INTEGRATED SYSTEM DYNAMICS: ANALYSIS OF POLICY OPTIONS FOR TOBACCO CONTROL IN NEW ZEALAND

Robert Y. Cavana[1*] and Martin Tobias[2]
[1]Victoria University of Wellington, PO Box 600, Wellington, New Zealand,
bob.cavana@vuw.ac.nz

[2]Ministry of Health, PO Box 5013, Wellington, New Zealand
martin_tobias@moh.govt.nz

*Correspondence can be directed to this author, as the primary contact.

ABSTRACT

This paper addresses the conference theme of "Integrated Systems Sciences: Systems Thinking, Modeling and Practice" by providing a case study using Integrated System Dynamics. The paper uses the five phase integrated system dynamics approach outlined by Maani and Cavana involving: problem structuring, causal loop modelling [systems thinking]; dynamic modelling, scenario planning & modelling [systems modeling]; and implementation & organisational learning [systems practice]. The paper provides an overview of the system dynamics model that has been developed to assist the Ministry of Health to evaluate the dynamic consequences of tobacco control policies in New Zealand. The model consists of 4 sectors: population; smoking prevalences; second hand smoke; and tobacco attributable deaths. The model is simulated for 20-30 years into the future. The simulation package used is *'iThink'*, and a user interface is presented for policy analysis. A range of illustrative scenarios are provided, including: business as usual; fiscal strategies involving less affordable cigarettes; harm minimisation strategies involving either less addictive cigarettes or less toxic cigarettes; and combinations of the above policies. The main output variables (performance measures) include current smoking prevalence, tobacco consumption, and tobacco attibutable mortality. Finally areas for future model enhancement are identified.

Keywords: system dynamics; dynamic simulation; tobacco policy model; tobacco control policies; New Zealand Ministry of Health

INTRODUCTION

This paper describes a system dynamics model that has been developed to help the Ministry of Health (MOH) to evaluate the dynamic consequences of tobacco control policies in New Zealand (NZ).

Traditional epidemiological methods (eg randomised control trials, cohort studies) help us understand the parts (eg effectiveness of nicotine replacement therapy) but not the whole. Tobacco use can be thought of as a ‘system’ containing emergent properties, complexity, and nonlinear dynamics.

Traditional epidemiological methods deal with complexity by breaking the issue down into parts simple enough to be controlled (randomised control trials) or observed (cohort or case control study). System dynamics (SD) deals with complexity by abstracting the key elements and simulating their dynamic inter-relationships (using multiple simultaneous differential equations).

The focus of an SD model is on the behaviour of the system *as a system*. Elements are retained only if necessary, and only relevant attributes incorporated.

> "*Everything should be made as simple as possible – but not simpler*"
> - Albert Einstein

The specific objectives of the SD tobacco control model are:

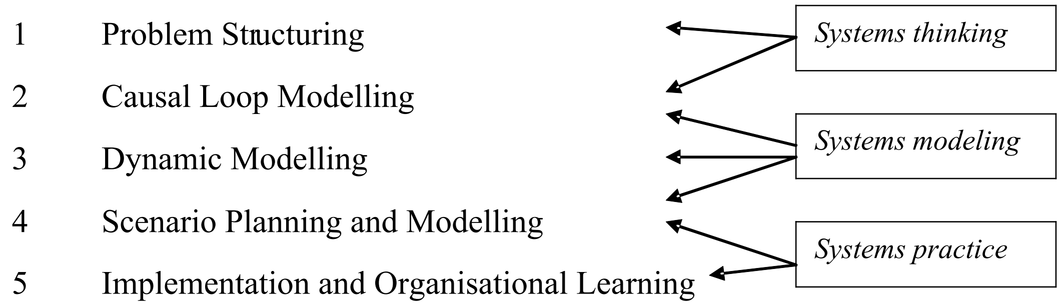
(a) to support evidence-informed tobacco control policy;
(b) to provide a decision support tool when considering strategic policy options in tobacco control; and
(c) to assess the utility of system dynamics in formulating public health policy in the NZ context.

