lifetime risk to per-episode risk of needle sharing in the model. We assumed that, for the baseline scenario, 50% of the drug parties organized involved needle sharing activities among participating IDU members, and that an IDU had an equal chance of going to either needle sharing or non-needle sharing drug parties. We are aware that this assumption could lead to either an overestimation or underestimation of needle sharing levels given the randomness of the model. To overcome this limitation, we ran the model a number of times and tuned it until we got the desired results. It is noted that, for the purpose of demonstrating and comparing the impact of *behavioral change interventions on HIV infections, we rounded the baseline of 46% needle sharing among IDUs (as obtained from the IBBS study) up to 50% to make comparisons with subsequent intervention scenarios easier for readers to follow and imagine.*

- Five scenarios lowering the level of needle sharing among IDUs while retaining the level of consistent condom use, as in the baseline scenario:
    - 40% needle sharing among IDUs (i.e., NS_40%).
    - 30% needle sharing among IDUs (i.e., NS_30%).
    - 20% needle sharing among IDUs (i.e., NS_20%).
    - 10% needle sharing among IDUs (i.e., NS_10%).
    - 0% needle sharing among IDUs (i.e., NS_0%).
- Four scenarios increasing the level of consistent condom use among both male IDUs and FSWs, while retaining the level of lifetime needle sharing among IDUs, as in the baseline scenario:
    - 70% consistent condom use (i.e., CU_70%).
    - 80% consistent condom use (i.e., CU_80%).
    - 90% consistent condom use (i.e., CU_90%).
    - 100% consistent condom use (i.e., CU_100%).
- Five scenarios with a combination of lowering the level of needle sharing among IDUs while increasing the level of consistent condom use among male IDUs and FSWs:
    - 40% needle sharing among IDUs & 70% consistent condom use among both male IDUs and FSWs (i.e., NS_40% & CU_70%).
    - 30% needle sharing among IDUs & 70% consistent condom use among both male IDUs and FSWs (i.e., NS_30% & CU_70%).
    - 30% needle sharing among IDUs & 80% consistent condom use among both male IDUs and FSWs (i.e., NS_30% & CU_80%).
    - 20% needle sharing among IDUs & 80% consistent condom use among both male IDUs and FSWs (i.e., NS_20% & CU_80%).
    - 10% needle sharing among IDUs & 90% consistent condom use among both male IDUs and FSWs (i.e., NS_10% & CU_90%).

Various outputs from the simulation process were generated and examined, such as:

- Prevalence of HIV infection,

- HIV prevalent case counts,
- Incidence rate of HIV infection,
- HIV incident case counts,
- Cumulative number (or cumulative count) of HIV infections over time.

Outputs from each intervention scenario were compared with those from the baseline scenario to examine which intervention scenario helped reduce HIV infections the most in each HIV high-risk population and in the overall population. The purpose of running these hypothetical simulation experiments is not to serve as exemplars for action, but to increase understandings of the impact of risk behavior change (mostly attributed to HIV prevention interventions) on HIV infection risk. Policy makers could be provided with policy recommendations based on these findings.

3.3.5. Software

In this thesis, AnyLogic 7.1.2 was used as a platform to construct and simulate the ABM.

4. CHAPTER 4: RESULTS

This chapter presents the results from the secondary analysis of the IBBS data and from the ABM simulation. The chapter includes two main sections: (i) Analysis results of 2009 IBBS data for male IDUs and FSWs and (ii) ABM simulation results.

4.1. RESULTS OF THE 2009 IBBS DATA

4.1.1. Male injecting drug users

4.1.1.1. Socio-demographic and behavioral characteristics

Socio-demographic and behavioral characteristics of the aggregate male IDU population from 10 provinces in Vietnam are shown in Table 4-1. The mean age of male IDUs across 10 provinces was 30.5 years (SD = ±8.4). Fifty-nine percent of the study population achieved up to a secondary education and 60% of the IDUs reported never getting married. Male IDUs initiated injecting drug use at an average age of 24.6 years (SD = ±7.4), with a mean duration of injection of 5.8 years (SD = ±5.3). A third of the study population reported a history of having been detained in a drug rehabilitation center.

Fifty-two percent of the IDUs injected drugs at least twice a day and 46% reported having shared needles and syringes in their lifetime. While 23% of the IDUs reported needle sharing behavior in the past six months, the percentage of sharing either drugs or drug mixing equipment within the same time frame doubled (51%). Consistent condom use practice was uncommon among male IDUs, especially with regular sexual partners (32%). Eleven percent of the participants reported having sexual partners of any kinds who also injected drugs.

Twenty-five percent of the IDU population could accurately identify ways of preventing HIV infection and reject misconception of HIV transmission. More than half of those surveyed (54%) also perceived themselves at low-risk or no-risk of HIV infection. In terms of the exposure to HIV prevention interventions, 18% of the participants reported having tested for HIV and knew their test results in the past 12 months, 23% reported exposure and access to condom and needle/syringe distribution programs, and 53% had received Information-Education-Counseling (IEC) materials in the past six months.

Table 4-1. Socio-demographic and behavioral characteristics of male injecting drug users in Vietnam, IBBS 2009.

Characteristics	n (%)
Socio-demographic characteristics	
Age	
Mean in years (SD) [a]	30.5 (±8.4)
Educational level	
No formal schooling	120 (4.0)
Primary school (1-5)	450 (15.0)
Secondary school (6-9)	1,210 (40.2)
High school (10-12)	1,098 (36.5)
College/University	132 (4.4)
Monthly income	
Mean (million VND) [b]	2,900,000
Marital status	
Had never been married	1,814 (59.8)
Currently married	799 (26.3)
Divorced	289 (9.5)
Separated	112 (3.7)
Widowed	20 (0.7)
Age at first sex	
Mean in years (SD)	19.8 (±3.3)
Age initiating drug injection	
Mean in years (SD)	24.6 (±7.4)
Duration of drug injection	
Mean in years (SD)	5.8 (±5.3)
Ever injected drugs in other provinces in the past 12 months	393 (13.0)
History of being detained in a drug rehabilitation center	1,007 (33.3)
Drug injection related behaviors	
Frequency of drug injection in the past month	
4 times or more/day	95 (3.2)
2 – 3 times/day	1,480 (49.0)
Once/day	841 (27.9)
Less than once/day	602 (20.0)
Shared needles/syringes when injecting drugs	
Ever	1,399 (46.1)
In the past 6 months	695 (22.9)
Sharing drugs/drug mixing equipment when injecting drugs in the past 6 months	1,545 (50.9)
Number of partners sharing needles/syringes in the past month	
None	2,472 (88.1)
1 partner	102 (3.6)
≥ 2 partners	233 (8.3)
Sexual behaviors	
Total number of sexual partners in the past 12 months	
None	959 (32.5)
1 partner	995 (33.7)
2 partners	317 (10.8)
≥ 3 partners	678 (23.0)
Condom use in the last sex with:	
Regular sex partner	847 (50.8)
Commercial sex partner	630 (79.3)
Casual sex partner	201 (59.1)
Male sex partner	19 (47.5)
Consistent condom use in the past 12 months with:	

Characteristics	n (%)
Regular sex partner	532 (31.9)
Commercial sex partner	484 (60.7)
Casual sexual partner	129 (37.3)
Male sexual partner	17 (42.5)
Had sexual partners who injected drugs	
Regular sexual partner	101 (6.1)
Commercial sexual partner	94 (11.8)
Casual sexual partner	47 (13.7)
Male sexual partner	13 (31.7)
HIV knowledge and perception	
Accurately identifying ways of preventing HIV infection and rejecting misconception of HIV transmission	760 (25.0)
Self-perceived HIV risk	
High risk	1,216 (45.6)
Low risk	967 (36.2)
No risk	486 (18.2)
Sexually transmitted infections	
Self-reported abnormal discharge, genital pain and ulcers in the past 12 months	122 (4.0)
Exposure to HIV prevention interventions	
Had tested for HIV and knew test results in the past 12 months	555 (18.3)
Received free/cheap condoms in the past 6 months	711 (23.4)
Received free/cheap sterile N/S in the past 6 months	711 (23.4)
Received free IEC materials in the past 6 months	1,620 (53.3)

[a] *Standard deviation*

[b] *One U.S dollar was roughly equivalent to VND 18,500 at the time of IBBS data collection*

N = 3,038

4.1.1.2. Prevalence of HIV and syphilis infections

Of a total of 3,037 male IDUs who tested for HIV, 930 were HIV positive, revealing a point prevalence of 30.6%. The prevalence, however, varied significantly across the 10 study provinces. While the prevalence remained relatively low in the central coast province of Da Nang (1%, n = 3), the figures were particularly high in the two northern coast provinces of Quang Ninh (55.7%, n = 167) and Hai Phong (48%, n = 144) and in HCMC, the biggest city in Vietnam (46.1%, n = 143). (Figure 4-1)

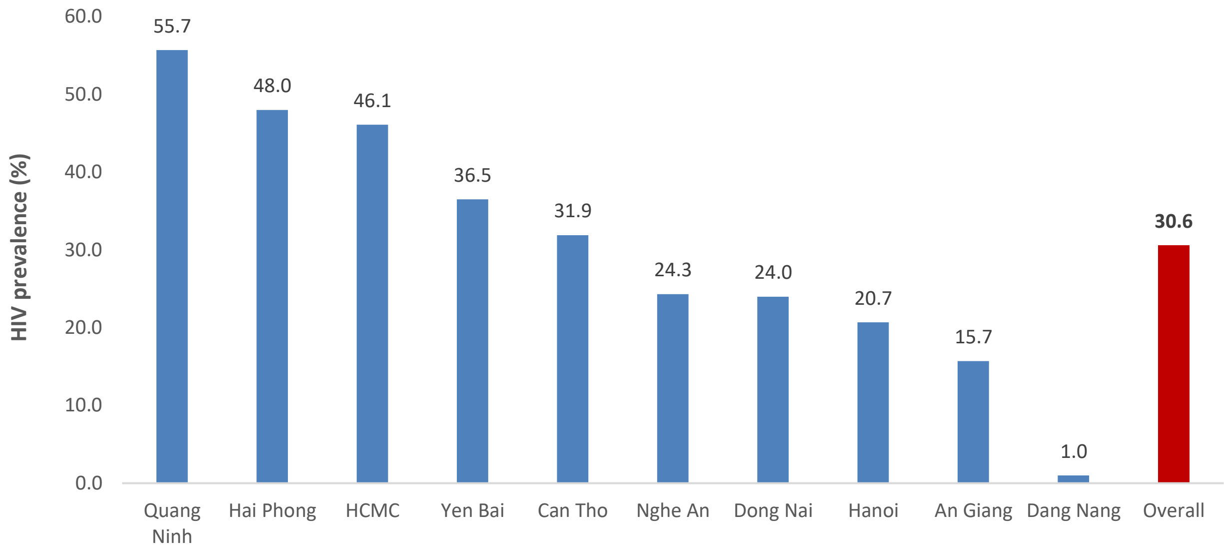


Figure 4-1. HIV prevalence among male IDUs by province, IBBS 2009.

The prevalence of syphilis, however, was relatively low among male IDUs across all provinces. The aggregated prevalence of syphilis among IDUs in all 10 provinces was 0.76% (n = 23). Syphilis was not detected among IDU samples in Hanoi and Dong Nai. Syphilis prevalence was highest in Hai Phong (1.67%, n = 5) (data not shown).

4.1.1.3 Factors associated with HIV infection

The results of logistic regression analyses undertaken to identify factors associated with HIV infection among male IDUs in Vietnam are presented in Table 4-2. Factors significantly associated with HIV infection in bivariate analysis include socio-demographic characteristics (age, marital status, duration of injecting, age at first sex, mobility, history of being detained in a drug rehabilitation center), drug injection-related behaviors (lifetime needle sharing, multiple needle sharing partners), sexual behaviors (multiple sexual partners, consistent condom use, having regular sexual partners who injected drugs), HIV knowledge, self-perception of HIV risk, and self-reported STI symptoms.

No interaction among factors was found in a multivariable model. Multivariable analysis, however, further identified eight factors independently associated with HIV infection. Male IDUs who reported ever sharing needles and syringes when injected drugs (AOR = 1.91; 95% CI: 1.40, 2.61; $p < 0.001$), injecting drugs for at least five years (AOR = 2.44; 95% CI: 1.81, 3.31; $p < 0.001$), and having regular sexual partners who also injected drugs (AOR = 2.48; 95% CI: 1.44, 4.26; $p = 0.001$) were at double risk of acquiring HIV as compared to those who did not report such behaviors. Another factor associated with an increased risk of HIV infection was a high self-perception of HIV risk (AOR = 3.07; 95% CI: 2.26, 4.16; $p < 0.001$).

Having two or more needle and syringe sharing partners when injecting drugs (AOR = 0.51; 95% CI: 0.30, 0.86; $p = 0.01$) and having more than two sexual partners in the past 12 months (AOR = 0.42; 95% CI: 0.29, 0.61; $p < 0.001$) were associated with half the risk of becoming HIV infected. Other factors associated with a reduced risk of HIV infection included mobility (AOR = 0.52; 95% CI: 0.34, 0.79; $p = 0.002$) and inconsistent condom use with regular sexual partners (AOR = 0.55; 95% CI: 0.41, 0.74; $p < 0.001$).

Table 4-2. Factors associated with HIV infection among male injecting drug users in Vietnam, IBBS 2009.

	Bivariate analysis			Multivariate analysis		
Characteristics	OR	95% CI	p-value	AOR [a]	95% CI	p-value
Socio-demographic characteristics						
Age						
< 30 years	1.00	-				
≥ 30 years	1.87	1.60, 2.19	<0.001			
Marital status						
Never been married	1.00	-				
Ever been married	1.31	1.12, 1.53	0.001			
Age at first sex						
≥ 20 years	1.00	-				
< 20 years	0.69	0.58, 0.81	<0.001			
Duration of injection						
< 5 years	1.00	-		1.00	-	
≥ 5 years	4.16	3.52, 4.93	<0.001	2.44	1.81, 3.31	**<0.001**
Ever injected drugs in other provinces in the past 12 months						
No	1.00	-		1.00	-	
Yes	0.60	0.46, 0.77	<0.001	0.52	0.34, 0.79	**0.002**
Ever been detained in a rehabilitation center						
No	1.00	-				
Yes	2.05	1.75, 2.41	<0.001			
Drug injection related behaviors						
Had ever shared needles/syringes when injecting drugs						
No	1.00	-		1.00	-	
Yes	2.39	2.04, 2.80	<0.001	1.91	1.40, 2.61	**<0.001**
Number of partners sharing needles/syringes in the past month						
< 2 partners	1.00	-		1.00		
≥ 2 partners	0.41	0.29, 0.59	<0.001	0.51	0.30, 0.86	**0.01**
Sexual behaviors						
Total number of sexual partners in the past 12 months						
≤ 2 partners	1.00	-		1.00	-	
> 2 partners	0.33	0.27, 0.42	<0.001	0.42	0.29, 0.61	**<0.001**
Condom use in the last sex with regular sexual partners						
Yes	1.00	-				
No	0.47	0.37, 0.59	<0.001			
Consistent condom use with regular sexual partners in the past 12 months						
Yes	1.00	-		1.00	-	
No	0.39	0.31, 0.48	<0.001	0.55	0.41, 0.74	**<0.001**
Had regular sexual partners who injected drugs						
No	1.00	-		1.00	-	
Yes	2.03	1.34, 3.07	0.001	2.48	1.44, 4.26	**0.001**
HIV knowledge and perception						
Accurately identifying ways of preventing HIV infection and rejecting misconception of HIV transmission						
Yes	1.00	-				
No	0.59	0.50, 0.70	<0.001			
Self-perceived HIV risk						

	Bivariate analysis			Multivariate analysis		
Characteristics	OR	95% CI	p-value	AOR [a]	95% CI	p-value
Low risk/No risk	1.00			1.00		
High risk	3.41	2.87, 4.05	<0.001	3.07	2.26, 4.16	**<0.001**
Sexually transmitted infections						
Self-reported abnormal discharge, genital pain and ulcers in the past 12 months						
No	1.00	-				
Yes	0.26	0.15, 0.46	<0.001			

[a] *AOR - Adjusted odds ratio: Estimates were adjusted for all other variables in the model*
N=3,037

4.1.2. Female sex workers

4.1.2.1. Socio-demographic and behavioral characteristics

Socio-demographic and behavioral characteristics of the aggregate FSW population from 10 provinces in Vietnam are shown in Table 4-3. The mean age of FSWs across 10 provinces was 28.8 years (SD = ±7.7). On average, the participants started selling sex at 24.5 years old (SD = ±6.9) and the mean duration in sex work was 4.3 years (SD = ±4.1). A FSW reported an average of 22.5 sexual partners (SD = ±15.8) in the past month. While 85% of the participants (n = 4,455) reported using a condom with clients the last time they had sex, only 62% (n = 3,265) used condoms consistently with their clients in the past month. Ten percent of the study population reported having used illicit drugs in their lifetime, half of whom reported injecting drug use. Only 10% of the FSWs surveyed could accurately identify ways of preventing HIV infection and reject misconceptions about HIV transmission. Seventy-one percent of the FSW population perceived themselves to be at low-risk or no-risk of HIV infection. Regarding exposure to HIV prevention interventions, around a third of the FSWs had tested for HIV in the past 12 months and knew their test results. Sixty-six percent of FSWs reported exposure to free/cheap condom distribution programs in the past six months. Almost the same number of FSWs (65%) reported receiving Information-Education-Counseling (IEC) materials in the past six months. Eighty-six percent of injecting FSWs reported receiving sterile needles and syringes during the same period.

Across the two FSW sub-populations, there were notable differences between SSWs and VSWs. Compared with VSWs, SSWs were significantly older (30.5 years for SSWs vs. 27.3 years for VSWs, p-value < 0.001), initiated sex work at a later age (25.6 years for SSWs vs. 23.5 years for VSWs, p-value < 0.001), and were involved in sex work for longer period of time (4.9 years for SSWs vs. 3.7 years for VSWs, p-value < 0.001). SSWs reported a higher number of sexual partners in the past month than VSWs did (27 clients for SSWs vs. 19 clients for VSWs, p-value < 0.001). They were also significantly more likely than VSWs to report having sexual partners who injected drugs (10.1%, n = 255 for SSWs vs. 6.4%, n = 178 for VSWs, p-value < 0.001). Drug use behavior was also significantly more prevalent among SSWs; the percentage of injecting drug use reported among these women was three times higher (7.3%, n = 184) than that among VSWs (2.4%, n = 67) (p-value < 0.001). SSWs, however, were more likely to perceive themselves as at low-risk of HIV infection (46%, n = 1,034) compared with their VSW counterparts (41%, n = 1,020). The rates of exposure and access to both condom and needle/syringe distribution programs were higher among SSWs than among VSWs (p-value

= 0.001 and 0.002, respectively).

Table 4-3. Socio-demographic and behavioral characteristics of female sex workers in Vietnam, IBBS 2009.

Characteristics	SSW (n, %)	VSW (n, %)	Total FSW (n, %)	P-value [c]
Socio-demographic characteristics				
Age				
Mean in years (SD) [a]	30.5 (±8.7)	27.3 (±6.3)	28.8 (±7.7)	<0.001
Age of initiating sex work				
Mean in years (SD) [a]	25.6 (±7.8)	23.5 (±5.8)	24.5 (±6.9)	<0.001
Duration of sex work				
Mean in years (SD) [a]	4.9 (±4.7)	3.7 (±3.3)	4.3 (±4.1)	<0.001
Educational level				
No formal schooling	202 (8.0)	112 (4.1)	314 (5.9)	<0.001
Primary school (1-5)	704 (27.8)	599 (21.7)	1,303 (24.6)	
Secondary school (6-9)	1,123 (44.4)	1,368 (49.5)	2,491 (47.1)	
High school (10-12)	474 (18.7)	655 (23.7)	1,129 (21.3)	
College/University	26 (1.0)	31 (1.1)	57 (1.1)	
Marital status				
Never been married	220 (8.7)	160 (5.8)	380 (7.2)	<0.001
Currently married	179 (7.1)	172 (6.2)	351 (6.6)	
Divorced	882 (34.9)	832 (30.1)	1,714 (32.4)	
Separated	356 (14.1)	322 (11.7)	678 (12.8)	
Widowed	891 (35.3)	1,298 (46.2)	2,169 (41.0)	
Monthly income from sex work				
Mean (million VND) [b]	4.0 (±1.2)	4.8 (±3.6)	4,4 (±0.9)	0.03
Ever sold sex in other provinces	377 (15.0)	410 (14.9)	787 (14.9)	0.91
Sexual behaviors				
Number of sexual partners in the past month				
Mean (SD) [a]	27.0 (±22.2)	18.6 (±11.3)	22.5 (±15.8)	<0.001
Condom use with clients in last sex	2,128 (84.6)	2,327 (84.5)	4,455 (84.6)	0.91
Consistent condom use with clients in the past month	1,537 (61.0)	1,728 (62.7)	3,265 (61.9)	0.208
Having sexual partners who injected illicit drugs	255 (10.1)	178 (6.4)	433 (8.2)	<0.001
Drug use behaviors				
Ever used illicit drugs	319 (12.7)	200 (7.2)	519 (9.8)	<0.001
Ever injected illicit drugs	184 (7.3)	67 (2.4)	251 (4.7)	<0.001
HIV knowledge and perception				
Accurately identifying ways of preventing HIV infection and rejecting misconception of HIV transmission	232 (9.7)	281 (10.8)	513 (10.3)	0.23
Self-perceived HIV risk				
High risk	617 (27.2)	760 (30.8)	1,377 (29.1)	0.01
Low risk	1,034 (45.6)	1,020 (41.4)	2,054 (43.4)	
No risk	617 (27.2)	687 (27.8)	1,304 (27.5)	
Sexually transmitted infections				
Self-reported abnormal discharge, genital pain and ulcers in the past 12 months	1,100 (39.8)	1,065 (42.1)	2,165 (40.9)	0.09

Characteristics	SSW	VSW	Total FSW	P-value [c]
	(n, %)	(n, %)	(n, %)	
Exposure to HIV prevention interventions				
Had tested for HIV and knew test results in the past 12 months	940 (37.2)	1,000 (36.2)	1,940 (36.7)	0.42
Received free/cheap condoms in the past 6 months	1,735 (68.6)	1,773 (64.1)	3,508 (66.2)	0.001
Injecting FSWs who received free/cheap sterile N/S in the past 6 months	167 (89.8)	54 (75.0)	221 (85.7)	0.002
Received free IEC [d] materials in the past 6 months	1,615 (63.8)	1,823 (69.9)	3,438 (64.9)	0.12

[a] *Standard deviation*

[b] *One U.S dollar was roughly equivalent to VND 18,500 at the time of IBBS data collection*

[c] *P-value regarding the differences between SSWs and VSWs*

[d] *Information-Education-Counseling*

N_Total = 5,298; N_SSW = 2,530; N_VSW = 2,768

4.1.2.2. Prevalence of HIV and syphilis infection

The aggregated HIV prevalence among FSWs in all 10 provinces surveyed was 8.6% (n = 453). The extent of HIV prevalence, however, varied significantly across provinces. The prevalence was particularly high in cities such as Hanoi (18.7%, n = 112), Hai Phong (17.3%, n = 104), and HCMC (16.6%, n = 100), while it was relatively low in the central coast province of Da Nang (0.4%, n = 2). Figure 4-2 presents the prevalence of HIV infection among FSWs across 10 provinces in Vietnam in 2009.

