Social, sexual network formation and HIV transmission

Presented by
Edinah Mudimu

University of South Africa

Institute for Disease modelling Symposium

16 April 2018

UNISA university of south africa

Presentation Overview

- Introduction
- Conceptual model
- Results
- Conclusion

Introduction

- Approximately 6 000 new HIV infections occur globally each day, two of three are in sub-Saharan Africa.
- In particular, South Africa accounted for one third of the region's new infections in 2016.
- Great strides have been made in developing models to model the spread of the virus.
- However gaps still exist in fully understanding the propagation of the virus in a population.

Introduction continued...

- Microsimulation models – potential to explore some of the existing gaps
- Human behaviour is one of the factors believed to be at the core of HIV/AIDS
- Model that clearly explains
  - the influence of intervention programs on human behaviour
  - dispersion patterns, and
  - spreading mechanisms of HIV.

Research objectives

- To develop an agent-based model which closely depicts sexual relationships in a context of a specific culture based on available evidence.
- Validation of the model by comparing model results with available statistics.
- Superimpose HIV transmission process on the sexual network model and evaluate how the structure generated facilitate or limit HIV transmission.

Why Study in South Africa???

- Demographic and socio-economic characteristics that contribute to the spread of HIV
  - Cultural aspects – rites of initiation into adulthood, cohabitation, fragile marital bonds, male dominance, *etc.*
  - Education – basic education free to all but not sufficient: results in unskilled labour and high unemployment.
  - Health system – basic primary health free to all but under staffing, poor service, lack of resources.

Why Study in South Africa continued...

- HIV risks in South Africa
  - Behavioural determinants – Multiple sexual partners, intergenerational sex, early sexual debut, inconsistent use of condoms
  - Gender based violence – patriarchy system makes women more vulnerable to sexual violence
  - Migration – on the increase since 1990. Internal and international migration,
  - STI's – HSV-2 is one of the STI's common in SA

Conceptual Model

We consider three types of human interaction networks that have a hierarchical structure

- personal network
- dating and sexual network
- marriage network

New friendship, sexual and marriage links are formed and existing ones lost during the simulation

Social Network

- Each agent is assigned a maximum number of friendship connections at creation: Weibull(5,10)

Rules used for the development of the friendship network at each time step (modified Jin et al. 2001)

1. select randomly $n_p r_0$ agents at each time step $n_p = 0.5N(N-1)$

Social network continued...

- Create a link
  IF number of connections is less than the maximum degree assigned to an agent
  AND
  IF (absolute age difference is less or equal to 5)
  agent connects to friend;
  IF (absolute age difference is between 5 and 10 years)
  agent connects to friend with α_1 probability;
  IF (absolute age difference is between 10 and 15 years)
  agent connects to friend with α_2 probability;
  IF (absolute age difference is greater than 15)
  agent connects to friend with α_3 probability;

Social network continued...

2. select randomly $n_m r_1$ agents where $n_m = 0.5 \sum_{\forall i} z_i(z_i - 1)$

   -for each agent selected connect one pair of its neighbours

3. select randomly $n_e \gamma$ agents where $n_e = 0.5 \sum_{\forall i} z_i$

   -for each agent selected remove one random connection if the connection is not romantic

Agent characteristics

- Each agent has static and dynamic attributes

  Static attributes examples:
  gender, maximum number of date and sexual partners, maximum degree for social connections

  Dynamic attributes examples:
  age, number of date and sexual partners, marital status

Some agent States

An agent may be simultaneously involved in any of the following states:

1. young (under 15 years) or an adult
2. sexually active or not sexually active
3. Married, single, divorced, widowed or widower

