A System Dynamics Model for Intentional Transmission of HIV/AIDS using Cross Impact Analysis

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Abstract

The system dynamics approach is a holistic way of solving problems in real-time scenarios. This is a powerful methodology and computer simulation modeling technique for framing, understanding, and discussing complex issues and problems. System dynamics modeling and simulation is often the background of a systemic thinking approach and has become a management and organizational development paradigm. This paper proposes a system dynamics approach for modeling the phenomenon of intentional transmission of HIV/AIDS by non-disclosure. The model is proposed to be built using the Cross Impact Analysis (CIA) method of relating entities and attributes relevant to the risky conduct of HIV+ individuals in any given community. A questionnaire that would help collecting relevant data is prepared for researchers who might have direct access with HIV+ persons or AIDS patients. The questionnaire would enable researchers in the area to build the cross-impact correlation matrix and, hence, the viral transmission model and behavior that prevails in the analyzed community. The resulting model would enable us to predict the effects of

non-disclosure by HIV+ persons on the spread of the virus. This might induce policy makers to take more effective actions in campaigns and legal procedures.

Key words: *HIV/AIDS Viral Transmission, Cross Impact Analysis, Policies, Healthcare, System Dynamics, Operational Research, Dynamical Systems.*

1. Problem background

The epidemic of AIDS has been steadily spreading for the past two decades, and now affects every country in the world. Each year, more people die, and the number of HIV+ people continues to rise despite national and international HIV prevention policies and dedicated public healthcare strategies. Well known modes of transmission of HIV are sexual contact, direct contact with HIV-infected blood or fluids and perinatal transmission from mother to child. Transmission becomes intentional if the infected person knows that he/she is HIV+ and he/she does not disclose it when there is a risk of transmission, otherwise, transmission is not intentional.

Here, we propose to build a cross-impact model for the intentional transmission of HIV/AIDS in order to learn about the effects of intentional transmission on the spread of HIV/AIDS in correlation with certain socio-economic factors related to the individual and his/her surrounding community. Several versions of cross-impact analysis have been developed by researchers and applications exist in various social areas (Gordon and Hayward 1968, Mclean 1976, Sarin 1978, Novak and Lorant 1978, Wissema and Benes 1980, Helmer 1981, Gordon 1994, Pedamallu 2001).

The proposed cross impact model relates the intentional transmission of HIV to factors such as the donor's income level, educational background, strength of family ties, criminal and psychological records, as well as attributes pertaining to members of his/her family, work colleagues and the surrounding community's conservativeness and beliefs. If this model can be built with appropriate data collected from HIV+ patients, then the significance of intentional transmission can be measured versus the unintentional transmission rate, and it might be possible to adapt or adjust public policies to eliminate or reduce the risk of HIV transmission.

2. Literature survey

Many studies exist on HIV transmission, however, mostly, these studies do not differentiate between intentional and non-intentional transmission. Early surveys of mathematical and statistical methods developed for HIV/AIDS transmission are found in Isham (1988), Anderson (1991), Schwager et al. (1989) and Fusaro et al. (1989). An early approach used for the prediction of AIDS cases is extrapolation (Morgan and Curran 1986, Karon et al. 1989) where separate curves and extrapolations are carried out for various risk groups. Advantages of extrapolation are its simplicity and ease of use, but it does not consider factors such as behavioral changes or saturation in the high risk groups. Another approach is back calculation (Brookmeyer and Gail 1988) which is a deconvolution process that uses a given AIDS incidence up to time t and an estimated distribution for the AIDS incubation period to estimate the HIV incidence up to time t. Similar to extrapolation, back calculation does not yield any information on the HIV transmission dynamics. May and Anderson (1988) develop HIV transmission dynamics models that represent the progression from HIV+ status to AIDS where the population is divided into categories of progressive infectious stages. These models translate the movements between these stages into difference equations in the deterministic case and into state transition probabilities in the stochastic case. Comparisons between deterministic and stochastic models are made using expected values and simulation (Mode et al. 1989) and reviews on both types of models exist in the literature (e.g., Anderson and May 1991). Tan (1991) proposes general stochastic models for the simulation of various transmittable diseases including AIDS. Hyman and Stanley (1989) consider both continuous and discrete HIV/AIDS models with heterogeneity and different mixing structures that analyze the spread from high to low risk groups, the effects of variable infectivity and the instability of the back calculation procedure. Dietz and Hadeler (1988) consider the dynamics of pairs of individuals and the duration of their partnerships explicitly in their dynamic pair formation and dissolution models. This approach is distinctly different from the contact rate mixing matrix models used by many researchers. A more detailed review on these early models developed for HIV transmission in the United States is available in http://biotech.law.lsu.edu/cphl/Models/aids/. A web site that summarizes such analytical tools and models with an extensive bibliography is maintained by International Aids Economics Network (IAEN: http://www.iaen.org/models/).