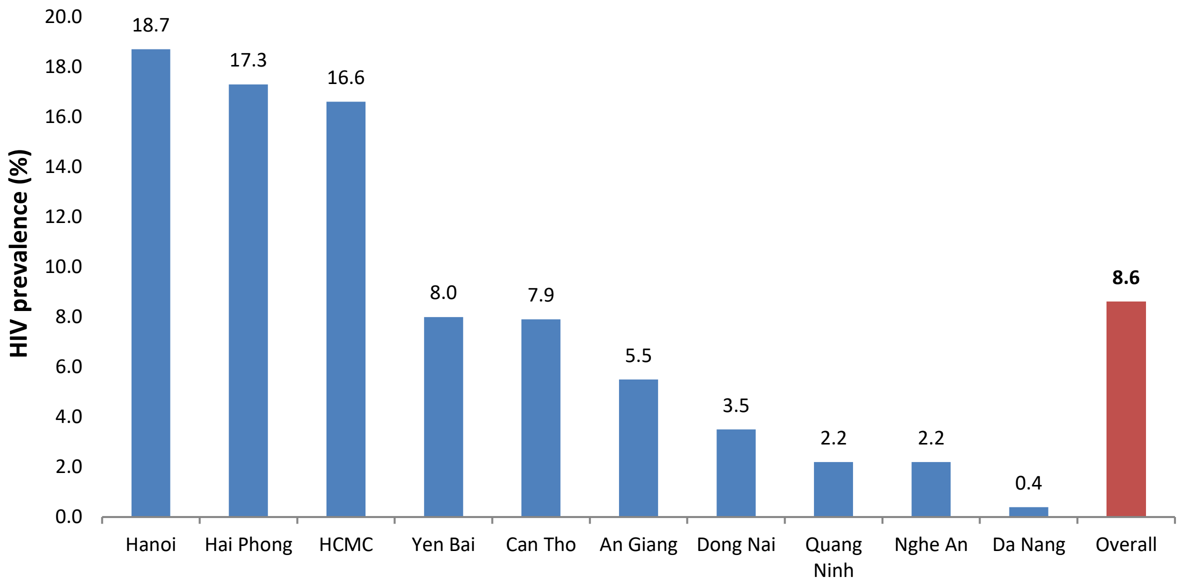


Figure 4-2. HIV prevalence among female sex workers by province, IBBS 2009.

Overall, HIV prevalence was significantly higher among SSWs (10.6%, n = 267) than among VSWs (6.7%, n = 186) ($p<0.001$). This trend was observed consistently in seven out of the 10 surveyed provinces, with as much as a six-fold difference in HIV prevalence between SSWs and VSWs in Can Tho (HIV prevalence of 19.6%, n = 27 for SSWs vs. 3.4%, n = 12 for VSWs). In the remaining three provinces, the prevalence was slightly higher among VSWs than among SSWs (Figure 4-3).

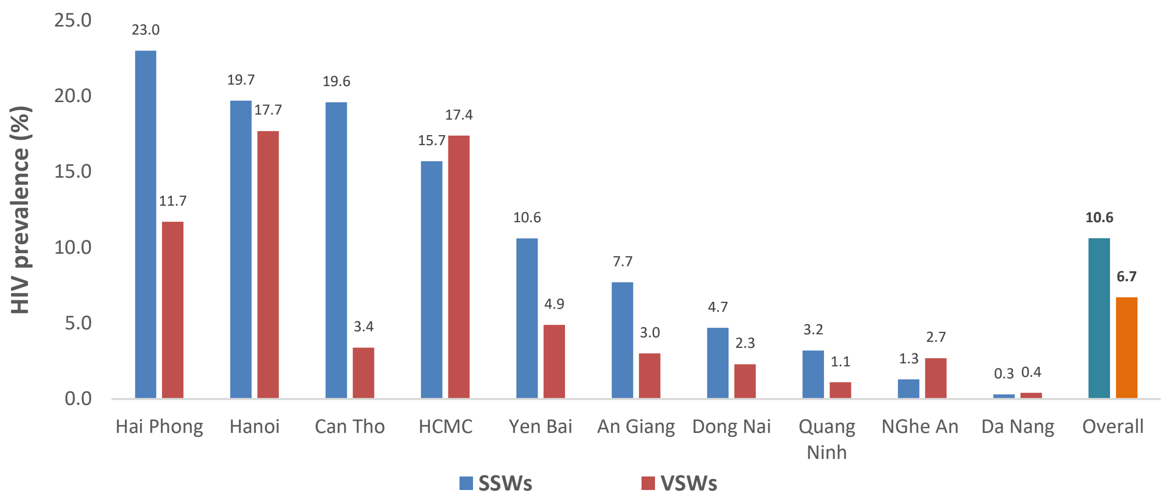


Figure 4-3. HIV prevalence among street-based and venue-based sex workers by province, IBBS 2009.

The pooled prevalence of syphilis infection among FSWs across 10 provinces was 1.6% (n= 86). As with HIV infection, syphilis prevalence varied by geographical region, with no syphilis infections reported among FSWs in Quang Ninh and the highest syphilis prevalence of 5.9% (n=33) in An Giang. Stratified by FSW subgroups, the aggregated prevalence of syphilis was almost double among SSWs (2.1%, n = 54) compared to VSWs (1.2%, n = 32). However, there was a wide variation by province and by FSW sub-populations in prevalence as well as in the pattern of infection.

The prevalence of syphilis was highest in An Giang (7.3%, n = 22 among SSWs, and 4.2%, n = 1 among VSWs) and lowest in Quang Ninh, with no cases of syphilis detected in either SSWs or VSWs. Syphilis prevalence was higher among SSWs than among VSWs in five provinces (An Giang, Can Tho, HCMC, Nghe An, and Da Nang), the same between SSWs and VSWs in Hai Phong, and lower among SSWs in three provinces (Hanoi, Yen Bai, and Dong Nai). Figure 4-4 presents the extent of syphilis infection among SSWs and VSWs in 10 provinces in Vietnam in 2009.

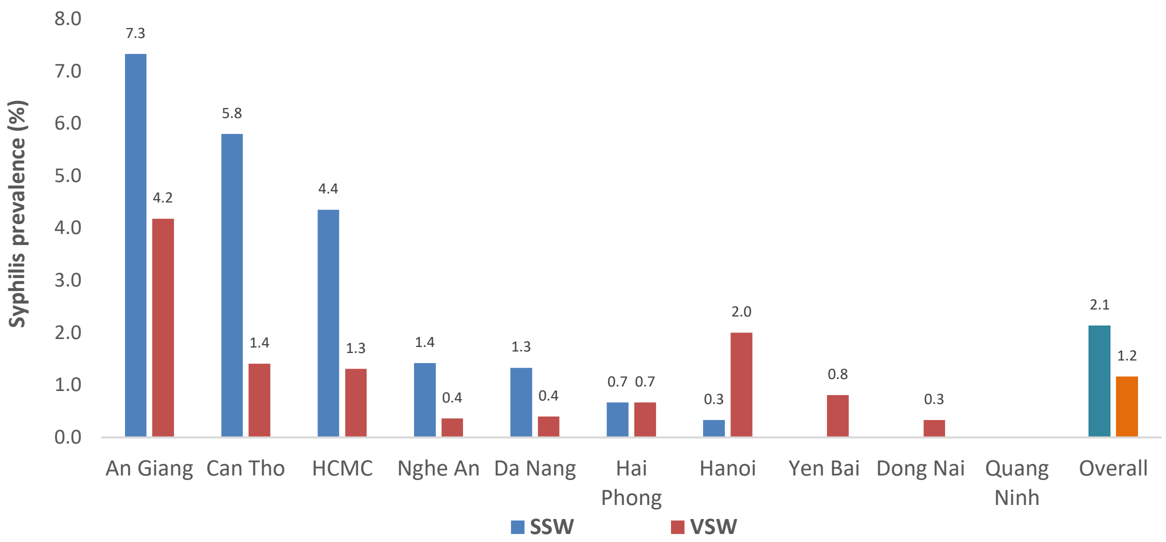


Figure 4-4. Syphilis prevalence among street-based and venue-based sex workers by province, IBBS 2009.

4.1.2.3. Factors associated with HIV infection

The results of logistic regression analysis among the overall FSW population in Vietnam are presented in Table 9. Bivariate analysis identified 13 factors associated with HIV infection. Socio-demographic characteristics included age, marital status, the price charges for sexual transactions, the duration of sex work, a history of being detained in a drug rehabilitation center, and the type of sex work. Sexual behaviors included condom use at last sex, consistent condom use in the past month, and having sex partners who injected drugs. Drug injection-related behaviors included lifetime drug use and lifetime drug injection. Other significant factors from the bivariate analysis included HIV knowledge and the self-perception of HIV risk. Self-reported STI symptoms was marginally associated with HIV infection in the bivariate analysis ($p = 0.08$).

Of a number of variables associated with HIV infection in the bivariate analysis, seven variables retained statistical significance in the multivariate analysis though no interaction was found among these variables. Injecting drug use was most strong factor independently associated with HIV infection; the odds of HIV infection increased by almost five times if a FSW reported having ever injected drugs (AOR = 4.92, 95% CI 3.60 - 6.73; $p < 0.001$). Type of sex work was also significantly associated with HIV infection, with SSWs being 34% more likely than VSWs to be HIV-seropositive (AOR = 1.34, 95% CI 1.08 - 1.67; $p = 0.01$). Other variables independently associated with higher odds of HIV infection included older age, having been married, inconsistent condom use with clients, having sexual partners who injected drugs, and a high self-perceived HIV risk.

Table 4-4. Factors associated with HIV infection among female sex workers in Vietnam, IBBS 2009.

Variables	Bivariate analysis			Multivariate analysis		
	OR	95% CI	P-value	AOR [a]	95% CI	P-value
Socio-demographic characteristics						
Age group						
<25 years	1.00	-		1.00	-	
>=25 years	2.54	1.97, 3.23	<0.001	1.68	1.26, 2.23	**<0.001**
Marital status						
Never been married	1.00	-		1.00	-	
Ever been married	1.98	1.60, 2.46	<0.001	1.34	1.03, 1.75	**0.03**
Price per sexual transaction excluding overnight stay						
≥ VND 150,000	1.00	-				
< VND 150,000	1.64	1.35, 1.99	<0.001			
Years in sex work						
≤ 3 years	1.00	-				
> 3 years	2.02	1.64, 2.49	<0.001			
Ever detained in rehabilitation center						
No	1.00	-				
Yes	3.25	2.36, 4.48	<0.001			
Type of sex work						
Venue-based sex worker	1.00	-		1.00	-	
Street-based sex worker	1.64	1.35, 1.99	<0.001	1.34	1.08, 1.67	**0.01**
Sexual behaviors						
Condom use with clients in last sex						
Yes	1.00	-				
No	1.45	1.14, 1.85	0.003			
Consistent condom use with clients in the past month						
Yes	1.00	-		1.00	-	
No	1.60	1.32, 1.95	<0.001	1.30	1.04, 1.61	**0.02**
Having sexual partners who injected drugs						
No	1.00	-		1.00	-	
Yes	2.83	2.18, 3.68	<0.001	1.45	1.07, 1.97	**0.02**
Drug use behaviors						
Ever used drugs						
No	1.00	-				
Yes	6.00	4.81, 7.50	<0.001			
Ever injected drugs						
No	1.00	-		1.00	-	
Yes	9.71	7.39, 12.76	<0.001	4.92	3.60, 6.73	**<0.001**
HIV knowledge and perception						
Accurately identifying ways of preventing HIV infection and rejecting misconception of HIV transmission						
Yes	1.00	-				
No	0.70	0.52, 0.94	0.02			
Self-perceived HIV risk						
Low risk/No risk	1.00	-		1.00	-	
High risk	4.05	3.30, 4.97	<0.001	2.65	2.11, 3.33	**<0.001**
Sexually transmitted infections						
Self-reported genital pains and ulcers in the past 12 months						
No	1.00	-				
Yes	1.24	0.98, 1.58	0.08			

[a] AOR - Adjusted odds ratio: Estimates were adjusted for all other variables in the model
N_total = 5,297

Table 4-5 presents variables independently associated with HIV infection in the multivariate analysis within each FSW sub-population. For both SSWs and VSWs, injecting drug use remained the most significant factor associated with HIV infection, yet the magnitude of the association appeared to be higher among VSWs (AOR = 6.04, 95% CI 3.42, 10.68; p-value < 0.001) than among SSWs (AOR = 4.47, 95% CI 3.06, 6.53; p-value < 0.001). The risk of HIV infection was 76% higher among SSWs aged ≥ 25 years (AOR = 1.76, 95% CI 1.16, 2.67; p-value = 0.01) compared with those younger than 25 years old. In both FSW sub-populations, the odds of getting infected were almost three times higher among women who perceived themselves as being at high risk of HIV infection (AOR = 2.82, 95% CI 2.06, 2.85; p-value < 0.001 for SSWs and AOR = 2.54, 95% CI 1.81, 3.57; p-value < 0.001 for VSWs)

In addition to HIV correlates common to both SSWs and VSWs, there were variables specifically associated with HIV infection for each sub-population. Within the SSW sub-population, the odds of having HIV increased by 47% (AOR = 1.47, 95% CI 1.01, 2.14; p-value = 0.04) if a SSW reported ever having been married. Reported inconsistent condom use with clients and having sexual partners who injected drugs were relatively strong correlates of HIV infection among VSWs, but not for SSWs. Inconsistent condom use with clients increased the odds of a VSW having HIV by 77% (AOR = 1.77, 95% CI 1.27, 2.47; p-value = 0.001) while it doubled if a VSW reported that their sexual partners injected drugs (AOR = 2.03, 95% CI 1.27, 3.23; p-value = 0.003).

Table 4-5. Factors associated with HIV infection among street-based and venue-based sex workers in Vietnam, IBBS 2009.

Variables	SSW			VSW		
	AOR [a]	95% CI	P-value	AOR [a]	95% CI	P-value
Socio-demographic characteristics						
Age group						
<25 years	1.00	-		1.00	-	
>=25 years	1.76	1.16, 2.67	**0.01**	1.63	1.09, 2. 45	**0.02**
Marital status						
Never been married	1.00	-		1.00		
Ever been married	1.47	1.01, 2.14	**0.04**	1.234	0.85, 1.80	0.27
Sexual behaviors						
Consistent condom use with clients in the past month						
Yes	1.00	-		1.00	-	
No	1.02	0.76, 1.36	0.92	1.77	1.27, 2.47	**0.001**
Having sexual partners who injected drugs						
No	1.00	-		1.00	-	
Yes	1.14	0.76, 1.71	0.53	2.03	1.27, 3.23	**0.003**
Drug use behaviors						
Ever injected drugs						
No	1.00	-		1.00	-	
Yes	4.47	3.06, 6.53	**<0.001**	6.04	3.42, 10.68	**<0.001**
HIV perception						
Self-perceived HIV risk						
Low risk/No risk	1.00	-		1.00	-	
High risk	2.82	2.06, 2.85	**<0.001**	2.54	1.81, 3.57	**<0.001**

[a] AOR = Adjusted odds ratio: Estimates were adjusted for all other variables in the model
N_SSW = 2,529; N_VSW = 2,768

4.1.2.4. Differences in the likelihood of reporting factors associated with HIV infection between street-based and venue-based sex workers

As shown in Table 4-6, SSWs were significantly more likely than VSWs to report three out of four correlates of HIV infection, including being in an older age group, having been married, and injecting drug use. SSWs were, however, less likely than their VSW counterparts to perceive themselves to be at high risk of HIV infection.

Table 4-6. Differences in the likelihood of reporting factors associated with HIV infection between street-based and venue-based sex workers in Vietnam, IBBS 2009.

Characteristics	AOR [a]	95% CI	P-value
Age >=25			
VSW	1.00	-	
SSW	1.31	1.14, 1.51	**<0.001**
Ever been married			**<0.001**
VSW	1.00	-	
SSW	1.47	1.28, 1.69	
Ever injecting drugs			
VSW	1.00	-	
SSW	3.58	2.64, 4.86	**<0.001**
High self-perception of HIV risk			
VSW	1.00	-	
SSW	0.68	0.60, 0.78	**<0.001**

[a] AOR = Adjusted odds ratio: Estimates were adjusted for all other variables in the model
N_SSW = 2,529; N_VSW = 2,768

4.2. AGENT-BASED MODEL SIMULATION RESULTS

This section presents the results obtained from the Agent-based model (ABM) simulation of the HIV epidemic in Vietnam and is divided into four parts. The first part presents the results from a hypothetical baseline scenario of the HIV epidemic among key populations in Vietnam, with key risk behavioral data being drawn from the 2009 IBBS study. The remaining three parts subsequently compare results from the baseline scenario with results from experimentations with three different sets of intervention scenarios of behavioral changes: (i) Intervention scenarios investigating the impact of lowering needle sharing level among IDUs, (ii) Intervention scenarios examining results of increasing consistent condom use level among male IDUs and FSWs, and (iii) Combined intervention scenarios involving lowering needle sharing level among IDUs and increasing consistent condom use level among male IDUs and FSWs.

Among various HIV outputs generated from the ABM, the prevalence of HIV and the cumulative number of HIV infections over time are presented as a showcase to demonstrate the effectiveness of behavioral change interventions in lowering HIV infection among different high-risk HIV populations and among the overall population. Each result presented in the graphs was averaged from the outputs of 100 replication runs, as previously described in Section 3.3.3.

4.2.1. Hypothetical baseline scenario of the HIV epidemic in Vietnam

As presented in the series of graphs in Figure 4-5, if risk behaviors of IDUs and FSWs remained at the levels observed in the 2009 IBBS study, both the prevalence of HIV infection and the number of cumulative HIV cases tended to increase over time among all high-risk populations as well as among the overall population. The HIV prevalence kept increasing over time from almost zero percent since the model started to reach 36.1% (n = 372) among male IDUs (Figure 4-5.a, blue line) and 3.8% (n = 23) among FSWs in year 50 (data for the overall FSW population are not shown). An increase in HIV prevalence was observed among both SSWs and VSWs; however, the prevalence was almost four times higher among SSWs (6.5%, n = 17) (Figure 4-5.a, grey line) compared to their VSW counterparts (1.7%, n = 6) (Figure 4-5.a, yellow line) at year 50. HIV prevalence among injecting FSWs also increased from almost zero percent at the beginning of the model to 32.9% (n = 10) at year 50 (Figure 4-5.a, orange line), close to the level observed among male IDUs (36.1%). While an increase in HIV prevalence was consistently observed in all high-risk populations, the pattern of increase was different between IDUs and FSWs. For both male IDUs and FSWs who injected drugs, HIV prevalence accelerated right after the model started and kept increasing rapidly over the course of the model. For both SSWs and VSWs, however, it took a longer time for HIV to spread in the population (i.e., up to 10 years), with HIV prevalence gradually increasing over time. Due to the increase in HIV prevalence among all high-risk populations, HIV prevalence also increased in the overall population, from almost zero percent at the beginning of the model to 0.5% (n = 500) at year 50 (Figure 4-5.c).

There was a cumulative count of 1,383 HIV cases among male IDUs (Figure 4-5.b, blue line), 119 cases among FSWs (in which 72 cases were among SSWs (Figure 4-5.b, grey line), of which 47 cases were among VSWs (Figure 4-5.b, yellow line) and 57 cases among injecting FSWs (Figure 4-5.b, orange line)), and 1,699 cases among the overall population (Figure 4-5.d) over 50 years. It is noted that injecting FSWs is a sub-population of the overall FSW population and data for FSWs, SSWs, or VSWs also included injecting FSWs. The 57 cases of injecting FSWs could therefore be embedded in the 72 cases among SSWs, the 47 cases among VSWs., or both. Given the relatively small sizes of the simulated populations for injecting FSWs, SSWs, and VSWs, the gaps between the orange, grey, and yellow lines that represent these populations is not obvious in Figure 4-5.b.

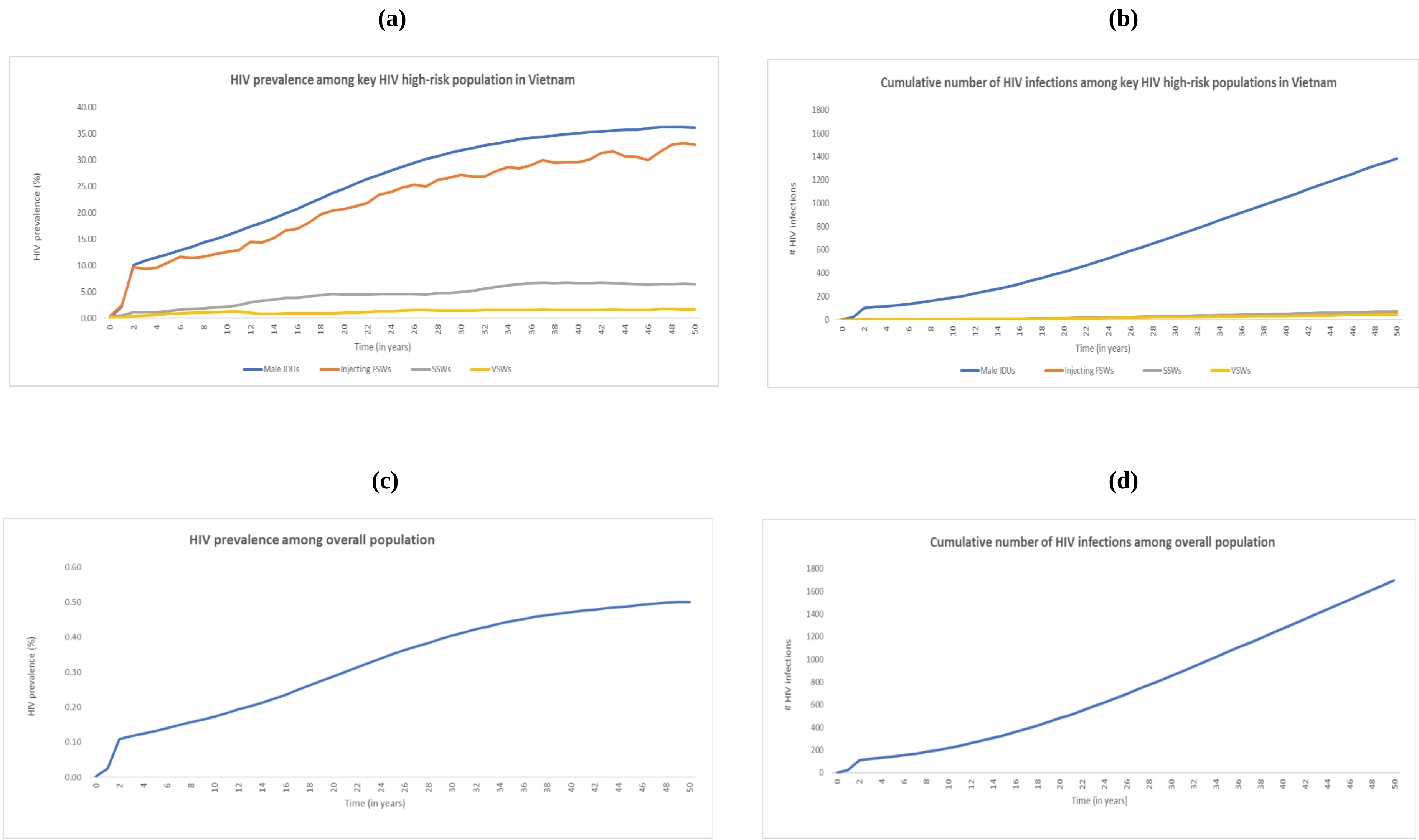


Figure 4-5. HIV situations among key populations in Vietnam in baseline scenario.

4.2.2. Intervention scenarios of lowering needle sharing levels among injecting drug users

As shown in the series of graphs in Figure 4-6, if everything remained the same as in the baseline scenario, lowering needle sharing levels among IDUs reduced both the prevalence and cumulative number of HIV infections in all simulated populations. For male IDUs, HIV prevalence decreased from 36.1% in the baseline scenario (Figure 4-6.a, dark blue line) to 23.2% in NS_40% (Figure 4-6.a, orange line), 6.81% in NS_30% (Figure 4-6a, grey line), and to less than 1% in the three other scenarios at year 50 (Figure 4-6.a, yellow, light blue, and green line. The light blue and green line were overlapped since the HIV prevalence was almost 0%). Such a reduction is sharply non-linear; lowering the needle sharing level among IDUs by a factor of two (i.e., from 40% to 20%) reduced the prevalence in this population by far more than a factor of two (i.e., from 23.2% to less than 1.0%).

