HIV/AIDS: Trends, Forecasts, Exploring HIV Policy and Program Alternative Predictions Using Deterministic Asian Epidemic Model

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Abstract

Estimates and projections of HIV infections make an important contribution to public health policy in India. In addition, identification of right target populations for intervention could be the most cost effective strategy in the realm of AIDS control program. The epidemiological, behavioral, programmatic, policy, resource allocation and program coverage data from Mumbai was used in AEM, a deterministic model to estimate the current and future course of the epidemic. The results indicate that the non-brothel based sex work is increasing over the period in Mumbai. Nine out of every ten infections occurring are due to heterosexual transmission, mainly from non-brothel based sex worker to clients to their wives. Universal coverage and condom promotion among non-brothel based sex workers can avert eighty eight percent of the new infections. Targeting non-brothel based sex workers offers a critical window of hope in responding to the burden of HIV incidence.

Background: The Need for Estimation and Projection

India has 5.2 million estimated numbers of persons living with HIV in the year 2005, although the overall prevalence remains low in Southeast Asian region. The prevalence varies across the country in geographic diversity and also varies among high-risk groups within states. Six states— Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu Manipur, and Nagaland — show 1 percent or higher prevalence rate among pregnant women in ante-natal clinics. In the mid- 1990s, a quarter or more of sex workers in big cities such as New Delhi, Hyderabad, Madurai, Pune, Tirupati, and Vellore tested sero-positive for HIV. By 1997 the prevalence of HIV among sex workers in Mumbai had

reached 71%. Mumbai has been home to many sex workers and has become the center of the HIV epidemic in India.

Although Mumbai has had substantial focus and success in HIV prevention efforts, still many new infections continue to occur and being reported in health care settings. While, the planning of 3rd phase of the national AIDS control programme is under way, information on number of infected individuals and the spread of the epidemic according to various types of target populations are required for strategic planning appropriate program for care, support and prevention. The planning of the program needs to be based on realistic assessments of what is required to improve the effectiveness of prevention efforts. Therefore, it is important to know trends high-risk groups, forecasts number of HIV population for HIV Policy and Program using suitable estimation and projection model.

During past decade, Epidemiologist and Biostatistician have made several attempts to estimate and project the HIV infections in India. Of these, the National Aids Control Organization (NACO), Government of India provides estimates number of HIV infections every year for the country as a whole using HIV sentinel surveillance (HSS) prevalence data in the absence of any other credible data since 1998. The methodology for estimating the HIV burden in the country is based assumptions deliberated and approved by working group's experts consisting of UNAIDS, WHO UNICEF, NACO, Biostatistician and Epidemiologists. It does not however provide the HIV incidence and mortality due to HIV/AIDS. Also, the method is not robust enough to provide HIV estimates at disaggregated sub-national level, which is important for effective programming implementation. The UNAIDS workbook and the Estimation and Projection Package (EPP) model has recently developed by UN groups and applied mostly in African countries for estimation of number of HIV infections using only epidemiological data. These models have provision of linking with Spectrum models to derive incidence, AIDS related mortality and other HIV/AIDS impact indicators. Most recently Tim Brown et. al. (2001) developed Asia Epidemic Model (AEM) to understand the differences in HIV prevalence between Asian countries. However, there is a need to

examine whether the model is flexible enough to address the mixture of generalized and concentrated epidemics in India with the existing data gaps. AEM is a process mathematical model designed to reflect the primary groups and transmission modes driving HIV transmission in Asia using epidemiological and behavioural input. It provides useful tool for policy and programme analysis (Tim , 2001).

Why Mumbai? Currently, in Mumbai and in many parts of India, a wealth of epidemiological and behavioural information has been collected. And, with continuous program efforts, significant changes in the epidemiological and behavioural situation are seen. For example, the prevalence among female sex workers has fallen from a peak of 71 percent in 1997 to around 28% in 2006. Condom use in commercial sex has continued to increase, while other sexually transmitted diseases among sex workers and clients have continued to fall. A rise in HIV infection among men having sex with men is seen in recent times. There is an increase in the proportion of non-brothel sex workers as against the brothel based sex workers. With all these changes happening in behaviour of individuals, the traditional mathematical models are not the effective tools to assess the epidemic.