MOH has a statutory responsibility to monitor use of, and harms caused by, tobacco products. Also this is required as signatory to the WHO Framework Convention on Tobacco Control (WHO, 2005).

Previous system dynamics studies related to tobacco policy includes: the DYNAMO based system dynamics modelling work at MIT in the late 1970s and early 1980s on the impacts of smoking by Roberts et al. (1982); the Markovian system dynamics computer based simulation model developed in the USA by Tengs et al. (2001a & b; 2004a & b), Ahmad (2005) and Ahmad & Billimek (2005) for analyzing tobacco related policies; the computer simulation model called SimSmoke developed by Levy et al. (2006a, & b) to assess the impacts of a broad array of public policies related to tobacco control; and the system dynamics pilot study by Cavana & Clifford (2006) at NZ Customs Service analysing the collection of tobacco excise duties and cigarette smoking in NZ.

The general approach used in this study follows the five phase integrated approach in Table 1, as outlined by Maani and Cavana (2000, 2007), following the general approach of the system dynamics methodology (e.g. see Forrester, 1961; Coyle, 1996; Sterman, 2000):

Table 1: Systems thinking and modelling methodology & ISSS 07 conference theme
(integrated systems science)



Source: Maani and Cavana (2000, Table 2.1, p16)

The theme of this conference is “Integrated Systems Sciences: Systems Thinking, Modeling and Practice”. ISSS (2007) defines this theme as follows: “It attempts to promote systems sciences as an approach to complexity in a broad sense, identified in organizations, communities and societies, and their environments, in such a holistic and integrated way that we draw on all of systems sciences from systems thinking and systems modeling to systems practice.” While SD does not draw on all the systems sciences, it is certainly concerned with the scope of the integrated systems sciences outlined by the ISSS conference organisers. The five phase integrated SD approach outlined in Table 1, shows the relationships to the integrated systems sciences as follows (ISSS, 2007):

> “*Systems thinking* promotes holism as its primary intellectual strategy for handling complexity, whether the approach is hard or soft, carried out by academia or practitioners. Instead of analyzing complex systems by breaking them down into their parts, it advocates studying them as `wholes' using systems concepts…” [this relates to the problem structuring and casual loop modelling phases summarised in Table 1].

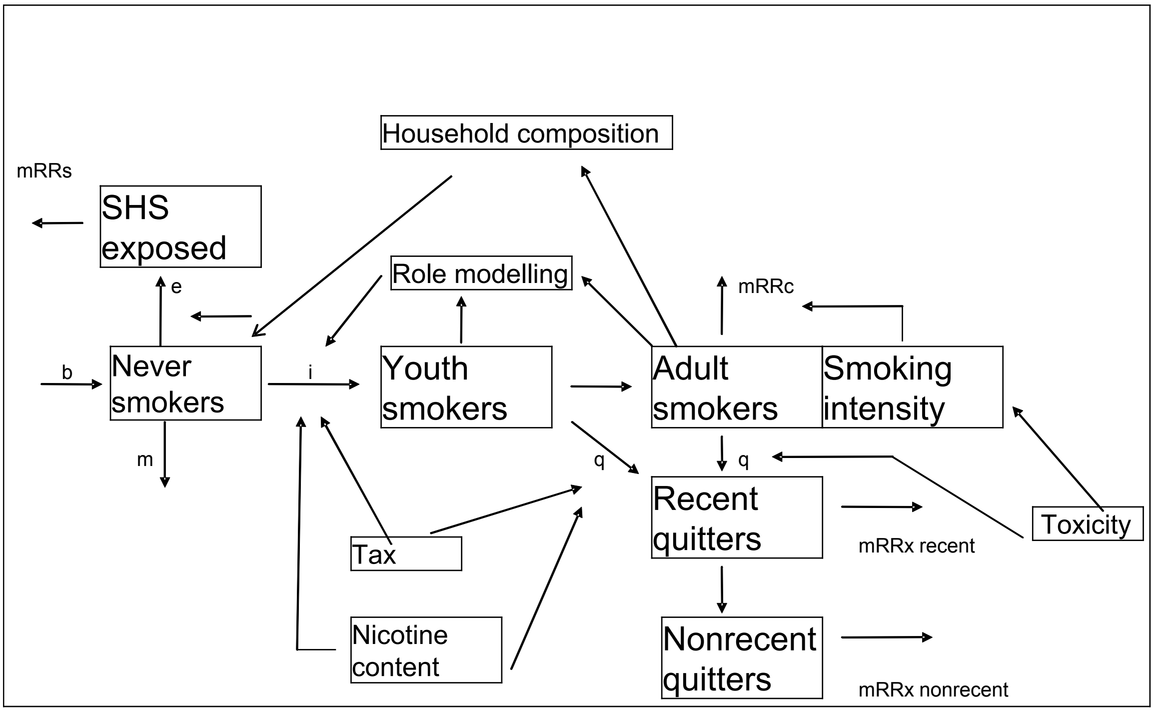
> “*Systems modeling* aims at describing, analyzing and prescribing a real entity or phenomenon by constructing a variety of systems models. It includes mathematical models, conceptual models, computer models and simulation tools…” [this relates to the casual loop modelling, dynamic modelling and scenario planning/modelling phases summarised in Table 1].

