A System Dynamics Approach to Assessing Policies to Tackle Alcohol Misuse

Anas Tawileh, Haya Almagwashi and Steve McIntosh
Cardiff University School of Computer Science
Queen's Buildings, 5 The Parade, Cardiff, CF24 3AA, Wales
+44(0)29 2087 4204/+44(0)29 2087 4598
m.a.tawileh@cs.cf.ac.uk, h.almagwashi@cs.cardiff.ac.uk, sbm@cs.cf.ac.uk

Abstract

This paper proposes a systems approach to tackling alcohol misuse based on System Dynamics modelling. The problem of binge drinking in the UK is first described along with its negative impact on health, society and the economy. A review of the current literature follows, and the systemic nature of the problem explained. System dynamics is proposed as a holistic approach to investigate the problematic situation. The paper describes the development of an initial influence diagram for alcohol misuse that captures the significant factors affecting the problem. The utility of this approach is demonstrated through a simulation model built based on the influence diagram. The simulation model acts as a vehicle for experimentation and testing of several possible policy options. This is shown through the several scenarios of possible interventions by the government to compare the potential impact and costs of each scenario. The paper concludes with a review of the findings and directions for further research.

Keywords: System Dynamics, alcohol misuse, binge drinking, government policy.

Introduction

Awareness of the negative consequences of alcohol misuse and binge drinking in the UK has been growing at a significant rate. In a recent study by Portman Group, 63% of respondents considered binge drinking to be a major problem in Britain (MORI, 2001). Binge drinking refers to "consumption of excessive amounts of alcohol within a limited time period." (POST, 2005). Several definitions exist for binge drinking; the most widely cited is the consumption of twice the daily benchmark given in the government's guidelines (a maximum alcohol intake of 3-4 units for men and 2-3 units for women).

Levels of binge drinking in the UK have consistently increased over the past few decades. A study by the European Union placed the UK in the top bingeing nations in Europe, which also found that the EU is the heaviest drinking region in the world (Anderson & Baumberg, 2006). Another study reports that binge drinking accounts for 40% of all drinking occasions among men and 22% among women in the country (Cabinet Office, 2003). The alcohol harm reduction strategy for England (2004)

shows an increase of 121 per cent in the per capita consumption of alcohol between the years 1951 and 2001.

Binge drinking has increased more sharply among young and underage drinkers (Coleman & Cater, 2003). Alcohol Concern (2004) reports that 56% of 15-16 year olds binge drink at least once a month, and 30% at least three times a month. Another study shows a significant increase in consumption of alcohol by 11-15 years old from 5.2 units per week in 1990 to 10.5 in 2001 (Boreham & McManus, 2003).

Evidence suggests that alcohol misuse is a major contributing factor to several societal, economic and health problems. High alcohol consumption levels are usually correlated with increased crime rates, less stable families and prevalence of anti-social behaviour. The costs to the economy of alcohol misuse (both direct costs that include health, judicial system and material damage and indirect costs that include premature deaths and excess morbidity and unemployment) are reported to be around 3% of the gross domestic product (GDP) in Europe (Klingemann, 2001). In the UK, this figure is estimated to be around 20 billion £ per year (Pincock, 2003).

Crime and violence are major issues arising from binge drinking. According to the British Crime Survey, the victim of more than half (53%) of violent incidents among strangers "described the perpetrator as being under the influence of alcohol" (Mattinson, 2001). Alcohol is believed to contribute to more than 40% of violent incidents in the UK (Graham & West, 2001). Additionally, one third of domestic violence incidents happen under the influence of alcohol (Cabinet Office, 2003). Figure 1 summarises the negative impact of alcohol in the UK (Cabinet Office, 2004).

