A System Dynamics Model of Smoking Prevalence in Pakistan

by

Heather Beil

Rhonda Belue

Saleha Naghmi Habibullah

I. Background:

Tobacco use is regarded as the single most important preventable cause of disease, and as many as 3.5 million premature deaths worldwide are attributed to this phenomenon [1]. In low and middle – income countries of the world, tobacco-related deaths are projected to rise dramatically in the future decades if the incidence of smoking is not reduced. [2]

Due to historical and socio-cultural reasons, the phenomenon of smoking in Pakistan and some of the Eastern and Arab countries is such that, whereas a sizeable proportion of the male population consists of smokers, a *very small* fraction of the female population belongs to this category [3]. In Pakistan, smoking by men is socially acceptable and considered to be 'quite normal'. On the other hand, smoking by women is considered a taboo, and in extremely rare cases is a woman found smoking a cigarette in public. As far as smoking among men is concerned, a large majority of them begin smoking in their teens, due to factors such as peer pressure, the urge for 'experimentation' and the like [1]. The overall smoking prevalence in Pakistani men is approximately 28.6% and as high as 40.9% among the middle – aged group (i.e. men aged 40 – 49 years) [4].

In addition to cigarettes and chilam / huqqa (smoke-related tobacco products), the use of *chewable items* such as paan, chhaalia, gutka, niswar and tumbaku is common in Pakistan. Having an ancient history, such items are an integral part of the culture, and population based studies carried out in India, Pakistan and Nepal have indicated a prevalence of use of such products between 20 and 40% [5]. The risks associated with chewable item s such as betel, areca and smokeless tobacco cannot be over-

emphasized, as they are known to be related with the development of debilitating diseases such as oral cavity and other head and neck cancers [5].

Combining the two categories of tobacco products, i.e. cigarettes / huqqa and chewable items, it is obvious that tobacco use is fairly common among the male population of Pakistan. According to some estimates, more than 54% of the Pakistani men use tobacco in one form or the other [6].

Whereas smoking cessation is on the increase in high – income countries, the situation of South / East Asian countries such as India, Vietnam and China seems to be quite different. In recent years, the percentage of *former* male smokers in India has been as low as 5% [7]. Due to cultural similarities, the situation of Pakistan would not be too different.

Although the detrimental affects of smoking on health are well-recognized, until very *recently,* there has been no well - defined anti-smoking policy in Pakistan [1], [4]. The Prohibition of Smoking and Protection of Non – Smokers Health Ordinance came into effect in 2002, under the provisions of which smoking was banned in public places such as restaurants, hotels, hospitals, schools, colleges and offices in Islamabad, the capital city of Pakistan) in 2006 [8]. In May 2004, the Ministry of Health launched a National Action Plan on Non Communicable Diseases (NAP-NCD) in collaboration with the World Health Organization and the NGO Heartfile, the first phase of implementation of which commenced in Jan 2006. The NAP-NCD's surveillance model includes population surveillance of primary NCD risk factors i.e. poor diet, physical inactivity and smoking. The tobacco control component of the NAP-NCD incorporates a range of policy and environmental strategies, and regulates access through advertising and promotion restrictions, prevention and cessation marketing campaigns, community and school interventions, and capacity building in the health system in support of tobacco control [9]. NAP-NCD supports the development of legislation in order to subject tobacco to stringent regulations, the adoption of measures to discourage tobacco cultivation and the incorporation of guidelines regarding tobacco use cessation into the health services system, and the promotion of access to nicotine replacement therapy [6]. Obviously, it will take a few years before the true impact of the NAP-NCD on population outcomes can be assessed.

II. Specific Aim

To employ system dynamics modeling to model the trajectory smoking prevalence in Pakistan over time assuming: variations in smoking uptake and smoking cessation rates.

III. Methods

System Dynamics Modeling:

System Dynamics is a set of methodologies for identifying problems, developing dynamic hypotheses, explaining potential causes for a problem, and building a model and testing the problem and informing solutions .

One of the uses of system dynamics (SD) methodologies is to identify leverage points, or to simultaneously model how changes in one component will affect all other system components based on their complex and synergistic interrelationships. It applies mathematical models to describe, evaluate, and analyze complex social systems. SD methodologies are based on sets of connected differential and algebraic equations. SD methodologies employ feedback loops to describe and account for the interrelationships between variables and systems. SD also has the ability to account for the nonlinearity of simple and complex systems. Computer software is used to simulate models of the situation being studied. Feedback loops are used to describe and account for the interrelationships between variables and systems; the nonlinearity of simple and complex systems can be accommodated (20). The SD framework enables use of computer software to simulate models of the situation being studied, in order to address questions concerning the likely outcome of various alternative intervention strategies. The simulations can incorporate a variety of components to model a community, such as health care services, population dynamics, health beliefs of the population, access to food, and community resources. SD can help inform and optimize how resources are used in order to maximize intervention effectiveness and positive community change not only at the present time but also longitudinally by modeling a variety of futures. SD enables planners, policymakers and interventionists to identify which relationships are necessary and sufficient between model components in order to produce the desired goals.

