A LIFETIME INDIVIDUAL SAMPLING MODEL (ISM) FOR HEROIN USE AND TREATMENT EVALUATION IN AUSTRALIA

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ABSTRACT

Illicit drug use has created an enormous burden at societal, family and personal levels. Every year a significant amount of resources is allocated for treatment and the consequences of illicit drug use in Australia and around the world. Heroin is one of the major forms of illicit drugs that are used illegally. Several independent heroin treatment strategies or interventions exist and state-of-the-art research demonstrates their efficacy and relative cost-effectiveness. However, assessing total potential gains and burden from providing all treatment interventions or varying the mix of heroin treatments has never been attempted. Furthermore, the need to include multiple treatments, multiple important outcomes, and the chaotic nature of drug dependence means cost-effectiveness studies are not able to provide evidence on net benefit of providing heroin treatments over the lifetime. Evaluations of the current mix of treatment provision remain very limited. Thus, this paper will discuss an individual level model which addresses net social benefit over a lifetime, also known as individual sampling model (ISM), that can accommodate the complexity of individuals going in and out of multiple treatments and their corresponding costs and benefits arising from different treatments during the life-course of heroin users in the context of New South Wales (NSW) Australia. This model is intended to serve as an effective tool for economic evaluation and policy making in illicit drug area in Australia.

Keywords: individual sampling model, illicit drug use, net social benefit, cost-effectiveness

1. INTRODUCTION

Governments, non-governmental organizations *(*NGOs) and International Organizations worldwide invest hundreds of billions of dollars in health care projects. Australia spends around 10% of its GDP or AUD 100 billion per year in recent years in health care (WDI, 2012). In area of illicit drug spending, Australian federal and state governments spend about AUD 1.7 billion per annum in prevention, treatment, harm reduction and law enforcement to combat illicit drugs. . Interestingly, the amount of spending and spending mix has remained relatively unchanged since 2000-2001, except there is a notable decrease in harm reduction to 2.1% (Ritter et al., 2013). There is an increasing pressure from both the government and the public to know whether the current spending is optimal or what needs to change to increase the benefits of spending. This is particularly important for complicated policies where there are many external costs and benefits, and as such; there are diverse views about the value of the projects.

Existing research demonstrates efficacy and relative cost-effectiveness for individual heroin treatments, such as pharmacotherapy maintenance. "Cost of illness" studies have estimated the total social burden related to all illicit drugs, and have been important in communicating this burden. But these studies do not provide evidence on the total potential gains from all interventions. And neither of these approaches can be used to value the net benefit, over the lifespan, of providing a system of heroin treatment interventions. There is a pressing need to demonstrate whether the existing combinations of heroin treatment interventions are a good investment for government. For this reason, this study will make a unique and fundamental contribution to the policy debate about investment in treatment mix for heroin dependence.

The aim of this study will be to assess the net social benefit of current heroin treatment strategies, and compare different combinations of treatment alternatives through modelled scenarios. This will lead to better informed policy decisions about the mix and type of treatments.

There are three original aspects to this study: 1. using a cost-benefit analysis (CBA) framework that provides a summative analysis across multiple treatment types; 2. taking a life-course perspective, which accommodates the multiple cycles into and out of treatment in a drug using career; and 3. using preference elicitation methods to quantify the economic burden to the family of the drug user, a neglected area in research to date. These unique elements require substantial

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methodological rigor. This study entails the development of a mathematical model that will be parameterised from secondary data sources.

The mathematical model needs to capture recurring events over time as well as reflect alternative trajectories for individuals who use heroin. The chosen model is a micro-simulation model, also referred to as an Individual Sampling Model (ISM). ISM depicts events and outcomes at the level of the individual. The ISM enables 'memory' for each individual of such things as the length of heroin use, past treatments and incarcerations. The model will simulate a life-course with a start age of between 18 and 24 and an end age of 60 or death, with individual paths through mutually exclusive states. The characteristics of individuals at the outset of the model will be based on age, gender, use status, and incarceration and treatment history. The time each person spends in a given state before potentially transitioning to another state will depend on these characteristics. The model will be built for one jurisdiction, NSW. This was a pragmatic decision, made based on data availability (including treatment data, outcome data and costing data) and the inability to represent different models of treatment funding which exist in other jurisdictions in Australia.