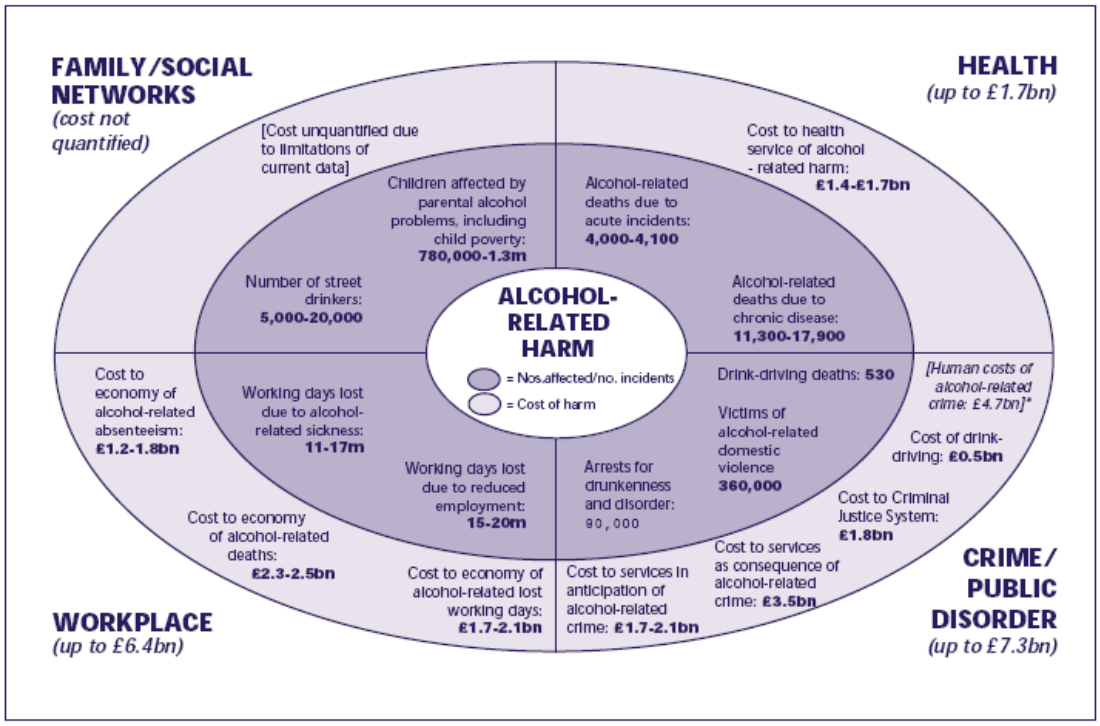

Figure 1: Alcohol Related Harm in the UK (Alcohol Harm Reduction Strategy, Cabinet Office, 2004)

The increasing negative impact of alcohol has placed a significant pressure on the government to undertake concrete action to address these issues. Possible actions may include rising the legal drinking age, tightening licensing legislations for alcohol sellers, increasing taxes, restricting alcohol advertising or implementing appropriate awareness programmes. Selecting the most appropriate policy intervention requires proper understanding of the problem situation in order to design effective and feasible action plans. Significant effort has been invested in producing evidence to explain the possible causes and consequences of alcohol misuse. Several published studies have catered for different aspects of the problem, including binge drinking effects on violence, anti-social behaviour, crime, etc. An interesting observation that can be made from the available literature is the wide spectrum of different, and sometimes contradictory, conclusions they draw. For example, one study argued, based on the results of a recent survey, that alcohol consumption among teenagers and consequently alcohol related violence are positively correlated to the excess income available to the teenagers (Sivarajasingam et al., 2006). On the other hand, another researcher suggests that the correlation between price and consumption for certain types of alcoholic drink is rather weak (Godfrey, 1988).

It can be argued that this dissonancy in the findings is the result of the limited ability of the applied research methods to account for the systemic nature of the problem under study. This reductionist approach minimises the insight that can be acquired about the problematic situation and is unlikely to produce rich enough understanding to inform effective policy making. In this paper, we propose a holistic approach to the investigation of alcohol misuse problem and its consequences, based on System Dynamics. In the next section, the holistic nature of the problem is explored, and the use of System Dynamics is justified. The model development process is then explained, along with its validation. The discussion then shifts to the exploitation of the developed System Dynamics model to inform the policy making process and to evaluate several possible policy and intervention options. The paper concludes with some lessons learned and directions for future research.

Method and Approach

Most of the existing studies in the alcohol misuse literature adopt research approaches that reduce the overall problem into the analysis of correlation between few factors and attempt to infer causal relationships between these factors. While this approach may be very effective in tackling well defined problematic situations where limited number of factors and relationships are at play, it suffers from serious limitations that inhibit its successful application to understand more complex, real world situations where the problem itself is ill defined, and the interacting factors are not clearly identifiable.

Unfortunately, alcohol misuse as a complex social phenomenon does not satisfy the requirements to enable the successful utilisation of the aforementioned “reductionist” approach. The problem situation is complex, messy and not very well defined. Moreover, while the large number of factors involved can be easily observed, identifying these factors and the dynamic relationships among them is a much more complex task. Such problems do not lend themselves well to traditional research

approaches. They require a significant change in the mindset of researchers to adopt a holistic view of the problem in such a way as to acknowledge the inherent complexity and to avoid conclusions and generalisations from being inferred from narrowly focussed investigations.

The same trend was observed in several other fields. Many real world phenomena can not be studied and explained using the reductionist approach of scientific research. Reality is rich and interconnected, and requires a holistic, systemic approach to gain insight into its dynamics. Several approaches have been developed specifically to cater for the complexity in real world problematic situations by acknowledging the large number of variables involved and the dynamic interrelationships among these variables. These approaches have been successfully applied to complex problems in fields as varied as social security, housing, public policy and organisational behaviour.

We propose the use of System Dynamics, first introduced by Jay Forrester (1973) as an appropriate method to study and analyse the problem of alcohol misuse. This problem is characterised by complexity, involves many interacting factors and encompasses feedback and delays. Therefore, it can reasonably be argued that alcohol misuse is a systemic problem, and that approaching the situation with a systems view may yield useful insights. System Dynamics provides a systemic approach to dealing with complex real world problem situations, that accounts for the interdependence and interactions between different elements of the system.