This paper presents a new set of projections for the past and future course of the Mumbai epidemic, which take into account the changes, which have occurred over the past few years. With the use of past and current behavioural information, the model that has been used in this paper estimates the current HIV infections levels, followed by the detailed projections. Recognizing that accelerated implementation of certain prevention and care alternatives can greatly affect the total number of people living with HIV and AIDS in the future, as well as the quality of their lives, a number of different policy relevant scenarios have been developed. Each scenario is a separate set of projections based on different assumptions about the impact of prevention program in Mumbai. These scenarios presented in this paper, are based on possible policy and program changes to achieve desired level of outcome indicators.

Data sources and Methodology:

In this paper, we have used the Asian Epidemic Model (AEM) developed by the Thai Working Group on HIV/AIDS Projection. The AEM is a process model – it seeks to model the key processes that give rise to HIV transmission. Because it is intended for application in understanding Asian epidemics, the primary emphasis is sex work, sharing of needles, and heterosexual transmission between males and their non-commercial female sexual partners including spouses. These have been the primary driving forces behind epidemics in the region.

The model has two major components – one that calculates heterosexual transmission and another, which handles transmission through needle sharing. These two components sub-divide the population into 7 sub-populations:

- Males who are clients of sex workers
- Males who are not clients of sex workers
- Male who are injecting drug users (IDUs) who share needles often
- Males who are injecting drug users who do not share often
- Females who are direct sex workers (many partners per night)
- Females who are indirect sex workers (fewer partners per night)
- Females who are not sex workers (general females)

Each of these sub-populations is further divided into those who are infected and those who are not. Each sub-population is assumed to consist of those ages 15 and above. Population projections from the Census Expert committee are used to bring the correct number of 15 year olds into the uninfected general male and female sub-populations each year. In the model, all possible combinations of the infection transmission and its dynamics were considered. A fuller description of the model is available in a separate document (Brown and Peerapatanapokin, 2000a).

Calculating new adult infections: Sexual transmission with HIV, which moves these men between the uninfected and infected sub-populations, is calculated using standard

epidemiological equation as illustrated in figure 2. The detailed formulas used account for a number factors infecting HIV transmission including.

- Infection status of sexual partner (e.g. sex worker prevalence)
- Number of contact between clients and sex workers
- Use of condoms (protects from infection)
- Presence of another sexually transmitted disease (increases transmission)
- Circumcision status of the partner (circumcised is lower risk)

$$[C_{std} F_{std}(t) + (1-F_{std}(t))] [C_{cc}F_{cc}(t) + (1-F_{cc}(t))] P_{f\_m}X_1V_1(t) (1-C_1(t)) [Y_3/(X_3+Y_3)]$$

Infection with STD	Infection with out STD	Infection with circum--cision	Infection without circum--cision	Total number of sex act	Fraction unprotected by condom	Prevalence of HIV among SWs

Probability of infection
From female to male

Figure 1. Example of the calculation of number of new infections among clients.

Addition terms in the equations address transmission from females to males through non-commercial female sexual partners, including casual partners and spouses/regulars partners. Similar approaches are used calculating sexual infections among women, who are divided into general population females, direct sex workers and indirect sex workers again; the interested reader is referred to Brown and Peerapatanapokin 2000a for more details on the specifics of the calculations.

The injecting drug user is divided into those who share needles significantly and those who do not. If drug user does not share at all or share rather infrequently, they are at comparatively low risk of HIV infection and will usually remain uninfected through injecting drug means. On the other hand if they share often, and the efficiency of HIV transmission through shared needles, they will become exposed and infected very quickly after HIV makes entries into the sub-population. If the population is not prevalence rises quickly to levels approaching 90 to 100 %. In practices the proportion sharing was adjusted empirically to reproduce the HIV infection level of 35 to 40 % observed among IDUs in surveillance data.