HIV researchers have long appreciated the need to understand the social and behavioral determinants of HIV related risk behavior, and the methods for this type of analysis are well established. Some of the mathematical models proposed for HIV / AIDS transmission are listed. Cassels et al. (2008) shows how mathematical modeling studies have contributed to understanding of the dynamics and disparities in the global spread of HIV. Ajay et al. (2009) developed a mathematical model with explicit behavioral foundations to explore an array of policy interventions related to HIV transmission among injection drug users. Since the epidemic began, injection drug use has directly and indirectly accounted for more than 36% of AIDS cases in the United States (http://www.cdc.gov/hiv/resources/Factsheets/idu.htm). The distributing trend appears to continuing. Kimbir and Oduwole (2008) proposed a mathematical model of HIV/ AIDS transmission dynamics considering counseling and antiretroviral therapy as major means of control of infection. Analytical and numerical results obtained indicate that ART and counseling could be effective methods in the control and eradication of HIV/ AIDS. Abdulkarim and Ndakwo (2007) studied the susceptible-exposed-infectious-aids, epidemic model for vertical transmission of HIV / AIDS in a homogeneous mixing population. Huiyu et al. (2009) developed an extended CA simulation model to study the dynamical behaviors of HIV/AIDS transmission. The model incorporates heterogeneity into agents' behaviors. Agents have various attributes such as infectivity and susceptibility, varying degrees of influence on their neighbors and different mobilities.

Although mathematical models on viral transmission exist, they are rather vague about accounting for the psyche and behavioral pattern of the HIV+ person. Under what conditions would an infected person disclose his/her condition to a potential partner or to work colleagues without damaging his social and financial states? The current approach about the disclosure of HIV status in many developing countries is to keep it under cover because of the possible physical isolation of the disclosing person and discrimination to an extreme extent, job loss, and so on. This does not change even when public awareness of transmission channels and protection against the virus is high (Odimegwu 2003). Stigmatization and the anger it creates on the part of the infected person, and the absence of learned social responsibility and selfishness all lead to the cover up of the infected person in the majority of homosexual / heterosexual casual / non-casual sexual encounters. It is possible to identify many non-disclosure cases in marital sex that lasts until the symptoms of the illness become too apparent to hide (Niccolai et al. 1999). In these cases, the patients family may get infected with the disease and also financially effected and out casted by their own community.

Previous studies have showed concerns on continuing risky sexual behavior among HIV+ individuals. Stein et al. (1998) interviewed 203 consecutive patients presenting for HIV at Boston city hospital and Rhode Island Hospital and found that 40% of a sample of HIV+ patients recorded at urban hospitals had not disclosed their HIV status to all sexual partners, and that among participants who did not disclose their status to their sexual partners, 57% used condoms less than all the time. Similarly, Singh et al. (1993) found that more than half of HIV+ men and nearly half of HIV+ women studied had not disclosed their HIV status to a sex partner in the previous six months. Among those who reported practicing unprotected anal or vaginal intercourse during their most recent sexual encounter, 57% of men and 71% of women had not disclosed their HIV status to that partner. 59% of men and 60% of women reported that their most recent partner with whom they had unprotected intercourse was not known to be HIV+. Wenger et al. (1994) reported that 22% of HIV+ study participants stated that their last partner was known to be HIV negative or that they did not know their partner's status, and that they had had unprotected vaginal, anal, or oral sex with that partner. Among those whose partners were HIV negative, 24% of the partners were unaware that the subject was HIV+, while 41% of partners of unknown status were aware that the subject was HIV+. Another study showed that 23% of HIV+ subjects reported not using a condom with a person to whom their status was not disclosed (Niccolai et al. 1999).