STEP 1: **Define the purpose of the model**—In this case, it will be to evaluate the relationship between population dynamics, smoking uptake, smoking prevalence, smoking cessation and smoking deaths overtime .

STEP 2: **Formulation—Convert feedback diagrams into level and rate.**

This process will involve defining feedback systems that indicate which factors produce positive feedback or growth of the system (e.g. smoking cessation,) and which factors cause negative feedback or system destabilization (e.g. increase in smoking prevalence and death).

STEP 3: **Testing**—Simulate the model and test the dynamic hypothesis, test the models hypothesis, and test model behavior and sensitivity to perturbations. In our case, we test how changes in the number of youth who begin smoking will affect adult smoking prevalence and smoking related deaths.

IV. System Dynamics Modeling of Smoking Prevalence in Pakistan

A dynamic model was used to forecast a variety of futures of smoking prevalence in Pakistan. Since the female smoking rate is *much* lower than the male smoking rate, the model was also created for men only.

System Dynamics diagram

Figure 1: System Dynamics Diagram
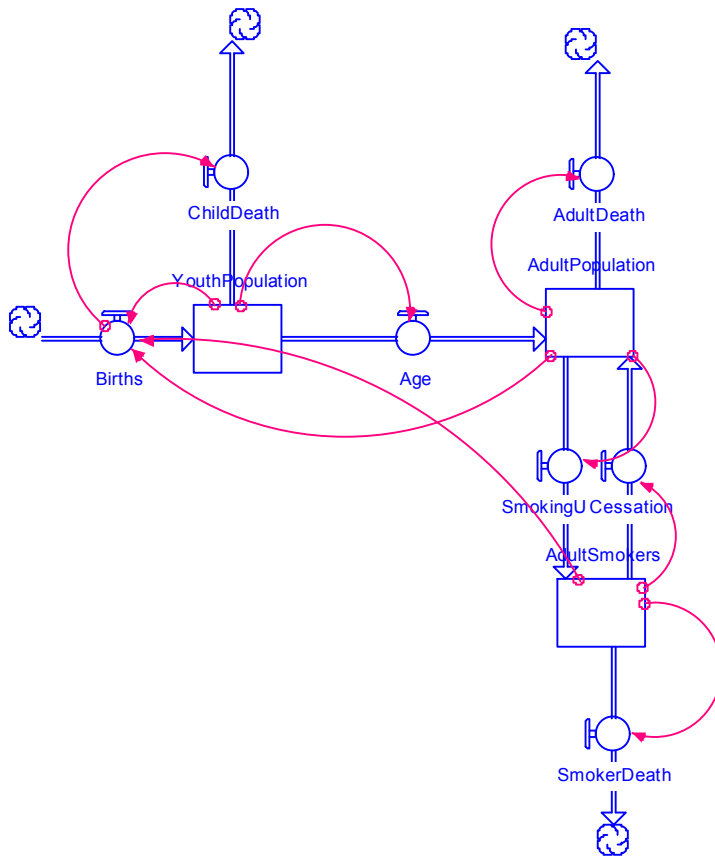
A System Dynamics diagram is made of four components, Stocks, Variables, Flows and Links.

A Link makes a value from one part of the diagram available to another. It transmits a number from a Variable or a Stock into a Stock or a Flow.

Stocks: is an aggregate variable, often representing the number of individuals in a population.

In our case, stocks include the youth population, youth smokers, adult population and the population of adult smokers.

Flows: Brings people or things in and out of the stocks. Flows include the birth rate, aging of individuals in each stock group, and the death rate out of each stock group.

Software: All system dynamic simulations were conducted using the Stella system dynamics toolkit. Stella is a program which has the ability to graphically visualize and analyze system dynamic simulation models.

Data Source:

Data for stocks and flows was obtained from the World Health Organization (WHO) Global infobase. The WHO Global infobase contains information regarding chronic disease and related risk factors for all member countries.

However, differing amounts of information are available for different countries. When data was not available for Pakistan specifically, we used data from western India, Afghanistan, or Iran.