For the IDUs who do share often, the number of new infections is calculated as shown in figure 5. The most significant factors here are:

- Frequency of infection
- Prevalence of HIV among other IDUs
- Use of bleach as a protective measure.
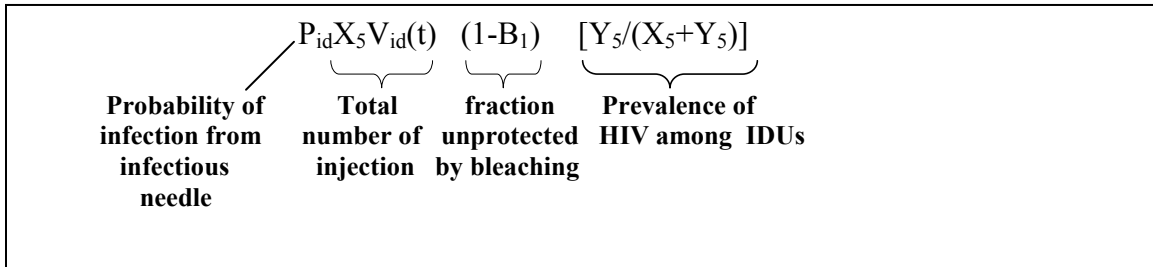- Probability of HIV transmission in using an infected shared needle

$$P_{id}X_5V_{id}(t) \quad (1-B_1) \quad [Y_5/(X_5+Y_5)]$$

| Probability of infection from infectious needle | Total number of injection | fraction unprotected by bleaching | Prevalence of HIV among IDUs |

Figure 2 Calculation of number of new infections among drug users who shares needles often.

Using a set of equations similar to those described above for each of the sub-populations, the number of new male and females HIV infections every year in each sub-population is calculated by the AEM.

Calculating adults living with HIV, AIDS cases and deaths

Once the new infections are available for adult men and women, a program module applies the progression rates from HIV infection to AIDS (approximately ten years on average) and from AIDS to death in order to calculate the number of surviving people living with HIV and AIDS, the numbers cases, and the number of deaths related to AIDS. This calculation is done exactly as in the Epi-model program [Chin and Lwanga 1991]. The UNAIDS slow progression rates from HIV to AIDS and form AIDS to death have been for adults.

The following section of the paper briefly describes the most important inputs used and the sources from which the data was obtained.

General population males and females. Population sizes for men and women aged 15 years and above are drawn from the published report of the Population Projection 2001-

2026 (RGI, 2006). There were quite reasonable fertility and the expert committee used mortality assumptions in order to project the population sizes.

Estimates of the risk populations (2002): Mapping exercise carried out by different research agencies in Mumbai has determined the size of female sex workers. National and state level surveys have determined the proportion of adult men visiting sex workers in the year 2002. In 2002, the behavioural surveillance survey (BSS I) found that 3.1 % of men visited sex workers and the survey carried out by the RISHTA (Research and Intervention in Sexual Health: Theory to Action) project found that 3.9% of the men in the age-group 21-40 years visiting sex workers. The BSS II also has found the figure of men visiting to sex workers had fallen to 3.8% at 2004. A linear decline in the proportion of clients was assumed between the two times. After 2004, the number of clients has been estimated to be proportional to the number of sex workers, which has been roughly constant. This implies an inherent assumption that the number of sex workers and clients is related.

At-risk population	Size (% 15-49 adults)	Average duration
Clients of sex workers	8 % of Male population	5 years

Female sex workers
    15,000 Brothel based
    20,000 Non-brothel based
	1 % of Females	**7.7 yrs for brothel
		5.2 yrs Non-brothel**

Injecting drug users 37,815	0.92% of males	2.5 years
Men having sex w/men 35,000- 150000	0.9% of males	10 years
Male sex workers 3,200	0.08% of males	1 year

Further, the mapping exercises carried out during 2002 has provided the proportion of injecting drug users, men having sex with men and the number of male sex workers in the total adult population. The average duration of clients visiting female sex workers, female sex workers into the profession, injecting drug users injecting duration, men

having sex with men with such behaviour was given the results from the behavioural surveillance survey.