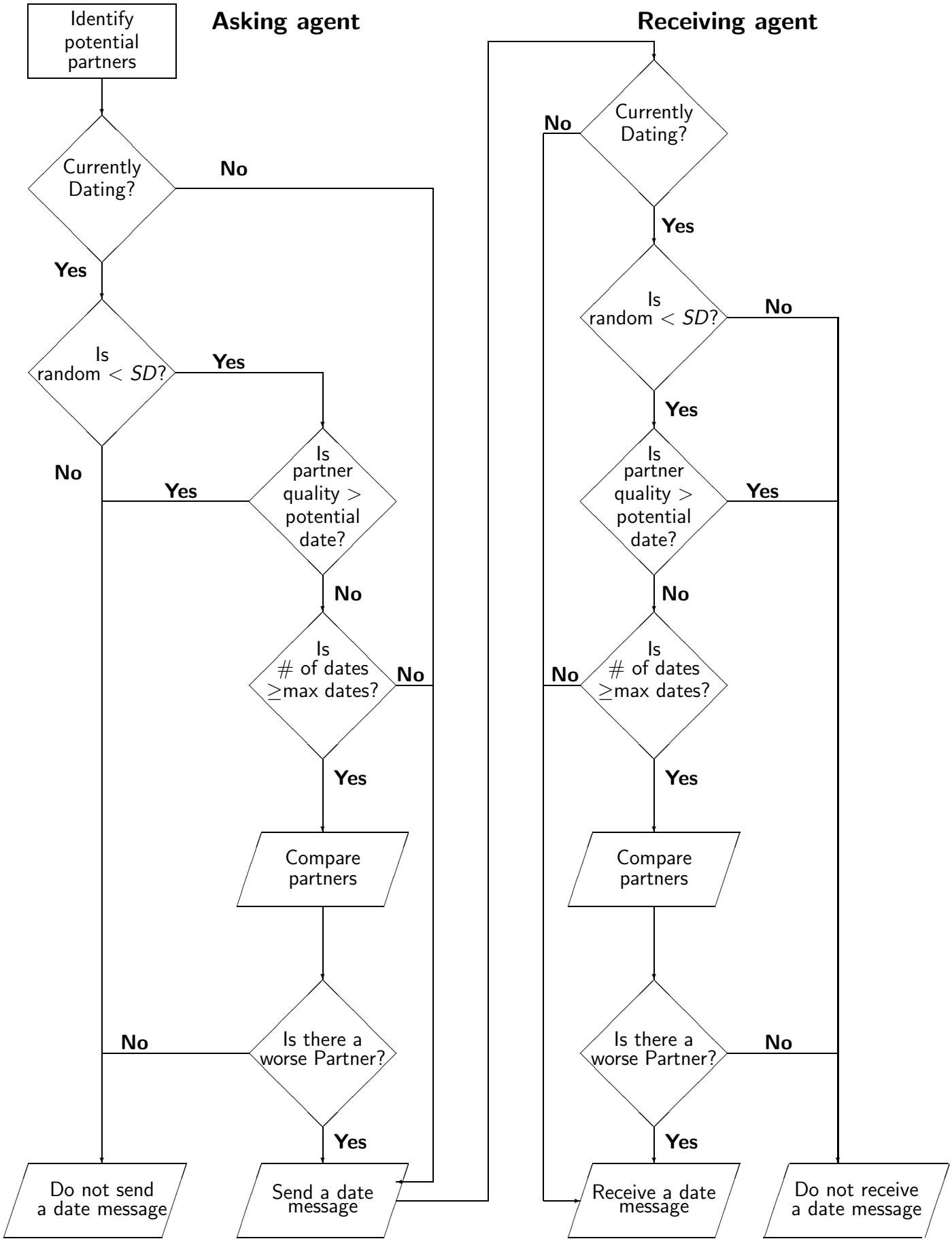
Main behaviour rules

1. Formation and breaking of friendship links
2. Dating relationship formation - an agent can send or accept one message at each time step
3. Sexual relationship formation - a decision has to be made to initiate a sexual relationship
4. Marriage rules: if not married a decision to marry must be made. If married a decision to divorce has to be made first before a moving on.

Dynamic Sexual and Marriage Network

1. Likeability index is used to search for potential partners
2. Likeability index is calculated using age, attractiveness and aspiration level.
3. Initial likeability threshold is 0.5
4. Starts to decrease when agent age is greater than mean age at first marriage

PartneringAlgorithm


Asking agent
Receiving agent
Identify potential partners
Currently Dating?
No
Yes
Is random < SD?
Yes
No
Is partner quality > potential date?
Yes
No
Is # of dates ≥max dates?
No
Yes
Compare partners
Is there a worse Partner?
No
Yes
Do not send a date message
Send a date message
Currently Dating?
No
Yes
Is random < SD?
No
Yes
Is partner quality > potential date?
Yes
No
Is # of dates ≥max dates?
No
Yes
Compare partners
Is there a worse Partner?
No
Yes
Receive a date message
Do not receive a date message

