An Evaluation of Healthcare Policy in Immunisation Coverage in Uganda

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Abstract.
This paper presents initial results from fieldwork on immunization coverage as part of improving health care policy implementation in Uganda. System Dynamics modeling and case study research methods are used to capture the complex and dynamic nature of the immunization process, to enhance the understanding of the immunization health care problems and to generate insights that may increase the immunization coverage effectiveness.

Field studies have been conducted to establish the operational immunization policy issues of concern to health care management, which included capturing reference modes for the key variables and developing causal loop diagrams to illustrate the dynamics among key variables. The paper suggests an initial model that could be used for theory building in immunization policy evaluation.

Keywords: System Dynamics, Modelling, Feedbacks, Delays Immunization Coverage, Health care policy

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Introduction

Understanding immunization health care policies is arguably one of the most important processes in evaluating health care strategies to eradicate childhood diseases. Increasing immunization coverage to prevent childhood diseases has become an important developmental issue (DISH 2002; WHO 2002; WHO 1999) and an area of critical research (Dexter *et al.* 1999; Edmunds, Hethcote 1997; Stafford and Aggarwal 1979; Subramanyan and Sekhar 1987). While global coverage for DPT3 (three doses of the combined Diphtheria/ Pertussis/Tetanus vaccine) remains between 70-76 per cent since 1990, significant variations exist between and within regions and countries. Coverage for South Asia and Latin America remain stagnant at 71 per cent and 89 per cent respectively. The Central Eastern Europe and the Commonwealth of Independent States (CEE CIS) region are experiencing a decline to 88 per cent. Sub-Saharan Africa, for example, lags behind, but continues to make steady progress with coverage at 60 per cent estimated in 2003 (UNICEF 2004).

Immunization coverage is lowest in poor countries and among poor populations (Gwatkin 2001). Although an effective measles vaccine was licensed in 1963, almost 30 million measles cases and 777,000 deaths occur every year, with most occurring in sub-Saharan Africa (WHO 2001). Measles immunization coverage in sub-Saharan Africa is estimated to have dropped from an average of 62% in 1990 to 50% in 1999 (UNICEF 2003). For instance in **Uganda**, the mortality rate among children < 5 years old is 152/1000 live births (UBOS 2001) with measles ranking fourth among the causes of morbidity and mortality.

The World Health Organisation has targeted measles for eradication in several regions of the world by the year 2010, but despite an effective vaccine there is still estimated to be 30-40 million measles cases and 800,000 deaths per year (WHO, 2002;1999). Immunization is currently high on both national and international policy and aid agendas especially in relation to Africa.

Although children's health can benefit greatly from immunization against infectious diseases, implementation of immunization programs creates problems of managerial nature. Many causes and solutions of poor immunization coverage have been suggested by various researchers (Borooah 2003; DISH 2002; Drain *et al*. 2003; Leask and McIntyre 2003; WHO 2002; Ymba and Perrey 2003) which clearly depict the complex nature of the immunization system thus the need to utilize System Dynamics which is increasingly being used in solving problems of complex nature such as these.

Origins of the present study

The authors, a PhD student and supervisor initiated this study with aim of using the System Dynamics methodology to understand the immunization health care problems and generate insights that may increase the immunization coverage effectiveness. Motivation of the study resulted from the fact that in Uganda, despite numerous immunisation campaigns over the media, health visits and improved health services; the coverage rates are generally still low (less than 60%) (WHO 2001). A lot of contributions by donor agencies and projects have been made towards the improvement of immunisation rates through the improvement of health infrastructure, financing, supplies, staffing and management of national immunisation programs.

The Problem

Despite a significant level of access to immunization services in Uganda as reflected by DPT1 coverage, the drop out rate 27% (DPT1 - DPT3) in more than 70% of the districts is still very high (WHO 2001). Due to low coverage, epidemics such as measles still occur in many countries in the world. The immunization coverage has continued to decline, mainly due to insufficient demand for immunization (DISH 2002). In the year 2001, 18% of the districts reported more than 80% completeness, 59% of the districts reported 50-79% completeness and 23% of the districts reported less than 50% completeness of DPT3 in the country (WHO 2002). This shows that 82% of the districts are still far below the immunization target for the year 2005, which has been set at 80%.