Direct (high frequency) and Indirect (low frequency) sex workers: The mapping of sex workers population had provided the information on the numbers and proportion of direct and indirect sex workers in Mumbai. Because probably the low frequency sex workers are usually not seen and majority of them work in bars and other locations, the numbers used for indirect sex workers has been doubled to the actual numbers. The information on the numbers of direct sex workers are drawn from the brothels they are closer to the estimate while the indirect sex workers are usually more in number.

Key assumptions:
- High frequency SW= 30%, Low frequency SW = 70%

Sexual behaviours over time:

The key sexual behaviours tracked overtime in the model are frequency of sexual contact with sex workers and other female partners and use of condoms with different partners. Because HIV transmission is significantly increased by the presence of other sexually transmitted diseases, data on the fraction of sexual encounters in the presence of STD is also needed.

Direct sex workers:

Frequency of sexual contact: The number of clients per night for direct sex worker has been collected in few studies conducted in Mumbai. Of those studies the behavioural surveillance survey (BSS) II provides the average number of clients per day to be 3.5, multiplying this number by 365 days in a year yields an estimate of 1278 clients per year. Because no time trends are available on this data, it has been kept fixed over the course of the projections.

Condom use over time: Rates of condom use among direct sex workers prior to epidemic began in 1989 are set to 10%. The results of the BSS I suggest the condom use among direct sex workers to be 69%. The consistent condom use is 63% and the condom use in last time sex is 75%. The results of BSS II found that the condom use has increased to 75% in 2003 from the 63% in 2000. A linear increase in the condom use during the two time points was assumed. A linear increase in the condom use from 1989 to 2000 was assumed. From 2003 forward, the condom use remains stable at 75%. This is lower than is often reported in surveys, but reflects concerns about over reporting of condom use and failure to report non-use with regular clients.

STD rates: The STD prevalence (percentage of sex workers infected with an STD on examination) as found by few studies was considered. It was assumed that most of the sex workers visited to STD clinics in 1986 were the direct sex workers and the prevalence of 61% was found, but it has fallen steadily to 16% in 2005 according to the reports of the Sentinel surveillance reports in Mumbai. Linear decline STD prevalence assumed between the two time points. The STD prevalence in the model after the year 2005 was assumed to be constant.

Indirect sex workers

Frequency of sexual contact: The number of clients per night for direct sex worker has been collected in few studies conducted in Mumbai. Of those studies the behavioural surveillance survey (BSS) II provides the average number of clients per day to be 3.5, multiplying this number by 365 days in a year yields an estimate of 1278 clients per year. Because no time trends are available on this data, it has been kept fixed over the course of the projections.

Condom use: The indirect sex workers condom use values are 53% according to BSS -I in 2000 and 53% according to BSS II in 2003. There was no change in condom use among the indirect sex workers during the two time points according to survey. The consistent condom use is low and the condom use reported in the last time sex is higher than the actual condom use. The actual condom use was calculated as the weighted

average in condom use with clients and non-paying partners and the number of times sex with clients and non-paying partners. The condom use in 1989 was set to be 10% and a gradual linear increase was assumed in the year 2000. The condom use values forward to the year 2003 were assumed to be constant.

STD prevalence: The STD prevalence found in 1986 by the study among sex workers was considered to be applicable to indirect sex workers. The STD prevalence according to the national BSS in Mumbai found that 37% of the indirect sex workers were infected to STD in the year 2000.

General males:

Sexual contact with sex workers in the last one year: The RISHTA survey among men conducted in the year 2004 in Mumbai found that 4% of men in the age-group of 21-40 years have visited a sex work in the last one year.