> “Finally, *systems practice*, or practical applications of systems thinking/ideas, is the greatest success of systems sciences in recent years. It has shown that systems sciences have the ability to translate theoretical notions into the practical domain through the use of systems methodologies, models and methods…” [this relates to the scenario planning/modelling and implementation/organisational learning phases summarised in Table 1].

This paper outlines progress to date of the tobacco policy modelling study. The next section provides the overview causal loop diagram that provided the conceptual framework for the development of the stock flow diagrams and simulation model outlined in the following section. The main part of this paper outlines a range of scenarios with the tobacco policy model describing the experiments and the model performance measures for a range of tobacco control policies. Finally some limitations and areas for further work are outlined in the concluding section.

CAUSAL LOOP MODELLING

The overall causal loop diagram for the model is provided in Fig 1. This diagram shows the population aging chain and the various categories of smokers and non-smokers. The feedback effects of adult smokers and peer group smokers can be clearly seen, and the effects of various tobacco control measures on initiation rates (smoking starts), quitting smoking, and smoking intensity can also be observed in this diagram.



Key: i = smoking initiation rate; b = birth rate; e = exposure to second hand smoke; q = net quit rate; m = never smoker mortality rate; RR = relative risks of mortality; c = current smokers; s = second hand smoke; x = ex-smokers.

Figure 1: Causal Loop Diagram for the NZ Tobacco Policy Model

This diagram provides the conceptual framework for the development of the 4 sector system dynamics simulation model, briefly outlined in the following section. It must be emphasised that this model represents work in progress, and the authors are continuing to develop it along the lines outlined in the final section of this paper.

Nevertheless, the model is currently very useful for demonstrating the impact of a range of tobacco control policies. In some cases the output measures have been summarised outside the SD model. These performance metrics will ultimately be endogenised within the model.

DYNAMIC MODELLING

Overview of the simulation model

The system dynamics simulation model consists of 4 sectors: population; smoking prevalences; second hand smoke; and tobacco attributable deaths.