Results

As seen in Figure 2, maintaining the rate at which adult males take up smoking at 0.5% per year kept the smoking prevalence relatively constant after 200 years. Decreasing the uptake rate from 4% to 0.5% resulted in a decrease in smoking prevalence over 200 years. The smoking prevalence decreased by approximately 75% after 50 years and 50% after 200 years by changing the smoking uptake rate from 4% per year to 0.5% per year.

Figure 2: Smoking Prevalence with Decreasing Uptake
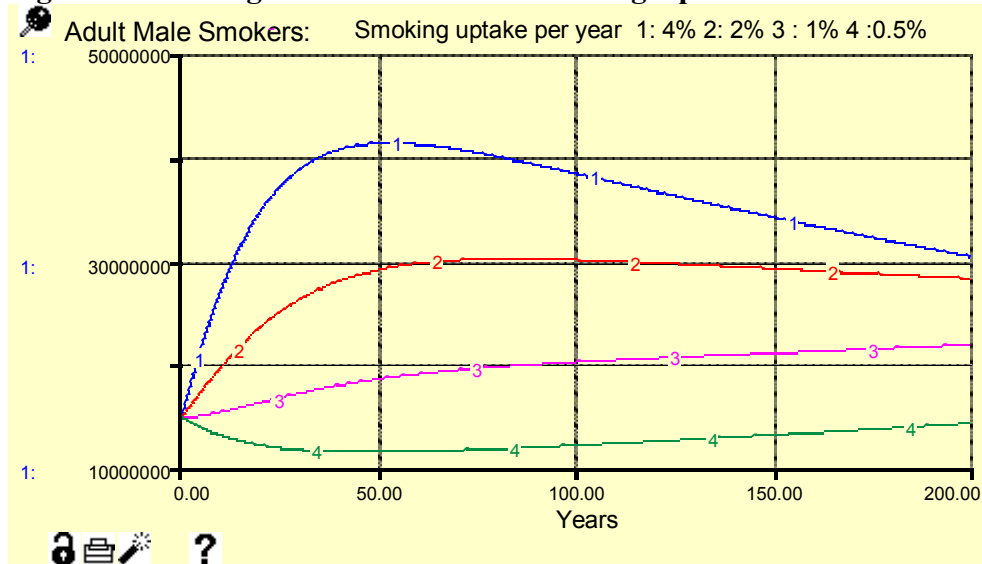
Regarding smoking cessation, our model indicated that increasing smoking cessation rates from 1% to 8% decreased the prevalence by approximately 60% after 50 years and 42% after 200 years (Figure 3)

Figure 3: Smoking Prevalence with Increasing Cessation
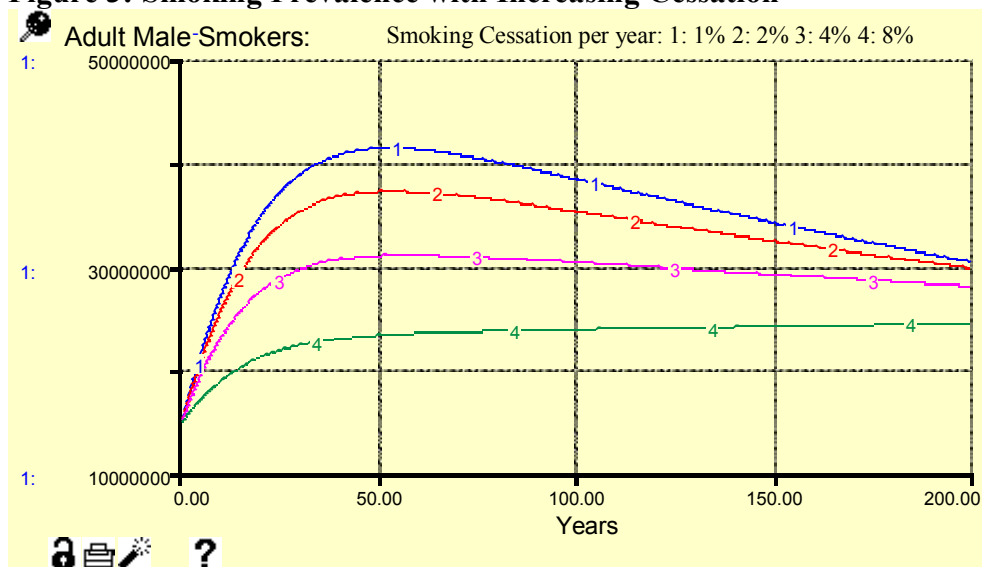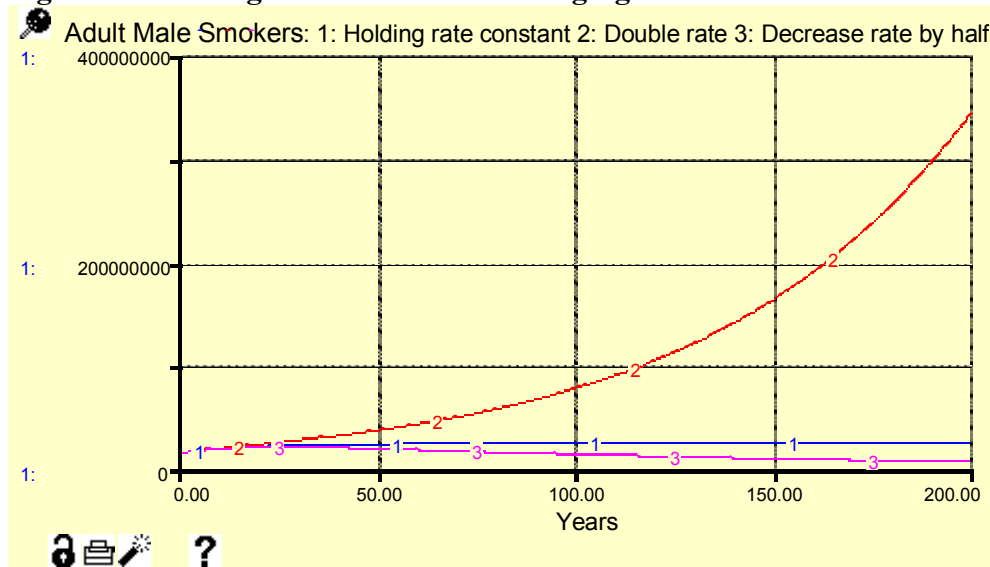