In order to understand immunization coverage problems this research set out to develop a system dynamics model as a decision support tool that would be used to evaluate the different potential effects of policies, in what if? dynamic analysis to understand the factors that influence insufficient demand for immunisation as well as propose operational policies for debate and development in Uganda. In order to achieve this, there was need to establish the key factors that contribute to the low immunisation rates by modeling the immunisation system to establish how these factors influence insufficient demand for immunisation.

Methods used to study Immunization

This section sets out to highlight some of the methodologies that have been used to study immunization. Surveys and statistical analysis have been widely used in immunization coverage (Ymba and Perrey 2003; Borooah 2003; Joseph and Goddard 2002; Lansley and Bedford 2003; Wilson *et al*. 2003; Berlioz-Arthaud, Perolat and Buisoon 2003). Case studies have been used in determining issues related to immunization coverage (Leask and McIntyre 2002; Lehmann *et al*. 2003; Bryce *et al. 2003*). Bozette e*t al*. (2003) used a model to form the debate for smallpox – vaccination policy for the United States. Ministry of Health, New Zealand, (1998) used a deterministic Susceptible, Infectives, Recovered (SIR) model to investigate the dynamics of measles in New Zealand, predict the timing of the next epidemic and explore the changes in the age distribution of measles cases. Hall *et al*. (2002) used the discrete choice modeling to predict vaccination rules as well as allow policy makers to design programs.

Subramanyam and Sekhar (1987) undertook an operations research to identify optimal distribution system for vaccines in the rural areas. The immunization system was divided into the following three subsystems: -

- supply subsystem which simulated the supply of vaccines,
- vaccination distribution subsystem which simulated the ordering and allocation process of vaccines
- immunisation subsystem which focused on the number of children immunized

The research highlights some key issues and delays in the supply and distribution of vaccines typical to a developing country and also provides key formulae and definitions as far as vaccine supplies are concerned. It demonstrates the effects of different supply and demand conditions of vaccines and suggests that irregular supply of vaccines from the manufacturers to the regular depot and hence to the health centers as being one of major hindrances of the implementation policy. The study, however, focuses on isolated events of vaccine distribution and supply and does not look at the immunisation system as a whole.

The methods that are mentioned in this section use linear approaches that leave out feedback loops which are important factors in the dynamics of immunization coverage. In this explorative study on existing variables, feedback loops that seem to govern the dynamics of the immunization system are covered.

Use of System Dynamics in Health Care

System dynamics which provides qualitative description, exploration of complex systems in terms of their processes, information, organizational boundaries and strategies (Wolstenholme, Henderson and Gavine 1993) has not been widely used in the study of immunization. What makes using system dynamics different from other approaches is that they look at the organization as a system made up of interacting parts as opposed to focusing on isolated events and causes. Studies focusing on various areas of immunization coverage have been carried out and a number of factors associated with it have been suggested.

Maani and Stephenson (2000) mention the key factors impacting immunization rates as provider incentives, strategy fragmentation and parent's role. The reasons why parents do not take their children for immunisation are grouped into two main categories namely apathy and fear. In a typical developing country such as Uganda, there are more fundamental issues related to the immunisation coverage such as the provision of health care services, distribution and delivery of vaccines, mother's availability and willingness to participate and availability of funds. In this study the researcher examines the various studies and takes a holistic approach to the immunization system by focusing on the Ugandan situation.

Edwards, Shachter and Owens (1996) developed a dynamic model of HIV transmission that would be used to evaluate the costs and benefits of HIV vaccines programs in a population of homosexual men. Results of the study showed that the cost effectiveness of vaccine programs depends on the epidemic growth rate. The study also shows that the behavioural changes that accompany a vaccine program can substantially influence the desirability of the program. The study suggests that policy makers should consider coupling vaccine programs with the state-of-the-art behavioural interventions. The effect of HIV vaccine program depends on transmission patterns on HIV within the population at risk. The dynamic model has some significance to this research particularly in showing the benefits vaccine programmes may have on behavioural changes of the population and the costs associated with them. However, one limitation that is presented here, is that the HIV epidemic heavily depends on human behaviour whereas the occurrence of immunisable disease epidemics do not necessarily depend on human behaviour.