3. Analysis of the problem

Non-disclosure of infection is deemed a criminal act in some countries even if sex is reported to be consensual. Intentional transmission of the virus also occurs through unconsensual sex by intimate partners and/or strangers, through prostitution, through the sales of infected blood for money, through syringe sharing among drug addicts, through biting and scratching by HIV+ persons, and through homosexual transmission among prison inmates (Human Rights Watch 2001). However, not much is being done in legal terms. For instance, a survey on HIV transmission prosecutions in USA is given by Bray (2003). In rape cases, the female gender is the target (ref. to Outwater et al. 2005 for violence, sexual abuse and intentional transmission of AIDS to women in South Africa) whereas in consensual sex and prostitution both genders become victims. Cases of deliberate syringe injection may target both passers-by who are subjected to robbery and security people who wish to enforce the law. Transmission through syringe injection and biting might usually target security people and others while settling disputes physically. Bray (2003) analyzes 316 cases from USA and arrives at the conclusion that prosecutions are few and they are not likely to serve the public health purpose of reducing HIV transmission from those who know they are infected.

An on-line survey conducted by UKC (UK Coalition of People living with HIV and AIDS) suggests that prosecution or criminalization of HIV transmission would not induce HIV disclosure. This view is also shared by some others (Kenney 1992, Hermann 1990). However, all parties agree that more stringent legal actions should be adopted against rape crimes (whether the crime is committed by an intimate partner, husband or stranger) in order to reduce HIV transmission. The latter is important in developed countries (Maman et al. 2000) as well as developing ones (Jewkes and Abrahams 2002) where sexual abuse is common and socio-economic and sexual empowerment of women is weak.

The goal in developing a cross-impact matrix here is to predict the effects of intentional transmission on the spread of HIV so that a discussion can be started on how to develop policies that induce openness about the HIV+ status of individuals. Once the outputs of the model become known with available data, intervention policies may be developed by societal problem handling methods such as COMPRAM (DeTombe 1994, 2003). A logical outcome of a widespread survey conducted with this purpose might have very beneficial outcomes. For instance, in developing countries, healthcare workers have particularly great risks of exposure to infectious diseases because of lack of good hygiene practices. These missing hygiene practices often endangered other patient and their relative's health. In some countries, government hospitals automatically run the HIV scan for patients who apply for other blood tests. However, it is not clear in practice how those spotted with the infection are followed up by treatment. Different countries have different schemes in preventing infectious diseases prevalent in their areas. For instance, a simple measure that works in the prevention of Tuberculosis (TB) in Turkey is to ask persons who apply for jobs to be X-rayed for TB. These simple policies help in prevent the spread of such diseases.

Here, we intend to analyze the phenomenon of intentional transmission of HIV/AIDS and its correlation to attributes related to the virus carrier and his/her community including family members, work colleagues and healthcare infrastructure. A CIA is proposed here to study the behavior of HIV+ persons with respect to the disclosure of their status. In this method, the cross impact among attributes can be measured by pairwise correlation analysis. These parameters are then fed into difference equations that change the level of variables throughout simulation iterations. The significance of intentional infection transmission rates due to various sources can then be identified and analyzed.

In the model proposed here, basic entities and their relationships with the behavior of HIV+ persons are described, and a list of attributes are provided. A partial cross impact matrix that conveys information on the influence of one variable over the other is illustrated using qualitative judgment. Then, the equations to be used in simulating the system using the cross impact matrix are described. Finally, the data requirements for the model are summarized along with a questionnaire to collect the data.

4. The cross impact method and system definition for intentional transmission and spread of HIV/AIDS

A CIA is one of the most popular systems thinking approaches developed for identifying the relationship among the variables defining systems. We first describe the steps to be followed for understanding and building a systems model.

4.1. Definition of the system

Systems are made of entities, which interact with each other and produce some outputs, which are either designed or natural. A system receives inputs and converts them through a process and produces outputs. All the outputs of a system need not be desirable. In the present context, the system represents the intentional transmission of HIV/AIDS.

a. Environment

Every system functions in an Environment, which provides inputs to the system and receives outputs from the system. In our context, the Environment is the society.

b. Structure

All systems have a Structure. The ‘body’ of a system’s structure is represented by the entities of the system and their interrelationships or linkages or connections. The entities in our system are defined as follows.