Sensitivity Analysis

In order to test the validity of the model, we conducted sensitivity analyses to evaluate how the smoking prevalence rates changed with changing population demographics. As seen in Figures 4 and 5, holding the birth rate and smoking related death rates constant resulted in relatively constant prevalence rates over 200 years. Increasing the birth rate by a factor of two lead to an exponential growth in smoking prevalence, while dividing the rate by a factor of two caused the prevalence to decrease. Likewise,

increasing the death rate for smoking related deaths resulted in a lower smoking prevalence and decreasing the death rate caused the smoking prevalence to increase.

Figure 4: Smoking Prevalence with Changing Birth Rates

Adult Male Smokers: 1: Holding rate constant 2: Double rate 3: Decrease rate by half

Figure 5: Smoking Prevalence with Changing Smoking Related Death Rates

Adult Male Smokers: 1: Holding rate constant 2: Decrease rate by 25% 3: Increase rate by 25% 4: Decrease rate by 50%

Discussion:

System dynamics models can be a useful tool to explore how changes in one component of a system will affect all other system components based on their complex relationships. Identifying such leverage points is important in making policy decisions such as how to spend limited funding. We built a system dynamics model to explore the relationships between population demographics, smoking uptake and

smoking cessation rates on smoking prevalence in adult males in Pakistan. The model showed that focusing on prevention, i.e. reducing the rate at which men start smoking, rather than cessation will result in lower smoking prevalence rates after an extended time period. Therefore, the model indicates that tobacco control efforts and spending in Pakistan would have a greater effect on smoking prevalence by focusing on reducing smoking uptake.

The sensitivity analysis we conducted indicates that the model has face validity. The prevalence rates changed appropriately with changing population demographics. Furthermore, it is interesting to note the increase in smoking prevalence rates with decreasing death rates. That is, if the Pakistan medical system improves by reducing smoking related mortality, it could reflect negatively on the public health system as the smoking prevalence rates will increase.

Limitations

There are several limitations to our model. The model is based on limited data due to the lack of available longitudinal data on smoking prevalence in Pakistan. The model is limited in scope by its focus on prevalence alone; it does not incorporate more complex components that would have to be considered in policy decisions such as health effects of smoking. Moreover, recent work on tobacco models has shown that when health effects are included, it is more cost effective to focus on cessation rather than prevention. This could be because the health effects from prevention take much longer to show any cost savings. Further research could incorporate health effects into our model to test if this is also true in Pakistan.

Conclusions

Given the enormity of the problem of tobacco use in Pakistan and its effects on the health and cost to the nation, it is important to explore where tobacco control efforts will be the most effective. Our model indicates that focusing on smoking prevention will have a greater effect on prevalence. Further work should explore how adding more complex features such as health effects to the model could change the outcomes.

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