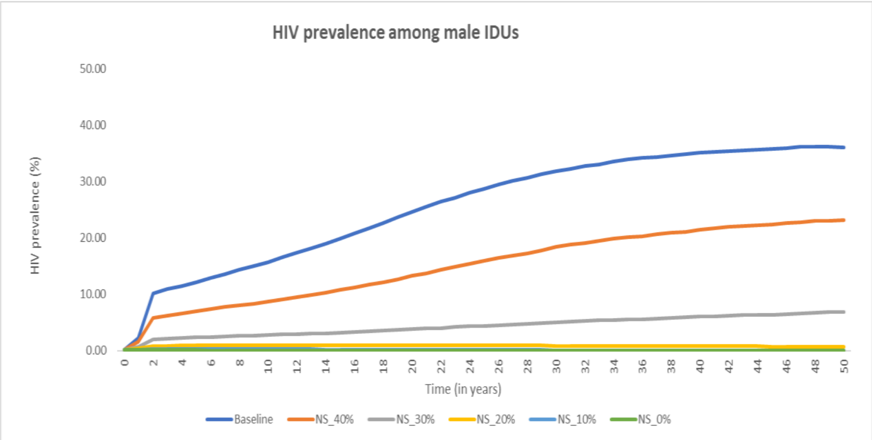
Compared with the baseline scenario (Figure 4-6.b, blue line), there was a 35% reduction in cumulative HIV cases (n = 490) among male IDUs in NS_40% (Figure 4-6.b, orange line), an 80% reduction (n = 1,105) in NS_30% (Figure 4-6.b, grey line), a 97% reduction (n = 1,338) in NS_20% (Figure 4-6.b, yellow line), and almost a 100% reduction (n = 1,378-1,383) in the remaining two intervention scenarios over 50 years (Figure 4-6.b, light blue and green line. These two lines were overlapped since the number of HIV infections was almost zero). The largest reduction of 44% (615 cases) was observed when needle sharing levels were lowered from 40% to 30%. The same pattern of reduction was observed among injecting FSWs, though the magnitude of reduction was less obvious given the small size of the injecting FSW population simulated.

HIV prevalence among SSWs reduced from 6.5% in the baseline scenario (Figure 4-6.g, blue line) to 4.2% in NS_40% (Figure 4-6.g, orange line), 1.2% in NS_30% (Figure 4-6.g, grey line), and less than 1.0% in the other three scenarios (Figure 4-6.g, yellow, light blue, and green line). For VSWs, HIV prevalence decreased from 1.7% at in the baseline scenario (Figure 4-6.i, blue line) to 1.1% in NS_40% (Figure 4-6.i, orange line), 0.3% in NS_30% (Figure 4-6.i, grey line), and less than 0.1% in the other three scenarios.

Compared with the baseline scenario (Figure 4-6.f, blue line), there was a 39% reduction in cumulative HIV cases (n = 46) among FSWs in NS_40% (Figure 4-6.f, orange line), an 81% reduction (n = 96) in NS_30% (Figure 4-6.f, grey line), a 96% reduction (n = 114) in NS_20% (Figure 4-6.f, yellow line), and almost a 100% reduction (n = 117-118) over 50 years if needle sharing among IDUs was 10% or less (Figure 4-6.f, light blue and green line. These two lines were overlapped since the number of HIV infections were almost zero). The largest reduction was observed between the NS_40% and NS_30% scenario, when 50 cases of HIV infections were averted (68% reduction) over 50 years.

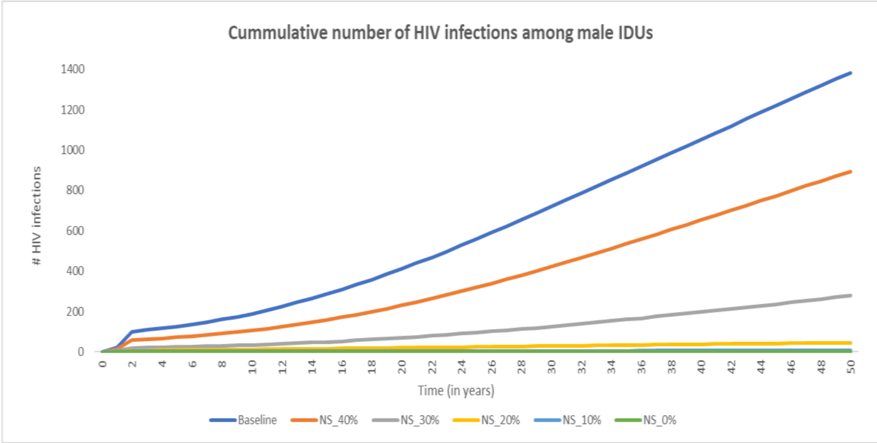
HIV prevalence among the overall population reduced from 0.5% in the baseline scenario (Figure 4-6.k, blue line) to 0.35% in NS_40% (Figure 4-6.k, orange line), 0.11% in NS_30% (Figure 4-6.k, grey line), 0.01% in NS_20% (Figure 4-6.k, yellow line), and 0% in the remaining two scenarios. Compared with the baseline scenario (Figure 4-6.l, blue line), there was a 35% reduction in cumulative HIV cases (n = 602) in NS_40% (Figure 4-6.l, orange line), an 80% reduction (n = 1,356) in NS_30% (Figure 4-6.l, grey line), a 97% reduction (n = 1,641) in NS_20%, and almost a 100% reduction (n = 1690-1697) in the remaining two scenarios over 50 years (Figure 4-6.l, light blue and green line. These two lines were overlapped since the number of HIV infections were almost zero). The largest reduction (69%, n = 754) among the overall population was observed when needle sharing levels decreased from 40% to 30%.

(a)



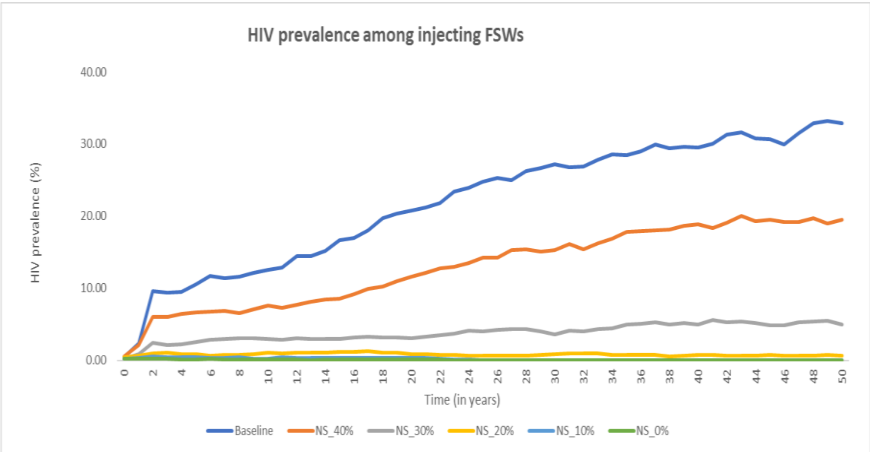
HIV prevalence among male IDUs
HIV prevalence (%)
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

(b)



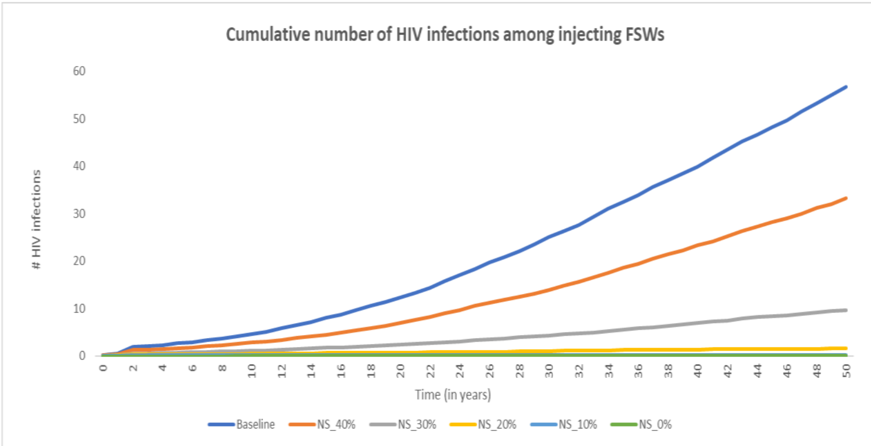
Cummulative number of HIV infections among male IDUs
HIV infections
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

(c)



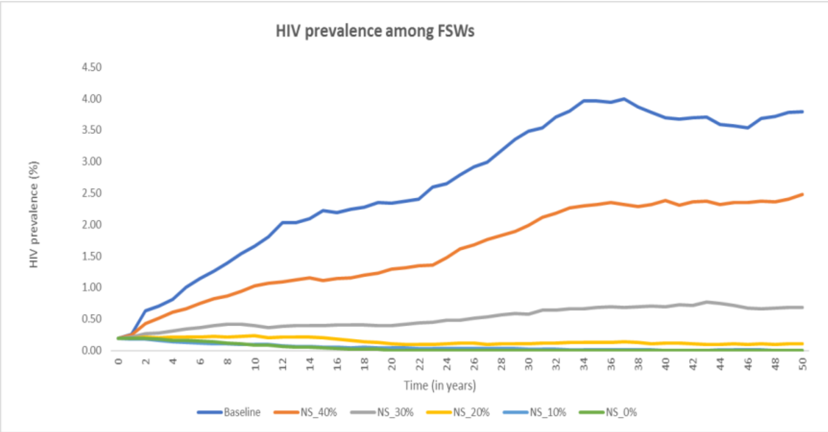
HIV prevalence among injecting FSWs
HIV prevalence (%)
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

(d)

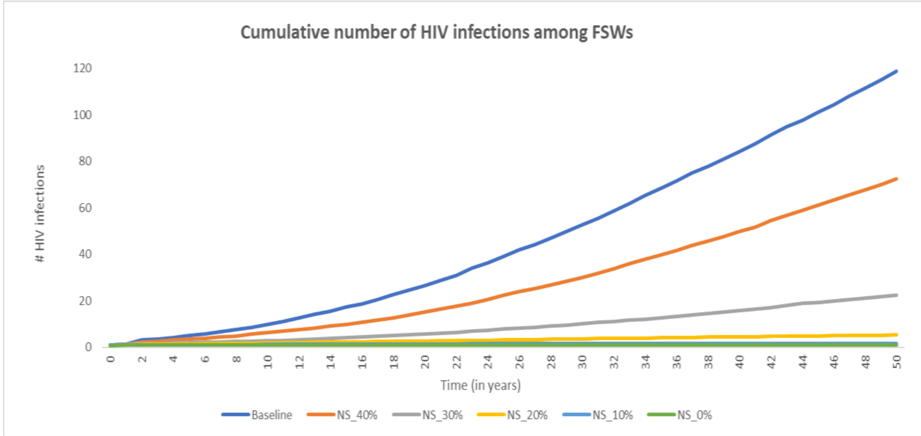


Cumulative number of HIV infections among injecting FSWs
HIV infections
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

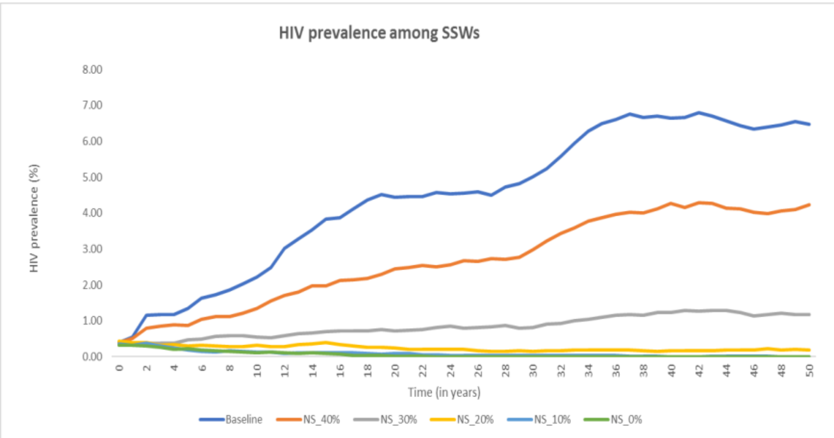
(e)


HIV prevalence among FSWs
HIV prevalence (%)
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

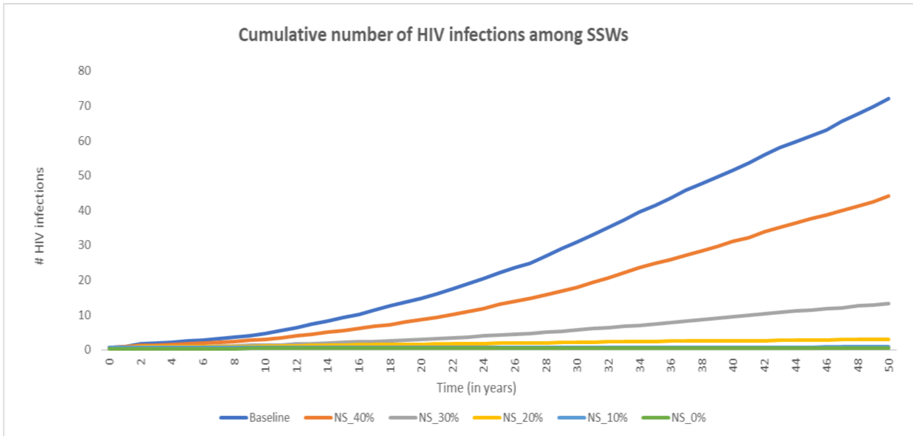
(f)


Cumulative number of HIV infections among FSWs
HIV infections
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

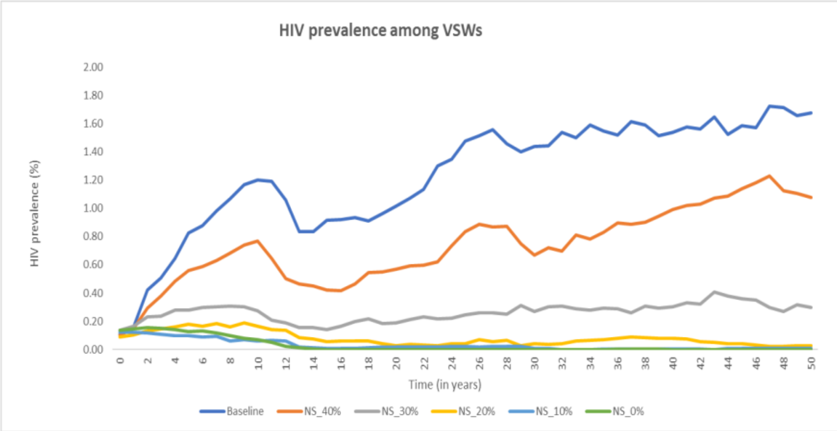
(g)


HIV prevalence among SSWs
HIV prevalence (%)
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

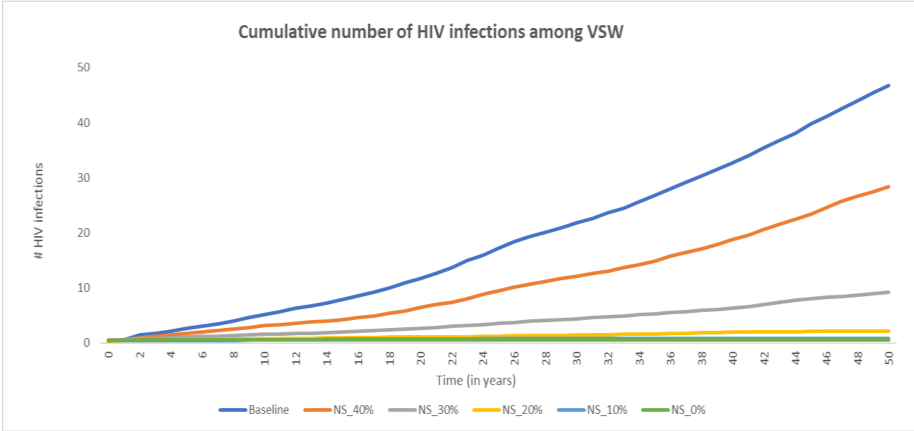
(h)


Cumulative number of HIV infections among SSWs
HIV infections
Time (in years)
Baseline
NS_40%
NS_30%
NS_20%
NS_10%
NS_0%

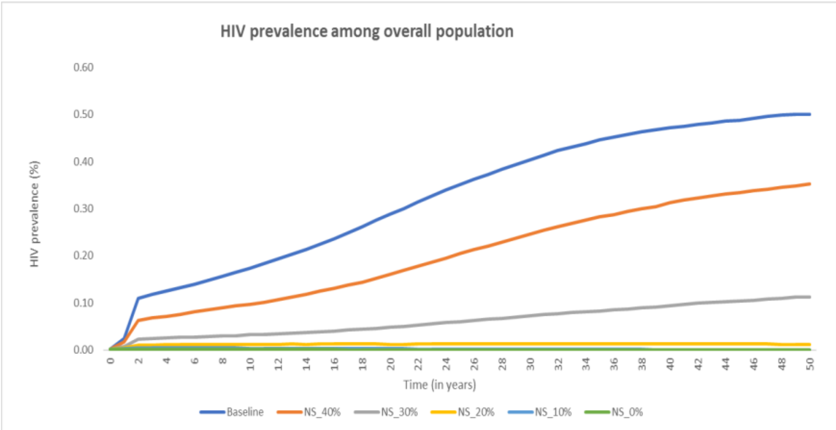
(i)



(j)



(k)



(l)

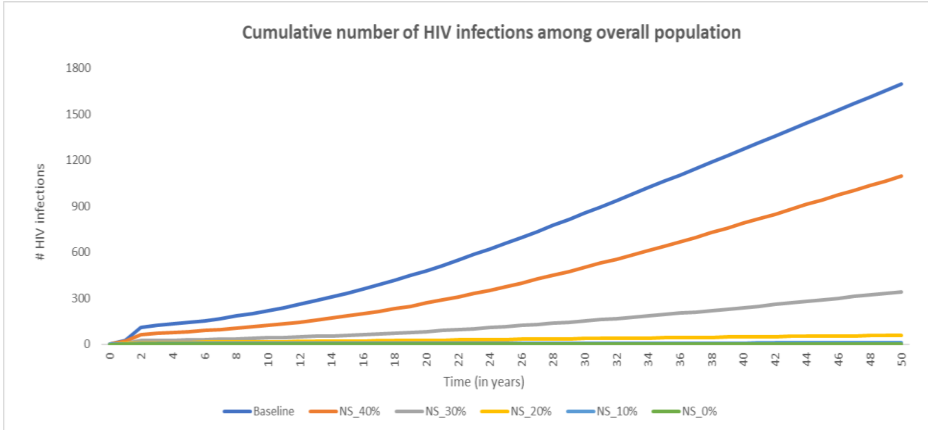


Figure 4-6. Comparisons between the baseline scenario and intervention scenarios of lowering needle sharing levels among injecting drug users.

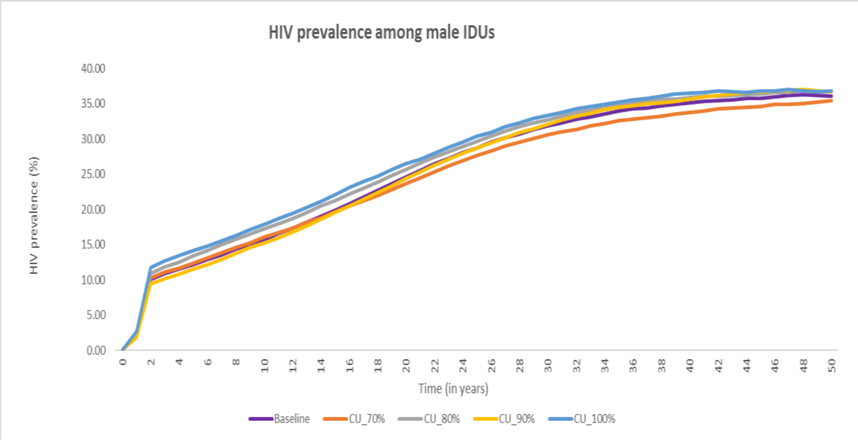
4.2.3. Intervention scenarios increasing consistent condom use level among male injecting drug users and female sex workers

As shown in the series of graphs in Figure 4-7, increasing condom use among male IDUs and FSWs did not appear to have a significant impact on the extent of HIV infection among male IDUs and injecting FSWs. This is reflected in the slight gaps and overlaps between the five lines representing the baseline scenario (purple line) and the four intervention scenarios (orange, grey, yellow, and blue lines) in Figure 4-7.a - d. As consistent condom use increased from the baseline level to 70%, HIV prevalence among IDUs decreased slightly from 36.1% (Figure 4-7.a, purple line) to 35.4% (Figure 4-7.a, orange line) (p-value = 0.02 for baseline vs. CU_70% by Mann-Whitney U-test for non-parametric data). For the other three intervention scenarios for an increase in consistent condom use (Figure 4-7.a, grey, yellow, and blue lines), an increase in the prevalence of HIV infection among male IDUs compared with the baseline scenario was observed (Figure 4-7.a, purple line). However, these differences can probably be attributed to the stochastics of the ABM since the Mann-Whitney U-test suggested non-significant differences between the baseline and intervention scenarios (p-value = 0.41 for baseline vs. CU_80%; p-value = 0.45 for baseline vs. CU_90%; p-value = 0.28 for baseline vs. CU_100%). A 3% reduction (n = 41) in cumulative HIV cases among male IDUs over 50 years was only observed in CU_70% (Figure 4-7.b, orange line) compared with the baseline scenario (Figure 4-7.b, purple line). However, the differences observed across all four scenarios were not statistically significant (p-value = 0.85 for baseline vs. CU_70%; p-value = 0.75 for baseline vs. CU_80%; p-value = 0.98 for baseline vs. CU_90%; p-value = 0.62 for baseline vs. CU_100%). Similarly, the results for injecting FSWs overlapped and no significant differences were found between the various intervention scenarios of consistent condom use increase and the baseline scenario.

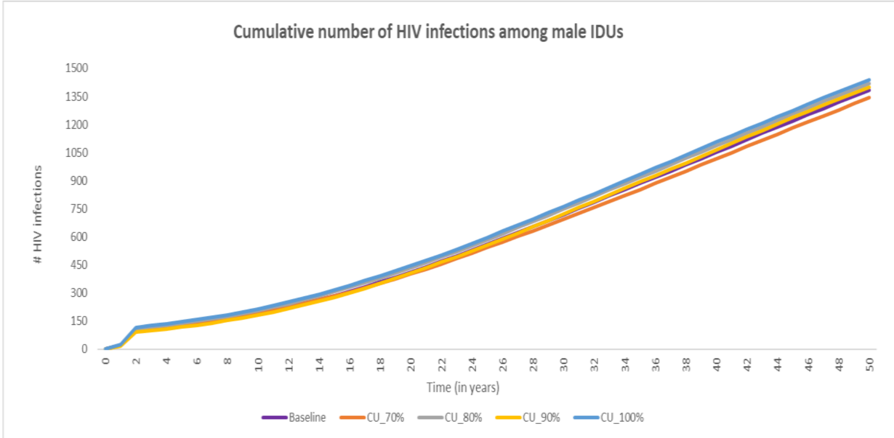
Increasing the level of consistent condom use among male IDUs and FSWs, however, did have an impact on reducing HIV infection among the FSW population over time in all intervention scenarios. For SSWs, HIV prevalence was consistently lowered in all four intervention scenarios compared with the baseline. At year 50, HIV prevalence among SSWs reduced from 6.5% at the baseline (Figure 4-7.g, purple line) to 5.3% in CU_70% (Figure 4-7.g, orange line), 4.9% in CU_80% (Figure 4-7.g, grey line), 3.7% in CU_90% (Figure 4-7.g, yellow line), and 3.2% in CU_100% (Figure 4-7.g, blue line). The cumulative number of HIV infections among SSWs decreased as consistent condom use increased, though the magnitude of the increase was not large in absolute terms given the smaller size of the FSW population simulated. Compared with the baseline scenario (Figure 4-7.h, purple line), there was a 11% reduction (n = 8) in cumulative HIV cases among SSWs in CU_70% (Figure 4-7.h, orange line), a 17% reduction (n = 12) in CU_80% (Figure 4-7.h, grey line), a 29% reduction (n = 21) in CU_90% (Figure 4-7.h, yellow line), and a 38% reduction (n = 27) in CU_100% (Figure 4-7.h, blue line) over 50 years. The same pattern of HIV reduction was also observed among VSWs. Since VSWs accounted for a larger proportion of the FSW population simulated in this model, compared with the baseline (Figure 4-7.j, purple line) the total reduction in cumulative HIV cases over time was larger, with a 19% reduction (n = 9) in CU_70% (Figure 4-7.j, orange line), a 32% reduction (n = 15) in CU_80% (Figure 4-7.j, grey line), a 53% reduction (n = 25) in CU_90% (Figure 4-7.j, yellow line), and a 72% reduction (n = 34) in CU_100% (Figure 4-7.j, blue line) over 50 years.