Comparing partner attractiveness/quality

1. Depends on the duration of current relationship
2. Assume two types of love: passionate and companionate

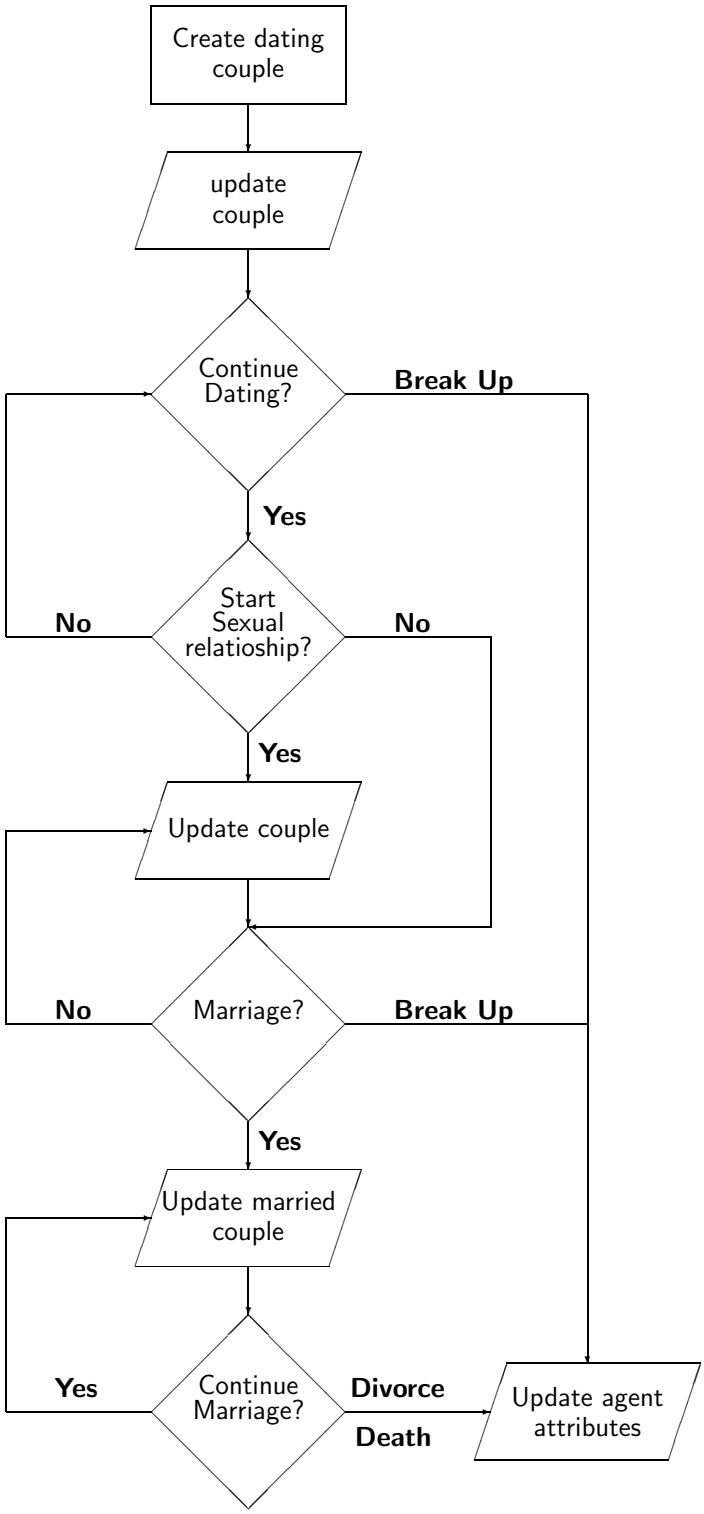
   - Passionate love develops immediately, approaches a peak fairly rapidly

   - Companionate love develop at a slower rate and usually last for a lifetime (Sternberg 2004 OR http://en.wikipedia.org/wiki/Triangular theory of love)

Couple Update

1. A dating couple is formed once a receiving agent accepts the proposal
2. A sexual relationship is initiated
   - IF a dating couple exceeds the non-sexual dating period: N(0,24,10,2) AND
   - both agents are sexually active (sexual maturity distribution 2003) AND
   - random() $>$ 0.98

- IF courting couple exceeds courtship duration the couple may decide to marry


Create dating couple
update couple
Continue Dating?
Break Up
Yes
Start Sexual relatioship?
No
No
Yes
Update couple
Marriage?
No
Break Up
Yes
Update married couple
Continue Marriage?
Yes
Divorce
Death
Update agent attributes

Child-birth procedure

- Child birth is dependant on the social and sexual network
- Only female agents in a sexual relationship and in the child-bearing age group (15-49) can fall pregnant
- Cohabitation is common in South Africa
- Fertility is uniform through out the fertile period of a female