There are limitations in using micro simulations. The most important one is that the model is 'data intensive'. To represent the heterogeneity (multiple states, multiple transitions between states, multiple outcomes and costs), a large number of parameter estimations are required. Therefore it needs to be kept as simple as possible, while also representing reality.

2. LITERATURE REVIEW
ISM has been widely used to evaluate health policies and other social and economic policies in many countries. It serves as an effective tool for policy evaluation, decision making and allocation of scarce financial resources. Many large ISM models have been built in Australia and overseas. There are a number of papers that describe the basic framework of the micro simulation model in health policy evaluation (Karnon, 2003, Briggs and Sculpher 1998, Zucchelli et al., 2012, Rutter et al., 2011, Ringel et al., 2010, Harding et al., 2010). Li and O'Donoghue (2013) provide a comprehensive review of micro simulation models up to recently, as well as highlighting some current methodological issues and future research directions.
However, there are very few ISM models that have been built to specifically evaluate illicit drug treatment policies. It is noted that it is important to build an ISM specifically for a country/state due to the differences in health care financing structure, costs and benefits, as well as the substantial difference in the availability of treatment methods.

There are two models in the context of the U.S. First, RAND Marijuana Micro simulation Model models the use of marijuana over the life course in the U.S. The model follows a cohort of 12 year olds representative of the United States population in 2004.

This is a key paper in modelling of drug epidemiology over the life course (Paddock et al., 2012). Second, a paper by Zarkin et al., (2005) models the costs and benefits of methadone treatment related to heroin use, treatment for heroin use, criminal activity, labour market participation and health care utilization. This model follows 1,000,000 individuals from 18 to 60 year olds who are representative of the United States population.

Despite taking into account the life-course perspective of illicit drug use, they only evaluate a single treatment method and few states of drug use. In addition, these models make many simplifications about internal and external costs and benefits.

Another health model developed for Australian population is Australian Population and Policy Simulation Model-Health Module (APPSIM). It models the government spending on health care from 2002 to 2050. The model follows 1% of Australian population or 180,000 individuals over time. Individual characteristics such as disability, demographics, household formation, education, earnings, social security and taxation, health and aged care are estimated at any time period in the model (Lymer and Brown, 2012).

A population model, Population Health Model (POHEM), is developed for health care utilisation evolution in Canada. This is a population-based model, which takes into account a set of specific diseases and health risk factors at the individual level)Statistics Canada, 2010).

3. MODEL OVERVIEW
The ISM model for heroin use careers will create a population of individuals who ever used heroin and currently use heroin in the community and in prison. These individuals are distributed in various health/treatment states (eg, abstinence, irregular use, dependent use, various treatment and prison states). There are six model components which are to be conceptually defined, namely, initial population, states, transition matrix, transition probability, outcomes, and resource implications (these will be 'attached' where relevant to being in a given state i.e. treatment, prison, societal costs of crime).

Schematic representation of working of the proposed model is illustrated in Figure 1. The proposed model starts with the initial population of current heroin users and heroin abstainers. This population of individuals are transitioned from one health state to other using predefined (individual based) state transition probabilities. After each state transition, outcomes such as heroin use, crime committed; and resource implications are computed. This process is repeated at each time step (where time step is defined as the length of stay in each state, individually driven) until the end of simulation time period is reached. Each year, a sub-population of new drug initiators is added to the current population to include new drug users. Finally, net social benefit is computed based on the outcomes of the

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simulation model. Following section provides more detail on each of the model components.

3.1. Data Sources

The following data sources will be used to establish the initial proportions in each state, individual length of stay and the transition probabilities between states, cost/awards and outcomes estimation:

3.1.1. Australian Treatment Outcome Study (ATOS) Dataset

ATOS is a longitudinal study of entrants to treatment for heroin dependence. The study originally followed up heroin users for 3, 6 and 12 months in three Australian states (New South Wales, South Australia and Victoria), and at 24 and 36 months in NSW. The cohort consisted of entrants to all three major heroin treatment modalities: methadone/buprenorphine maintenance, drug free residential rehabilitation (RR) and detoxification as well as a group not in or not seeking treatment (Darke et al., 2007, Teesson et al., 2007).