Extramarital sexual contacts (other than sex worker): The RISHTA survey found that 8% of men in 2004 have had sexual contacts with other women in the last one year. Since, there was no data available from Mumbai on the other times, it was assumed to be constant over the period.

Sexual contact among general couples: The RISHTA survey found the coital contacts between husband and wife to be 4 times in a month (once in a week). The condom use among general couples was 3%.

The key input indicators on injecting drug use behaviours over time:

- % in high risk networks is low (15%) till 1995 and increases to 60% by 2001 and stays on.
- Number of injections each day: 2.5 until 2001 and 2.2 in 2004
- Percent of IDUs sharing is 30% until 2000 and 34% in 2003 (between 2000 and 2003, the values were interpolated) and continues at 34% further

- Sharing to non-sharing movement in a year: 10%
- 24% visiting FSWs in 2004 and 46% of them used condom last time with any FSW
- condom use with high frequency sex workers: 46; low frequency sex workers: 37 in 2004 (in 1985: 10)

The key input indicators on men having sex with men over time:

- 87% MSM reported anal sex, 0.5 contact per week
- % Condom use in anal sex: 1980 – 10; 2000 – 41
- 2% MSM visiting female sex workers
- 41% MSM visiting male sex workers in 2000
- 2% of MSM were suffering with STI
- 41% consistent condom use among MSM in 2000 (1980 – 10%); 78% in 2003
- 29% condom use with higher frequency sex workers
- 10% condom use with lower frequency sex workers

Other parameters in the model

The population size and behavioral inputs to the modeled specified above are determined from external data sources, primary surveys and research studies in Mumbai and Maharashtra. Following are the data sources used:

- Epidemiological trend data: Published study data, US Census Surveillance Bureau, Sentinel surveillance data
- Size estimation data: Mapping of high risk group populations
- Few published articles on MSM, sex worker populations
- Behavioural data available at two time points:
    - BSS I done in 2002;
    - BSS II done in 2004;
    - the third round is in progress.

There are a number of additional parameters which describe the transmission of the virus in a sexual or needle sharing contact. The most important of these parameters are:

- The start year of the sexual and injecting drug use epidemics (Epidemic in Mumbai spread majority through sexual contact. In fact, the epidemic start is much later for injecting drug users and the impact of injecting drug users on the epidemic spread is almost negligible).

- Probability of transmission from female with HIV to male sexual partner in a single sexual contact assumed to be 0.00114.

- Probability of transmission from male with HIV to female sexual partner in a single sexual contact assumed to be 0.0005.

- The ratio of male to female infection in Mumbai considered to be 3:1.

- Multipliers on the per contact transmission probability for sex where one partner has another sexually transmitted disease. The presence of other sexually transmitted diseases can significantly increase the transmission of HIV. The Indian literature has estimated that factors of male to female transmission are 45% to 7.5% for female to male transmission.

Results: Fitting the model:

The AEM model was fitted with the input data discussed above and the results on the estimated HIV prevalence was obtained for general male, general female, sex workers, drug users and male who have sex with males. The results of estimated HIV prevalence were compared with the observed prevalence data among sub-populations. To simplify the fit of estimated HIV prevalence with the observed HIV prevalence, the program has had an interface, which allowed it to display the prevalence trends from each epidemiological data set on the same graphs as the prevalence curves produced by the model. For example, the following figure explains the estimated and observed prevalence curves on the same graph for each risk sub-population.
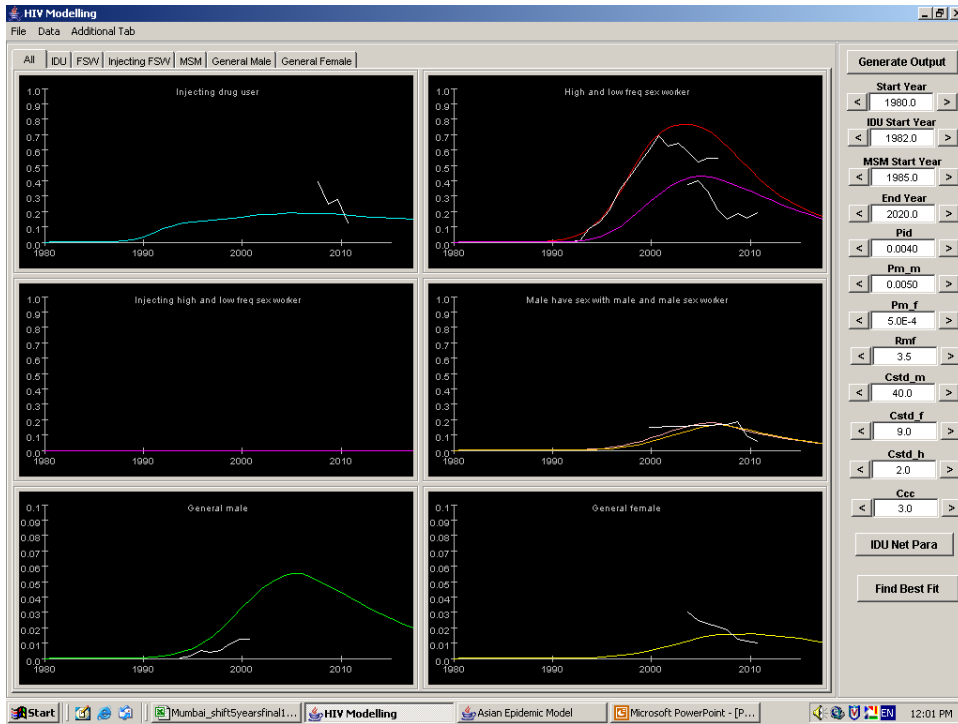
The estimated prevalence curves are adjusted to the observed HIV prevalence curves so that the model is best fit with certain parameters. By adjusting the parameters and start years, a set of parameters was found for which the model reproduced the time trends in prevalence in all the epidemiological data sets fairly matches. The parameter values that were described in the methodology section were the values obtained after the best fit of the model. The HIV infections, AIDS cases and Deaths according to each sub-population were calculated from this fit is discussed in the next section.

The comparisons of the projected HIV prevalence from the model with historical trends in direct and indirect sex workers is as follows. Non-brothel based sex workers are increasing over the years.
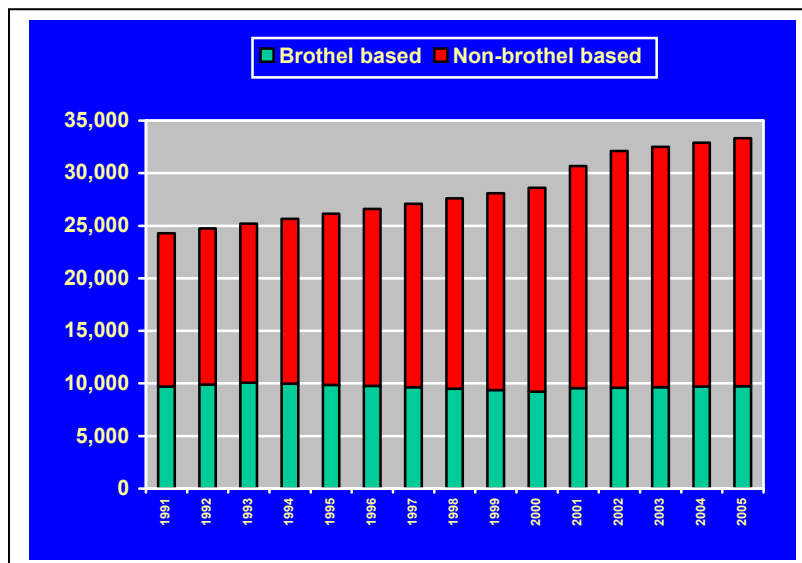
HIV infection contribution by type of sub-populations in Mumbai
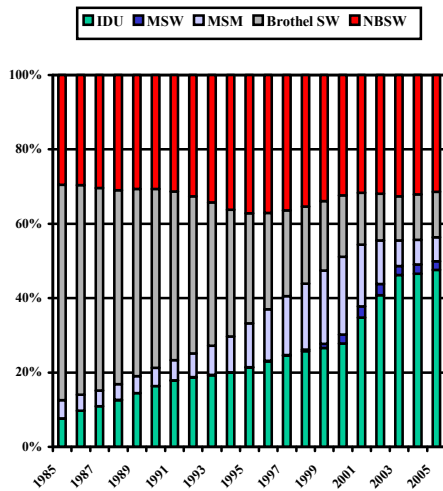
- Infection among IDUs is increasing rapidly, however, they constitute a very small number in Mumbai and currently the intervention program is targeting them.
- Around 30% of the infections occurring among the high-risk populations are the non-brothel based sex workers.
- No intervention for non-brothel based sex workers particularly keeps them more at risk.
- In behavioural surveillance survey (BSS, 2004), 37% of the non-brothel based sex workers were reported to have active STIs.