Child birth procedure parameters

Parameter	**Default value**	**Source**
FirstPregProb	0.01	Assumption
BirthPregProb	0.15	Assumption
Postpartum	six weeks	Catalyst (2002)
WaitingPeriod	N(6,52,26,4)	Assumption
PregDuration	N(34,42,40,1)	Kieler et al. (1995)
StopChildBirth	0,025	Assumption

Commercial sex workers

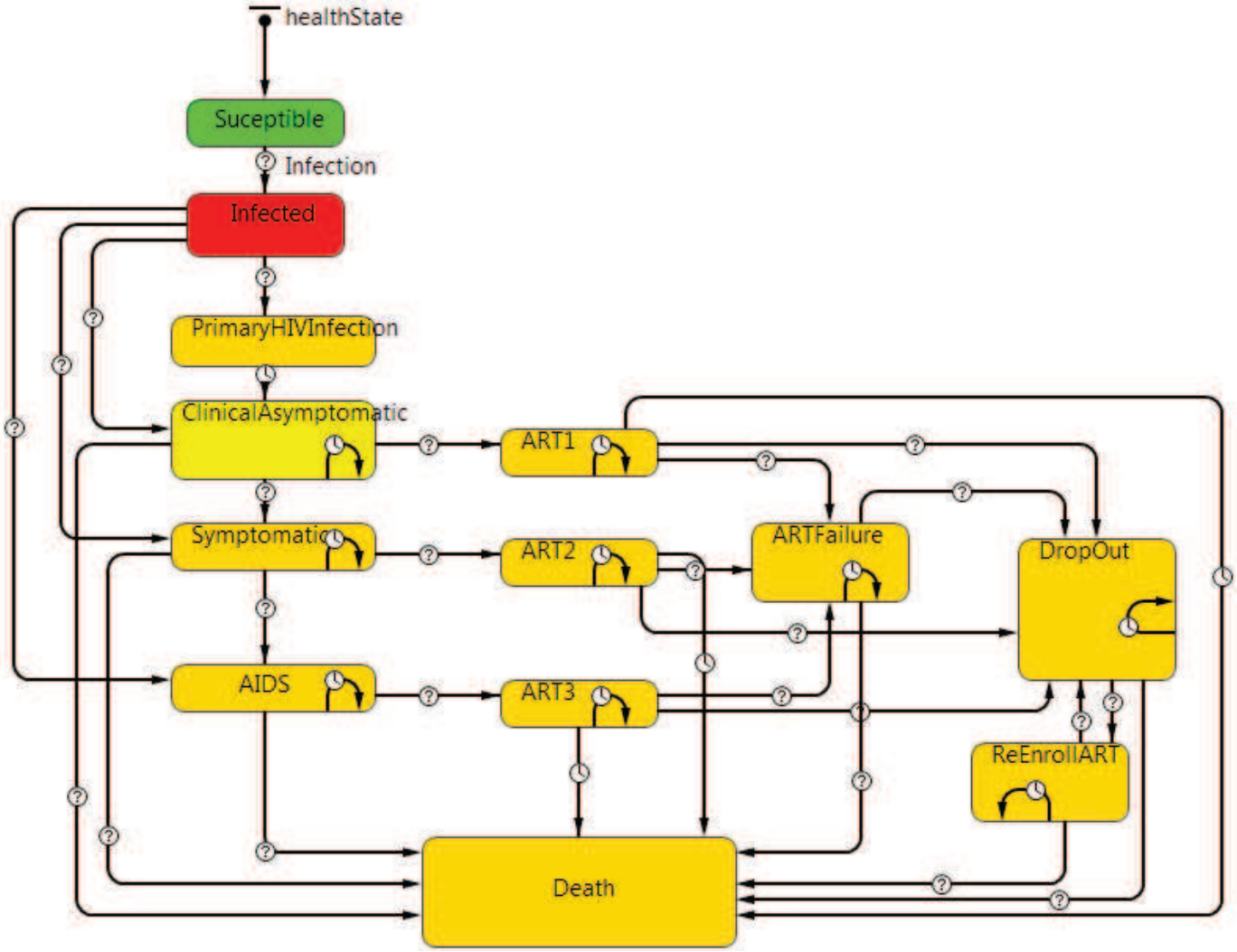
- Interaction of sex work and "normal" dynamics of sexual mixing not clear
- Direct sex work (CSW) – service offered solely for money ($\approx=$ 1% of adult female pop)
- Indirect sex work (OPSW) – service offered for gifts or favours (outside wife, roll-on $\approx=$ 5% of adult female pop)
- Clients are married or single males