System Dynamics models capture the interrelationships between the system's elements and enable the analysis of causal loops that affect the behaviour of the overall system. Furthermore, by using appropriate computer software, simulation models can be built to experiment with different scenarios and policy options. Such experimentation can provide valuable insights into the system's behaviour and inform the decision making process. In the context of this paper, a simulation model would facilitate the testing of several policy options before the policy is implemented. It can also weigh different options against each other in order to produce the optimum and most cost effective intervention scenario.

User interaction with the simulation model can be facilitated through a simple, intuitive graphical user interface that would provide a visual, easy to interpret representation of the dynamic behaviour of the system. The interface also offers users a flight simulator-like dashboard to change the model's parameters and to immediately observe the impact of these changes. For example, the model user can change the alcohol taxation policy or strengthen law enforcement against underage drinking in order to examine the changes in the system's behaviour and the expected outcomes. The model development process is explained in detail in the next section.

Model Development

The aim of this modelling exercise is to produce a simulation model that could assist the decision makers in evaluating the outcomes of several policy interventions to tackle alcohol misuse. It can also aid researchers in identifying and capturing the

relevant variables and to represent the relationships among these variables. This step is of particular value in determining information requirements for research, as it can pinpoint the areas that require further research and investigation to improve understanding of the alcohol misuse problem.

This structure of relationships is captured diagrammatically in an influence diagram. Influence diagrams facilitate holistic thinking and offer an excellent communication tool to surface the mental models of different stakeholders in such a way as to ensure a common understanding of the problem under study among all participants. They can also be used as a requirements elicitation tool to determine the quantitative data that should be collected through surveys or other research methods, and the relationships that need further study. The development of the influence diagram for some of the factors affecting alcohol misuse is presented in following figures.

In order to establish the extent of alcohol misuse in the UK, the total alcohol consumption of the population should be considered. This is calculated by multiplying the average alcohol consumption per capita by the drinking population (Figure 2). Because underage drinking is a growing concern, and as underage drinkers have significantly different drinking patterns, the drinking population is divided into those who are over the legal drinking age and those below (mostly in the 16-18 age bracket). The average consumption per capita is based on the unit measure (in the UK, a unit is defined as 8 grams of alcohol – Office of National Statistics, 2008) and is calculated for both underage and legal drinkers.

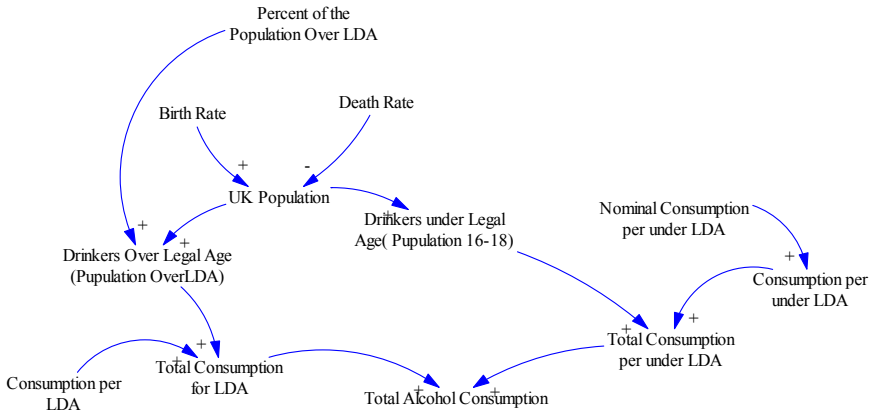

Figure 2: Alcohol Consumption in the UK

The overall cost of alcohol misuse to the economy is based on the aggregate cost of the medical costs and policing costs (including the judicial system). This paper focuses on the costs to the economy of the violence that result from alcohol misuse. Apparently, the increased alcohol consumption in the country will lead to more alcohol related incidents that require both hospitalisation and policing. Moreover, the negative health consequences of alcohol misuse will also require medical care, adding to the total medical bill to the economy (Figure 3).