3.1.2. MIX study dataset

MIX is a prospective cohort study of people who inject drugs (PWID) conducted in Melbourne, Victoria. Baseline interviews were conducted with 688 people over the period November 2008 – November January 2010. Data collected includes data on demographics, drug use history and market access patterns, treatment history, criminal involvement, and current psychological, social and health states were conducted with information and consent collected at baseline allows linkage to a variety of objective datasets such as the National Death Index and Ambulance Victoria's ADIS system (Horyniak et al., 2013).

3.1.3. National Opioid Pharmacotherapy Statistics Annual Data (NOPSAD)

The NOPSAD collection is an administrative by-product collection which is collated in each jurisdiction and is a census of all people receiving opioid pharmacotherapy maintenance (methadone and buprenorphine) on a typical day in a year and provided to Australian Institute of Health and Welfare (AIHW). Data in the NOPSAD collection relate to a 'specified/snapshot' day, usually in June (AIHW 2013a). On this day the number of clients is counted for the NOPSAD collection permitting the number of clients to be estimated at a single point in time. The snapshot day varies slightly between states and territories, however is usually 30 June.

3.1.4. Alcohol and Other Drug Treatment Services National Minimum Data Set (AODTS-NMDS treatment data)

The AODTS-NMDS captures the number of closed treatment episodes in government funded alcohol and other drug treatment services across Australia. This number does not equate to the total number of people in Australia receiving treatment for alcohol and other drug use. The current collection methodology does not identify when a client receives multiple treatment episodes in the same or different agencies, either concurrently or consecutively (AIHW 2013b website).

3.1.5. Other datasets

Other datasets that will be used in the model development are: Australian National Drug Strategy Household Survey; Drug Use Monitoring Data; NSW Prisoners Health Survey; Bureau of Crime Statistics and Research crime data; Australian Bureau of Statistics data; and National Coronial Information System data.
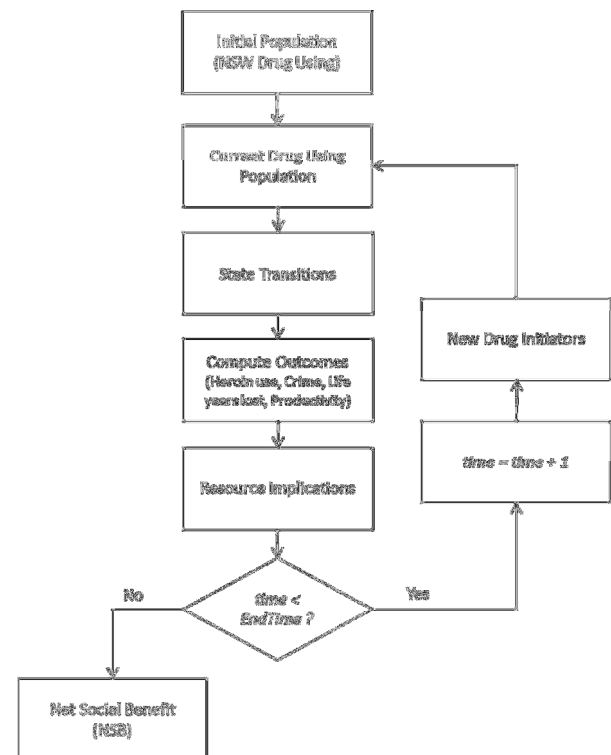

Figure 1: Conceptual working of proposed model

3.2. Model Components

3.2.1. Initial Population

The initial population in the current model is the estimated current NSW heroin using population. This will include those currently abstinent, those in treatment subgroups as well as those currently in the heroin using subgroup. The characteristics of the initial population are age, gender, among others; which will be obtained from various data sources. Once the initial cohort is defined across the various modelling states, there will be subgroup of new initiates which will be introduced every year into the simulation run.