System dynamics provides us with tools which help to better understand difficult management problems such as faced by the immunization system in Uganda. Many health care systems are very complex with many interested parties (clients, doctors, nurses, managers, policy implementers) and are demanding to manage. One possible step towards effective decision making is good communication where all interested parties must be able to interact effectively with all other parties to promote understanding.

Research Design

Finkelstein (1994) calls for identification of appropriate research methodologies, ”notably those that combine the use of observation, experiment, case study and mathematical proofs”. This research combines field studies-based case study research method (Yin 1984) and system dynamics simulation modeling (Forrester 1961; Richardson and Pugh 1981; Sterman 2000). Simulation modeling (Law and Kelton 1991) provides an opportunity to study situations through experimentation that might otherwise be impossible to analyse, while case studies (Yin 1984) capture reality in greater detail and enables analysis of more variables than is possible using other research strategies (Galliers 1984).

Field Studies

Field studies to determine the full range of activities and events that are associated with immunization coverage and to examine the various acknowledged factors associated with the provision and utilization of immunization services were carried out. The study was both qualitative and quantitative. Data was collected through interviews using semi-structured questionnaires from various stakeholders who are functional agents interested in the current immunisation system with national and district policy makers, health workers and mothers.

The study was carried in Mukono district which lies in the central region of Uganda. Mukono was purposely selected as the area of study since it has a good representation of both rural and urban population. The people of Mukono district reside both on the islands (1 county) and the mainland (3 counties) and the population of consists of more than 18 tribes which would benefit the research by gathering cultural beliefs and opinions from the various tribes.

Interviews with the stake holders of the immunization process, field observation of some activities and also other sources of data especially those that would be able to highlight the historical, social, political and economic context within which the case resides have been carried out. Stakeholders who are functional agents interested in the current immunisation system include mothers (caretakers), health workers, district health officials, implementers of policy (UNEPI), policy makers (government) and community leaders.

Reference Modes

The key variables in the immunisation system are the immunisation coverage rate and the drop out rate. Immunisation coverage refers to the proportion of the population or age group receiving a vaccine or a series of vaccines out of the total target population or the total target age group (Guerin 1998). The drop out rate refers to the number of children who have not been fully immunized out of the number of children who have been immunized at least once. The historical reference modes for the key variables are shown in Figure 1 above. The immunisation coverage rates in Uganda, improve for a while though the effect wares off after some time which is an indication that the existing models have not fully solved the problem. As more campaigns and programs are launched, the rates seem to improve after a while the rates begin to drop. Similarly, the percentage of dropouts improves for a while though the effect wares off after some time.

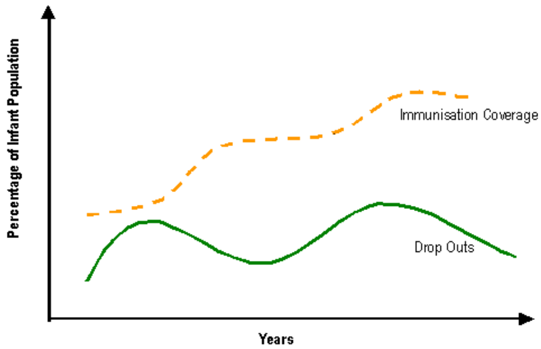

Figure 1 : Historical Reference Modes for the Immunisation System

Dynamic Hypothesis

In this section, the main feedback processes that influence the immunisation process are presented and the resulting dynamic behaviour is also discussed. The hypothesis provides a starting point for the understanding of the key factors that affect immunization coverage. Five balancing loops (*B1*,*B2*, *B3*,*B4*,*B5*) have been identified as shown in figure 2.