Alternative scenarios

Scenario 1 - Baseline

Prevention efforts: The baseline scenario projects into the future assuming that the prevention and behavioral situation remain the same as they are today.

Behavioral target. Percent of males visiting sex workers remains stable until the year 2020 as is the situation in the year 2004.Condom use in commercial sex remains same from the year 2004 until the year 2020. STD prevalence remains at current levels until the year 2020.

Results of the baseline scenario: The baseline scenario shows where the Mumbai epidemic is today. The number of estimated HIV infections is 15267. The estimated number of individuals infected with AIDS are 5405. The epidemic is majority concentrated among the clients of the sex workers and their wives. Majority of the clients of the sex workers who were infected to HIV during this period and in future are the ones who have sexual contacts with the indirect sex workers. The program

alternatives here fore were developed for programmatic response to the indirect sex workers.

Why indirect sex workers?

Coverage and condom promotion among non-brothel based sex workers could be primary means of reducing overall HIV in Mumbai. While much remains to be done, important progress is under way in reducing the incidence of HIV in Mumbai through the interventions among brothel based sex workers, IDUs, MSM, and MSWs.

We strongly believe that ensuring universal coverage of sex workers must be the next major priority towards slowing the spread of HIV, supporting the infected. Experts knowing the epidemiology of HIV in Mumbai (India) agree that condom promotion among sex workers ranks among the most cost effective means of HIV prevention. In particular, condom promotion among non-brothel based sex workers, who are often excluded from the targeted interventions on HIV prevention, will help slow the spread of HIV.

70% of the non-brothel based sex workers now account for 10% of new HIV infections in Mumbai. At the same time, HIV is spreading rapidly among the clients – having devastating effects on their families, support systems and transmission to the low risk wives.

The estimates on HIV suggest that around 70% of sex workers in India operate either from streets/hotel/houses. Currently, 35% of them are infected with HIV. If they are not covered by HIV programme and condom use promotion is not done in time, then 75% of them will be infected to HIV by 2010. This would have impact on the clients and their wives subsequently.

**Scenario 2 – Increased coverage of the program for indirect sex workers**

The coverage and condom promotion among brothel based sex workers correlates directly to better knowledge, increased condom use and reduced HIV infection rates in Mumbai. The currently umbrella agenda of targeted interventions among sex workers

accidentally covers only about 20% of non-brothel based sex workers. Our analysis suggests that if the program could cover 60% of the sex workers by 2010, as many as 6599 cases of HIV could be prevented each year.