1. HIV+: Informed and disclosing HIV+ patient,
2. FM: Family Members of HIV+ patient,
3. WC: Work Colleagues of HIV+ patient,
4. HI: Healthcare Infrastructure, i.e., hospital, clinic, lab facilities used by HIV+ patients in the sample,
5. OI: Other Infrastructure, i.e., barber shops, public facilities, and so on used by HIV+ patients in the sample where the disease might be contracted, and
6. LC: Local Community in which HIV+ patient lives.

c. Linkages

The linkages among entities may be physical (e.g., sexual contacts, medical equipment, syringes and so on), electro-magnetic (e.g., electrical, electronic and communications systems, and so on), and information-based (e.g., mass communications systems, legal systems, and so on). It is important to try and understand, what linkages make the system’s structure, which entities are linked with each other, and the implications of these linkages on the behavior of the entities in particular. The entity relationship diagram of the system is transformed into a matrix for better illustration of relationships among the entities identified above. Exchange of matter, information and/or spirit between two entities causes a change in the state of both entities. This is reflected as system behavior.

In our context, three types of linkages exist. These are listed below and tabulated in Table 1.

a. Contact : Physical (implying constant intimacy, sharing an apartment, and so on),

b. Visit : Physical (occasional contact/usage),

c. Influence : Psychological.

	HIV+	FM	WC	HI	OI	LC
HIV+	-	Contact / Visits	Contact / Visits	Visits/Inpatient	Visits	Influence
FM		-	Contact / Visits	Visits/Inpatient	Visits	Influence
WC			-	Visits/Inpatient	Visits	Influence
HI				-	Visits	Influence
OI					-	Influence

Table 1. Entity relationship matrix for intentional transmission and spread of HIV/AIDS.

4.2. System entities and relationships equations

The dynamic change of the system state is referred to as system behavior. The state of a system is an instantaneous snapshot of levels (or, amounts) of the relevant attributes (or, characteristics) possessed by the entities that constitute the system. In all systems, every entity possesses many attributes, but only a few attributes are 'relevant' with reference to the problem at hand. Some attributes are of immediate or short-term relevance while others may be of relevance in the long run. The choice of relevant attributes has to be made carefully, keeping in mind both the short-term and long-term consequences of solutions (decisions). All attributes can be associated with given levels that may indicate quantitative or qualitative possession.

The set of attributes identified for the model are given below.

Entity 1. HIV+ Patient:

1.1. Level of income.

1.2. Level of awareness related to viral transmission channels.

1.3. Level of anti-social attitude and intentional harming potential (records of vandalism, psychological disturbances and aggressive behavior exhibited in public, and so on).

1.4. Level of criminal record (non-existence of, or, if existent, then the number of crimes and their types, imprisonment).

1.5. Level of education.

1.6. Level of sexual activity pattern, duration and type of relationships (homosexual/heterosexual).

1.7. Usage of common drug syringes.

1.8. For females: Level of empowerment in sexual relationships (ability to avoid unconsensual and unsafe sex with intimate partners, husbands).

1.9. Level of good family relationships (living with family, or, frequency of visits).

1.10. Frequency of unsafe sexual intercourse and disclosure or non-disclosure patterns.

Entity 2. Family Members (FM):

2.1. Level of income.

2.2. Level of awareness related to viral transmission channels.

2.3. Level of psychological and financial support for family members with HIV+.

2.4. Level of education.

2.5. Usage of common drug syringes.

Entity 3. Work Colleagues (WC):

3.1. Level of income.

3.2. Level of awareness related to viral transmission channels.

3.3. Level of competition and professional aggression.

3.4. Level of social conscience (e.g., involvement in social aid activities).

3.5. Level of education.

3.6. Usage of common drug syringes.

3.7. Level of exposure to previous infection cases.

Entity 4. Healthcare Infrastructure (HI):