Commercial sex workers continued

- Females age range – 15 to 45 years
- Career duration – Weibull(3,10)
- Number of CSW's and OPSW's in model is 1% and 3% of adult females respectively
- Males age range – 15 to 60 years
- 10% selected at each time step to visit CSW's
- No repeat visits and visits are independent

Infection transmission

- Stages of HIV infection



Infection transmission continued

- CD4 decrease $= (24.363 - 16.672f)^2$ cells/μL (Bershteyn et al. 2012)
  where f is a fraction of the total survival time sampled from the Weibull distribution.
- CD4 increase $= (15.584t - 0.2113t^2)$ cells/μL (Bershteyn et al. 2012)
  where t represents time in months since ART initiation.

Infection transmission continued

Number of coital acts per relationship type in a week

Relationship type	**Coital acts**
Courting (no concurrency)	N(1,5,3,1)
Courting (concurrency)	N(1,3,2,1)
Married (no extra-marital affairs)	N(1,7,4,1)
Married (extra-marital affairs)	N(1,3,2,1)

Infection transmission continued

HIV infection stage transmission probabilities per coital act

Stage	**Probability**	
	M to F	F to M
Primary infection	0.028	0.014
Clinical asymptomatic	0.002	0.001
Symptomatic	0.006	0.003
AIDS	0.014	0.007

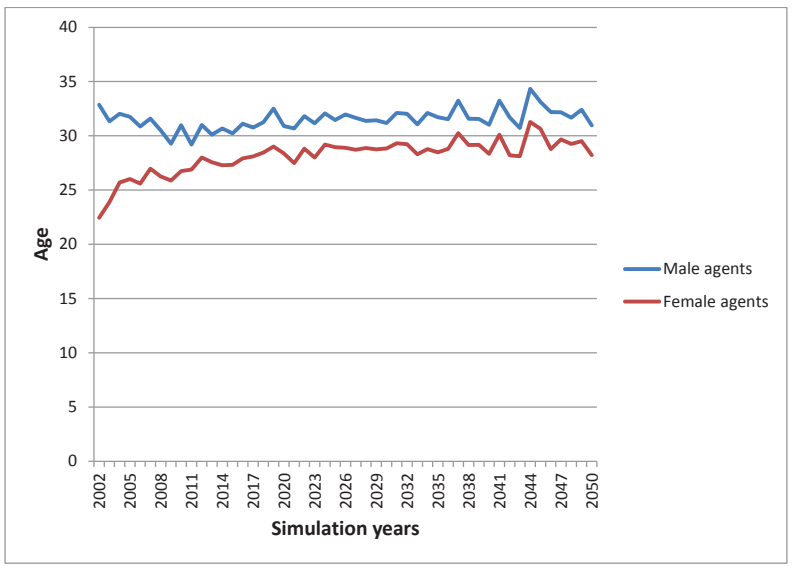
Model Initialisation

- Start date 1 January 2002, 2600 time steps $\approx$ 50 years
- Social network connections
- Married couples, couples in a sexual relationship and dating couples
- Some females have kids, waiting between kids
- Pregnant females
- HIV infected in all stages without ART

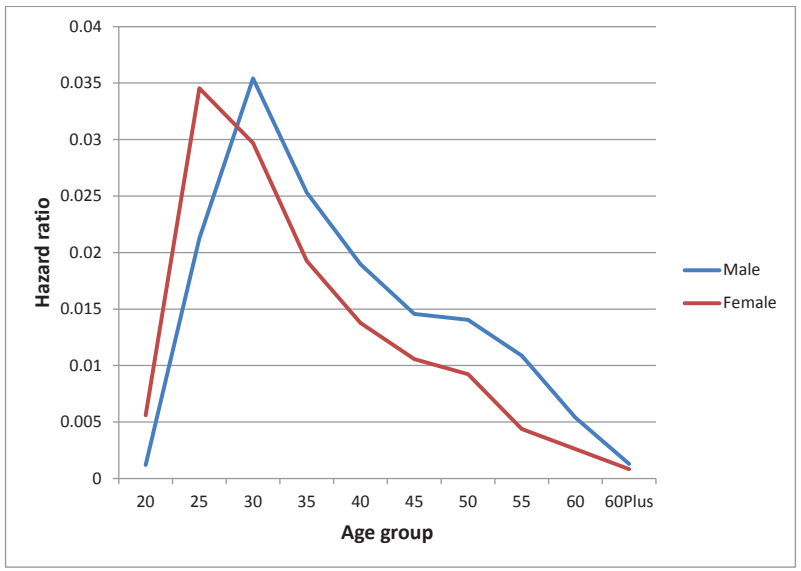
Model results

(a) Average age at first marriage – 27 and 31 years for females and males respectively