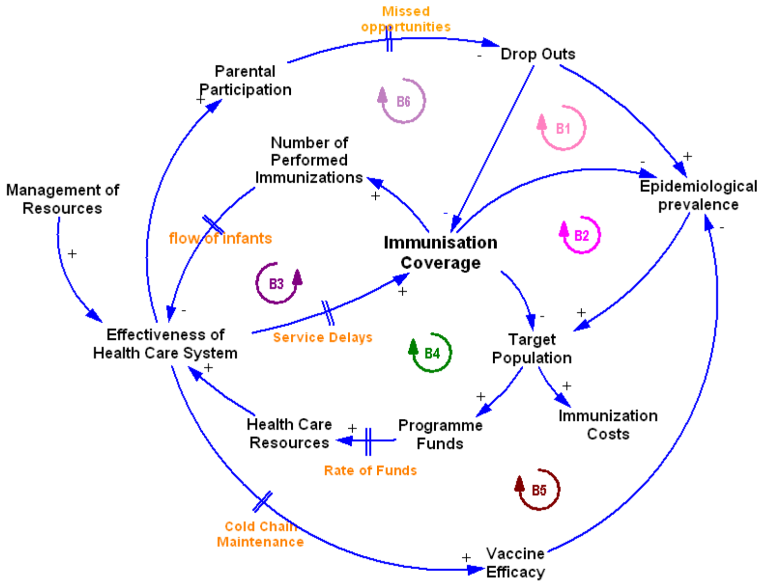

Figure 2: The Dynamic Hypothesis for Immunisation

The goal of **Loop B1** is to increase parental participation in immunisation coverage and hence reduce the dropouts. A decrease in parental participation increases the number of dropouts with some delays arising from missed opportunities, which lower the immunisation coverage. An increase in immunisation coverage lowers population that has been targeted for immunisation coverage. An increase in the target population requires more programme funds and more resources. An increase in the health care resources coupled with increase in management of resources will result in increased effectiveness of the health system that will increase parental participation.

Loop B2 is the main loop of the system that acts to reduce the prevalence of epidemics. An increase in the occurrence of epidemics results into an increase in the target population which requires more programme funds. When programme funds are increased, the provision of health care resources becomes better. Health care resources coupled with good management of the resources increases the effectiveness of the health care system which results in increased parental participation. Increase in parental participation lowers drop outs with delays arising from failure to follow the schedule which in turn reduces the occurrence of epidemics.

Loop B3 acts to deplete the effectiveness of health care system. With wider immunisation coverage, the number of performed immunizations increases which in turn reduces the effectiveness of the health system with some delays arising as the numbers increase. As the effectiveness of health care system deteriorate, the immunisation coverage reduces over time.

The goal of **Loop B4** is to provide the targeted population with immunisation services. An increase in immunisation coverage reduces the population that is being targeted. An increase in the target population requires more programme funds and more resources. An increase in the health care resources coupled with increase in management of resources will result in increased effectiveness of the health system which will increase immunisation coverage and as such lowering the target population.

The goal of **Loop B5** is to maintain vaccine efficacy which is the relative reduction in susceptibility to infection, given a specified exposure to infection. Vaccine efficacy contributes to a reduction in the occurrence of epidemics. The effectiveness of the health care systems provides well serviced equipment and health workers, which are key in the maintenance of the cold chain system as such, help in the maintenance of vaccine efficacy.

Loop B6 acts to increase immunisation coverage by reducing the number of dropouts. With increased effectiveness in the health system, more parents participate in immunisation coverage. Increased parental participation reduces the number of dropouts which in turn increases immunisation coverage.

Initial Results

The immunisation system at the operational level has been divided into three-sub systems namely health care system, parental participation and vaccine management. In this paper causal loop diagrams of the health care system and parental participation system have been developed.