HIV prevalence among the overall population was slightly lower in the four intervention scenarios (0.47% - 0.49%) (Figure 4-7.k, orange, grey, yellow, and blue lines) than in the baseline scenario (0.5%) (Figure 4-7.k, purple line). This is reflected in the slight gaps and overlaps in the five lines representing the baseline scenario and the four intervention scenarios. Compared with the baseline scenario (Figure 4-7.l, purple line), reductions in the cumulative number of HIV infections over 50 years were observed in three out of four intervention scenarios: CU_70% (4.1% reduction, n = 70) (Figure 4-7.l, orange line), CU_90% (2.4% reduction, n = 40) (Figure 4-7.l, yellow line), and CU_100% (0.9% reduction, n = 16) (Figure 4-7.l, blue line). There was a 0.1% increase (n = 2) in cumulative HIV cases over 50 years in CU_80% (Figure 4-7.l, grey line) compared with the baseline scenario (Figure 4-7.l, purple line). However, the increase was not statistically significant (p-value = 0.83) and is probably due to the stochastics of the ABM.

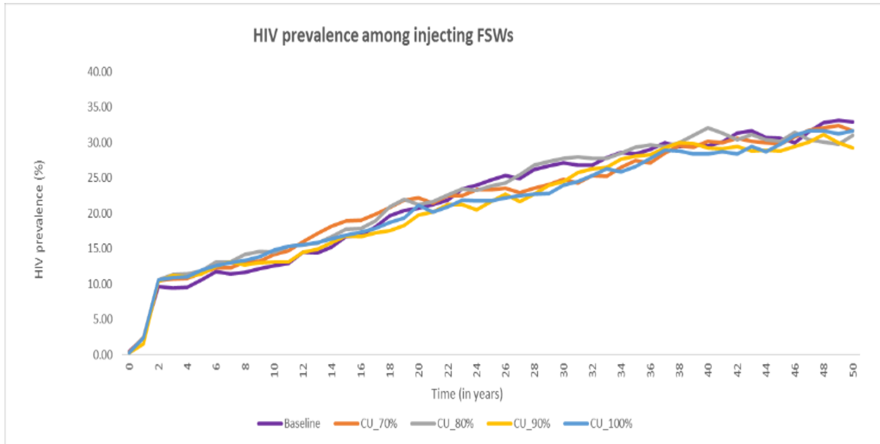
(a)


HIV prevalence among male IDUs
HIV prevalence (%)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline CU_70% CU_80% CU_90% CU_100%

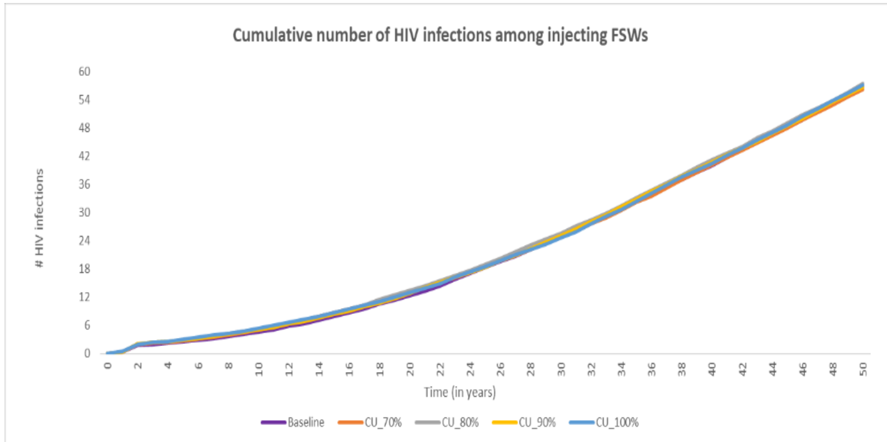
(b)


Cumulative number of HIV infections among male IDUs
HIV infections
1500
1350
1200
1050
900
750
600
450
300
150
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline CU_70% CU_80% CU_90% CU_100%

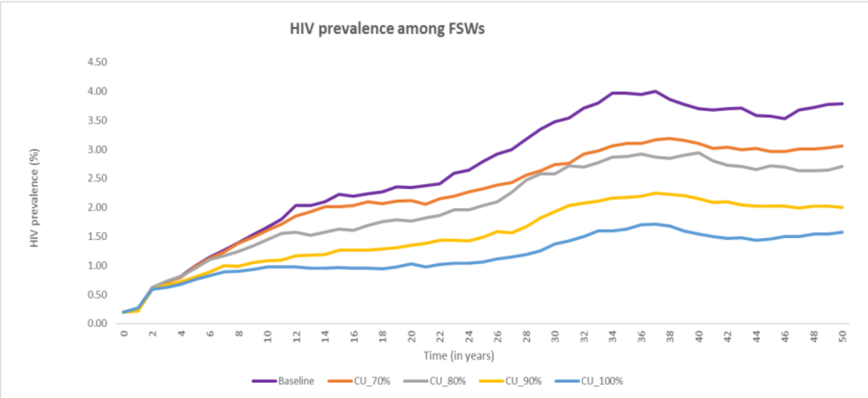
(c)

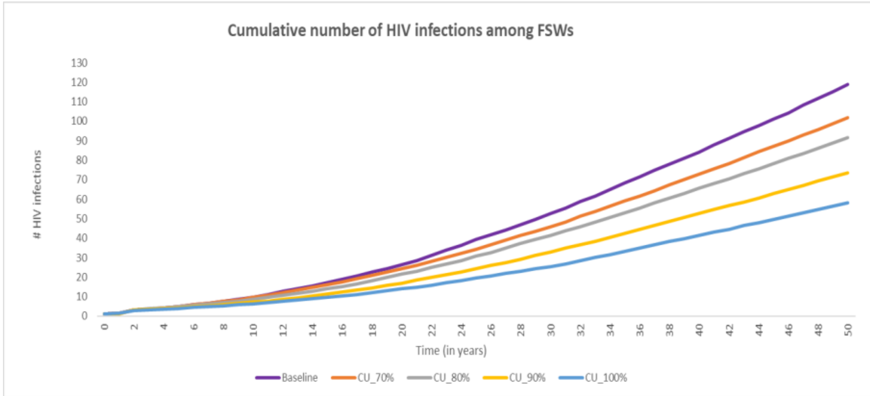

HIV prevalence among injecting FSWs
HIV prevalence (%)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline CU_70% CU_80% CU_90% CU_100%

(d)

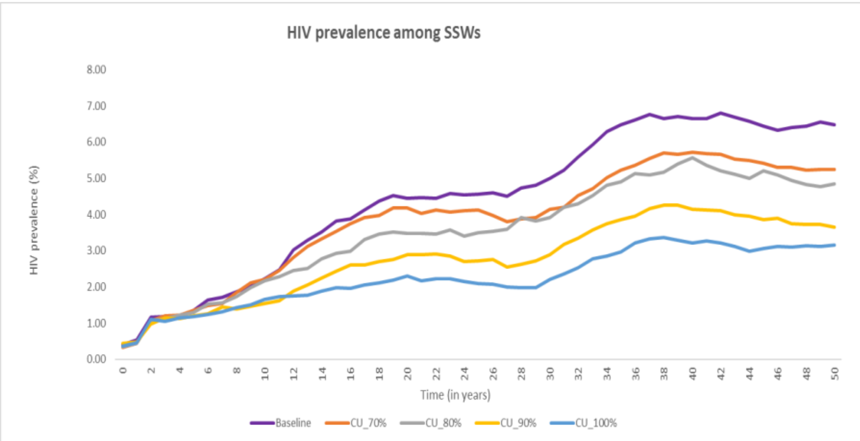

Cumulative number of HIV infections among injecting FSWs
HIV infections
60
54
48
42
36
30
24
18
12
6
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline CU_70% CU_80% CU_90% CU_100%

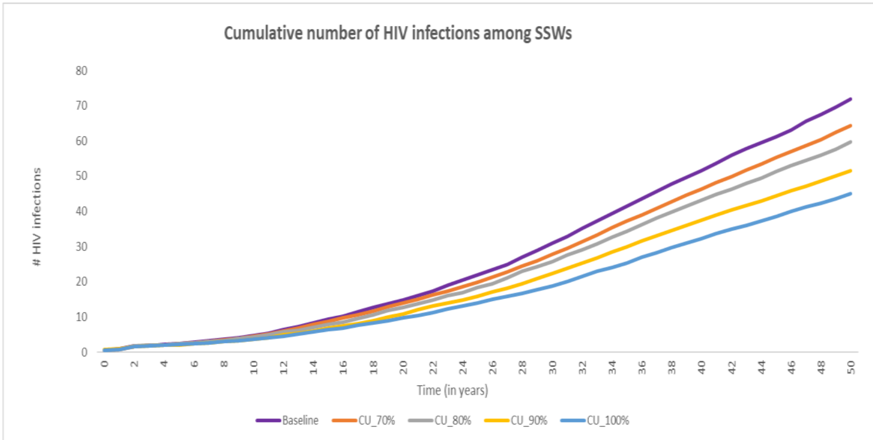
(e) **(f)**


HIV prevalence among FSWs
HIV prevalence (%)
Time (in years)
Baseline
CU_70%
CU_80%
CU_90%
CU_100%

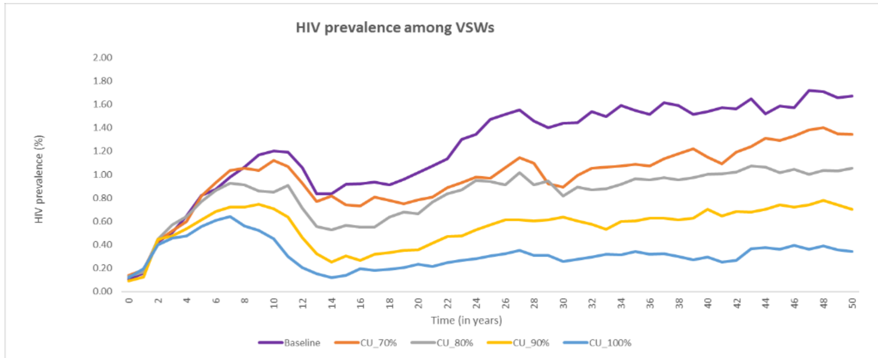

Cumulative number of HIV infections among FSWs
HIV infections
Time (in years)
Baseline
CU_70%
CU_80%
CU_90%
CU_100%

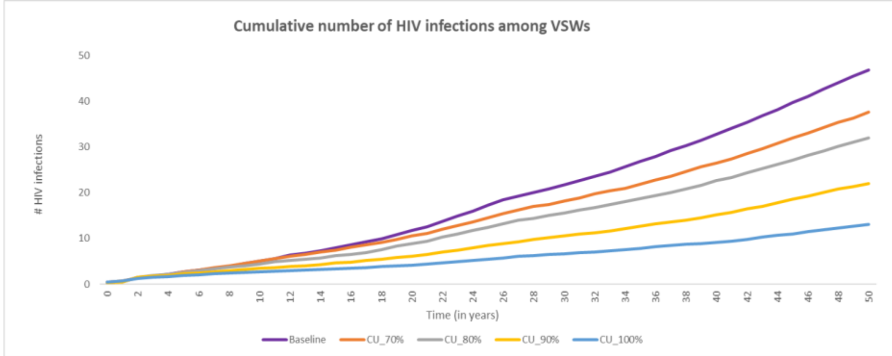
(g) **(h)**


HIV prevalence among SSWs
HIV prevalence (%)
Time (in years)
Baseline
CU_70%
CU_80%
CU_90%
CU_100%


Cumulative number of HIV infections among SSWs
HIV infections
Time (in years)
Baseline
CU_70%
CU_80%
CU_90%
CU_100%

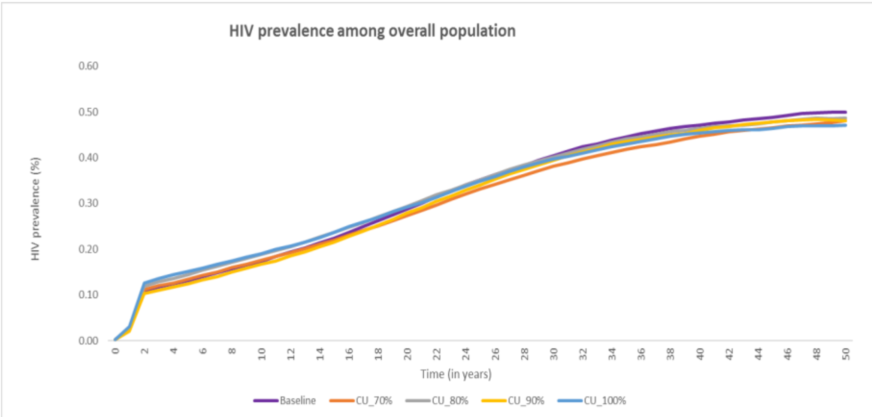
(i) **(j)**





(k)

(l)



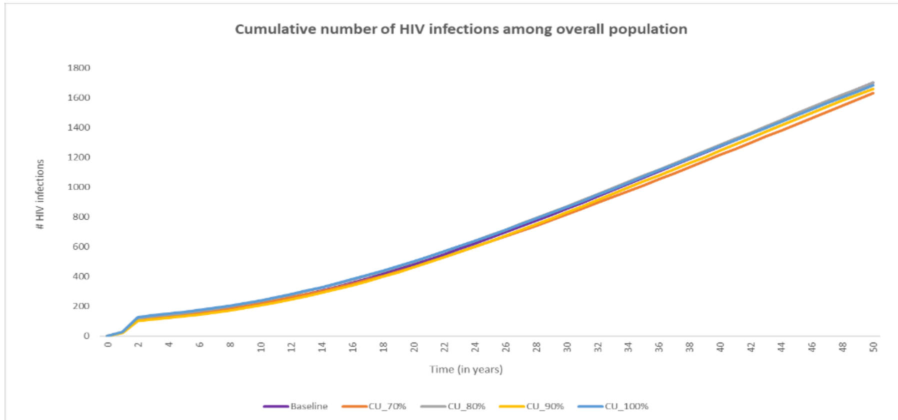


Figure 4-7. Comparisons between the baseline scenario and intervention scenarios involving increasing consistent condom use levels among male injecting drug users and female sex workers.

4.2.4. Combined intervention scenarios of lowering needle sharing levels among injecting drug users while simultaneously increasing consistent condom use levels among male injecting drug users and female sex workers

As shown in the series of graphs in Figure 4-8, combined intervention scenarios targeting dual behavioral changes added impact from both needle sharing decrease and consistent condom use increase. Overall, the patterns of HIV reduction in combined intervention scenarios appeared to be relatively similar to those observed in intervention scenarios involving lowered needle sharing levels among IDUs.

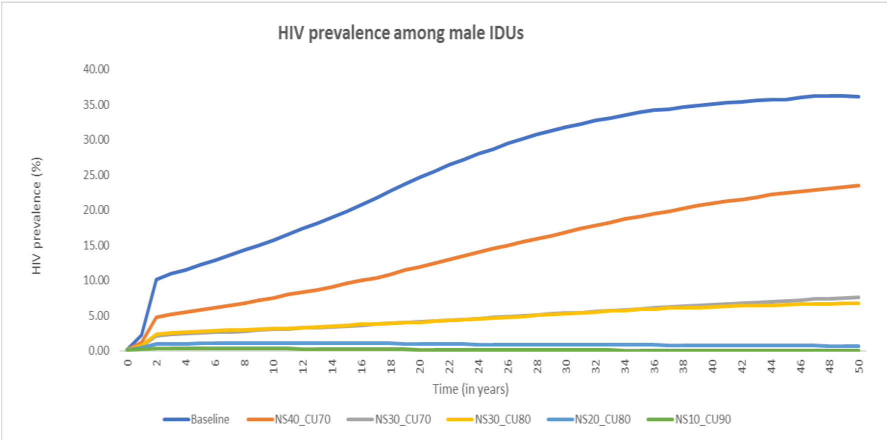
For male IDUs, the first three intervention scenarios resulted in the most noticeable reductions in HIV prevalence. For example, HIV prevalence at year 50 decreased from 36.1% in the baseline scenario (Figure 4-8.a, dark blue line) to 23.5% in NS_40% & CU_70% (Figure 4-8.a, orange line) and from 23.5% in NS_40% & CU_70% to 7.6% in NS_30% & CU_70% (Figure 4-8.a, grey line). When needle sharing levels were lowered to 30%, increasing the level of consistent condom use from 70% to 80% further decreased HIV prevalence from 7.6% (Figure 4-8.a, grey line) to 6.8% (Figure 4-8.a, yellow line). The grey and yellow lines almost overlap given then slight difference in HIV prevalence between the two intervention scenarios. Compared with the baseline scenario (Figure 4-8.b, dark blue line), there was a 37% reduction (n = 511) in cumulative HIV cases over 50 years among male IDUs in NS_40% & CU_70% (Figure 4-8.b, orange line). A further 65% reduction (n = 565) was observed during the same period if needle sharing decreased from 40% (Figure 4-8.b, orange line) to 30% while the consistent condom use level remained at 70% (Figure 4-8.b, grey line). Once the needle sharing level was lowered to 30%, efforts to increase consistent condom use from 70% (Figure 4-8.b, grey line) to 80% (Figure 4-8.b, yellow line) resulted in a further 4% reduction (n = 12) in cumulative HIV cases among male IDUs over 50 years. However, the difference was too small to be noticed and the grey and the yellow lines in Figure 4-8.b almost overlap. Injecting FSWs followed the same pattern of HIV reduction as male IDUs across all five intervention scenarios, though the reduction in the cumulative HIV cases among injecting FSWs over 50 years was much smaller given the small size of this FSW sub-population (Figure 4-8.c & Figure 4-8.d).

For both SSWs and VSWs, the most noticeable HIV reductions were found in the first two intervention scenarios. For example, HIV prevalence among SSWs at year 50 decreased from 6.5% at the baseline (Figure 4-8.g, dark blue line) to 3.6% in NS_40% & CU_70% (Figure 4-8.g, orange line), and to 1.3% in NS_30% & CU_70% (Figure 4-8.g, grey line). In the same scenarios, the reduction in HIV prevalence among VSWs at year 50 went from 1.7% at the baseline (Figure 4-8.i, dark blue line) to 0.9% (Figure 4-8.i, orange line) and to 0.3% (Figure 4-8.i, grey line), respectively. For the remaining three intervention scenarios, the prevalence of HIV infection was less than 1% for both SSWs and VSWs at year 50. Despite the consistent reduction in HIV prevalence among both FSW sub-populations, the prevalence was approximately four times higher among SSWs than among VSWs in all intervention scenarios.

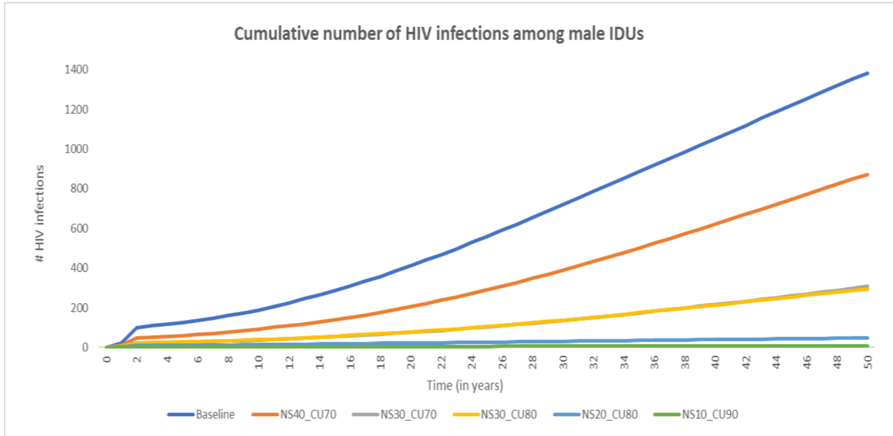
The decrease in HIV prevalence also resulted in a reduction in the cumulative number of HIV infections among each FSW sub-population and among the overall FSW population. Compared with the baseline scenario (Figure 4-8.e, dark blue line), there was a 48% reduction (n = 57) in cumulative HIV cases among FSWs in NS_40% & CU_70% (Figure 4-8.e, orange line) and a further 65% reduction (n = 40) from NS_40% & CU_70% (Figure 4-8.e, orange line) to NS_30% & CU_70% (Figure 4-8.e, grey line) over 50 years. If needle sharing levels remained at 30%, efforts to increase consistent condom use from 70% (Figure 4-8.e, grey line) to 80% (Figure 4-8.e, yellow line) resulted in an additional 18% reduction (n = 4) in the number of HIV infections among FSWs over 50 years.

For the overall population, the prevalence of HIV infection decreased from 0.50% at the baseline (Figure 4-8.k, dark blue line) to 0.35% in NS_40% & CU_70% (Figure 4-8.k, orange line), to 0.13% in NS_30% & CU_70% (Figure 4-8.k, grey line), to 0.11% in NS_30% & CU_80% (Figure 4-8.k, yellow line), and to less than 0.01% in the remaining two scenarios (Figure 4-8.k, light blue and green lines). The largest reductions in the cumulative HIV cases over 50 years among the overall population were observed between the baseline scenario (Figure 4-8.l, dark blue line) and NS_40% & CU_70% (37% reduction, n = 637) (Figure 4-8.l, orange line), and between NS_40% & CU_70% (Figure 4-8.l, orange line) and NS_30% & CU_70% (65% reduction, n = 687) (Figure 4-8.l, grey line). Compared with the intervention scenario of solely lowering the needle sharing level to 40% (Figure 4-6.l, orange line), the combined intervention scenario of lowering needle sharing levels to 40% while simultaneously increasing consistent condom use levels to 70% (Figure 4-8.l, orange line) contributed to an additional 3% reduction (n = 35) in cumulative HIV cases among the overall population over 50 years.