(b) Peak hazard ratio – 20-25 and 25-30 years for females and males respectively



(a)



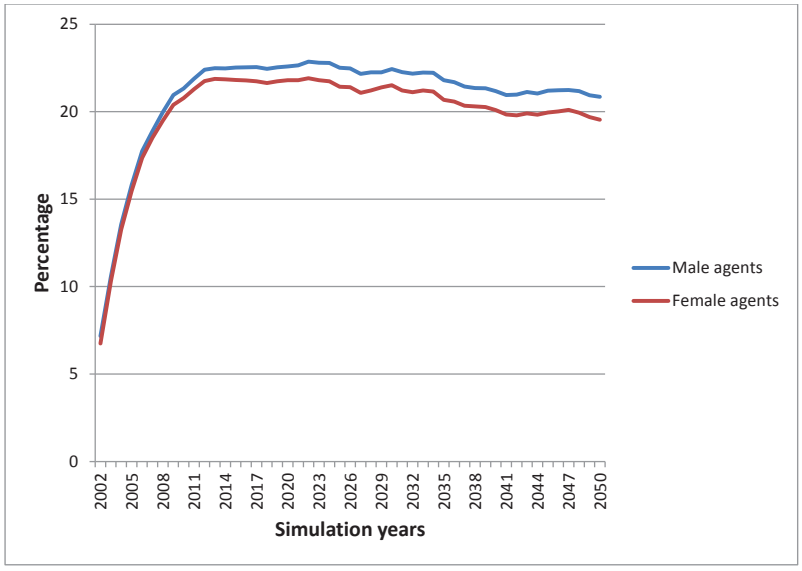
(b)

UNISA university of south africa

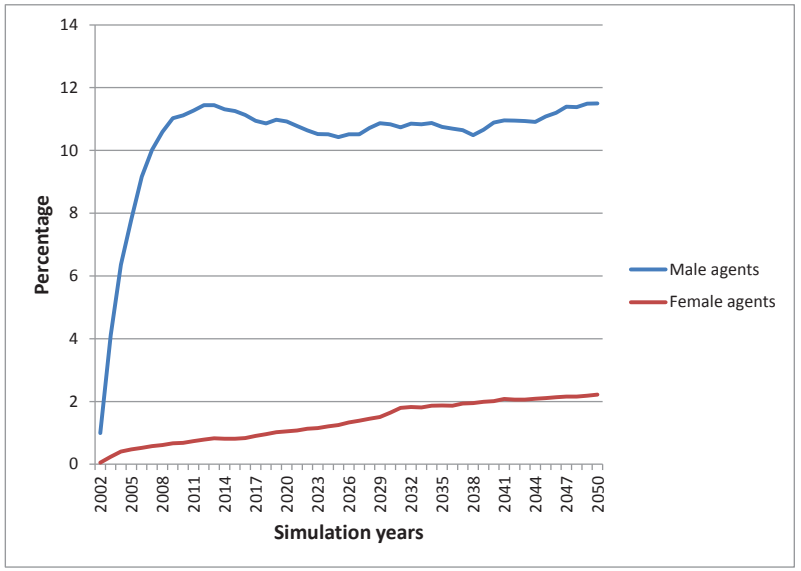
Model results continued

(a) Percentage of male and female agents involved in sexual activities outside marriage $\approx 21\%$

(b) Male and females with concurrent partners stabilises at $\approx 11\%$ and 2% respectively



(c)



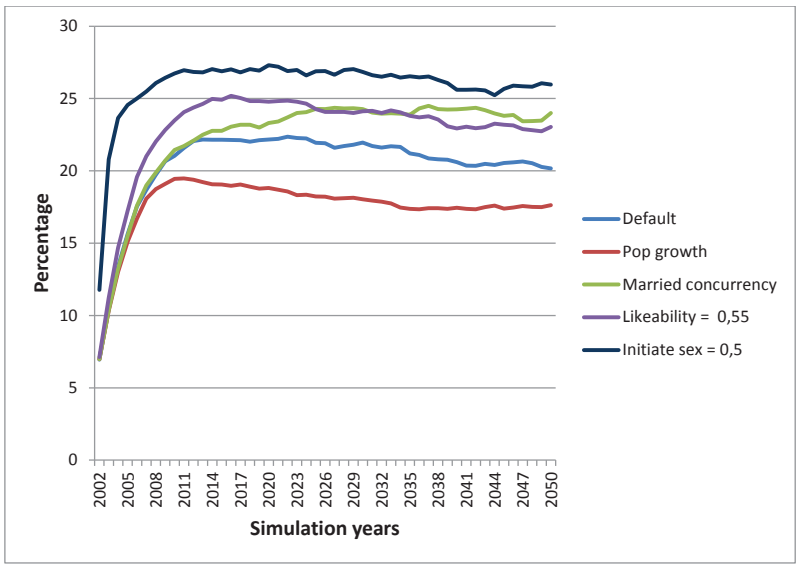
(d)