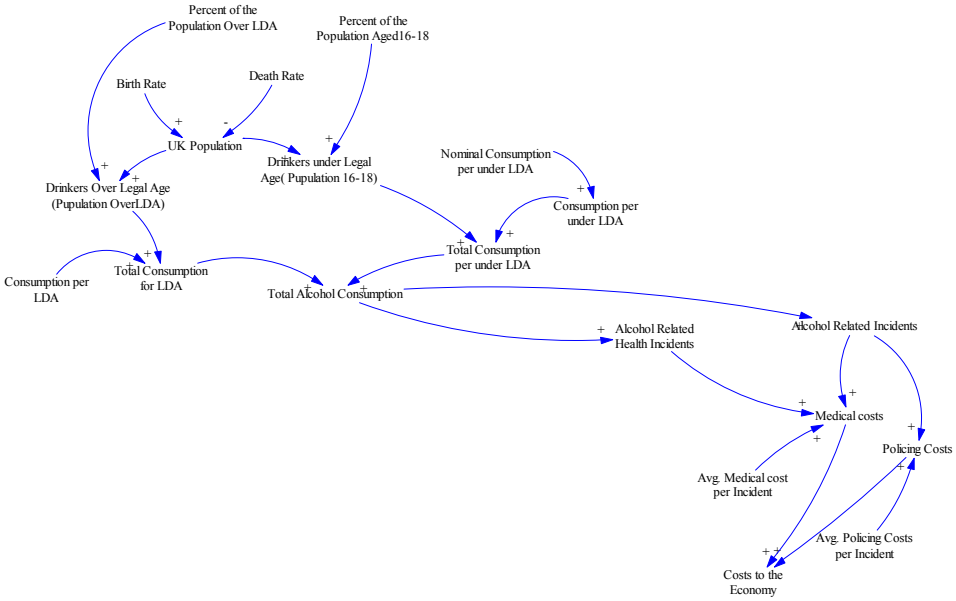

Figure 3: Costs to the Economy

The higher costs to the UK economy imposed by excessive drinking will lead to increasing pressure on the government to tackle the problem and intervene through several policy options, among which tough taxation, more restricted licensing policies and tightened law enforcement are currently being considered. The government could also undertake other interventions, such as implementing public awareness programmes about the negative impact of alcohol misuse. These measures would probably lead to reduced levels of binge drinking, and thus reduce the costs to the economy and consequently the pressure on the government (Figure 4).

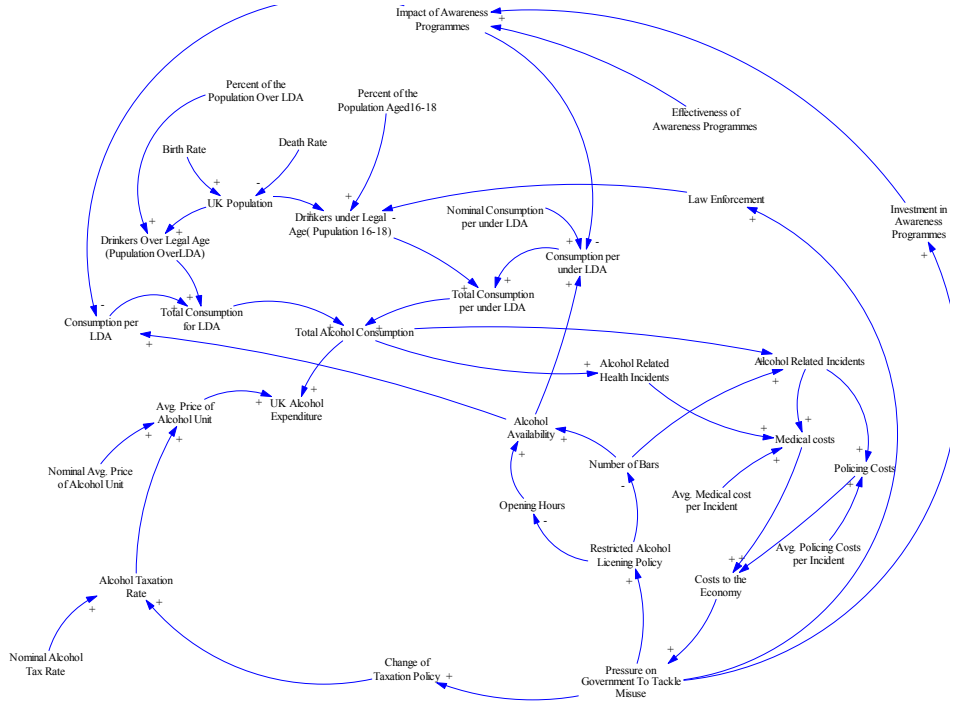

Figure 4: Policy Intervention

However, the government is also subjected to other pressures that push in the opposite direction. As alcohol consumption in the country increases, alcohol tax revenue will increase as well. This will offset, and probably exceed, the costs to the economy caused by alcohol misuse, resulting in ease the pressure on the government to take action. Additionally, as alcohol expenditure decreases, profits of the industry will plummet, which would force the industry to exercise pressure on the government to relax the taxation policy (Figure 5).