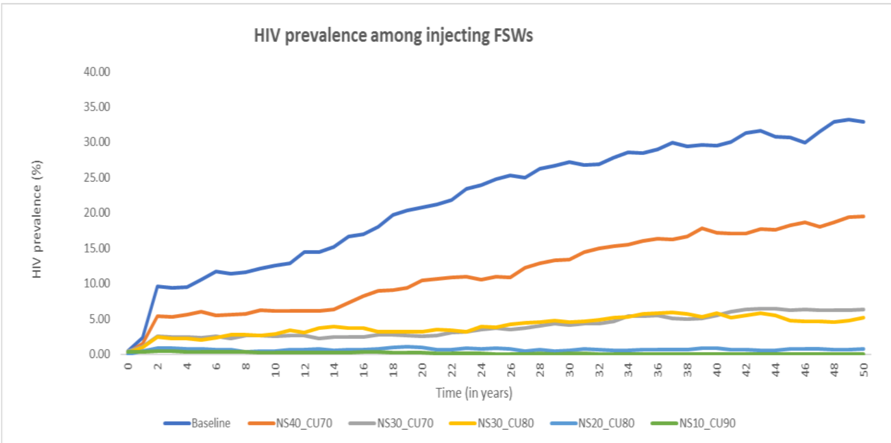
(a)


HIV prevalence among male IDUs
HIV prevalence (%)
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

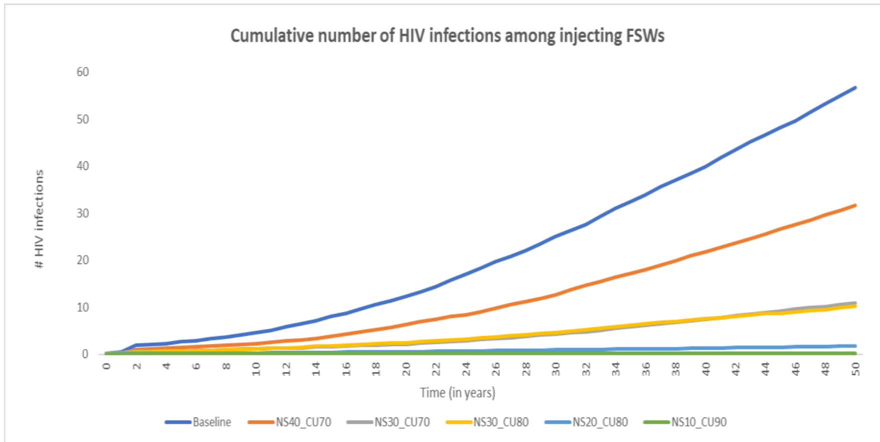
(b)


Cumulative number of HIV infections among male IDUs
HIV infections
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

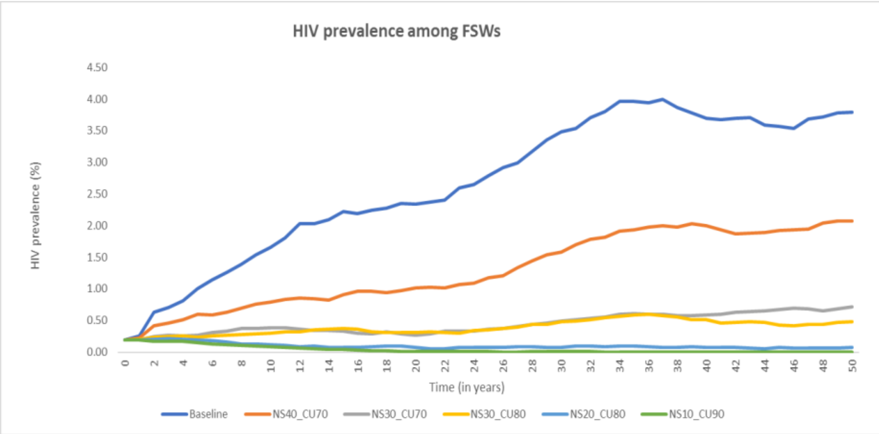
(c)


HIV prevalence among injecting FSWs
HIV prevalence (%)
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

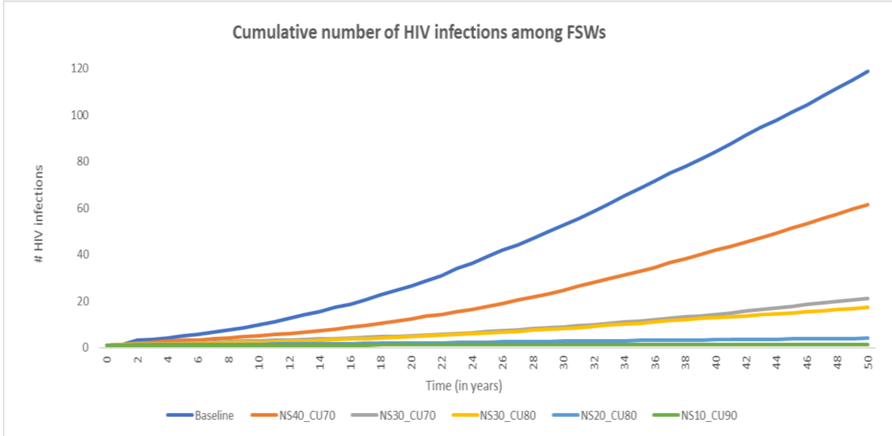
(d)


Cumulative number of HIV infections among injecting FSWs
HIV infections
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

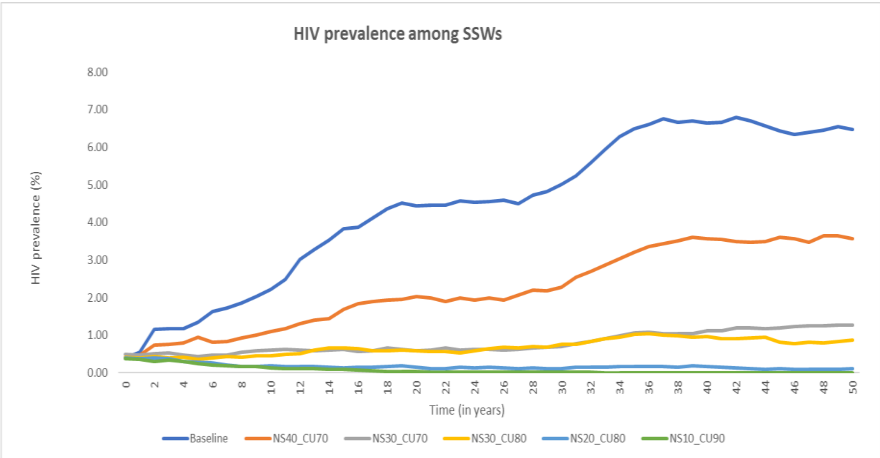
(e)


HIV prevalence among FSWs
HIV prevalence (%)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

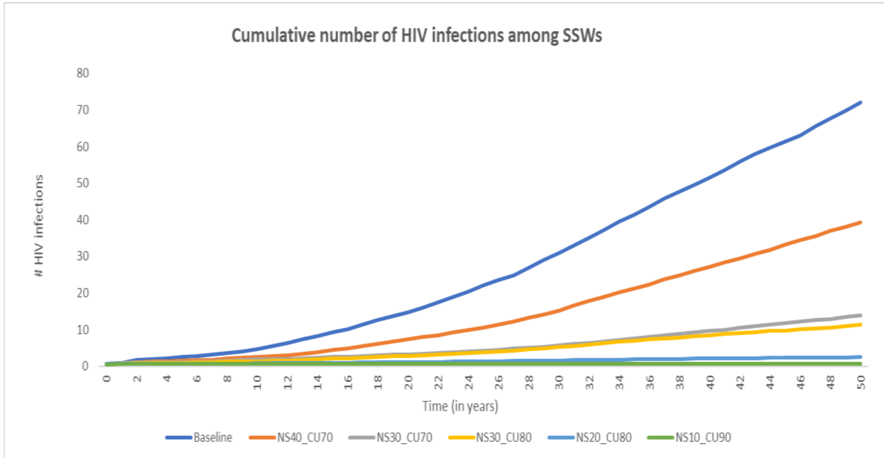
(f)


Cumulative number of HIV infections among FSWs
HIV infections
120
100
80
60
40
20
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

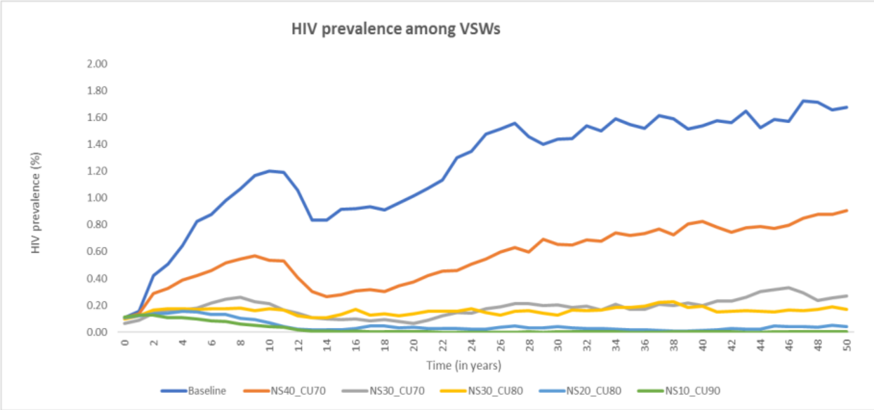
(g)


HIV prevalence among SSWs
HIV prevalence (%)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

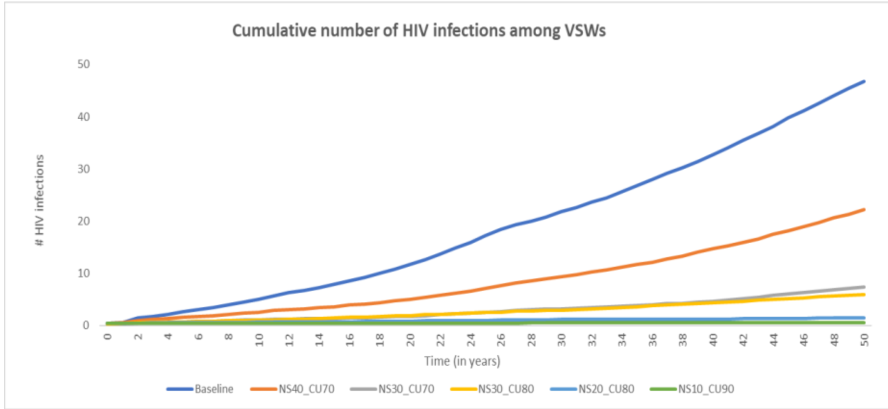
(h)


Cumulative number of HIV infections among SSWs
HIV infections
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Time (in years)
Baseline
NS40_CU70
NS30_CU70
NS30_CU80
NS20_CU80
NS10_CU90

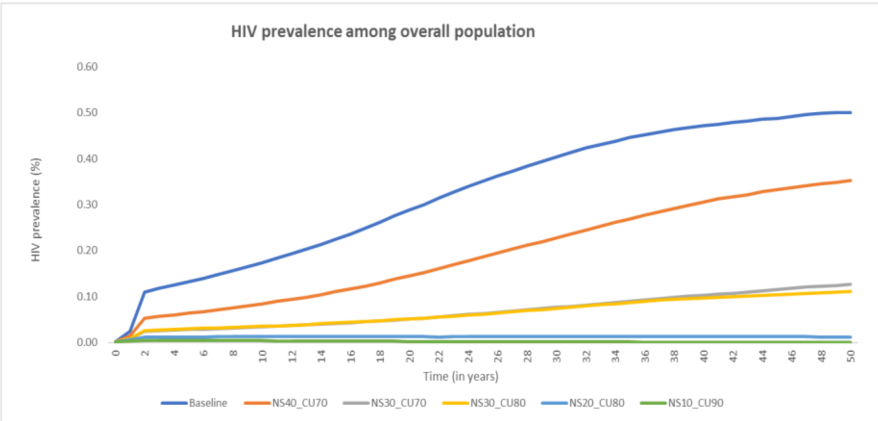
(i)



(j)



(k)



(l)

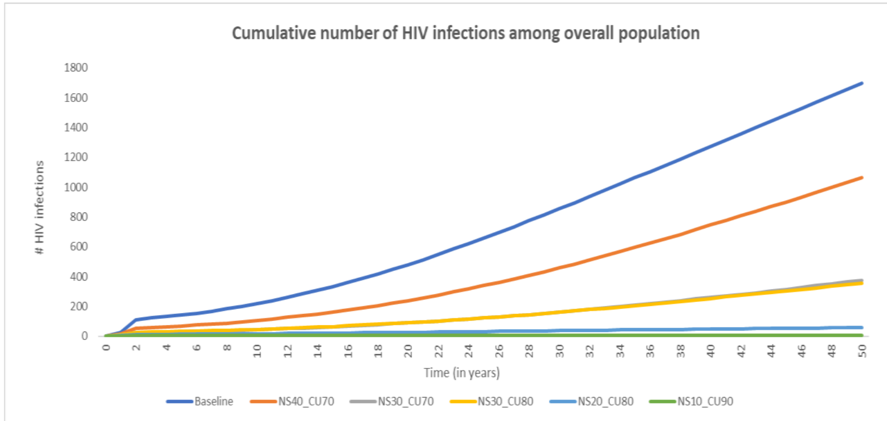


Figure 4-8. Comparisons between the baseline scenario and different combined intervention scenarios of lowering needle sharing levels and increasing consistent condom use levels.

5. CHAPTER 5: DISCUSSION

This chapter discusses the results of this thesis and is divided into two sections. The first section focuses on the results of the 2009 IBBS study and their implications. The second section discusses the ABM simulation results and their implications.

5.1. IMPLICATIONS FROM THE IBBS STUDY

Geographical differences in the prevalence of HIV infection were observed in both male IDUs and FSWs. This is in agreement with observations from the Vietnam HSS system and indicates that HIV epidemics started at different times and developed at different rates in male IDUs and FSWs. This thesis also indicates significant heterogeneity in HIV infection levels across the two sub-populations of FSWs in Vietnam. The comparatively higher levels of HIV prevalence observed among SSWs are in line with previous studies (5, 23, 24, 26, 29-33, 64-69) and reinforce the idea that prevention interventions should take into consideration the structure of commercial sex work with regard to different sub-populations of FSWs.

Observations from this thesis demonstrate the close links between the drug injection-related and heterosexual epidemics. First, male IDUs were linked sexually with both FSWs and their regular sexual partners. For example, 25% of male IDUs in all provinces reported sexual relationships with FSWs and 55% reported such relationships with regular sexual partners in the 12 months prior to the survey (data not shown). Second, apart from engaging in commercial sex work, close to 50% of FSWs also reported sexual relationships with regular sexual partners in the month prior to the survey (data not shown). Approximately 10% of the FSWs also reported sexual relationships with male IDUs within the same time frame. Finally, condom use was not widely practiced in either population, especially among male IDUs. The proportion of consistent condom use among male IDUs was 61% with FSWs and 32% with regular sexual partners. FSWs report particularly low levels of condom use with regular sexual partners (38%).

5.1.1. Injecting drug users

Results from this thesis suggest that drug injection-related risks play an important role in fueling the HIV epidemic in Vietnam. For male IDUs, the most noticeable drug injection-related risks that were positively associated with HIV infection included the sharing of needles and syringes and the duration of injecting drug use. These associations are consistent with various studies among IDUs from multiple settings (4, 9, 73, 76, 77, 82, 84, 86, 96, 101, 102, 106, 107, 124, 128-142).

Despite the heightened risk of HIV infection attributed to the sharing of contaminated needles and syringes, almost half of the study participants reported having shared needles in their lifetime. This support existing evidence that needle sharing is widely practiced among Vietnamese IDUs (4, 11). Literature has documented various examples of successful harm reduction interventions targeting this particular injecting risk behavior, including NEPs (46) and community-based outreach programs (297-299). Community-based outreach programs have been shown to be the most relevant strategy where needle sharing is highly prevalent, while NEPs are not considered to be a politically viable public health option (298). However, with the Vietnamese government's increasing recognition of the critical role of NEPs in minimizing HIV risks associated with needle sharing, NEPs and other HIV prevention, care, and treatment services are being recommended in conjunction with community-based outreach programs to reach IDU populations and provide them with effective methods to change their habits and reduce their exposure to HIV infection (297, 298).

Needle sharing has been widespread in shooting galleries in Vietnam (4). Research has shown that injecting alone in comparison to injecting with someone else reduces the opportunity to share needles (338, 339). Thus, a higher incidence of needle sharing in shooting galleries is possibly due to the fact that an IDU has a greater chance of finding other IDUs with whom to share needles and syringes in a shooting gallery. Another explanation could be the unavailability of sterile needles and syringes at shooting galleries. Different types of shooting galleries exist in Vietnam that serve IDUs from different socioeconomic statuses (78). Shooting galleries for poor IDUs, who constitute a significant part of the IDU population, are often located in public or semi-public places (78). Many IDUs are reluctant to carry needles and syringes in such open settings because they might get them arrested on charges of engaging in illegal activities. This works to promote needle and syringe sharing (78). The need for hurried injections in open settings also fosters the use of previously used needles and syringes, as documented in other studies (340, 341). Findings from this thesis underscore the need to expand access to sterile needles and syringes in an effort to avert widespread HIV transmission. Research has indicated that increased and easy access to sterile injection equipment helps motivate IDUs, and especially young and new injectors, to adopt safer behaviors (342, 343). It may be difficult to implement HIV prevention interventions in shooting galleries in Vietnam given that IDUs are often mobile to avoid police campaigns. However, in some IBBS study provinces, the research team did not experience problems recruiting IDUs at shooting galleries. This suggests that it may still be possible to introduce HIV harm reduction interventions which include components such as NEPs and the distribution of bleach for disinfecting needles and syringes in these settings.

The duration of injecting drug use had a significantly association with HIV seroconversion in this thesis. The association between the long duration of injecting drug use and increased odds of HIV infection possibly reflects a cumulative injection risk for HIV infection (75, 103-107). The ideal HIV/AIDS prevention strategy is thus to address risk factors for initiating drug use and/or injecting drug use (179). However, once people inject drugs, harm reduction interventions addressing unsafe drug injection behaviors such as sharing needles, syringes, and other injecting equipment should be a major focus. Also, such interventions need to be put in place as soon as people start injecting to reduce the cumulative injection risk due to long term involvement in drug injection. Of equal importance are strategies to convert drug consumption via injection to non-injection by providing access to drug substitution programs such as MMT program for both IDUs and their sexual partners. This is considered a critical point for the success of HIV/AIDS prevention efforts (344), as evidenced in the literature in many different settings (46). In Vietnam, MMT program were first piloted in Hai Phong and Ho Chi Minh City in 2008 (300). Over the years, MMT services have rapidly expanded, from 41 sites (6,931 subjects) in 2011, to 60 sites (12,253 subjects) in 2012, and to 80 sites (15,542 subjects) across 30 provinces in Vietnam in 2013 (10). The program has received strong supports from the Government, and Ministries at all levels (300). The recently released Law on Handling Administrative Sanctions is also considered an important legal framework to promote drug treatment in the community (300). However, current drug-control policies and HIV/AIDS prevention and treatment strategies are not yet harmonized to maximize these programs' advantages (300). Addressing these challenges is of critical importance for the expansion and maintenance of the MMT program (300).

5.1.2. Female sex workers

Among FSWs, injecting drug use was found to be most strongly associated with HIV infection, regardless of sex work venue, as reported previously in multiple settings (5, 27, 29, 30, 53, 67, 68, 87, 141, 179, 192, 194, 200, 203, 204, 233, 250, 256-267). The combination of sex work and drug use puts injecting FSWs at extremely high risk of HIV infection and makes them an important source of transmission to other populations (30-32, 51). The dual risks from sex work and drug injection also place injecting FSWs at greater stigmatization from society and even from their peers in the sex work industry, leading to their perceived low social status, feelings of inferiority, and less concern about their potential infection risks (32). Although FSWs who injected drugs accounted for roughly 5% of the overall FSW population in this thesis, if left uncontrolled, the HIV epidemic will continue to expand within this population and from this population to others through its networks of sexual behavioral practices (32). This finding from the IBBS study is worrisome since, although injecting drug use remains the predominant route of HIV transmission in Vietnam, FSWs who inject drugs have received little specific programmatic attention and FSWs and IDUs are separately targeted by most HIV/AIDS prevention interventions (345). Intervention strategies addressing drug injection-related risks are, therefore, not only essential for male IDUs but also relevant and critical for FSWs who inject drugs.

Socio-demographic characteristics associated with HIV infection included older age (for both SSWs and VSWs) and having been married (for SSWs only). The association between age and HIV risk remains inconsistent in the literature (26, 32, 66, 68, 85, 175-187). For this thesis, older age may reflect a cumulative HIV risk as a result of the longer duration of involvement in sex work, more risk behaviors such as large number of sexual partners, a high concurrency among these partners, unprotected sex, alcohol and injecting drug use, and having sexual partners who are IDUs (32, 68).

Regarding the relationship between marital status and HIV risk among FSWs, the increased odds of HIV infection among FSWs who have been married, as is evident in this thesis, possibly results from the economic vulnerability of those women, who earned significantly less income than single FSWs (data not shown). This explanation fits previously reported associations between low income and an elevated risk of HIV (186, 191, 195). According to Kakchapati et al., family responsibility, in combination with economic deprivation and a lack of alternative options push women into sex work and engaging in high risk behaviors (32). Another possible explanation for the observed association between marital status and HIV is that marital status may correlate with age in the sense that married FSWs tend to be older than single ones, which in turn increases their chance of getting infected due to cumulative HIV risk.

This thesis found significant heterogeneity in behavioral risk profiles between the two sub-populations of FSWs in Vietnam. While injecting drug use is the predominant behavior associated with HIV among SSWs, high risk sexual practices (i.e., inconsistent condom use with clients and having sexual partners who inject drugs) represented additional risks for HIV infection among VSWs, apart from the risk from injecting drug use. The association between HIV infection and these sexual behaviors was also observed in previous studies of FSWs, although not specifically among VSWs (53, 141, 188, 195).

Findings from this thesis suggest that prevention interventions should be tailored specifically to different FSW sub-populations and should target both injecting and sexual risks among FSWs. This is especially the case for VSWs given that the combination of unprotected sexual behaviors and injecting drug use puts them at increased risk of HIV acquisition. Apart from interventions addressing injecting risks, promoting safe sex practices is also of critical importance in reducing the risk of HIV acquisition and transmission among the FSW population. The success of the 100% condom campaigns and other community empowerment interventions in Thailand, Cambodia, and a number of other countries in Asia have shown the ability of such prevention efforts to reduce HIV and other STIs among FSWs in Vietnam (303, 307, 310, 312).

The finding that SSWs were more likely than VSWs to report risk behaviors associated with HIV infection are consistent with previous research (16, 24, 26, 30-32, 65, 188, 287, 292, 295). Results from the IBBS study are alarming given that SSWs engaged in higher risk behaviors and were at a significantly higher risk of HIV, but were more likely to perceive themselves as having little or no risk of contracting HIV. These women will facilitate the spread of HIV in the community if no effective intervention strategies are put in place. Interventions that help improve the self-efficacy of SSWs and of other HIV high-risk populations in recognizing modes of HIV transmission and risky behaviors are thus strongly recommended to reduce HIV acquisition and transmission (5).

In the context of constrained resources for HIV programs in Vietnam, prevention interventions targeting SSWs should be prioritized. However, prevention efforts targeting VSWs should not be ignored in the long-run. Research in Vietnam revealed a tendency for FSWs to start sex work at entertainment establishments and gradually move into the streets as they become older or begin injecting drugs (5, 12, 226). Interventions targeting VSWs are, therefore, not only beneficial for VSWs but also help prevent further HIV risk among SSWs in the long term.

5.1.3. Common correlates of HIV infection among male injecting drug users and female sex workers

For both male IDUs and FSWs, having sexual partners who injected drugs was associated with HIV seroconversion. This result is consistent with other studies (53, 66, 79, 179, 194, 233-235) and suggests an intersection between sex work and drug use. Such findings highlight the importance of HIV prevention efforts in targeting both people who inject drugs no matter if they are male IDUs or injecting FSWs and their injecting sexual partners.

In addition to drug injection-related and sexual behaviors, self-perception of HIV risk was also found to be associated with HIV infection in both the male IDUs and FSWs studied. Findings from this thesis suggest that male IDUs and FSWs who perceived themselves at high risk of HIV infection were significantly more likely to be infected compared to those who only perceived that they were at low or no risk of HIV infection. There are two possible explanations for this. On the one hand, individuals with a fatalistic perception of their risk, who believe that their past behavior has already made them highly vulnerable to HIV infection, are prone to continuing their risk behavior and are thus more likely to be at risk (346). On the other hand, individuals' perception of their own risk is more of a reaction to their high-risk behavior (346). In this case, an IDU or a FSW may simply be indicating their realistic awareness of their heightened risk for HIV acquisition (346). In both cases, since feelings of hopelessness or fatalism about getting HIV may inhibit risk reduction, apart from efforts to provide HIV prevention commodities such as condoms and sterile needles and syringes, emphasis should also be placed on educating those at risk, no matter if they are male IDUs or FSWs, about the potential benefits of behavioral change (346).

5.1.4. Findings that need further investigation

The observed association between HIV seroconversion and factors including the number of needle sharing partners, the number of sexual partners, condom use practice, mobility among male IDUs, and HIV knowledge among FSWs in this thesis was inconsistent with other studies (30, 31, 86, 114-116, 166, 215, 268, 283). The reasons for these inconsistencies are puzzling. The cross-sectional nature of the IBBS study makes it impossible to draw definitive conclusions about the presence or direction of causal effects. However, further data analysis (data not presented in this thesis) suggests that IDUs who shared needles and syringes with multiple partners were also more likely to clean contaminated needles and syringes before injecting drugs. Similarly, those who have multiple sexual partners were found to be more likely to use a condom consistently with their regular sexual partners.

Similar to Mutagoma et al.’s study (182), this thesis found an independent association between consistent condom use and an increased risk of HIV seroconversion among male IDUs. We agree with Mutagoma and colleagues’ argument that the observed association may reflect a reverse causality, where HIV-positive IDUs previously aware of their HIV-positive status, and possibly already involved in HIV prevention efforts, care, and treatment services, had received greater education and counseling regarding preventing the spread of HIV to their sex partners and had easier access to condoms and other HIV prevention commodities (182).

In this thesis, injecting drugs in provinces other than those surveyed in the previous 12 months had a protective effect on HIV infection among male IDUs. One of the possible explanations for the discrepancy between this finding and those from previous studies (86, 115) could be that, due to their frequent travels, mobile IDUs are less likely to have well-established networks of IDUs, which could facilitate needle sharing, than IDUs who reside in a single province for a long period of time.