4.1. Level of sterility.

4.2. Level of facility maintenance.

4.3. Level of facility usage.

4.4. Level of healthcare worker awareness.

4.5. Level of negligence and sloppy behavior at work.

4.6. Level of support and acceptance for HIV+ patients with known status.

4.7. Frequency that the facility accepts HIV+ patients.

4.8. Annual volume of patients treated by the facility.

Entity 5. Other infrastructure (OI):

5.1. Level of sterility.

5.2. Level of facility maintenance.

5.3. Level of facility usage.

5.4. Level of operator awareness for infectious diseases.

Entity 6. Local Community (LC):

6.1. Level of awareness of HIV infection and AIDS.

6.2. Level of community solidarity and compassion.

6.3. Level of taboo in the community – conservatism caused by religion and other social factors.

When entities interact through their attributes, the levels of the attributes might change, i.e., the system behaves in certain directions. Some changes in attribute levels may be desirable while others may not be so. Each attribute influences several others, thus creating a web of complex interactions that eventually determine system behavior. In other terms, attributes are variables that vary from time to time. They can vary in an unsupervised way in the system. However, variables can be controlled directly or indirectly, and partially by introducing new intervention policies. However, interrelationships among variables should be analyzed carefully before introducing new policies.

The following conjectures are valid in the systems approach (the following subsection is motivated from Julius 2002).

a. Modeling and forecasting the behavior of complex systems are necessary if we are to exert some degree of control over them.

b. Properties of variables and interactions in large scale system variables are bounded such that:

i. System variables are bounded. It is now widely recognized that any variable of human significance cannot increase indefinitely. There must be distinct limits. In an appropriate set of units these can always be set to one and zero.

ii. A variable increases or decreases according to whether the net impact of the other variables is positive or negative.

iii. A variables response to a given impact decreases to zero as that variable approaches its upper or lower bound. It is generally found that bounded growth and decay processes exhibit this sigmoidal character.

iv. All other things being equal, a variable (attribute) will produce greater impact on the system as it grows larger (ceteris paribus).

v. Complex interactions are described by a looped network of binary interactions (this is the basis of cross impact analysis).

With these conditions in mind consider the following mathematical structure. Since state variables ($x_i(t)$) are bounded above and below, they can be rescaled to the range zero to one. Thus for each variable we have

$$0 < x_i(t) < 1, \text{ for all } i = 1, 2, \ldots, N \text{ and all } t > 0 \qquad (1)$$

where, $x_i(t)$ is the level of variable i in period t.

To preserve boundedness, $x_i(t + \Delta t)$ is calculated by the transformation

$$x_i(t + \Delta t) = x_i(t)^{P_i} \qquad (2)$$

where the exponent $P_i(t)$ is given by

$$P_i(t) = \frac{1 + \frac{\Delta t}{2} \sum_{j=1}^{N} (|\alpha_{ij}| - \alpha_{ij}) x_j}{1 + \frac{\Delta t}{2} \sum_{j=1}^{N} (|\alpha_{ij}| + \alpha_{ij}) x_j}. \qquad (3)$$

where α_{ij} are matrix elements giving the impact of variable x_j on x_i and Δt is the time period of one iteration of the system's simulation.

Equation (3) guarantees that $P_i(t) > 0$ for all $i = 1, 2, \ldots, N$ and all $t > 0$. Thus the transformation (2) maps the open interval (0, 1) onto itself, preserving boundedness of the state variables (condition 1 above). Equation (3) can be made somewhat clearer if we write it in the following form:

$$P_i(t) = \frac{1 + \Delta t \,|\text{sum of negative impacts on } x_i|}{1 + \Delta t \,|\text{sum of positive impacts on } x_i|}. \qquad (4)$$

The rate of change in the level of an attribute is defined as:

$$\frac{dx_i}{dt} = -\sum_{j=1}^{N} \alpha_{ij}\, x_j(t)\, x_i(t) \ln(x_j(t)). \qquad (5)$$

5. Simulating the system using cross impact analysis

There are four steps to follow while implementing the CIA in our case. We should first conduct the simulation by considering HIV+ patients who do not disclose their status. Then, we can either conduct the same analysis for HIV+ patients who disclose their status or we can compare the first simulation with the current rate of transmission in the system including all patients. Hence, we can measure the impact of intentional transmission on the total system state. The four steps of model construction are explained below.

Step 1. Set the initial values to identified attributes.