Parental Participation sub-system

The parental participation subsystem is based on the case study that was undertaken and immunisation studies of other researchers (Borooah 2003; DISH 2002; Drain *et al*. 2003; Leask and McIntyre 2003; WHO 2002; Ymba and Perrey 2003). From the study the key issues that affect parental participation are grouped under the following as shown in the causal loop diagram (Figure 3) :

- Availability of immunisation services – issues such as vaccination schedules, number of vaccination providers and access to health facility reduce the availability of immunisation services to mothers.
- Mother's availability - issues that affect the availability of mothers includes family problems, high poverty levels, single parenting, number of children in the household, mother's age, time schedule for mothers at their workplaces
- Level of trust in health system - as the effectiveness of the health centers increases, level of trust in health system increases resulting into a change in attitude towards increased demand in immunisation. Issues that are associated with the effectiveness of health centers include hygiene, levels of injection safety, number of health workers at the health center, and health workers response to the mothers.
- Level of immunisation awareness – factors affecting parental attitude are mother's level of literacy, belief in myths, effect of media, level of educational activities and effectiveness of community mobilization.
- Immunisation drop outs – various factors are associated with the level of civil unrest, children's ill health, level of complexity of immunisation schedule and provision of health cards.

Health Care sub-system

The health care sub system is based on field studies carried out in a number of health centers in Mukono district and various studies. From the study the key issues that are associated with the health care system are grouped under the following as shown in the causal loop diagram (Figure 4) :

- Levels of motivation of health workers - issues affecting health worker motivation include level of facilitation, remuneration, workload, provision of quality training which includes number of trainers, frequency of refresher courses, level of clinical practice and use of materials relevant to local culture.
- Effectiveness of outreach sessions (immunisation services provided to the communities) – factors associated with the effectiveness of outreach sessions are ease of accessibility of venue where the session are done, number of health workers per session, availability of outreach allowances, well defined area, time of day scheduled for the session, level of participation of community leaders and availability of village mobilisers.
- Effectiveness of monitoring of immunisation activities – this involves the following monitoring systems fir adverse events, documentation of immunisation activities, display of immunisation activities, reporting of immunisation activities and reviews of immunisation plans.
- Effectiveness of immunisation campaigns which is affected by the frequency of change in schedule (how often the vaccine schedules are changed), number of

campaigns in a year, availability of allowances, sufficient time for planning and effectiveness of communication.

- Efficiency of health facilities - this is affected by the availability of financial resources, availability of equipment, promotional activities and number of skilled health workers and proper management.

Figure 3 : Factors associated with Parental Participation

The figure shows the variables that are associated with parental participation in the immunisation process.

Figure 4 : Factors associated with Health System

The figure shows the factors that are associated with the health care system in Uganda.

Work in Progress

Reviews and development of the causal loop diagrams of the sub systems are being done. The defined system structures will be formulated as quantitative model with the aim of formulating the dynamic behaviour implied by the model assumptions. Stella modeling software on Windows platform will be used to develop a differential equation model. Model will focus on the measles epidemic and will be tested against different policies run for 15 years. The data from the field studies will be used to populate the model and test the propositions identified above with the aim of examining and evaluating the policies in the current immunization system in Uganda from a feedback control point of view. Policy analysis will be done by exploring different scenarios using model simulations.

Model Validation

Three modeling validation techniques will be employed to test the model.

- Structure based validation test is concerned with the formulation, ensures that the model is suitable for its purpose and consistent with the real system. This will involve judging the models representatives by discussing the structure with district health officials as well as the national health officials (UNEPI) who are concerned with the immunisation system in Uganda.
- Behaviour based validation test applies tests to policy analysis runs during the simulation. Model simulations will be used to test validity of the model construction.
- A modeling team will be used to test for suitability of the model for its purpose and problem being addressed. The team will comprise of experienced modelers.

Summary and Future Directions

This paper indicates that various studies on immunization coverage have been carried out using different methodologies but very little has been undertaken with the System Dynamics methodology. Several factors have been identified in the literature and validated to have specific influence on immunization demand and coverage administration. In order to understand immunization coverage problems this research will develop a system dynamics model as a decision support tool that would be used to evaluate the different potential effects of policies, in “what if?” dynamic analysis to understand the factors that influence insufficient demand for immunization as well as propose policies for debate and development in Uganda.

System dynamics methodology has been preferred since it has the advantage of capturing the complex nature of the immunization system as well as imploring the effect of various variables in relation to immunization coverage over time.

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