Having accurate knowledge of HIV risks and prevention methods was associated with increased odds of HIV infection in bivariate analysis among FSWs. Although this association did not persist in multivariate analyses, this result is generally inconsistent with previous studies (182, 215, 268, 283, 347, 348). A possible explanation for this association is that HIV-positive participants were previously tested for HIV via existing HIV testing services in Vietnam and got pre- and post-test counseling on HIV risk reduction and behavioral change.

Despite a large body of evidence suggesting the strong association between STIs and HIV risk (26, 32, 68, 85, 180, 186, 190, 194, 196, 203, 205, 227, 230, 231, 233, 236, 242, 243, 268-281), no independent associations were found between syphilis positivity and HIV or between self-reported STI symptoms and HIV. This was true among both male IDUs and FSWs. The lack of observed association may be due in part to the low prevalence of syphilis in the study populations. For both SSWs and VSWs, syphilis prevalence was much lower than HIV prevalence, given the same levels of risk behaviors among these women. The relatively low prevalence of syphilis among FSWs, especially among VSWs, may be contributed to the compulsory STI screening most entertainment establishment owners require sex workers to have every six-month. For SSWs, community-based programs that provide STI screening and referral to health care facilities for treatment may lead to the low prevalence of syphilis among these women as compared with HIV.

Similarly, the risk of HIV was not associated with exposure to HIV prevention interventions in this thesis. Most notably, there was no association between HIV risk and access to HIV testing services in either IDUs and FSWs. Research evidence has shown that HIV testing can reduce sexual risk behaviors among HIV positives and, eventually, HIV incidence (306). Despite their substantial benefits, HIV testing services had the least coverage among all available HIV prevention interventions that target IDUs and FSWs (306). The IBBS study showed that, despite the high prevalence of HIV among both IDUs and FSWs, the rate of HIV testing uptake was extremely low, especially among IDUs. Less than one-fifth of the IDU population under study reported having had an HIV test in the previous 12 months and knowing their results. Of equal concern, both IDUs and FSWs in the IBBS study possessed very poor HIV-related knowledge. Twenty-five percent of IDUs and only 10% of FSWs could accurately identify how to prevent HIV infection and could reject misconception about HIV transmission. Many, especially SSWs, perceived themselves as having little or even no risk of HIV, despite their high levels of engagement in risk behaviors. This means that there are still many HIV-positive IDUs and FSWs in the community who lack knowledge about HIV and do not know their infection status, but perceive themselves to be at low-risk of HIV infection and thus continue to engage in high-risk behaviors and spread the virus to others (32).

Improving HIV testing uptake has an indispensable role in improving HIV programs' efficiency and outcomes. As a result, scaling-up HIV testing services has been a priority in Vietnam's National HIV/AIDS Strategic Plan (306). The last decade has witnessed significant progress in scaling-up HIV testing services with the establishment of 1,345 HIV testing clinics around Vietnam. These clinics provided services for 260,000 clients in 2015 (306). However, despite the rapid expansion of HTC services, communication, education, and community-based outreach programs need to expand to increase intervention coverage among populations with low accessibility (e.g., those with drug use, inconsistent condom use, sex partners who inject drugs, and who work in entertainment establishments) (5). Tran et al. (5) and Ganju et al. (349) found that FSWs who perceived themselves at risk of HIV were more likely to take the HTC, suggesting the importance of strategies to build awareness of personal risk. Findings from Tran et al.'s study also inform the selection of media for HIV information, communication, and education campaigns targeting HIV high-risk populations. Both radio and TV programs were good sources of HIV information and were associated with HTC uptake, while newspapers showed limited impact (5).

Even when IDUs and FSWs are aware of their HIV risk, there are multiple barriers that influence their decision to undergo HIV testing. Individual-level barriers include anxiety about a positive test result, lack of awareness about ART treatment, low HIV risk perception, and a fear of being seen when accessing HIV services (305). Structural barriers may relate to HIV-related stigma, the criminalization of drug use, the poor quality of care and discrimination by health care providers, and accessibility issues such as inconvenient testing hours, cost of travel, lengthy registration process, and long waiting time to receive test results (305). Such barriers need to be addressed in order to improve the uptake of HIV testing among those high-risk populations.

5.1.5. Strengths and limitations

This thesis uses data drawn from the 2009 IBBS study to describe the extent of HIV infection in Vietnam and to identify factors associated with HIV infection among male IDUs and FSWs. Using data from the IBBS study, which had a large sample size and wide geographic coverage, was expected to generate more reliable estimates than previous studies, which had large variance with respect to the measures of association. Findings from this thesis also provide important insights into the profile and burden of HIV, as well as the correlates of HIV infection among key populations at high risk of HIV infection in Vietnam. This information is important to informing future HIV prevention interventions and policies in Vietnam and in countries with similar environments.

The secondary analysis of the IBBS study presented in this thesis has several limitations. First, the utilization of cross-sectional IBBS data did not allow temporal associations between HIV infection and key behaviors to be established, preventing the identification of risk factors. Second, self-reported risk behaviors such as injecting drug use could be underreported due to social stigma and discrimination attached to this behavior, while condom use practice could be over-reported due to a social desirability bias. Third, for FSW datasets, weighted analysis that takes into account the unequal sizes of the two FSW sub-populations, and the unequal number of FSWs selected in some clusters, would have facilitated representative estimates at the population level (350). However, such an analysis could not be performed since size estimates for each sub-population were not complete at the time of the parent IBBS study. Fourth, for the IDU dataset, where the RDS method was used in four study provinces, compensating for the fact that the sample was collected in a non-random way would have facilitated representative estimates at the population level. Therefore, it would have been useful to conduct a network and weighted analyses that take into account the size of the IDU network. Instead of this, however, several of the assumptions required for RDS to be valid were not made, resulting in the possibility that the last sample might not represent the whole population due, for example, to the overrepresentation of easy-to-reach individuals in the sampled population. For this reason, weighted analysis was not performed in this thesis.

5.2. IMPLICATIONS FROM THE AGENT-BASED MODEL SIMULATION RESULTS

5.2.1. Implications from the results of baseline scenario

Using key risk behavioral data from the 2009 IBBS study as inputs to develop a hypothetical baseline scenario in ABM yielded scenario results in agreement with the observations from the 2009 IBBS study. Specifically, baseline scenario results also indicated a striking difference in HIV prevalence between IDUs and FSWs, as well as a significant heterogeneity in HIV infection levels between SSWs and VSWs. The difference in the increase pattern of HIV prevalence observed between IDUs and FSWs also confirmed previous epidemiological research, which suggested that sharing contaminated needles and syringes offered a more efficient transmission pathway for HIV compared with unsafe sexual practices (330). The high efficiency of HIV transmission via needle sharing facilitated the spread of HIV among IDUs and provides an explanation as to why HIV prevalence among this population not only accelerated more quickly but also remained at a higher level than that observed among FSWs.

According to the IBBS study, the pooled HIV prevalence was 30.6% among male IDUs and 8.6% among the overall FSWs (10.6% among SSWs and 6.7% among VSWs) in 2009, approximately two decades after the HIV epidemic began. The comparable HIV prevalence at year 20 in the baseline scenario was 24.6% among male IDUs and 2.3% among FSWs (4.5% among SSWs and 1.0% among VSWs). There are several reasons why these discrepancies between the IBBS data and ABM hypothetical data exist. For example, results from the IBBS study were drawn from 10 out of 63 provinces of the country and the focus on these 10 sentinel provinces with a relatively high prevalence of HIV infection might not represent the HIV situation across the whole country. The ABM in this thesis, however, simulated a hypothetical population without taking into account geographical differences across provinces. Another reason that could help explain the differences observed was that only key behavioral data from the IBBS study was selected to construct the baseline scenario. A sophisticated model that matches the information-rich IBBS dataset could generate different results than those obtained from this model. Despite the discrepancies in the absolute number obtained, the significant differences in the HIV situation among different HIV high-risk populations observed from the IBBS study was confirmed by the ABM results presented in this thesis.

5.2.2. Implications from the results of different intervention scenarios involving behavioral change

Varying the levels of risk behaviors in different "what-if" intervention scenarios confirmed needle sharing and inconsistent condom use as the major risk factors for HIV infection among both IDUs and FSWs, though needle sharing is recognized as a predominant risk behavior that fuels the HIV epidemic in Vietnam. Decreasing needle sharing levels among IDUs and/or increasing the level of consistent condom use among male IDUs and FSWs all contribute to the reduction of HIV infection among high-risk HIV populations, as well as among the overall population. However, the magnitude of the reduction varies by the type of intervention implemented. Results from the three different sets of intervention scenarios suggest that, while prevention interventions to increase consistent condom use among male IDUs and FSWs have an impact on the reduction of HIV infections among the FSW population (including both SSWs and VSWs), there is only a minimal impact on the IDU population itself and among the overall population as a whole. In contrast, prevention interventions to lower the level of needle sharing among people who injected drugs resulted in a sizable reduction in HIV infection not only among IDUs but also among FSWs and among the overall population. There are two explanations for this. First, the FSW population simulated in this thesis was not large enough to result in a large number of HIV infection cases within this population, regardless of the type of prevention interventions implemented. Second, an overlap between the IDU and FSW population was observed when a proportion of FSWs injected drugs and a proportion of male clients of FSWs were IDUs. Lowering needle sharing levels, therefore, reduced HIV spread not only among male IDUs themselves but also among female IDUs, injecting FSWs, and male clients of FSWs, which in turn had an impact on FSWs and on the overall population. In places where drug injection fuels the HIV epidemic, prevention interventions targeting major drug injection-related behaviors, such as the sharing of contaminated needles and syringes, appear to result in greater HIV reduction than those targeting sexual practices.

Results from these three different sets of intervention scenarios suggest that intervention scenarios that focus solely on lowering needle sharing levels among IDUs resulted in the largest reduction in HIV infection in all investigated populations, even compared with the combined intervention scenarios of both lowering needle sharing levels and increasing consistent condom use levels. As explained above, these unexpected results could be due to the stochastics of the ABM (i.e., the results presented in this thesis were the average of 100 replication runs. The results from another 100 replication runs could be different) and the relatively small size of the population simulated. However, these results are particularly useful for policy makers to set priorities for HIV prevention interventions. The combination of decreasing needle sharing and increasing consistent condom use should be the ideal intervention strategy where resources are available. However, in resource constrained settings, where resources cannot be equally contributed to different HIV high-risk populations, intervention efforts to decrease needle sharing should be prioritized. This will result in the largest reductions in HIV infections, not just among IDUs, but also among FSWs and the overall population.

Results from five intervention scenarios involving lowering needle sharing levels among IDUs suggest the greatest reductions in HIV infection in all populations occurred when needle sharing was lowered from the baseline level to 40% and then to 30%. Once needle sharing reached these levels, further decreases in needle sharing (e.g., to 20% or 10%), which probably requires significant effort and resources, result in less obvious reductions in infection. It is possible that at this point, the HIV prevalence among IDUs and FSWs are already kept at low enough levels (i.e., less than 1.0%) that it is difficult to see any further significant reduction. Equally, results from these scenarios also indicated that achieving any reduction (e.g., even several percent) from the baseline's high level of needle sharing could nevertheless yield a disproportionate reduction in the prevalence of HIV infection. These experimentation results could therefore serve as a guide for policy makers on setting proper targets for prevention interventions, given the availability of resources as well as the feasibility of achieving the target.

5.2.3. Relevance of the agent-based approach in HIV modeling

Since the first HIV case was detected in Vietnam in the early 1990s, many efforts have been put in place to estimate and project the scope of the epidemic in order to curb it. The EPP has been the most popular tool to model the HIV epidemic across different provinces in Vietnam given the model's ease of use. In 2009, the AEM was first applied to examine the HIV situation in key high-risk HIV populations in HCMC and Hai Phong (351, 352) and, three years later, in Can Tho and An Giang. In these four provinces, AEM showed good agreement with observed epidemiological trends among the surveillance populations. However, given that both EPP and AEM are extrapolated models incapable of addressing the complex dynamics from which the HIV epidemic emerges, it may no longer be sufficient to model such a complicatedly evolving epidemic as the one currently occurring in Vietnam.

The ABM presented in this thesis and its associated results provide a showcase for the relevance of using ABM in modeling the HIV epidemic in Vietnam. On a technical, the model successfully represents the complex dynamics of the epidemic in Vietnam, where the two high-risk HIV populations (i.e., male IDUs and FSWs) and their risk behaviors overlap and interlink. An agent-based approach allows the addition of as many details in the model as the author wishes during the model building process in order to gain an understanding of the characteristics and behaviors of the model, as well as to examine the logic of the model. The ability to include a great level of details in the model is an advantage of ABM over the EPP and AEM models, which are easier to implement due to the simple input data required and quick processor time but that sacrifice quality and reliability in the process.

In terms of the outputs generated from this model, the ABM results help confirm epidemiological data from the IBBS study on the major correlates of HIV infection among male IDUs and FSWs in Vietnam. They further strengthen the IBBS results by pointing out the predominant risk factor driving the epidemic, which is the sharing of contaminated needles and syringes when injecting drugs. The discrepancies between epidemiological data and ABM outputs represents not a failure of modeling but a success in learning. We learn things that we probably wouldn't have learned without a model. They help us think through our assumptions more systematically, articulate those assumptions in a way that can effectively be communicated with others, and provide insights into whether the logical consequences of those assumptions match the reality. The uncertainties observed in the ABM outputs help us find latent inconsistencies between the hypotheses and what the empirical evidence suggests, and thus rule out hypotheses more quickly. Such discrepancies and uncertainties therefore help us regenerate future hypotheses, improve study designs and sampling strategies, set priorities for data collection, and develop better proxy measures for the level of risk behaviors.

The experimentation with different "what-if" intervention scenarios makes ABM a useful modeling tool for policy makers to evaluate the effectiveness of different prevention intervention strategies in reducing HIV infection. The ability to capture behaviors over time of the model allows us to look at the time to effect of observations (i.e., how quickly we may see effects realized when we undertake different types of prevention interventions). The model therefore also serves as an effective communication tool to help stakeholders at different levels identify area of focus for prevention efforts and set proper targets for intervention strategies in order to achieve the greatest reductions in HIV infection.

Results from this model point to the usefulness of using the same agent-based approach in modeling the HIV epidemic in regions and/or populations with similar settings and characteristics. More specifically, agent-based modeling can be applied to simulate the HIV spread in Saskatchewan, given the similarities in the epidemics in the two places.

Preliminary numbers from the Saskatchewan Ministry of Health revealed 170 new HIV cases in Saskatchewan in 2016, an increase of 10 cases since 2015 (353, 354). This makes Saskatchewan the province with the highest rate of HIV infection in Canada, with a rate of more than double the national average (353, 354). It is also estimated that 79% of new HIV infection cases occur in the First Nations and Métis communities (354, 355). Injection drug use, as opposed to heterosexual or homosexual contact, has been driving the epidemic in Saskatchewan, making the HIV situation in Saskatchewan unique across North America (355) but similar to Vietnam. The application of ABM to simulate HIV spread in Saskatchewan could therefore help researchers understanding the characteristics of the local epidemic and serve as a useful guide for prevention intervention efforts in the province.

Early diagnosis and treatment pose a major challenge in combatting HIV in Vietnam. At the time the IBBS study was conducted in 2009, the percentage of people living with HIV/AIDS who received ARV drugs in Vietnam was only 17% (356). Given the low coverage of ART in the country, the impact of ART treatment on the progression of HIV infection among IDUs and FSWs has not been investigated in the model presented in this thesis. However, unlike the situation in Vietnam, the availability and accessibility of ART in Canada in particular and in other developed countries in general have improved life expectancy for the majority of people living with HIV in these countries, and thus play a crucial role in the course of the epidemic (354, 357). For this reason, if ABM is used to model the HIV epidemic in Saskatchewan, the current ABM would have to be modified to take this into account and to explore the impact of screening, diagnosis, and treatment at different stages of HIV infection.

5.2.4. Strengths and limitations

The application of the agent-based approach in this thesis provides significant insights into the complex dynamics of the HIV epidemic in Vietnam. This thesis has shown that ABM serves as an important tool that supplements the insufficiency of epidemiological research in addressing the underlying mechanisms of the HIV epidemic. The ABM results not only help strengthen the IBBS epidemiological data, but also provide a guide for policy makers in the design and implementation of appropriate prevention interventions targeting different HIV high-risk populations.

The ABM presented in this thesis, however, has several limitations. First, the relatively small size of the population simulated (i.e., 100,000 agents) might lead to large variation in results. This is illustrated by the results obtained for injecting FSWs. Since the size of this population was relatively small compared with other populations, the change in even one case of HIV infection could make a significant difference in the HIV prevalence obtained. The issue of sample size was also one among various reasons that probably explained the insignificant differences obtained from various intervention scenarios involving increased condom use.

Second, there is a trade-off between the level of detail in the ABM and the processor time needed for the model to execute. For example, it took almost three days for the ABM presented in this thesis to complete one intervention scenario with 100,000 agents, 100 replication runs, and a 50 years simulation horizon. For this reason, the model constructed in this thesis was relatively simple and did not match the rich-information IBBS dataset with hundreds of indicators. Only selected socio-demographic factors of biological importance (i.e., sex and age), key sexual risk behaviors (i.e., condom use and number of sexual partners, number of FSWs visited), and drug injection-related behaviors (i.e., prevalence of drug injection, frequency of drug injection, prevalence of needle sharing among IDUs, and size of IDU network) were included in the model. There was no opportunity to look at other factors that have been recognized as important contributors to the acquisition and transmission of HIV infection, such as educational attainment, occupation, income, mobility, location, knowledge of HIV/AIDS, STIs, TB co-infections, and ART. The inclusion of these factors in the model would likely generate different results than those obtained from this model and, thus, would require further investigation. However, it is noteworthy that, for those factors included in this thesis, the model does yield results that are relatively rich in the sense that they capture behaviors and change in clinical status, risk exposure, and networks over time. Such results could be compared with richer epidemiological data sources.

Third, for all behavior change intervention scenarios simulated in this model, the level of risk behaviors was kept steady for the whole period of 50 years. As a consequence, though comparisons could still be made between the baseline scenario and other intervention scenarios, the impact of prevention interventions if behavioral change occurs from a certain point during the model run time was not assessed. Questions related to decreases or increases in the number of HIV cases by year 50 of the model if behavioral change occurred from year 20 were left for future exploration.

6. CHAPTER 6: CONCLUSION

The HIV epidemic in Vietnam requires targeted prevention interventions among populations at high-risk of HIV infection. Results from the thesis suggest drug injection-related risks play an important role in fueling the epidemic and thus underscore the need to strengthen HIV harm reduction services in Vietnam. In the context of constrained resources for HIV programs in Vietnam, where resources cannot be equally contributed to different HIV high-risk populations, harm reduction strategies to decrease needle sharing practice should be prioritized. This is of critical importance not only for IDU population itself but also for FSWs, given the gains to FSWs extending from the reductions in needle sharing among IDUs.

While traditional epidemiological analyses from the IBBS study promotes thinking about multilevel determinants of HIV, the exclusive use of a regression-based approach may constrain the types of questions asked, the answers received, and the hypotheses and theoretical explanations that are developed (35). By allowing users to explore dynamic, nonlinear, heterogeneous, reciprocal, and spatiotemporal processes, agent-based modeling sheds lights on the ways individuals interact with each other and with their environments and open up our thinking to new conceptualizations. Results from this thesis support Auchincloss and Diez Roux's argument (35) and demonstrate that the use of ABM complements traditional regression-based analysis and offers important insights into the complex dynamics from which the HIV epidemic emerges. Results from this thesis also highlight the usefulness of combining modeling methodologies in understanding complex health issues like HIV/AIDS.

As with other types of models, challenges exist in ABMs. One of these is to make the model simple enough to yield useful insights but sufficiently informative so that they do not misrepresent the real-world situation (35). Another challenge in the application of ABMs is to make abstract models useful and friendly communication tools for policy and program analysis (35). Despite all these challenges, ABMs do promote more realistic thinking and understanding of the complex processes involved in the HIV epidemic (35). This may allow us to develop more sophisticated theoretical models that could subsequently be tested empirically using a variety of approaches, from experimental, observational, to complex systems modeling (35).

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APPENDICES

8.1. APPENDIX A. QUESTIONNAIRE FOR MALE INJECTING DRUG USERS

QUESTIONNAIRE FOR MALE INJECTING DRUG USERS

001 QUESTIONNAIRE IDENTIFICATION NUMBER |____________________________|
(Paste participant identification number here)

002 CITY

Hanoi	1
Hai Phong	2
Quang Ninh	3
Da Nang	4
HCMC	5
Can Tho	6
An Giang	7

03 WARD/COMMUNE___________________
NUMBER (The same code as in recruitment script) |_C_|_A_|_ _|_ _|__|__|__|__|
(the first 2 boxes: 2 initials of district/commune's name; the following 3 boxes: code of cluster; the last box: order number of participant invited in that cluster)

Introduction: "My name is… I'm working for the Provincial health Service. We're interviewing people in this area in order to find out about HIV/AIDS prevention information. Have you already been interviewed for this survey in the past few weeks?

If the respondent has been interviewed already for this study, do not interview this person again. Tell them you cannot interview them a second time, thank them, and end the interview. If they have not been interviewed before, continue:

Confidentiality and consent: "I'm going to ask you some very personal questions that some people find difficult to answer. Your answers are completely confidential. Your name will not be written on this questionnaire and will never be used in connection with any of the information you tell me. You do not have to answer any questions that you do not want to answer, and you may end this interview at any time you want to. However, your honest answers to these questions will help us better understand what people think, say and do about certain kinds of behaviors. We would greatly appreciate your help in responding to this survey. The survey will take about 40 minutes to ask and answer the questions. Would you like to know more?"

004 Perform Consent Process: Completed 1 Refused 2

005 NAME OF INTERVIEWER: ____________________Signature ___________________

006 DATE OF INTERVIEW: __/ ____ / 2005

007 CHECKED BY LOCAL SUPERVISOR: Name: ___________Signature ____________

DATE CHECKED: __/ ____ / 2005

008 CHECKED BY NATIONAL SUPERVISOR: Name: ___________Signature ____________

DATE CHECKED: __/ ____ / 2005

1

DATA MANAGEMENT

FOR OFFICE USE	EDITED BY:	CODED BY:	KEYED BY:	KEYED BY:	CHECKED BY:
NAME					
DATE					

SECTION 1: BACKGROUND CHARACTERISTICS

No.	Questions	Coding of answers	Skip to
Q101	In what month and year were you born?	Month |__|__| Year |__|__| Don't remember 99	
Q102	What is the highest level of education you have finished? ***Read out the possible answers and circle one.***	Illiterate 1 Primary (Grade 1-5) 2 Secondary school (Grade 6-9) 3 High school (Grade 10 – 12) 4 College, university (>12) 5	
Q103	How long have you lived here in (name of this city/province)?	Number of months |__|__| Number of years |__|__| Record 01 if less than 01 month	
Q104	***During the last 12 months,*** have you been away from (name of this city/province) for more than one month continuously?	Yes 1 No 2 Don't remember 9	
Q105	***Currently***, whom are you living with? ***Read out the possible answers and circle one only***	Alone 1 With wife/ Girlfriend 2 With relatives 3 With friends 4 No fixed address (unsettled) 5 Other (specify) 6 …………………………………………..	
Q106	***During the last 1 month,*** how often have you had beer/alcoholic drinks? ***Read out the possible answers and circle one only***	Every day 1 At least once a week 2 Less than once a week 3 Not at all 4	
Q107	***During the last 12 months***, what was your average household income? ***Explain: income from all resources***	______________VND Don't remember/No response 99	
Q108	***Currently***, what occupations do you have to support yourself? (Probe: anything else? Explain self-employed: driver, etc. Explain illegal activities: gambling, selling drugs, etc.) ***Read out list - Circle all appropriate answers***	**Y N** Farmer 1 2 Government employee 1 2 Entertainment employee 1 2 Sales/office clerk 1 2 Business person 1 2 Student 1 2 Self-employed 1 2 Illegal activities 1 2 Currently unemployed 1 2 Others (specify) 1 2 …………………………………..	