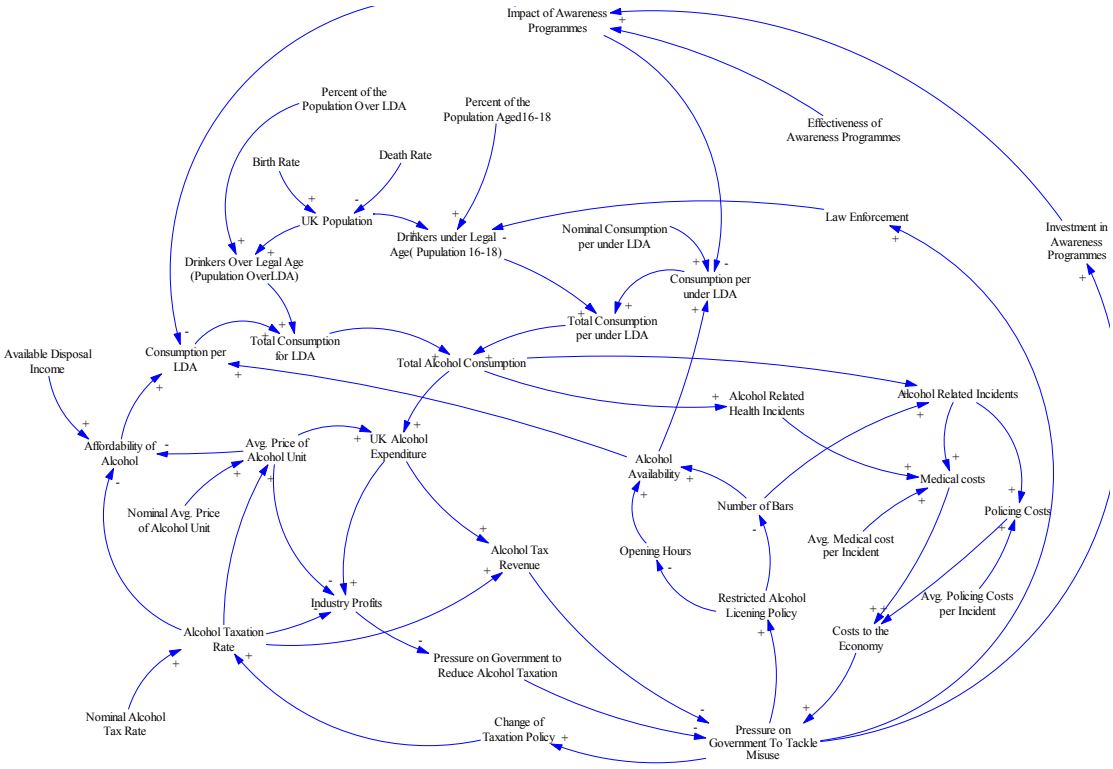

Figure 5: Influence Diagram of Alcohol Misuse

The influence diagram contains several reinforcing and balancing loops, two of which deserve further elaboration. The balancing loop links alcohol consumption to the costs to the economy and taxation. As drinking rises among the population, the number of alcohol-related incidents will increase, placing higher economic burden on the economy and intensifying pressure on the government to intervene. The government could react by imposing higher taxes on alcohol, which will make it less affordable, and therefore reduce consumption. On the other hand, higher levels of alcohol consumption will lead to higher tax revenues for the government. The tax revenue may compensate for some of the costs incurred as a result of alcohol misuse, and would therefore reduce pressure on the government to tackle the problem. The fading pressure may lead the government to cut back on its spending on law enforcement and awareness programmes, which would in turn increase alcohol consumption, particularly among those under the legal drinking age.

Based on this influence diagram, a simulation model was developed to enable the quantitative investigation of the problematic situation and to provide a test vehicle to

experiment with different policy options and evaluate the outcomes of each possible intervention. The developed simulation model is shown in Figure 6.