The individual attributes/characteristics are:
- Age: starting with 18 to 60 years spread
- Gender: male or female
- State: current state
- Opioid use history
- Incarceration history
- Treatment history

This initial population is evolved over the lifetime to model and record the transitions from one state to

another which represent discrete events in the ISM simulation model.

3.2.2. States

In the proposed ISM, we have used two types of states – drug using state, and treatment states. For the drug using states (in the absence of treatment) we have selected 3 states - i) abstinence; ii) irregular use; iii) regular/dependent use. For the treatment states, we have included four mutually exclusive states – i) withdrawal from heroin (at this stage not withdrawal from methadone); ii) Residential rehabilitation (RR); iii) Pharmacotherapy maintenance (Opioid Treatment Program (OTP)); and, iv) counselling only.

In addition to these states, we have also considered the three important locations (stages) in the drug using individual's trajectory such as i) in community, ii) in prison; and, iii) death stage. The first two stages are considered in this study to model the cost, benefit and treatment variations in drug using population. Exit from the model occurs if alive at age 60, death from drug related or non-drug related causes. Hence the total number of states is provided in Table 1. It should be noted that we have used only one treatment state in the prison stage. This is due to the fact that we do not have sufficient in-prison treatment data to be able to distinguish transition probabilities between all the different prison treatment states. For this reason, we have simplified prison treatment down to one state.

Table 1: Total number of states when combined with stages

State Name	Stage
Abstinence (S1)	COMMUNITY
Irregular use (S2)	COMMUNITY
No Treatment & Use (S3)	COMMUNITY
Withdrawal (S4)	COMMUNITY
Residential rehabilitation (S5)	COMMUNITY
Pharmacotherapy (OTP) (S6)	COMMUNITY
Counselling Only (S7)	COMMUNITY
Abstinence (S8)	PRISON
No Treatment & Use (S9)	PRISON
Treatment (S10)	PRISON
Drug related (Death) or 60+ years old (S11)	DEATH
Non-Drug related (Death) (S12)	DEATH

The descriptions of each of the model states are:

In community Stage:

Abstinence: individuals in this state are not using heroin but have used heroin at some previous time.

Irregular use: individuals in this state use heroin irregularly, as defined as less than weekly or "weekly or less" (as compared to 'more than weekly but not daily").

Not in Treatment & Use: individuals in this state use heroin regularly and they are not in receipt of any type of treatment

Withdrawal: Withdrawal treatment is concerned with neuro-adapation reversal, involves about 5-7 days care (in inpatient or outpatient setting) and includes medications to manage symptoms, supportive care and case management.

Residential rehabilitation (RR): RR is concerned with behavioural change across all life areas, including relapse prevention, psychological well-being, physical health, nutrition etc. It is provided in residential settings, and an ideal treatment program is 6-9 months long although it will have many who leave in the first week.

Opioid Treatment Program -Pharmacotherapy (OTP): the provision of a legal, safe opioid (either methadone or buprenorphine), dispensed daily or less frequently with take-away doses; requires prescriber and attendance at a pharmacy (primary care or clinic settings).

Counselling Only: Provision of psychological therapy only, on outpatient basis, (weekly or fortnightly) with case management.

In prison Stage:

Abstinence: individuals in this state are not using heroin but have previously used heroin and are incarcerated. We assume that no-one commences heroin use in prison (this is a simplifying assumption).

No Treatment & Use: individuals in this state are incarcerated, use heroin and are not having any type of treatment

Treatment: In prison treatment is mainly happening in the form of pharmacotherapy.

Death Stage:

Drug Related: A drug-related death is one where the cause of death is directly attributable to heroin (overdose, or cardiac arrest etc. caused by heroin use in immediate or long-term).

Non-Drug Related: Death from any causes not directly attributable to heroin: car accident, homicide, cancer, heart attack etc.

In summary, we have selected a set of mutually exclusive states large enough to capture the complexity of the treatment process and low enough to ensure the resulting model is tractable and does not overburden the model with very detailed and specific data requirements.

3.2.3. Transition Time

In this model, we have used an approach which provides heterogeneous 'time to transition' for each individual in the model based on his/her attributes such as age, sex, treatment history, and state. For this, we are using length of stay (LOS) distributions for each state in the ISM stratified by age, sex, history. These distributions are derived from a number of different datasets. As a result, this approach is free from

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traditional fixed time steps for individual movements across states as we use continuous function for individual's length of stay determination.