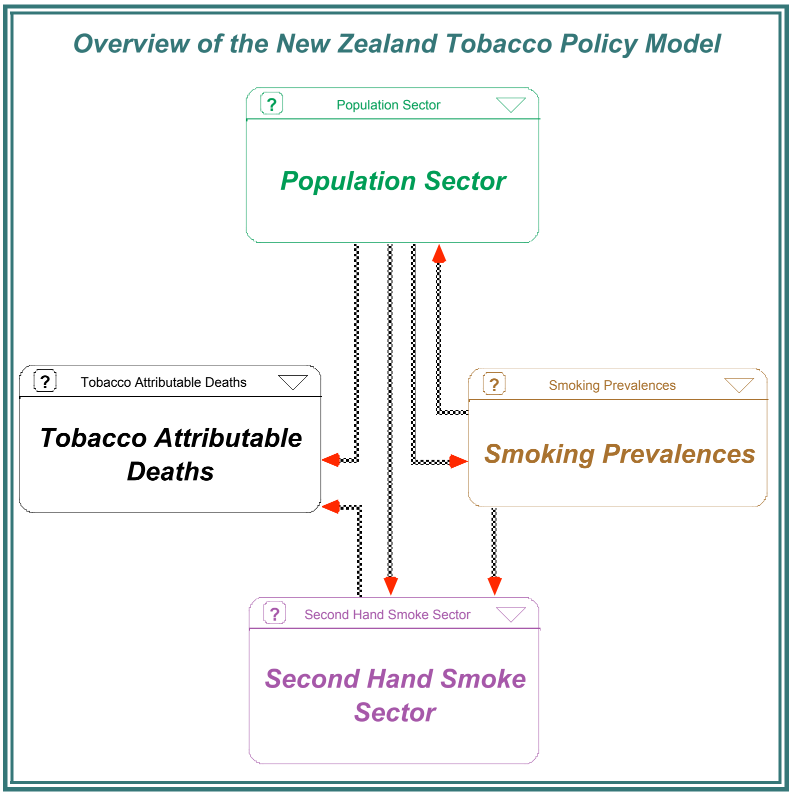


Figure 2: Overview of the MOH tobacco policy model

The tobacco sector consists of population aging chains broken down into approximately 10 year age groups representing stocks of 'never smokers', current smokers', 'recent ex-smokers', and 'non recent ex-smokers'. Flows are provided for births, aging between cohorts, initiation and net-quitting smoking, and mortality associated with smoking & ex-smoking related risks. The prevalences sector calculates ratios for each of the stocks or combination of age related stocks in the population sector. The second hand smoke sector calculates the exposure and mortality associated with second hand (passive) smoking by age group in NZ. Finally the tobacco attributable deaths sector summarises the mortality associated with smoking and second hand smoke by age cohort in NZ.

Only the simplified stock flow diagram for the population sector will be provided in this paper (see Figure 3). The variable names are classified as acronyms, *where for example*:

- 10G = age group from 10 to 19 years old
- NS = never smokers
- CS = current smokers
- XSR = recent ex-smokers
- XSNR = non recent ex-smokers
- Births = annual births
- D = annual deaths
- NSD 70G = annual deaths of never smokers in the 70 plus age group
- NS to 10G = annual aging into the age group starting at age 10 (flow - aging between the 1st two age cohorts)
- q = annual net-quit rate (ie rate of quitting smoking less restarting smoking)
- m = mortality rate
- ir = initiation rate
- RR CS30T69G = relative risk of mortality of current smokers in the 30 to 69 year old age group

The model is developed using the ***iThink*** v9.01 dynamic simulation software package (iSee systems, 2005). The sources for the data used to initialise the model are summarised in Table 2 below. The model will be available from the authors when the project is completed. The model can be simulated for 50 years, although the focus is on the medium term, 20-30 years into the future.

Table 2: Initialising the Tobacco Policy Model

Prevalence (current, ex-smoking)	NZHS 02/03
Initiation rate (and responsiveness to parental and peer role modelling)	Clements (modelled from Aus and NZ data 1990s)
Net quit rates	Clements (as above)
Smoking intensity distribution	NZHS 02/03
Never smoker mortality rates	$m_o = m / [p_c(RRc - 1) + p_x (RRx - 1) + 1]$
RR current smokers (by duration and intensity)	CPS II (duration = age –15)
RR ex-smokers (by duration)	Clements
RR SHS exposure	NZCMS (Ministry of Health 2005)
Never smokers exposed to SHS	NZHS 02/03 (Ministry of Health 2004)
Population estimates and projections (including mortality trend)	SNZ