SECTION 2: DRUG USE

No.	Questions	Coding of answers	Skip to
Q201	In what month and year did you start using drugs?	Month |__|__| Don't remember 99 Year |__|__|__|__| Don't remember 9999	
Q202	In what month and year did you start injecting drugs?	Month |__|__| Don't remember 99 Year |__|__|__|__| Don't remember 9999	
Q203	***<u>During the last 1 month,</u>*** which of the following drugs did you inject? ***Read list*** ***Circle all appropriate answers*** a. Opium "black" b. Heroin "white" c. Anti-anxiety drugs (seduxen, pipolphen, Novocain…) e. Others (specify) ________________	Yes No 1 2 1 2 1 2 1 2	
Q203a	***<u>During the last 1 month,</u>*** which kind of drugs have you used? ***Read list and circle all appropriate answers***	Yes No Amphetamine 1 2 Ecstasy 1 2 Others (specify) 1 2 …………………………………...	
Q204	***<u>During the last 1 month</u>***, how often have you injected drugs? ***Probe for response. Circle only one response***	≥ 4 times/day 1 2-3 times a day 2 1 time/day 3 < 1 time/day 4 Don't know/no response 9	
Q205	***<u>During the last 1 month</u>***, where did you most often get your needle/syringe? ***Do not read responses. Mark one response only***	Pharmacy 1 Health establishment 2 Drug seller 3 Fellow drug user 4 Outreach health workers 5 Peer educators 6 Drop in center 7 Other (specify)…………...8	

SECTION 3: NEEDLE SHARING BEHAVIORS

No.	Questions	Coding of answers	Skip to
Q301	***<u>During the last 6 months,</u>*** when you injected, how often have you used needles/syringes **that had previously been used** by someone else, OR **given syringes and needles that you *had already used*** to someone else?	Always 1 Most of the time 2 Occasionally 3 Never 4 No response 9	→307
Q302	***<u>During the last 1 month,</u>*** how often have you given needles/syringes that ***you had already used*** to someone else?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q303	***<u>During the last 1 month,</u>*** how often have you used needles/syringes that had ***previously been used*** by someone else?	Always 1 Most of the time 2 Occasionally 3 Never 4	→306
Q304	***<u>During the last 1 month,</u>*** how often did you clean the needle/syringe that had ***previously been used*** by someone else before you used it again?	Always 1 Most of the time 2 Occasionally 3 Never 4 No response 9	→306
Q305	***<u>If cleaned,</u>*** how did you usually clean the needle/syringe? ***Read list. Circle all appropriate answers***	Yes No Cold water 1 2 Hot water 1 2 Bleach 1 2 Alcohol 1 2 Others (specify) 1 2 ……………………………	
Q306	***<u>During the last 6 months</u>***, whom did you shared needles/syringes with: *Sharing means* using the same needles/syringes that had ***previously been used*** by someone else *or* giving syringes and needles that you ***had already used*** to someone else ***Read list and circle all appropriate answers***	Yes No Wife/girlfriend 1 2 Female sex worker 1 2 Someone who paid you for sex 1 2 Other sexual partner 1 2 Other Injecting drug user 1 2 Shooting gallery person 1 2 Others (specify) 1 2 ……………………………………………	
Q307	***<u>During the last 6 months</u>***, When you injected, how	Always 1	

5

No.	Questions	Coding of answers	Skip to
	often have you shared drugs/drug containers with someone else? *Sharing means using drugs from the same container*	Most of the time 2 Occasionally 3 Never 4 No response 9	 →309
Q308	***<u>During the last 6 months</u>***, whom have you shared drugs/drug containers with: *Sharing means using drugs from the same container* ***Read list and circle all appropriate answers***	Yes No Wife/girlfriend 1 2 Female sex worker 1 2 Someone who paid you for sex 1 2 Other sexual partner 1 2 Other Injecting drug user 1 2 Shooting gallery person 1 2 Others (specify) 1 2 ……………………………………………	
Q309	***<u>During the last 12 months,</u>*** have you ever injected drugs in another city/province?	Yes 1 No 2 Don't remember 8 No response 9	 → **311**
Q310	***<u>If yes</u>***, in which other city/provinces did you inject, including city/provinces in other countries?	…………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………	
Q311	Do you know of any place where you can obtain/buy new needles/syringes?	Yes 1 No 2	 → **401**
Q312	***<u>If yes</u>***, where can you obtain/buy new needles/syringes? ***Read list and circle all appropriate answers***	Yes No Pharmacy 1 2 Health establishment 1 2 Drug seller 1 2 Fellow drug user 1 2 Peer educator 1 2 Outreach health workers 1 2 Drop-in center 1 2 Others (specify) 1 2 …………………………………	
Q313	Can you get a clean needle/syringe any time you need one? ***Read options, mark one response only***	Yes 1 No 2 No response 9	→ **401** → **401**

No.	Questions	Coding of answers			Skip to
Q313 a	What are your main reasons for not getting clean needles/syringes? ***Don't read. Just probe for more answers***		Yes	No	
		No money	1	2	
		Don't want to spend money on that	1	2	
		Needles/syringes too expensive	1	2	
		Vendor closed	1	2	
		Preferred size not available	1	2	
		Vendor ran out	1	2	
		Vendor too far away	1	2	
		Do not know where to get/buy	1	2	
		Other (specify)……………………	1	2	

SECTION 4: BEHAVIORS AT THE LAST INJECTION

No.	Questions	Coding of answers	Skip to
Q401	When was the last day you injected drugs?	_____days (Today code 00) Don't remember 99	
Q402	***The last time you injected***, what kind of drug did you use? ***Do not read responses; Mark one response only***	Heroin 1 Opium 2 Anti-anxiety drugs 3 Others ___________________ 4 Don't know/Don't remember 9	
Q403	***The last time you injected***, how much did you spend on the drugs? ***(if they give a range, provide the average)***	_____________ VND Got these drugs for free 00	
Q404	***The last time you injected***, where were you when you injected? ***Do not read responses. Mark one response only***	At home 1 At boyfriend's/girlfriend's home 2 At injecting partner's home 3 At a public place (street/park) 4 At a shooting venue for IDUs 5 At drug seller venue 6 With FSW 7 Other (specify) …………………….8	
Q405	***The last time you injected***, did you use a clean needle/syringe? *Clean needle/syringe is a sterilized or new needle/syringe*	Yes 1 No 2 Don't know 9	
Q406	***The last time you injected***, did you share a needle/syringe with anyone else?	Yes 1 No 2 No response 9	**→411**
Q407	***The last time you injected***, how many other injectors shared the same needle/syringe?	_______________ injectors Don't remember/No response 99	

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No.	Questions	Coding of answers		Skip to
Q408	***The last time*** you shared needles/syringes with other users, what was the main reason? ***Do not read responses. Code response that is closest to the client's wording. Mark one response only***	Needles/syringes too expensive Prefer to share with friend Other injector wanted me to Did not have enough money to inject alone Cannot inject myself Syringes/needles not available Other (specify)………………. No response	1 2 3 4 5 6 7 9	
Q409	***The last time*** you shared needle/syringe with other users, was the needle/syringe cleaned between users?	Yes No Don't know	1 2 9	 **→411**
Q410	***If yes***, what did you use to clean the needle/syringe? ***Do not read responses. Mark one response only***	Cold water Hot water Bleach Alcohol Soap Other (specify)………………….	1 2 3 4 5 6	
Q411	***The last time you injected***, did you share drugs or drug containers with other users? *Sharing means using drugs from the same container*	Yes No No response/Don't remember	1 2 9	 **→501**
Q412	***The last time you injected*** drugs with others, how many other injectors shared drugs or drug containers with you? *Sharing means using drugs from the same container*	_______________ injectors No response/Don't remember	 99	

SECTION 5: INJECTING DRUG USERS NETWORK

No.	Questions	Coding of answers	Skip to
Q501	How many other IDUs do you know personally who also know you (i.e., you know their name and they know you as well)?	|__|__|__| persons	
Q502	***During the last 1 month***, you have seen how many of them (repeat the number in Question 501)?	|__|__|__| persons	
Q503	How many IDUs that you know by name are (responses should not be larger than question 501): a) Under the age of 18? b) Currently in 06 center? c) Have ever been to 06 center? d) Homeless? e) Female?	 |__|__|__| persons |__|__|__| persons |__|__|__| persons |__|__|__| persons |__|__|__| persons	

No.	Questions	Coding of answers	Skip to
Q504	How many IDUs that you know **NEVER** buy or use drugs on the street, or where other IDUs gather	|__|__|__| persons Don't know 999	
Q505	***<u>During the last 1 month</u>***, if you share needles/syringes, how many other people have you shared with?	Don't share 000 |__|__|__| persons Don't remember/No response 999	

SECTION 6: SEXUAL HISTORY: NUMBERS AND TYPES OF SEXUAL PARTNERS

No.	Questions	Coding of answers	Skip to
Q601	Have you ever been married?	Never 1 Currently married 2 Divorced 3 Separated 4 Widowed 5	
Q602	Have you ever had sexual intercourse? *(By this we mean vaginal or anal intercourse)*	Yes 1 No 2	**→1102**
Q603	How old were you when you had sexual intercourse for ***the first time***?	Age |__|__| Don't remember 99	
Q604	***<u>During the last 12 months</u>***, how many different partners did you have sexual intercourse with? ***Read out: Please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Number of sexual partners in the last 12 months |__|__| None 00 Don't remember 99	**→1101**
Q605	***<u>During the last 12 months</u>***, among your sexual partners, how many were: ***Interviewer must read the following:*** **Wife/girlfriend**: who you have regular sex without money (or you are married/live with) **Female sex workers**: who you have sex with in exchange for money **Non-regular partners**: Any other sexual partners not including wife/girl friends or female sex workers **Male partners** with whom you had anal sex	605.1 **Wife/girlfriend** |__|__| Don't remember 99 605.2 **Female sex workers** |__|__| Don't remember 99 605.3 **Non-regular partners** |__|__| Don't remember 99 605.4 **Male partners** |__|__| Don't remember 99	

No.	Questions	Coding of answers	Skip to
		Note: Check number of sexual partners in Q604, 605 to ensure the numbers matched	
Q606	***The last time*** you had vaginal or anal sex with any partner ***OTHER THAN WIFE/GIRL FRIEND***, did you use a condom?	Yes 1 No 2 Don't remember 9	

SECTION 7: SEXUAL HISTORY: WIFE/GIRL FRIEND

This section is used if the answer 605.1 is 1 or more than 1 or Don't remember

No.	Questions	Coding of answers	Skip to
Q701	***During the last 1 month,*** how many times have you had vaginal or anal sex with your wife/ girlfriend?	Number of times |__|__| Don't remember 99	
Q702	***During the last 12 months,*** the last time you had sex with your wife/girlfriend, did you use a condom? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember 9	 **→ 704** **→ 704**
Q703	***If used***, who suggested condom use that time?	Myself 1 My partner 2 Joint decision 3	
Q704	***During the last 12 months,*** how often have you used condoms with your wife/girlfriend?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q705	***During the last 12 months***, do you think your wife/girl friend has injected drugs?	Yes 1 No 2 Don't know 9	

SECTION 8: SEXUAL HISTORY: FEMALE SEX WORKERS

This section is used if the answer 605.2 is 1 or more than 1 or Don't remember

No.	Questions	Coding of answers	Skip to
Q801	***During the last 1 month,*** how many times have you had vaginal or anal sex with female sex workers?	Number of times |__|__| Don't remember 99	
Q802	***In the last 12 months,*** the last time you had sex with a female sex worker, was a condom used? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember 9	 **→ 804** **→ 804**
Q803	***If used***, who suggested condom use that time?	Myself 1 My partner 2 Joint decision 3	
Q804	***During the last 12 months,*** how often have you used condoms with female sex workers?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q805	***During the last 12 months***, do you think any of female sex workers that you have sex with has injected drugs?	Yes 1 No 2 Don't know 9	

SECTION 9: SEXUAL HISTORY: NON-REGULAR PARTNERS

This section is used if the answer 605.3 is 1 or more than 1 or Don't remember

No.	Questions	Coding of answers	Skip to
Q901	***During the last month,*** how many times have you had vaginal or anal sex with your non-regular sexual partners (not including wife/girlfriend or female sex workers)	Number of times |__|__| Don't remember 99	
Q902	***During the last 12 months***, the last time you had sex with a non-regular partner, was a condom used? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember 9	 **→ 905** **→ 905**
Q903	***If used***, who suggested condom use that time?	Myself 1 My partner 2 Joint decision 3	
Q904	***During the last 12 months***, how often have you used condoms with your non-regular sexual partners?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q905	***During the last 12 months***, do you think any non-regular sex partner has injected drugs?	Yes 1 No 2 Don't know 9	

SECTION 10: SEXUAL HISTORY MALE PARTNERS

This section is used if the answer 605.4 is 1 or more than 1 or Don't remember

No.	Questions	Coding of answers	Skip to
Q1001	***During the last 1 month,*** how many times have you had anal sex with your male partners	Number of times |__|__| Don't remember 99	
Q1002	***During the last 12 months,*** how many times have you had anal sex with your male partners	Number of times |__|__|__| Don't remember 999	
Q1003	***During the last 12 months,*** the last time you had anal sex with a male partner, was a condom used? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember 9	 **→ 1005** **→ 1005**
Q1004	***If used***, who suggested condom use that time?	Myself 1 My partner 2 Joint decision 3	
Q1005	***During the last 12 months,*** how often have you used condoms with your male partners?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q1006	***During the last 12 months***, do you think any of your male partners has injected drugs?	Yes 1 No 2 Don't know 9	
Q1007	***During the last 12 months***, have you been paid for anal sex by any male partner?	Yes 1 No 2	

SECTION 11: CONDOM USE

No.	Questions	Coding of answers	Skip to
Q1101	Do you know of any place from which you can obtain/ buy condoms? ***Do not read list. Just probe for more responses. Circle all appropriate responses***	Yes No Pharmacy 1 2 Grocery store 1 2 Health establishment 1 2 Bar/restaurant/hotel 1 2 Peer educator 1 2 Outreach health workers 1 2 Drop-in center 1 2 Others (specify) 1 2 ………………………………	
Q1102	Have you ever used condoms?	Yes 1 No 2 No response 9	 **→ 1201**
Q1103	Can you always get a condom if you need one?	Yes 1 No 2 Never needed one 3 No response 9	 **→ 1201**
Q1104	Where do you usually get condoms? ***Do not read list. Just probe for more responses. Circle all appropriate responses***	Yes No Pharmacy 1 2 Grocery store 1 2 Health establishment 1 2	

No.	Questions	Coding of answers	Skip to
		Bar/restaurant/hotel 1 2 Peer educator 1 2 Outreach health workers 1 2 Drop-in center 1 2 Others (specify) 1 2 ………………………………	

SECTION 12: SEXUALLY TRANSMITTED INFECTIONS (STIs)

No.	Questions	Coding of answers			Skip to
Q1201	Can you tell me symptoms of diseases that can be transmitted through sexual intercourse? ***Do not read list. Just prompt for more responses. Circle all appropriate responses***		Yes	No	
		Abdominal Pain	1	2	
		Urethral Discharge	1	2	
		Pain with urination	1	2	
		Genital ulcer/sore	1	2	
		Genital itching	1	2	
		Other (specify) ……………………………………………………	1	2	
Q1202	***During the last 12 months,*** have you had unusual genital discharge?	Yes 1 No 2 Don't know 9			
Q1203	***During the last 12 months,*** have you had genital sores or ulcers?	Yes 1 No 2 Don't know 9			→ 1301 (No)
IF NO unusual genital discharge or ulcers→Q1301					
Q1204	***The last time*** you had genital sore, ulcer or unusual discharge what did you do? ***Read out the list. Circle all appropriate answers***		Yes	No	
	a. Did not do anything		1	2	
	b. Went to government heath establishment for examination and treatment		1	2	
	c. Went to private heath establishment for examination and treatment		1	2	
	d. Went to pharmacy to buy drugs		1	2	
	e. Went to traditional healer for examination and treatment		1	2	
	f. Cured myself at home		1	2	
	g. Told my sexual partner about the symptoms		1	2	
	h. Stopped having sexual intercourse when having the symptoms		1	2	
	i. Used condoms while having sexual intercourse during the time I had the symptoms		1	2	

SECTION 13: KNOWLEDGE, HIV RISK AND TESTING HISTORY

13

No.	Questions	Coding of answers			Skip to
Q1301	Have you ever heard of HIV/AIDS before this interview?	Yes 1 No 2 No response 9			→1401
Q1302	In your opinion, can you tell if someone is infected with HIV just by looking at him/her?	Yes 1 No 2 Don't know 9			
Q1303	***Now I am going to read some statements about HIV and AIDS. Some of them are true and some are not true. These are general statements and do not refer to your own experience or behavior. Please tell me whether you agree or disagree with each of the statements.***				
	Statement	**Response**			
		True	**False**	**Don't Know**	
A	Having sex with only one faithful partner reduces the risk of HIV transmission.	1	2	9	
B	One can get HIV if one uses public toilets.	1	2	9	
C	Using condom every time during vaginal sex prevents HIV transmission.	1	2	9	
D	Mosquitoes and other insect bites will transmit HIV.	1	2	9	
E	Sharing needles when injecting drugs will increase the risk of HIV infection.	1	2	9	
F	Cleaning needles and syringes between injections reduces the risk of HIV	1	2	9	
G	One can avoid becoming infected with HIV by not having sex at all.	1	2	9	
H	Using condom every time during anal intercourse prevents HIV transmission.	1	2	9	
Q1304	With your current behaviors, how do you think about your risk of HIV infection? ***Read list and mark one response only***	High risk 1 Low risk 2 No risk 3 Don't know 9			→ 1306
Q1305	Why do you feel that you are at risk for HIV infection? ***Multiple responses possible, but do not read choices aloud***	Y N Because I often change sexual partners 1 2 Because I don't always use a condom 1 2 Because I use injected drugs 1 2 Because I received blood transfusion 1 2 Other(s), specify …………………… 1 2			
Q1306	Why do you feel that you are not at risk for HIV infection? ***Multiple responses possible, but do not read choices aloud. Just probe for more answers***	Y N Because I am faithful 1 2 Because I always use condoms 1 2 Because I have never used injected narcotics 1 2 Because I'm convinced			

14

No.	Questions	Coding of answers	Skip to
		my partner is clean 1 2 Because I don't have anal sex 1 2 Because I never have sex with sex workers 1 2 Because I don't receive blood transfusion 1 2 Others (specify) __________________1 2	
Q1307	Do you know of a place in the city/province where you live where people can go to have a confidential test to find out if they are infected with HIV? ***Confidential means that nobody will know the test result unless you want them to know***	Yes 1 No 2 No response 9	
Q1308	Can you name these places?	LOCATION LIST ………………………..1 ………………………..2 ………………………..3	
Q1309	Have you ever had an HIV test ? *Explain that the interviewer does not want to know the test result*	Yes 1 No 2 Don't know/No response 9	**→ 1401**
Q1310	***If yes***, was the test done at your own request or you were required to?	Own request 1 Required 2 Don't know 9	
Q1311	When did you ***last*** request an HIV test for which you got the results?	In the last year 1 Over one year ago 2 Don't know/no response 9	
Q1312	***That time***, what pre-test counseling on HIV/AIDS did the health worker give you before the HIV test was taken? ***Read each from the list and, circle appropriate answers***	Y N Your risk of HIV infection 1 2 Meaning of test results 1 2 Ways of HIV prevention 1 2 What should do when you have test result 1 2 Other (specify)………………………..1 2	
Q1313	***That time***, what post-test counseling did the health worker give you when you took that HIV test result? ***Read each from the list and, circle appropriate answers***	Y N Meaning of test results 1 2 Ways of HIV prevention 1 2 What should do when you have test result 1 2 Appropriate referral services when necessary 1 2 Other (specify)………………………..1 2	
Q1314	***That time***, where did you take that test?	Preventive Health Center 1 VCT Center 2 Provincial/District Hospital 3	

No.	Questions	Coding of answers	Skip to
		06 Center 4 Others (specify)……………………………..5	

SECTION 14: ACCESS TO HIV PREVENTION INTERVENTIONS

No.	Questions	Coding of answers	Skip to
Q1401	How many times have you been in a drug reeducation (06) center?	Number of times [__|__] Don't remember/not sure 99 Never been in 06 center 00	 →1405
Q1402	When you ***last*** participated in a drug reeducation (06) program, how did you get admitted to the program? ***Do not read responses. Mark one response only***	Forced by local authority 1 Sent by the family 2 Self-referred 3 Other (specify) ……………………………4	
Q1403	***That time***, what was the total period of time you were in 06 Center?	months[__|__]	
Q1404	In what month and year when were you ***last released*** from 06 Center?	Month [__|__] Year [__|__|__|__]	
Q1405	***During the last 6 months,*** have you received free or cheap clean syringes and needles?	***Yes 1*** ***No 2***	 ***→1406***
Q1405a	***If Yes***, how many times ***in the last 6 months***?	[__|__|__] times	
Q1405b	From whom have you received? ***Read list and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Fellow drug users 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
Q1406	***During the last 6 months,*** have you received free or cheap condoms?	***Yes 1*** ***No 2***	 ***→1407***
Q1406a	***If Yes***, how many times ***in the last 6 months***?	[__|__] times	
Q1406b	From whom have you received? ***Read list and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Fellow drug users 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	

No.	Questions	Coding of answers	Skip to
Q1407	***<u>During the last 6 months,</u>*** has someone talked to you about safe injection?	***Yes 1*** ***No 2***	***→1408***
Q1407a	***<u>If Yes</u>***, how many times ***in the last 6 months***?	[|] times	
Q1407b	Who have talked to you? ***Read list and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Fellow drug users 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
Q1408	***<u>During the last 6 months,</u>*** has someone talked to you about safe sex?	***Yes 1*** ***No 2***	***→1409***
Q1408a	***<u>If Yes</u>***, how many times in the last 6 months?	[|] times	
Q1408b	Who have talked to you? ***Read list and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Fellow drug users 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
Q1409	***<u>During the last 6 months,</u>*** have you received information or materials directed at people who inject drugs on safe sex?	***Yes 1*** ***No 2***	***→ interview completed***
Q1409a	***<u>If Yes</u>***, how many times in the last 6 months?	[|] times	
Q1409b	How have you received these information? ***Read list and circle all appropriate answers***	Y N Television 1 2 Radio 1 2 Newspapers 1 2 Posters 1 2 Leaflets 1 2 Other (specify)……………………..1 2	

The Interview is completed here. Thank you very much for your help and time. Is there anything you want to discuss with us? Please go to the next room for counseling and testing procedure!

8.2. APPENDIX B. QUESTIONNAIRE FOR FEMALE SEX WORKERS

QUESTIONNAIRE FOR FEMALE SEX WORKERS

001 QUESTIONNAIRE IDENTIFICATION NUMBER |___|___|___|___|___|___|___|___|
(Paste participant identification number here)

002 CITY

Hanoi	1
Hai Phong	2
Quang Ninh	3
Da Nang	4
HCMC	5
Can Tho	6
An Giang	7

03 WARD/COMMUNE___________________
NUMBER (The same code as in recruitment script) |_C_|_C_|__|__|__|__|__|__|__|__|__|
(the first 2 boxes: abbreviation of participant classification (Street based FSW: DP or Karaoke based FSW: NH; the following 2 boxes: 2 initials of district/commune's name; the following 3 boxes: code of cluster; the last box: order number of participant invited in that cluster)

Introduction: "My name is… I'm working for the Provincial health Service. We're interviewing people in this area in order to find out about HIV/AIDS prevention information. Have you already been interviewed for this survey in the past few weeks?

If the respondent has been interviewed already for this study, do not interview this person again. Tell them you cannot interview them a second time, thank them, and end the interview. If they have not been interviewed before, continue:

Confidentiality and consent: "I'm going to ask you some very personal questions that some people find difficult to answer. Your answers are completely confidential. Your name will not be written on this questionnaire and will never be used in connection with any of the information you tell me. You do not have to answer any questions that you do not want to answer, and you may end this interview at any time you want to. However, your honest answers to these questions will help us better understand what people think, say and do about certain kinds of behaviors. We would greatly appreciate your help in responding to this survey. The survey will take about 40 minutes to ask and answer the questions. Would you like to know more?"