UNISA university of south africa

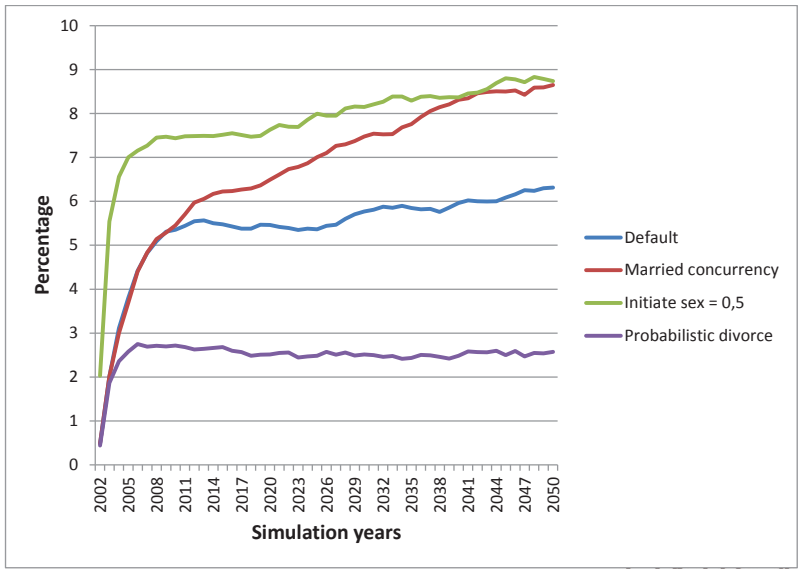
Parameter variation results

(a) Percentage of agents in sexual relationships outside marriage

(b) Concurrency levels – affected by an increase in concurrency levels for married individuals and probability to initiate sex



(e)

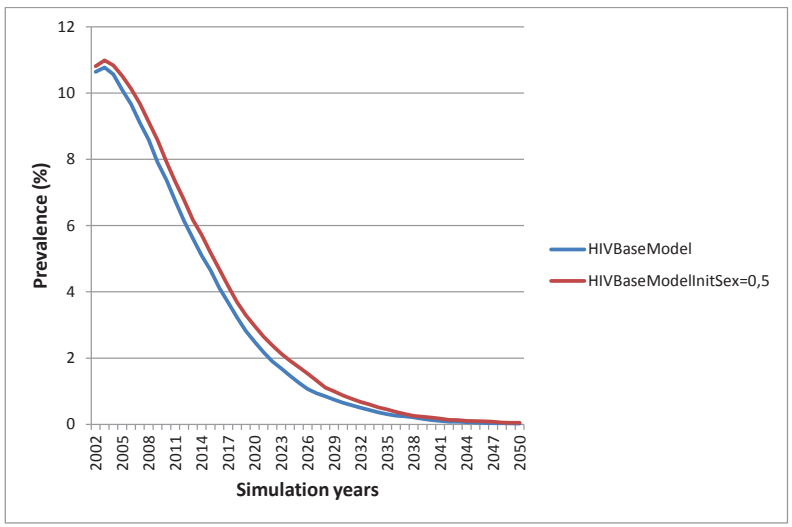


(f)