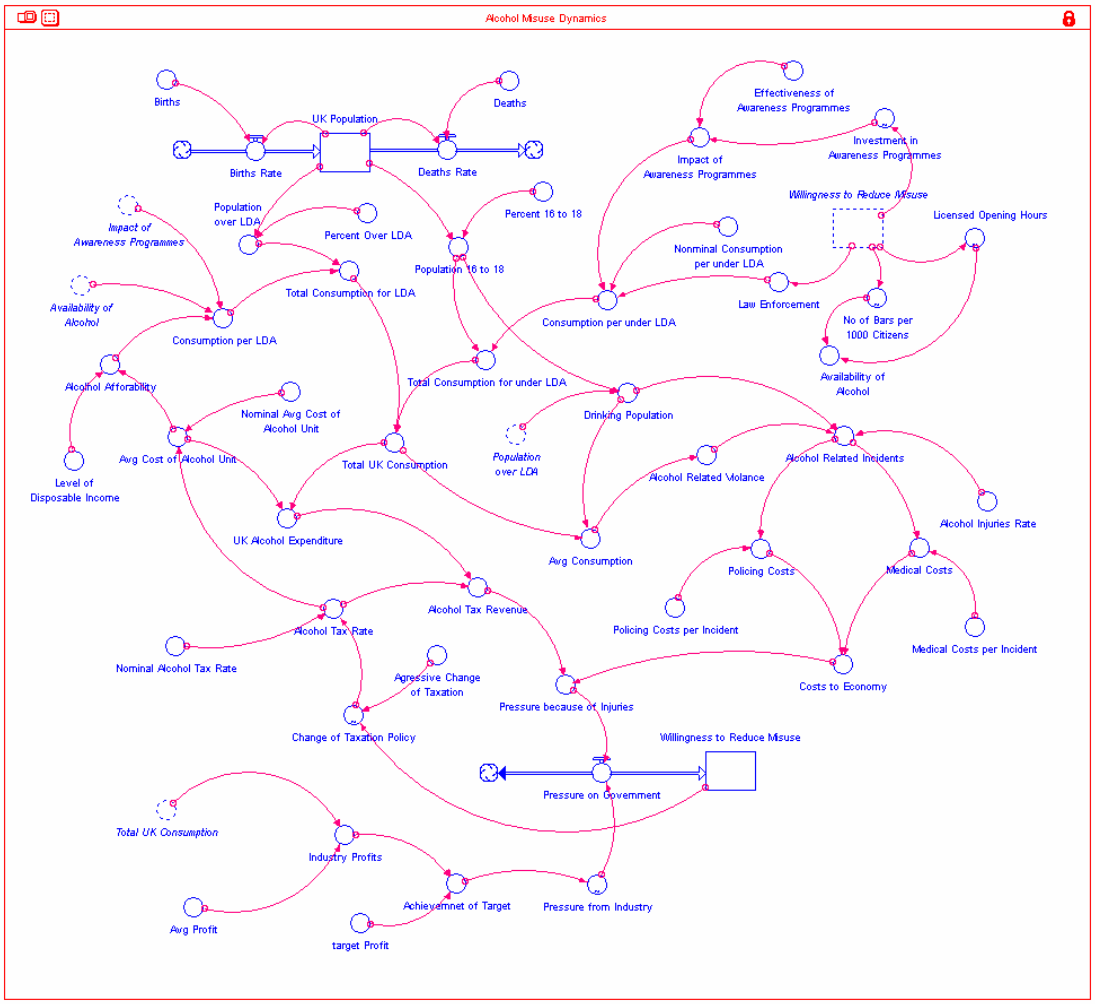

Figure 6: Alcohol Misuse Simulation Model

Model Validation

Before the developed model can be utilised to experiment with different possible scenarios and policy options, an acceptable level of confidence should be established in its behaviour. The validation process was conducted based on the sample amount of statistics and quantitative data published from several sources (The Home Office, 2006; Department of Health, 2005; Cabinet Office, 2003; NHS Health Development Agency, 2005). Table 1 shows the input parameters used in the simulation model and the results produced after running the model. The results produced by the validation simulations were highly comparable to previous statistics, which increases confidence in the validity of the model and its applicability to the problem under study.

Input Parameters			
Average price of alcohol unit	0.85 £	Number of licensed premises per 1000 citizens	2
Costs of policing and judicial system per incident	3400 £	Costs of policing and judicial system per incident	890 £
Results			
Costs to the UK Economy	8.4 Billion £	Alcohol Tax Revenue	14 Billion £
Average annual consumption for people above the legal drinking age	930 Unit		

Table 1: Base Case Simulation Inputs and Results

Model Exploitation

Once the model has been developed and validated, it can be utilised as a testing vehicle to experiment with different scenarios and policy options before these policies are implemented, and thus reduce the risk of negative consequences or unexpected outcomes. It also aids the ethical testing of policies and intervention as such testing does not require real world implementation before the outcomes can be evaluated. Another advantage is the ability to conduct these experiments in a very short period compared to the lengthy research projects that seek to evaluate the effects of policies and interventions in the real world. Apart from assessing the viability of each policy option, the model can provide great insight into the cost effectiveness and relative impact to compare several possible policies and facilitate the selection of those that have the highest leverage.

Moreover, the model can be effectively utilised to develop better understanding of the alcohol misuse problem and provide insight into the different factors involved and their interactions. It can also aid the formulation of a highly effective research agenda to address the areas that need further investigation. Two scenarios for tackling the alcohol misuse problem have been designed and tested using the model.

In the first scenario, the UK government was expected to take an aggressive stance towards the change of alcohol taxation policy to mitigate the impact of binge drinking. Figure 7 shows the values of two significant factors from the model, namely the Total UK Consumption and the UK Alcohol Expenditure. As increased pressure is exercised on the government to tackle alcohol misuse because of the growing concern of binge drinking, the government responds by introducing higher taxes on alcohol sales. With higher taxes, alcohol becomes less affordable, and overall consumption and expenditure plummet. The lower expenditure on alcohol will reduce the industry profits. The industry will react by pressuring the government to loosen its strict taxation policy. Given that at this stage the number of alcohol related incidents has declined and that tax revenues far exceeds the costs to the economy of binge drinking, the government will be more inclined to listen to the industry voices and reduce alcohol taxation. The graphs on Figure 7 show the zig-zag effect created as a result of the interaction of opposing pressures on the government to tackle alcohol misuse.