004 Perform Consent Process: Completed 1 Refused 2

005 NAME OF INTERVIEWER: ____________________Signature ___________________

006 DATE OF INTERVIEW: __/ ____ / 2005

007 CHECKED BY LOCAL SUPERVISOR: Name: ___________Signature ____________

DATE CHECKED: __/ ____ / 2005

008 CHECKED BY NATIONAL SUPERVISOR: Name: ___________Signature ____________
DATE CHECKED: __/ ____ / 2005

1

DATA MANAGEMENT

FOR OFFICE USE	EDITED BY:	CODED BY:	KEYED BY:	KEYED BY:	CHECKED BY:
NAME					
DATE					

2

SECTION 1: BACKGROUND CHARACTERISTICS

No.	Questions	Coding of answers	Skip to
Q101	In what month and year were you born?	Month [__|__] Year [__|__] Don't remember 99	
Q102	In what province/city were you born?	Name of province/city: ……………………………………… ……………………………………… ……………...	
Q103	What is the highest level of education you have finished? ***Read out the possible answers and circle one.***	Illiterate 1 Primary (Grade 1-5) 2 Secondary school (Grade 6-9) 3 High school (Grade 10 – 12) 4 College, university (>12) 5	
Q104	Currently, whom are you living with? ***Read out the possible answers. Circle one only***	Alone 1 With husband/boyfriend 2 With relatives 3 With friends 4 No fixed address (unsettled) 5 Others (specify) 6 ______________________	
Q105	During the last 4 weeks, how often have you had beer/alcoholic drinks? ***Read out the possible answers and circle one***	Every day 1 At least once a week 2 Less than once a week 3 Not at all 4	

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SECTION 2: MARRIAGE AND MOBILITY

No.	Questions	Coding of answers	Skip to
Q201	Have you ever been married?	Never married 1 Currently married 2 Divorced 3 Separated 4 Widowed 5	
Q202	In what month and year did you sell sex ***for the first time***?	Month |__|__| Don't remember 99 Year |__|__|__|__| *Record full number for year, for example 1998, 1999 ...* Don't remember 9999	
Q203	How long have you sold sex here? (name of city/province)	Number of months [__|__] If less than 1 month, record '01' Number of years [__|__]	
Q204	Which district in the city/province do you most often sell sex in?	…………………………………………… …….|__]	
Q205	Before selling sex here, did you ever sell sex in other provinces?	Yes 1 No 2	**→207**
Q206	***If yes***, in which other provinces in Vietnam did you sell sex before here?	Name of provinces:	
Q207	***During the last 12 months***, have you ever sold sex in other provinces continuously for 1 month or more?	Yes 1 No 2	
Q208	Have you ever sold sex in another country?	Yes 1 No 2	**→301a**
Q209	***If yes***, where? ***List name of province and country***	Name of the province/country:	
Q210	***During the last 12 months,*** have you ever sold sex abroad continuously for 1 month or more?	Yes 1 No 2	

SECTION 3: GENERAL SEX WORK QUESTIONS

No.	Questions	Coding of answers	Skip to
Q301 a	Where do you usually meet/wait for your clients? ***Read the responses and circle all appropriate answers***	Yes No Entertainment venue (bars) 1 2 Beauty, massage venue 1 2 Brothel 1 2 Guesthouse 1 2 Hotel 1 2 On the street 1 2 Other (specify)……………… 1 2	
Q301 b	Which is the most common place where do you usually meet/wait for your clients?	Entertainment venue (bars) 1 Beauty, massage venue 2 Brothel 3 Guesthouse 4 Hotel 5 On the street 6 Other (specify)……………… 7	
Q301 c	Where do you usually have sex with your clients? ***Read the responses and circle all appropriate answers***	Yes No Entertainment venue (bars) 1 2 Beauty, massage venue 1 2 Brothel 1 2 Guesthouse 1 2 Hotel 1 2 On the street 1 2 Other (specify)………………. 1 2	
Q301 d	Which is the most common place where do you usually have sex your clients?	Entertainment venue (bars) 1 Beauty, massage venue 2 Brothel 3 Guesthouse 4 Hotel 5 On the street 6 Other (specify)……………… 7	
Q302	***Last time***, where did you meet/wait for your client?	Entertainment venue (bars) 1 Beauty, massage venue 2 Brothel 3 Guesthouse 4 Hotel 5 On the street 6 Other (specify)……………… 7	
Q303	How many people do you know personally (i.e., you know their name, you know who they are and they know you and you have seen them ***in the last 6 months***) who trade sex for money?	[__|__] persons	

No.	Questions	Coding of answers	Skip to
Q304	***<u>During the last 1 month</u>***, how many of them have you seen (repeat the number in Question 303)?	|__|__|__| persons	
Q305	***<u>During the last 6 months</u>***, how many of sex workers that you know by name are (responses should not be larger than question 303):		
	Under the age of 18?	[__|__] persons	
	Inject drugs?	[__|__] persons	
	Direct sex workers (who solely live by selling sex)?	[__|__] persons	
	Indirect sex workers (who not only live by selling sex)?	[__|__] persons	
	Homeless?	[__|__] persons	
Q306	***<u>On average</u>***, how much do you usually charge for short-time sexual intercourse? ***Record the total money really received***	____________________ VND	
Q307	***<u>On average</u>***, how much do you usually charge for all night? ***Record the total money really received***	____________________ VND	
Q308	Do you have someone (i.e. "gatekeeper", establishment owner…) who helps you contact your clients?	Yes 1 No 2	
Q309	***<u>During the last 1 month</u>***, how many days did you sell sex for money?	[__|__] days	
Q310	What is your major source of income?	Selling sex 1 Tips 2 Other work not related to sex work 3	

SECTION 4: SEXUAL HISTORY: NUMBERS AND TYPES OF PARTNERS

No.	Questions	Coding of answers	Skip to
Q401	At what age did you have sexual intercourse (vaginal or anal sex) ***for the first time***?	Age |__|__| Don't remember 99	
Q402	***<u>During the last 1 month,</u>*** how many different sexual partners have you had sexual intercourse with?	|__|__|__| partners Don't remember 999	

No.	Questions	Coding of answers	Skip to
	Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential		
Q403	***During the last 1 month,*** among all of your sexual partners how many were: - ***One-time clients*** (had sexual intercourse in exchange for money one time) - ***Regular clients*** (had sexual intercourse in exchange for money many times) - ***Husband/boyfriend***	 403.1 |__|__|__| one-time clients Don't remember 999 403.2 |__|__|__| regular clients Don't remember 999 403.3 |__|__|__| husband/boyfriend Don't remember 999	
Q404	***During the last 1 month,*** how many different clients have you had oral or manual sex, but NO vaginal or anal sexual intercourse, with?	|__|__|__| clients Don't remember 999	

SECTION 5: SEXUAL HISTORY: ONE-TIME CLIENTS

This section is used if the answer 403.1 is 1, more than 1 or don't remember

No.	Questions	Coding of answers	Skip to
Q501	***On the last day you worked,*** how many one-time clients did you have vaginal or anal sex with?	|__|__| one-time clients Don't remember , No response 99	
Q502	***During the last week***, how many one-time clients did you have vaginal or anal sex with?	|__|__| one-time clients Don't remember /No response 99	
Q503	***In the last time*** you had vaginal or anal sex with a one- time client, did you ASK that client to use a condom? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember/ no response 9	
Q504	***That time***, did you and that client USE a condom?	Yes 1 No 2 Don't remember, no response 9	
Q505		Always 1	

No.	Questions	Coding of answers	Skip to
	<u>During the last 1 month,</u> how often have you used condoms with all of your one-time clients?	Most of the time 2 Occasionally 3 Never 4	
Q506	Do you think or know any of your one-time clients ***in the last 1 month*** were drug injectors?	Yes 1 No 2 Don't know 9	

SECTION 6: SEXUAL HISTORY: REGULAR CLIENTS

This section is used if the answer 403.2 is 1, more than 1 or don't remember

No.	Questions	Coding of answers	Skip to
Q601	***In the last day you worked,*** how many regular clients did you have vaginal or anal sex with?	|__|__| regular clients Don't remember 99	
Q602	***In the last week,*** how many regular clients did you have vaginal or anal sex with?	|__|__| regular clients Don't remember 99	
Q603	***The last time*** you had sex with a regular client, did you ASK that client to use condom? ***Read out: please think about this question for a while in order to give us the most correct answer. Your answer will be kept confidential***	Yes 1 No 2 Don't remember 9	
Q604	***That time***, did you and that client USE condom?	Yes 1 No 2 Don't remember 9	
Q605	***During the last 1 month,*** how often did you use condoms with all of your regular clients?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q606	Do you think any of your regular clients ***in the last 1 month*** were drug injectors?	Yes 1 No 2 Don't know 9	

SECTION 7: SEXUAL HHISTORY: HUSBAND AND BOYFRIEND

This section is used if the answer 403.3 is 1, more than 1 or don't remember

No.	Questions	Coding of answers	Skip to
Q701	***During the last 1 month,*** how many times did you have sexual intercourse with your husband/boyfriend?	|__|__| times Don't remember, No response 99	
Q702	***The last time*** you had vaginal or anal sex with a husband/boyfriend, did you use condom? ***Read out: please think about this question for a while in order to give us***	Yes 1 No 2 Don't remember 9	**→ 704** (No)

No.	Questions	Coding of answers	Skip to
	the most correct answer. Your answer will be kept confidential		
Q703	Who suggested condom use that time?	Myself 1 My husband/boyfriend 2 Joint decision 3	
Q704	***During the last 12 months,*** how often have you used condoms with your husband and boyfriend?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q705	Do you think your husband/boyfriend ***in the last month*** have injected drugs?	Yes 1 No 2 Don't know 9	

SECTION 8: CONDOM USE

No.	Questions	Coding of answers	Skip to
Q801	Have you ever used condoms?	Yes 1 No 2	
Q802	Do you know any place from which you can obtain/buy condoms? ***Don't read, just probe: Is there any other place?*** ***Circle all responses appropriate responses***	Yes No Pharmacy 1 2 Grocery store 1 2 Health establishment 1 2 Bar/restaurant/hotel 1 2 Peer educator 1 2 Health worker 1 2 Drop-in center 1 2 Others (specify) 1 2 ……………………………………	
Q803	Are condoms Available from the place where you pick up your clients?	Yes 1 No 2 Don't know 9	
Q804	How long does it take you to get a condom if you need one?	Under 15 minutes 1 15-60 minutes 2 Over one hour 3 Never needed one 4	
Q805	Can you please show me how many condoms you are carrying now? (Record number seen)	|__|__| condoms Don't have any 98 Don't answer 99	

SECTION 9: SEXUALLY TRANSMITTED INFECTIONS (STIs)

No.	Questions	Coding of answers			Skip to
			Yes	No	
Q901	Can you name any symptoms of diseases that can be transmitted through sexual intercourse?	Abdominal pain	1	2	
		Unusual genital discharge	1	2	
		Pain with urination	1	2	
		Genital ulcer/sore	1	2	
	Do not read list. Just prompt for more responses.	Genital itching	1	2	
	Circle all appropriate responses	Other (specify)	1	2	
Q902	***<u>During the last 12 months,</u>*** have you had unusual genital discharge?	Yes	1		
		No	2		
		Don't know	9		
Q903	***<u>During the last 12 months,</u>*** have you had genital sores or ulcers?	Yes	1		**→1001**
		No	2		**→1001**
		Don't know	9		

No.	Questions	Y	N	Skip to
Q904	***<u>The last time</u>*** you had genital sore, ulcer or unusual discharge what did you do? ***Read out the list. Circle all appropriate answers***	Y	N	
	a. Did not do anything	1	2	
	b. Went to government heath establishment for examination and treatment	1	2	
	c. Went to private heath establishment for examination and treatment	1	2	
	d. Went to pharmacy to buy drugs	1	2	
	e. Went to traditional healer for examination and treatment	1	2	
	f. Cured myself at home	1	2	
	g. Told my regular sexual partner about the symptoms	1	2	
	h. Stopped having sexual intercourse when having the symptoms	1	2	
	i. Used condoms while having sexual intercourse during the time I had the symptoms	1	2	

SECTION 10: DRUG USE

No.	Questions	Coding of answers	Skip to
Q1001	Have you ever used drugs?	Yes 1 No 2 Don't remember 9	 **→1101** **→1101**
Q1002	In what month and year did you use drugs *for **the first time***?	Month [__|__] Don't remember 99 Year [__|__|__|__] Don't remember 9999	
Q1003	In the last month, what kind of non-injection drugs did you use? ***Read list and circle all appropriate answers*** a. Opium "black" b. Heroin "white" c. Anti-anxiety drugs (methamphetamine) d. Amphetamine e. Other (specify)__________________ f. None	 Yes No 1 2 1 2 1 2 1 2 1 2 1 2	
Q1004	Have you ever injected drugs?	Yes 1 No 2 No response 9	 **→1101**
Q1005	In what month and year did you inject drugs for the first time?	Month [__|__] Don't remember 99 Year [__|__|__|__] Don't remember 9999	
Q1006	***During the last 1 month,*** which of the following drugs have you injected? ***Read from list. Circle all appropriate answers*** a. Opium "black" b. Heroin "white" c. Methamphetamine/Novocain d. Anti-anxiety drugs (Dolacgan/Seduxen) e. Other (specify)_______________	Yes No 1 2 1 2 1 2 1 2 1 2	
Q1007	***During the last 1 month***, how often have you injected drugs?	≥ 4 times/day 1 2-3 times a day 2 1 time/day 3 < 1 time/day 4 Don't know/no response 9	
Q1008	***During the last 1 month,*** how often have you used syringes/needles that had ***previously been used*** by someone else?	Always 1 Most of the time 2 Occasionally 3 Never 4	

No.	Questions	Coding of answers	Skip to
Q1009	***During the last 1 month,*** how often have you given syringes/needles that you ***had already used*** to someone else?	Always 1 Most of the time 2 Occasionally 3 Never 4	
Q1010	***During the last 1 month***, have you shared needles/syringes with : ***Read each statement*** a. Husband, boyfriend b. Someone who paid you for sex c. A friend/acquaintance you have sex with d. Someone you just met e. Another injection drug user f. Injecting venue owner g. Another sex worker h. Other (specify)________________ ***Sharing means using the same needles/syringes with someone else to inject drugs at the same time***	Yes No 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	
Q1011	When did the last time you inject drugs?	_____days Today 00	
Q1012	***The last time you injected***, how much did you spend on the drugs? ***If they give a range, provide the average***	______________ VND Got these drugs for free 00	
Q1013	***The last time you injected***, did you use a clean needle/syringe? ***Clean needle/syringe is sterilized or new needle/syringe***	Yes 1 No 2 Don't know 9	 **→1015** **→1015**
Q1014	***The last time you injected***, did you share a needle/ syringe, drug or drug container with some one else?	Yes 1 No 2 Don't know 9	 **→1101** **→1101**
Q1015	***The last time you injected***, how many other injectors shared the same needle/syringe, drug or drug container with you?	_______________ injectors Don't know 99	
Q1016	***The last time you shared needle/ syringe***, was the needle/syringe cleaned between users?	Yes 1 No 2 Don't know 9	 **→1101** **→1101**
Q1017	***The last time you shared needle/ syringe***, what did you use to clean the needle/syringe? ***Do not read responses. Mark one response only***	Cold water 1 Boiling water 2 Bleach 3 Alcohol 4 Soap 5 Other (specify) 6 ……………………………	

SECTION 11: KNOWLEDGE, RISK PERCEPTION AND TEST HISTORY

No.	Questions	Coding of answers	Skip to
Q1101	Have you ever heard of HIV/AIDS before this interview?	Yes 1 No 2	 →1201
Q1102	In your opinion, can you tell someone is infected with HIV just by looking at him/her?	Yes 1 No 2 Don't know 9	

Q1103	***Now I am going to read some statements about HIV and AIDS. Some of them are true and some are not true. These are general statements and do not refer to your own experience or behavior. Please tell me whether you agree or disagree with each of the statements.***				
	Statement	**Response**			
		True	**False**	**Don't Know**	
A	Having sex with only one faithful partner reduces the risk of HIV transmission.	1	2	9	
B	One can get HIV if one uses public toilets.	1	2	9	
C	Using condom every time during vaginal sex prevents HIV transmission.	1	2	9	
D	Mosquitoes and other insect bites will transmit HIV.	1	2	9	
E	Sharing needles when injecting drugs will increase the risk of HIV infection.	1	2	9	
F	Cleaning needles and syringes between injections reduces the risk of HIV	1	2	9	
G	One can avoid becoming infected with HIV by not having sex at all.	1	2	9	

No.	Questions	Coding of answers	Skip to
Q1104	With your current behaviors, how do you think about your risk of HIV infection? ***Interviewer needs to explore further***	High risk 1 Low risk 2 No risk 3 Don't know 9	 →1106
Q1105	Why do you feel that you are at risk for HIV infection? ***Multiple responses possible, but do not read choices aloud***	Y N Because I often change sexual partners 1 2 Because I don't always use a condom 1 2 Because I use injected drugs 1 2 Because I received blood transfusion 1 2 Others (specify) 1 2 ………………………………………………………	
Q1106	Why do you feel that you are not at risk for HIV infection? ***Multiple responses possible, but do not read choices aloud***	Y N Because I am faithful 1 2 Because I always use condoms (correctly) 1 2 Because I have never injected drug 1 2 Because I'm convinced my partner is clean 1 2 Because I don't have anal sex 1 2 Because I never have anal sex 1 2	

No.	Questions	Coding of answers	Skip to
		Because I don't receive blood transfusion 1 2 Others (specify) …………….1 2	
Q1107	Do you know of a place in the city where you live where people can go to have a confidential test to find out if they are infected with HIV? ***Confidential means that nobody will know the test result unless you want them to know***	Yes 1 No 2 No response/don't know 99	**→1109**
Q1108	Could you name these places?	Yes 1 No 2 No answer 99	
Q1109	Have you ever had an HIV test? ***Explain that the interviewer does not want to know the test result***	Yes 1 No 2 Don't know/No response 9	
Q1110	***If yes***, was the test done at your own request or you were required to?	Own request 1 Required 2 Don't know/No response 9	
Q1111	When was ***the last time*** you requested an HIV test for which you got the results?	In the last year 1 Over one year ago 2 Don't know/don't remember 9	
Q1112	***That time***, what pre-test counseling on HIV/AIDS did the health worker give you before the HIV test was taken?	Y N Your risk of HIV infection 1 2 Meaning of test results 1 2 Ways of HIV prevention 1 2 What should do when you have test result 1 2 Other (specify)………………....1 2	
Q1113	***That time***, what post-test counseling did the health worker give you when you took that HIV test result?	Y N Meaning of test results 1 2 Ways of HIV prevention 1 2 What should do when you have test result 1 2 Appropriate referral services when necessary 1 2 Other (specify)…………………….1 2	
Q1114	***That time***, where did you take that test?	Preventive Health Center 1 VCT Center 2 Provincial/District Hospital 3 05 Center 4 Others (specify)…………… 5	

SECTION 12: ACCESS TO HIV PREVENTION INTERVENTIONS

No.	Questions	Coding of answers	Skip to
Q1201	How many times have you been in a re-education (05) center?	[__|__] times Don't remember/not sure 99 Never been in 05center 00	→1205
Q1202	***The last time*** you were in 05 center, how did you get admitted to the center? ***Do not read responses. Mark one response only***	Forced by local authority 2 Forced by the family 3 Self-referred 1 Other (specify)…………………… 4	
Q1203	***That time***, what was the total period of time you were in 05 Center?	Months [__|__]	
Q1204	When were you last released from an 05 Center?	Month [__|__] Year [__|__|__|__]	
Q1205	***During the last 6 months,*** have you received free or cheap condoms?	***Yes 1*** ***No 2***	***→1206***
Q1205a	***If Yes***, how many times have you received ***in the last 6 months***?	[__|__]__] times	
Q1205b	From whom have you received? ***Read list, and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Venue owners 1 2 Other sex workers 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
Q1206	***During the last 6 months,*** have someone talked to you about safe sex?	***Yes 1*** ***No 2***	***→1207***
Q1206a	***If Yes***, how many times ***in the last 6 months***?	[__|__] times	
Q1206b	Who have talked to you received? ***Read list, and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Venue owners 1 2 Other sex workers 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
1207	***During the last 6 months,*** has someone talked to you about safe injection?	***Yes 1*** ***No 2***	***→1208***
1207a	***If Yes***, how many ***times in the last 6 months***?	[__|__] times	

No.	Questions	Coding of answers	Skip to
1207b	Who have talked to you? ***Read list, and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Venue owners 1 2 Other sex workers 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	
1208	***During the last 6 months***, have you received information directed at women who sell sex, on safe sex and safe injecting?	***Yes 1*** ***No 2***	***→1209***
1208a	***If Yes***, how many ***times in the last 6 months***?	[__|__] times	
1208b	How did you receive this information? ***Read list, and circle all appropriate answers***	Television 1 Radio 2 Newspapers 3 Posters 4 Leaflets 5 Other (specify)………………………... 6	
1209	***During the last 6 months,*** have you received free clean syringes and needles?	***Yes 1*** ***No 2***	***→ interview completed***
1209a	***If Yes***, how many times ***in the last 6 months***?	[__|__] times	
1209b	From whom have you received? ***Read list, and circle all appropriate answers***	Y N Peer educators/Health educators 1 2 Health workers 1 2 Venue owners 1 2 Other sex workers 1 2 VCT center 1 2 Drop-in center 1 2 Sexual partners 1 2 Others (specify)__________ 1 2	

The Interview is completed here. Thank you very much for your help and time. Is there anything you want to discuss with us? Please go to the next room for counseling and testing procedure!

8.3. APPENDIX C. ETHICAL APPROVAL FROM THE UNIVERSITY OF SASKATCHEWAN

UNIVERSITY OF SASKATCHEWAN

Research Ethics Office
NRC/PBI Building Box 5000 RPO University
1607 – 110 Gymnasium Place Saskatoon SK S7N 4J8 Canada
Telephone (306)966-2975 Facsimile: (306)966-2069

To: Hyun June Lim, Professor,
Community Health and Epidemiology
University of Saskatchewan

Student: Thuy Thi Cam Le

Date: June 20, 2014

Re: BEH 14-229

Thank you for submitting your study entitled: "*The HIV Epidemic Among Female Sex Workers, Injecting Drug Users and Men who have Sex with Men in Vietnam: Results from the 'HIV/STI Integrated Biological and Behavioural Surveillance*". It has been determined that it is a program evaluation and exempt as per **Article 2.4 of the Tri-Council Policy Statement [2010]** which states "REB review is not required for research that relies exclusively on secondary use of anonymous information, or anonymous human biological materials, so long as the process of data linkage or recording or dissemination of results does not generate identifiable information.."

It should be noted that though your project is exempt of ethics review, your project should be conducted in an ethical manner (i.e. in accordance with the information that you submitted). It should also be noted that any deviation from the original methodology and/or research question should be brought to the attention of the Behavioural Research Ethics Board for further review.

Beth Bilson, Chair
Behavioural Research Ethics Board
University of Saskatchewan

8.4. APPENDIX D. PERMISSION TO USE IBBS DATASET FROM FHI 360 VIETNAM

fhi 360
THE SCIENCE OF IMPROVING LIVES

Hanoi, 22 July 2013

TO WHOM IT MAY CONCERN

Dear Sirs and Madams,

I hereby confirm that FHI 360 permits Le Thi Cam Thuy who is currently pursuing her PhD degree in Epidemiology at the University of Saskatchewan to use the dataset of The Integrated Biological and Behavioral Surveillance (IBBS) rounds I and II, conducted by FHI 360 Vietnam in the cooperation with the Vietnam Authority of HIV/AIDS Control (VAAC) and National Institute of Health and Epidemics (NIHE) for her PhD's dissertation to fulfill requirement of the PhD program in Epidemiology at the University of Saskatchewan, Canada.

However, the student should understand the FHI publication and authorship policies that no publication other than the dissertation may be published without the written permission of FHI and that any publication would need to contain co-authorship of FHI staff and government partners.

Should you need more information or have question about this letter, please do not hesitate to contact me by email at quoc@fhi360.org or telephone at +84-4-3934 8560 or Fax at +84-4-3934 8650.

Yours sincerely,

Nguyen Cuong Quoc, MD, PhD, MPH
Associate Director/ Strategic Information
FHI 360 Vietnam Country Office

FHI 360/VIETNAM COUNTRY OFFICE | 7th floor, Hanoi Tourist Building | 18 Ly Thuong Kiet street | Hoan Kiem district| Hanoi
T: ++84-4-3934 8560 | F: ++84-4-3934 8650 | www.fhi360.org