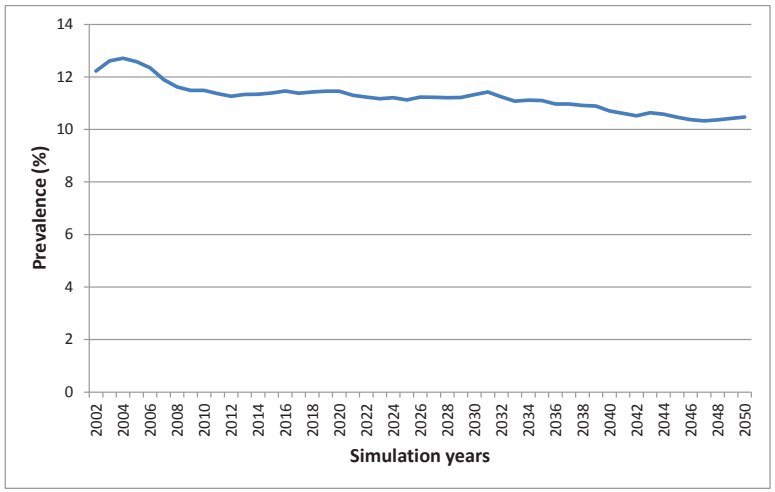
Model results continued

(a) HIV prevalence for base model (no CSWs, OPSWs and ART) - continuous decrease

(b) HIV prevalence for general simulation model (with CSWs, OPSWs and ART) - prevalence $\approx 10.5\%$



(g)



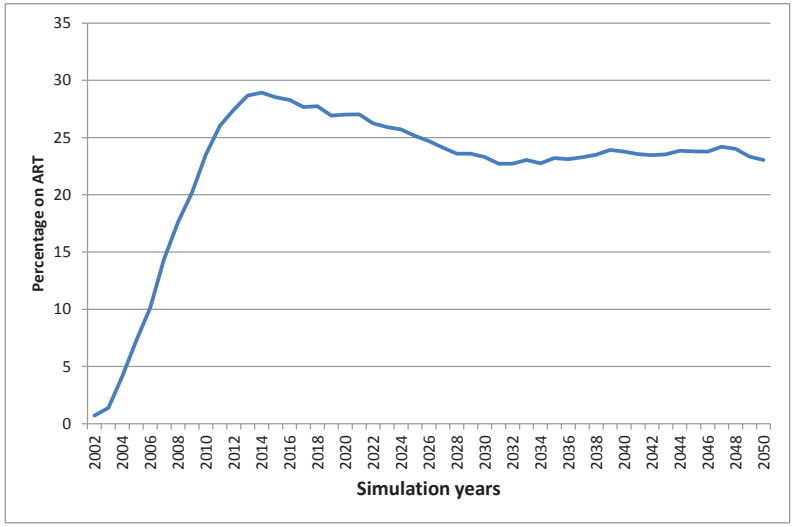
(h)

UNISA university of south africa

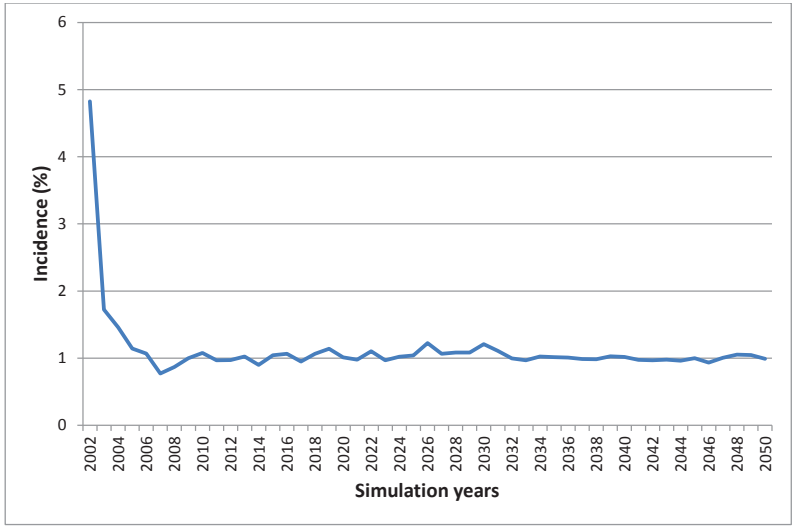
Model results continued

(a) People living with HIV (PLWHIV) on ART – there is an increase in ART uptake until 2012. Stabilises at $\approx 25\%$

(b) HIV incidence stabilises at $\approx 1\%$ 5 years from model initialisation



(i)



(j)

UNISA university of south africa

Discussion...

- Our agent-based model managed to capture important features of real world settings, however there is a need to improve on
  - the rules used to model formation of sexual relationships, child birth and the transmission of HIV
  - the parameters used in the model through calibration
- Once a model that closely resembles reality is developed researchers can use the model to
  - experiment with various intervention regimes
  - formulate strategies and policies to manage the epidemic

When we dream big, we can achieve

Michel Sidibé
UNAIDS Executive Director

UNISA university of south africa

THANK YOU!!!