3.2.4. State Transitions
Once individuals in each state finish their assigned LOS in a state, they transition to other state based on transition probability functions. These functions are dependent upon the individual's attributes. In the model, these probabilities will be estimated based on survey dataset or derived from literature. We will use ATOS dataset, MIX dataset, and review of relevant literature to estimate these probability functions. Two types of transition functions in the model are as follows:
1. An equation, empirically derived, that specifies the probability based on individual's characteristics and history of the transition. These will be derived from ATOS, MIX etc data.
2. A probability distribution of the likelihood of transition, based on a known distribution of an event (empirically derived from summary data). Once a distribution function is established, Monte Carlo sampling is used to choose transition probabilities

3.2.5. Costs and Outcomes
As already outlined, the model will run through cycles, and costs and outcomes (also referred to as rewards) are accrued within each cycle.

There will be resources attached to simply being in some states and are referred to as State Awards. For example, while in S4 (withdrawal in the community), there will be a cost per episode of withdrawal; similarly there will be a cost attached to residential rehabilitation (by days in RR); pharmacotherapy (by days in OTP); counselling (by visits); prison (days); treatment in prison (days in OTP). These will be average unit costs (more about this below).

The variation in resource use will be driven by the length of time in a state. There will also be resources attached to some transitions (transition awards) i.e. transitioning into prison would incur the costs of the police and court. For individuals in prison, the social costs of crime, police and courts would only occur once even if a person stayed in prison for several cycles but the cost of being in prison, or being in treatment in prison would be applied as long as the person remained in that state. Another example is the cost of moving from a live to a dead state; as obviously the cost of dying occurs only the one time; not in every subsequent cycle.

Overall, we focus on the main categories of costs and benefits because they account for the main outcomes of heroin treatment. We decide to leave out unimportant costs and benefits because of their insignificance in total costs and benefits and it is time consuming to obtain all those costs and benefits. Total costs include the following components (i) life-years (saved, or lost); (ii) treatment costs; (iii) other health care utilisation (i.e. hospital, emergency department visits, and treatment for specific diseases such as

Hepatitis B and C); (iv) crime costs; (v) and economic impact on family burden. Total benefits include: (i) earnings due to returning to work after successful treatments; (ii) cost-savings to the government and society due to successful treatments (e.g. reduction of crime and health care utilization).

Health care costs would be of two types – some which are one-off i.e. an overdose which results in hospitalisation but not death. And others which are ongoing i.e. Hepatitis – here the costs will be low in early years of the disease but with some probability will increase as some proportion of the cohort will develop chronic hepatitis its sequelae.

3.2.6. Net social benefit
Once the costs and benefits have been calculated, the criterion for assessing the overall efficiency of an intervention is the Net Social Benefit (NSB).

$$NSB = \sum_{t=1}^{T} \frac{B_t - C_t}{(1 + r)^{t-1}}$$

where B_t are benefits in year t, C_t are costs in year t, r is the discount rate, and T is the duration in years under consideration. The NSB is the sum of the present value of all benefits minus the sum of the present value of all costs. A policy is potentially worthwhile if NSB is > 0.

The time span of the model is about 40 years. Therefore, it is no doubt that NSB will be sensitive to discount rate. The discount rate reflects cost of capital and risk premium of the project. The cost of capital is the next best alternative use of capital if the project was not implemented. We can use the interest rate of the Australian government bond/or risk-free interest rate, which is about 3-4% per year as a proxy for discount rate. Risk premium is the extra return above risk-free return to compensate for the probability of project failure. However, it is thought that risk-premium in government project is small. It is very hard to precisely estimate a discount rate. Therefore, a base discount rate of 3% will be used to calculate NSB. In addition, a sensitivity analysis will be conducted using a range of discount rates, including 0%, 3%, 5% and 10%.