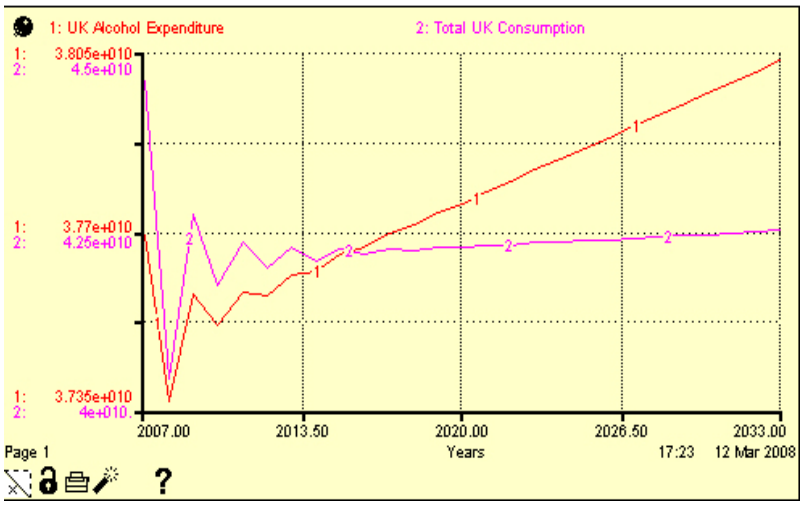

Figure 7: Aggressive Change of Taxation

Eventually, the system will reach a state of equilibrium where the government taxation policy stabilises and so does the alcohol consumption. The system is expected to stay in this state unless external circumstances change in the environment which may alter this balance. At this equilibrium, shown on the graph to be around the year 2033, policing and health costs of binge drinking to the economy are expected to reach 8 billion £. Total alcohol tax revenues are expected to reach 17.7 billion pounds.

The second scenario assumes that the government will not use taxation as a means to tackle alcohol misuse. In this case, the intervention is limited to three other areas, namely: restrictions on alcohol licensing (number of licenses granted to sell alcohol), bar and pub opening hours and awareness campaigns. Figure 8 shows the simulation results of this scenario. The trend shown in the figure reflects a steep slide in alcohol consumption as a result of the government's reaction to pressures to tackle misuse. This is mainly achieved by controlling licensed opening hours, number of granted licenses and alcohol awareness campaigns. The decrease in alcohol consumption will lead to lower alcohol related incidents and will consequently ease the pressure on the government to intervene. The situation then stabilises with steady, modest growth in consumption. Because no tax increases are introduced, prices of alcohol remain relatively stable, and per capita consumption will not be as volatile as it was in the first scenario. The increase in consumption over time could be attributed to the population growth in the country.

By the end of 2033 in the second scenario, total alcohol consumption would be around 6% higher than the total consumption in the first scenario. Costs to the economy would be expected to reach 8.5 billion £ while alcohol tax revenue would decrease to 10.8 billion £. The comparison between these two scenarios clearly indicates the effectiveness of taxation policy in tackling alcohol misuse and provides the decision makers with supported evidence to make undertake informed policy actions.

Other policy decisions that could be investigated include comparing the costs and return on investments of several possible interventions. The cost of running an extensive alcohol awareness campaign for example could be weighed against the expected benefits. It can also be compared against a stricter policy on licensed

opening hours so that any decision to choose a particular intervention, or a mix of possible options, could be justified.

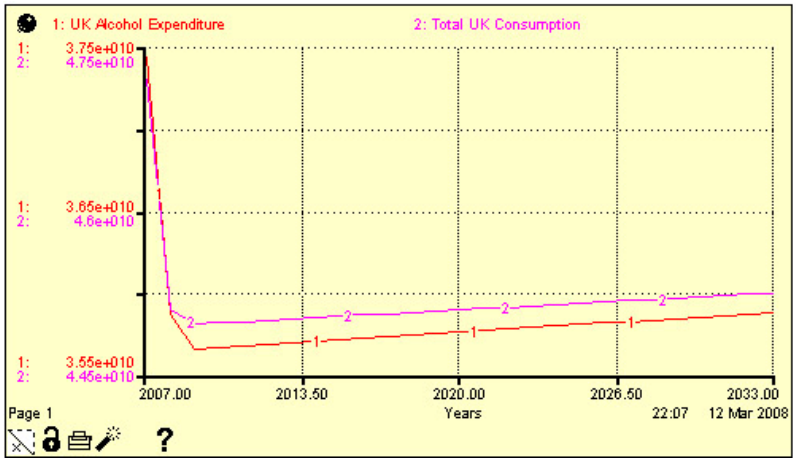

Figure 8: No Changes in Taxation Policy

The UK government could also use the model to communicate and justify its policy decisions with other stakeholders and the public. A useful advantage of System Dynamics modelling is that it reveals the implicit mental frameworks and assumptions of different stakeholders. By exposing what the government believes to be the structure of the alcohol misuse problem, others (including the public, the industry, the scientific community, etc) could challenge these assumptions and provide suggestions to refine the model.