Step 2. Build a cross impact matrix with the identified relevant attributes. Summing the effects of column attributes on rows indicates the effect of each attribute in the matrix. The parameters α_{ij} can be determined by creating a pairwise correlation matrix after collecting the data, and adjusted by subjective assessment. In Table 2, qualitative impacts are quantified subjectively. Qualitative impacts can be extracted from a questionnaire data set. The rates of intentional spread of HIV/AIDS through various sources and among population segments become visible by running the simulation model. An exemplary partial cross-impact matrix with the attributes listed above is illustrated in Figure 1.

Representation of Impact	**Value**	**Description**
++++	0.8	Very strong positive effect
+++	0.6	Strong positive effect
++	0.4	Moderate positive effect
+	0.2	Mild positive effect
0	0	Neutral
_	-0.2	Mild negative effect
_ _	-0.4	Moderate negative effect
_ _ _	-0.6	Strong negative effect
_ _ _ _	-0.8	Very strong negative effect

Table 2. Impact rates of variables (attributes).

		HIV +									
		Income	Awareness	Psychology	Criminal	Education	Sex partners	Syringe drug	Empowered	Family	Unsafe sex
HIV+	Income	*	0	-	- -	+ + +	0	+	+ + +	0	0
	Awareness		*	0	0	+	- - -	- -	0	0	- - -
	Psychology			*	+ +	-	+ +	+ + +	0	- - -	+ +
	Criminal				*	-	+ +	+ + +	0	- - -	+ +
	Education					*	-	-	+ +	+	- - -
	Sex partners						*	+ +	- - -	- -	+ + +
	Syringe drug							*	- -	- - -	+ +
	Empowered								*	0	- - - -
	Family									*	0
	Unsafe sex										*

Figure 1: Partial Cross Impact matrix

Step 3. Simulate the system for '*m*' iterations and tabulate the behavior of each and every attribute in each every iteration. Plot the results on a worksheet.

Step 4. Identify a policy variable to achieve the desired level or state and augment the cross impact matrix with this policy variable with qualitative assessment of pairwise attribute interactions. Observe the system for '*m*' iteration, and check if the desired state is achieved by introducing the policy variable. Compare the results.

6. Data acquisition: A Questionnaire

The cross impact systems model requires data from an unbiased sample of the community including HIV+ individuals from all income, education, profession and age categories so as to represent a wide diversity. Among HIV+ patients, both disclosing and non-disclosing patients should constitute the sample set for the first system simulation. Some of the personal information related to these patients (frequency of changes and duration of sexual partners, family relationships-frequency of contact, and empowerment of women in sexual intercourse) can be obtained only by conducting personal surveys from anonymous patients or by mining published data from various studies those includes psychological studies on HIV+ individuals, and so on in literature. In fact, this questionnaire is designed to obtain the information needed for the scenario model that may serve as an instrument for decision-making and an improvement of living conditions.

The questionnaire is by no means designed to invade someone's private sphere and we do not intend to criminalize anyone. Such a sample survey is given below.

HIV INFECTED PATIENT SURVEY

Patient Data:

1. What is your age?
2. What is your gender?
3. Are you married, couple or single?
4. Are you blue or white collar worker, businessman, free lance or unemployed? (Special clause: Student)
5. Do you live in your own rental or own house? If no, specify.
6. How would you rate your income level?
    a. Below poverty level.
    b. Just above poverty level.
    c. Medium level with occasional entertainment, holiday budget.
    d. High income level.
7. Do you have living close family members with whom you are in contact? If so, specify the relationships: frequent, occasional, rare contact.
8. Do you have financial support from any family members?
9. Are any of your family members informed of your HIV+ condition?
10. Are you heterosexual, bisexual or homosexual?
11. Are you a needle user? If so, since when? Do you share needles?
12. What is your level of education? (primary, high school, university degree, graduate education)
13. Have you been convicted or accused of any crime in the past?
14. If your answer is positive to Question 13, please classify your past crimes. (delinquency, theft, murder, assault, rape, sexual harassment)
15. When were you first identified as HIV+?
16. Do you know who infected you with HIV? If so, classify the relationship you had with that person. Did the person announce to you that he/she had HIV after or before you had sexual intercourse?
17. Did you have a blood transfusion before getting infected and identified with HIV?
18. Did you request for HIV testing or were you automatically scanned by government health system?
19. Were you aware of virus contraction channels before you were infected with the virus?
20. For how long have you been HIV asymptomatic?
21. Have you frequently or chronically been affected by any of the following symptoms:
    a. chronic oral or vaginal thrush (fungal rash or spots),
    b. recurrent herpes blisters on the mouth or genitals (cold sores),

    c. ongoing fever,
    d. persistent diarrhea,
    e. weight loss.