Scenario 3 : Universal coverage and condom promotion

The figure given below shows a clear link between increased coverage, condom promotion and reduced HIV infections. We have considered in the model keeping in mind the achievable target of 65 percent of condom use in the year 2010 from 53 percent at present the year 2005, in which program will covered 70 percent of non-BSWs. Within five year period the sensitivity analysis shows that there is a decline in percent of 27 percent if 70% non-BSWs are covered by 2010. Previous research clearly shows that coverage have lower rates of infection. If the condom promotion is made along with coverage

HIV prevalence by level of intervention:
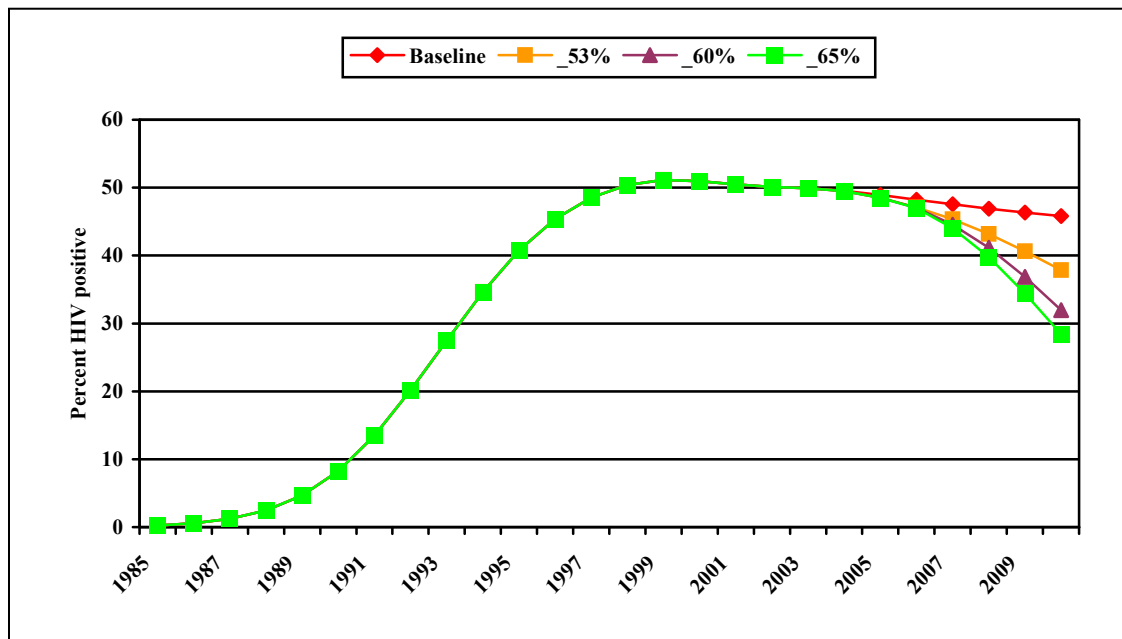
ADVOCACY AGENDA

Today, over 80% of the infections occurring among the clients are through the infected non-brothel based sex workers. With many more non-brothel based sex workers entering into population (due to stigma and reduction in number of clients in brothel based), HIV will continue to be serious threat to the city.

• **Adopt a policy on HIV intervention among non-brothel based sex workers.** Targeted intervention among umbrella quoted "sex workers" keep two-thirds of sex workers out of intervention. Many unidentified sex workers are dying daily due to HIV and their families are affected and children become orphans without the love of the mother. Therefore, there is a need to adopt a policy on the interventions to target non-brothel based sex workers through innovative strategies.

• **Mobilize Additional Resources to Achieve Universal Coverage.** India, specifically Mumbai need assistance in order to initiate and scale up of the program for non-brothel based sex workers. Specifically, funds are needed to find the strategies to reach such sex workers, provide education and condoms, promote safe sex behaviour. Additional resources are also needed to provide care and support to those infected sex workers who are still invisible due to stigma and discrimination.

CONCLUSION

Drafting and implementing a policy to target the non-brothel based sex workers through intervention for condom promotion offers a critical window of hope in responding to the burden of HIV incidence in Mumbai (India). Progress toward achieving universal coverage and condom promotion among non-brothel based sex workers will require advocacy that seeks to achieve political support and policy makers' persuasion to get necessary resources.

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