4. MODEL ARCHITECHTURE
A survey of existing modelling software packages indicated lack of adequate existing software that would enable ISM modelling for heroin users. Therefore, a customised software platform is designed. Figure 2 illustrates the software architecture for the simulation model. Major opensource software tools used in developing the simulation model include; the Java for coding the simulation model components, Java swing for GUI development, and PostgreSQL databases for storing model inputs, intermediate and final outputs. The functions of each are briefly discussed in the following subsections:

Java: The general-purpose, concurrent, object-oriented programming language is used to implement algorithms

managing the creation of the initial population of individuals, individual transitions from one state to another based on transition probabilities, and estimating state and transition awards and outcomes. The Eclipse Integrated Development Environment (IDE) is used as the main development platform. There are three components which have been embedded in Java Eclipse:

Population Generation – creates the initial population for heroin use with age, gender, initial state, opioid use and incarceration history attributes. It also adds new heroin initiating population sub-group which enters the simulation at the start of every year.

State Transition Algorithm – it makes the individuals in the population move from one state to other. Based on individual attributes such as age, gender, state, opioid use and incarceration history, it calculates

   a. The length of stay (LOS) that each individual needs to serve in the current state (in community or prison).
   b. The probability of transition, for each individual, to transition to next state at the end of LOS.

Cost/Benefit Estimation – computes the benefits and costs which is attached to each individual in the simulation model
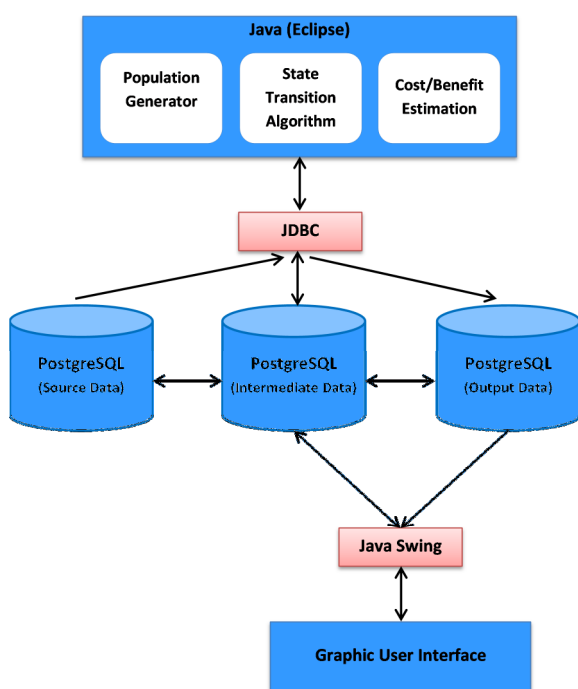

Figure 2: Software architecture of the simulation model

PostgreSQL: an open source object-relational database system, which is used to record (i) inputs to the model; (ii) intermediate data; and, (iii) model outputs. The main database tables are:

Model Configuration – stores all parameters required to run the simulation model such as simulation time period, number of individuals in initial population of heroin users in NSW, and new heroin users per year.

Costs Table – stores all cost data attached with the states (per unit LOS in a state cost) and transitions cost (as per event cost).

Benefits Table – stores all the benefits data attached with states and transitions

Current population table – stores simulated population generated at each year of the simulation.

Intermediate state transition table – stores the state transition trajectory of individuals in the simulation model

Intermediate cost table – stores the accumulated cost of each individual in the simulation model

Intermediate benefit table – stores the accumulated benefits of each individual in the simulation model

Output tables – stores the overall costs, benefits, mortality, and others at the end of the simulation

Java Swing: a pure Java widget toolkit is used to provide a graphic user interface (GUI). As a part of Oracle's Java Foundation Classes (JFC), it provides a native look for GUI and can be used across multi-platforms.

Graphic User Interface (GUI): a user interface that allows policy makers to interact with the model as well as allowing visualization of the model output and intermediate data in form of graphs and tables. Policy makers can plan new "what-if" scenarios, which can then be used for scenario based comparison analysis.

5. WORK IN PROGRESS

This study involves the development of lifetime state transition model of heroin using population in NSW, Australia. The conceptual model for the simulation is developed to identify i) crucial model elements such as states, transitions, costs, and benefits; and, ii) data sources to estimate transition probabilities, costs, benefits.