22. If your answer is positive to Question 21, then since when did you start showing these symptoms?
23. During the time when you felt healthy and asymptomatic, did you have sexual or oral intercourse without informing your partner?
24. How frequent were your sexual intercourses? How often did you disclose your infection to your partner?
25. How frequent did you have oral sex? How often did you disclose your infection to your partner?
26. During the time mentioned in Question 23, how often did you change your partner? (or, how many different partners have you had?) How many were uninformed about your condition?
27. Regardless of whether your partner was informed or not, did you have protected sex? How often did you have unprotected sex?
28. What is the expected number of professional sex workers you have had intercourse with or oral sex with during your asymptomatic phase? Did you inform them?
29. Based on your responses to Questions 16, 21-28, what is the expected number of people that you put in danger of infection during your asymptomatic phase whether or not they were informed?
30. Do you have children? If yes, how many? Are any of your children infected? Did you have a child after you were identified as HIV+?
31. Did you donate blood after you were identified as HIV+? If yes, how often did you do that?
32. Did you visit any health institute after you were identified with HIV? If so, have you informed healthcare workers about your condition before being accepted to a hospital or day clinic? How often did you visit a healthcare institute or a doctor without informing them of your condition?
33. Do you know any persons who have been infected through you by sex or by syringe?

Family Data:

1. Please classify the education levels of your parents and brothers/sisters.
2. How many brothers/sisters do you have?
3. Are your family members fully informed of HIV transmission channels?
4. Explain how often you meet with your family members and if they support you in spells of bad health and morale?
5. Are there any other HIV+ patients among your close kins? If so, is there viral transmission among family members? If such transmission exists, explain the transmission channel.
6. Do you share syringes with any of your family members?

Work Environment Data:

1. How do you rate your relationships with your colleagues at your workplace?
2. Are your colleagues informed about your condition?

3. Has there been any stigmatizing or discriminatory behavior at the workplace after disclosure?
4. Are your colleagues supportive of patients with infectious diseases and of causes that require social empathy?
5. Are there any other infected patients in the work place?
6. Is the work environment competitive? Do colleagues compete for each other's duties and jobs?
7. What is the level of education of the manager and peers?
8. Are there any drug users among your colleagues and do you share syringes? If so, how often?
9. What is the general level of income among your peers?

<u>Healthcare Infrastructure Data</u>:

1. When you were first informed by a healthcare official that you were infected with HIV, what was your reaction?
2. Did all labs where you had blood tests execute the HIV detection test automatically?
3. Did those particular personnel who informed you about your condition report you as an HIV carrier to the authorities? Were you asked to sign any forms related to your condition?
4. Did the healthcare officer who informed you guide you to a public or private hospital where you should attend regularly for check ups?
5. How often have you visited a hospital after you were informed? How often have you been an inpatient as an informed patient? Have you disclosed your condition each and every time? If not, did you get away with it without being noticed?
6. Do you have a permanent healthcare clinic that pursues your treatment?
7. In general, have you noticed sloppy behavior on the part of nurses and technicians who take your blood, in terms of using new syringes, protective gloves, etc.? Have you encountered any accidental blood contamination while dealing with syringes or catheters?
8. Have you had surgery after you were informed?
9. Did any doctor, clinic or hospital deny you treatment after your disclosure of your condition? If so, have you taken legal action against it?
10. Do the hospitals you visit take extra caution on used equipment such as oxygen mask, toilet facilities, and so on after your disclosure? In particular, do you have access to a special AIDS clinic?
11. Have you had emergency situations where you were taken to the hospital but unable to disclose your condition?