Conclusions

Alcohol misuse is a growing problem in the UK which is causing the economy billions of pounds per year. Existing evidence suggests a close link between binge drinking and anti-social behaviour, increased assaults and more health problems. The government has been trying to tackle the problem through several policy tools and interventions. Much research has been undertaken to explore the nature of the problem in order to derive recommendations for the most effective methods to tackle the problem. Surprisingly, little consensus exists in the literature about the causal relationships that affect binge drinking.

In this paper, we argued that alcohol misuse is a systemic problem that involves a large number of interacting factors. The traditional reductionist approach to scientific research is not well suited to address these problems, and would at best produce a limited understanding of the observed phenomenon. We propose the use of System Dynamics as a holistic approach to exploring the alcohol misuse problem.

Based on an extensive review of the existing literature, an influence diagram of alcohol misuse was developed. This diagram depicts many interacting factors believed to have a significant impact on the problem being investigated. An initial quantitative simulation model was then built to server as a testing vehicle for different policy options. The simulation model was validated against published statistics to establish reasonable level of confidence in its behaviour. Once validated, the model was used to

simulate the possible impact of several policies and to evaluate potential scenarios that may happen in the future. We demonstrated that this approach could offer great value to decision makers by allowing the testing of different proposed policies without the expensive and lengthy real world policy experimentation.

Further Work

This work should be extended through more research into the relationships and quantitative values that could be used in the model. The influence diagram is of significant value to identify areas for further research. For example, measuring the impact of an alcohol awareness programme is an area that requires more investigation. The initial model could also be extended to include more elements, such as the impact of advertising on those above or below the legal drinking age. The age group can be expanded to include younger drinkers from age 12 and more investigations could be done to study different factors that affect the drinking habits of different age groups in order to design and test programs and policies that target problems associated with each group. More policy experiments should be designed, executed and analysed and the model's utility validated based on the outcomes.

References

Anderson, P. & Baumberg, B. 2006. *Alcohol in Europe*. London: Institute of Alcohol Studies.

Boreham, R. and McManus, S. 2003. *Smoking, drinking and drug use among young teenagers in 2002: A survey carried out on behalf of the Department of Health by the National Centre for Social Research and the National Foundations for Educational Research*. The Stationery Office, London.

Cabinet Office 2003. *Alcohol misuse: How much does it cost?* London.

Cabinet Office, 2004. *Alcohol Harm Reduction Strategy for England*. London.

Cabinet Office Strategy Unit Alcohol Harm Reduction Project, 2003. Interim analytical report. London.

Coleman, L. M., & Cater, S. 2004. Fourteen to 17-year-olds' experience of 'risky' drinking—a cross sectional survey undertaken in south-east England. Drug and Alcohol Review, 23, pp. 351–353.

Department of Health 2005. Alcohol Misuse Interventions, Guidance on developing a local programme of improvement.

Forrester, J. W. 1973. *Industrial Dynamics*. MIT Press: Cambridge, MA.

Godfrey, C. 1988. *Licensing and the Demand for Alcoho*l. Applied Economics, 20, pp. 1541-1558.

Graham, K. and West, P. 2001. Alcohol and crime. *International handbook of alcohol dependence and problems*. John Wiley and Sons, London, pp. 439–470.

Klingemann, H. 2001. *Alcohol and its social consequences – the forgotten dimension*. WHO Regional Office for Europe, Copenhagen.

Mattinson, J. 2001. *Stranger and Acquaintance Violence: Practice British Crime Survey, Briefing Note 7/01*. London: Home Office.

MORI 2001. *Alcohol and Society*. London: Portman Group.

NHS Health Development Agency 2005. *Prevention and reduction of alcohol misuse - Evidence briefing* (2nd edition).

Parliamentary Office of Science and Technology (POST), 2005. *Binge Drinking and Public Health*. London.

Pincock, S. 2003. *Binge drinking on rise in UK and elsewhere*. The Lancet, Vol 362, Issue 9390, pp. 1126-1127.

Plant, M. 2006. *Binge Britain: Alcohol and the national response*. Oxford: Oxford University Press.

Sivarajasingam, V., Matthews, K. and Shepherd, J. 2006. *Price of beer and violence-related injury in England and Wales*. Injury, Vol. 37, Issue 5, pp. 388-394.

The Home Office 2006. *Underage drinking: findings from the 2004 Offending, Crime and Justice Survey*. London.

Varney, S. J. and Guest, J. F. 2002. "The Annual Societal Costs of Alcohol Misuse in Scotland". Pharmaco Economics, 20(13):891-907.