Thus far, we have built an initial prototype simulation model which creates the initial heroin using population, new heroin initiators, and transitions to different states. We are in the process of feeding the model with validated transition functions, per unit/event costs, and benefits; derived from historical heroin using individual datasets or literature review. Figure 3 illustrates the graphical user interface which is developed to support users to interact with the model to design and run different scenarios.

The final step in the modelling will be to validate whether the model is consistent with heroin user career trajectory. Various key outcomes from the model such as the distribution of participants across states, mortality rate and like these others will be verified with other datasets/sources that were not used to parameterize the model.

6. CONCLUSION

This paper presents a simulation modelling framework and concepts for the development of individual sampling model (micro-simulation) for lifetime simulation of the heroin using population in one Australian jurisdiction, NSW. This study will evaluate the long term (lifetime) cost-effectiveness of a set of

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treatment options available for heroin users together with the societal costs and benefits. The proposed methodology involves creating realistic initial population of heroin users, development of state transition algorithm, and estimating costs and benefits from the heroin treatments in a lifetime. This is a work in progress study and the next steps are to i) feed the input datasets to estimate individual state transitions, costs and benefits; and ii) validate and verify the model outputs with other data sources.
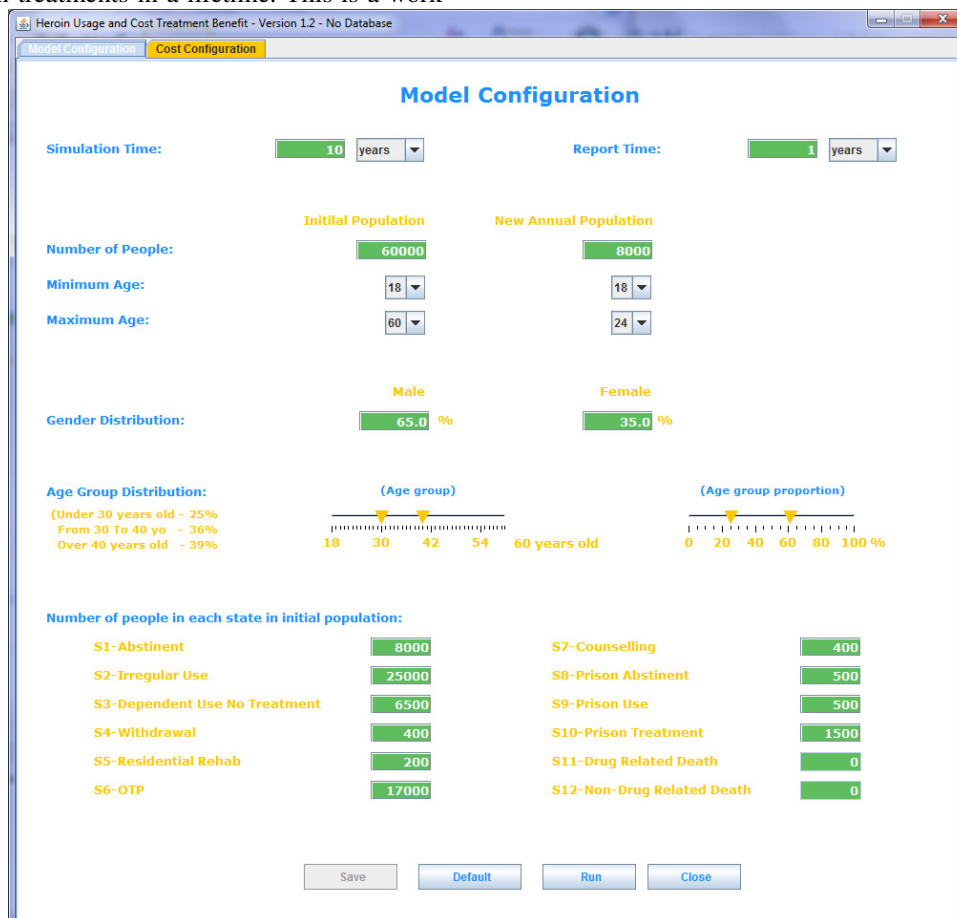

Figure 3: GUI for model interaction and scenario analysis

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