<u>Other Infrastructure Data</u>:

1. How often do you visit a barber's shop, a manicure-pedicure facility, a public recreation facility such as a Jacuzzi, hot bath, and pool?
2. Do any of these facilities request infection detection tests including HIV before members start using them?
3. Have you been denied entry to any such facility after disclosure?
4. If so, have you found other facilities that serve the needs of HIV+ patients?

<u>Community Data</u>:

1. Have you disclosed your condition to the community of friends and neighbors you live among?
2. Is community you live is in stigmatize HIV+ patients?
3. If so, is this discrimination/isolation policy a result of strong religious beliefs or a result of the fear of contracting the disease?
4. How educated is the community you live in? Is HIV/AIDS a taboo subject or is it taught in schools? Do parents receive any education on sexually transmitted diseases (STDs)?
5. Does your community have a private social aid committee or does it depend only on government sources for helping the unemployed and sick?
6. Have you been forced to move out of your neighborhood after the disclosure of your condition?

The information extracted from the questionnaire can be converted into meaningful qualitative and quantitative impact factors after being normalized. Then, the initial values for the attribute levels x_i (0) can be set accordingly. Once initial attribute levels are determined from the data and cross impact parameters α_{ij} are calculated, the model is simulated for HIV+ patients who do not disclose their status to their partners and immediate community, and for those who do. These simulations illustrate the effects of intentional transmission of HIV+ over time. The rate of the epidemic's spread under non-disclosure can then be compared with the known general rate of spread in that environment and its significance can be determined in the total transmission rate.

7. Generalizations of the dynamical system

The approach proposed in this paper is a pioneering one. It employs methods of operational research and, in particular, the model based approaches of mathematics, as expressed by systems theory and dynamical systems. This led us to the model which we introduced in Section 4.

This is a system of nonlinear ordinary differential equations. However, in the sensitive domain which this paper investigates, there are some additional phenomena in the time dependence of the system. In fact, on the one hand there are *delays* and further inclusions of the system's *memory* (dependence on the past). Let us give the examples of incubation times and of retardation caused by medical means and healthcare measurements which do not have a direct effect, and of a decision making which is not continuous but takes place at the beginning of individual or institutional planning periods. Furthermore, not only the first day of a given planning period has an influence at any present state but, via future plans, goals and wishes of various kinds, also the beginning of the following period or even periods. By this a so-called *anticipation* becomes included into the system. For closer information about the system's aspects and investigation in terms of delay and anticipation, we refer to the paper Akhmet et al. (2006b) which studies and integrates both memory and anticipation for the example of a generalized Malthusian model in population dynamics; a similarly motivated model can also be found in the context of this paper's theme.

In addition to memory and anticipation, also *impulsive* behaviour can be observed. For example, in medicine, the reaching and transversal of a threshold indicated, e.g., in terms of doses, of the intensity of attacks on a biological or genetic system by various kinds of deficiencies in nutrition, can lead to a collapse of the immune system of an individual. The same can be said about social communities, populations or societies and the outbreak of epidemics therein. In the fields of HIV/AIDS, impulsive behaviour can also occur depending on when salaries are paid or when holidays or feast and festivals of various kinds begin or end. For closer information on modeling, investigation and control of impulsive systems we refer to Akhmet et al. (2006a).

8. Summary and Conclusion

A cross-impact model is developed here to study the intentional transmission of HIV by non-disclosure of status in various risky situations. The cross-impact matrix illustrates the influence of one variable over the others and it also has a provision to identify the impact variables (i.e., policy variables) to control this epidemic. Here, we identify certain entities and attributes that might affect an HIV+ patient's attitude towards disclosure. We describe the simulation method and the data to be collected if such a model is to be executed.

Two policy variables may be proposed as intervention to non-disclosure. The first could be investing funds in improving hygiene and preventive measures in healthcare institutions. However, such a policy should be accompanied by supporting the HIV+ individuals with economic aid if they are unemployed, free access to special AIDS clinics and access to housing units where they will not be subjected to any harassment. If such policies are adopted along with special welfare access, then, the proposed cross impact matrix could be augmented with these two policy variables and re-running the simulation would demonstrate the effectiveness of intervention methods.

The proposed cross impact model enables the identification of important factors that result in non-disclosure and could invoke new intervention policies and regulations to prevent the intentional transmission of HIV/AIDS in different countries and societal environments.

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