

Economic Burden of the Nova Scotia Mumps Outbreak

by

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at

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DALHOUSIE UNIVERSITY

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## DEDICATION PAGE

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## **ABSTRACT**

Infectious disease outbreaks can have a significant impact on healthcare resources and are disruptive to routine healthcare programs and services. There is very little literature on the economic burden of infectious disease outbreaks; thus, this research attempts to provide insight into the healthcare resources used to contain a mumps outbreak.

The Nova Scotia 2007 mumps outbreak provides an opportunity to produce a costing framework to capture the economic burden an outbreak has on the Nova Scotia healthcare system. The costing framework for this study used an accounting model to costing; in particular, it used an activity-based costing approach. The total mumps outbreak cost is estimated at \$2,478,500 or \$3,511 per mumps case.

Given the significant impact an infectious disease outbreak has on healthcare resources, more economic evaluations should be done to help guide policies around infectious disease prevention strategies, and to maximize the allocation of healthcare resources.

## LIST OF ABBREVIATIONS USED

AVDHA	Annapolis Valley District Health Authority
BCR	Benefit-Cost Ratio
CBDHA	Cape Breton District Health Authority
CDHA	Capital District Health Authority
CEHDHA	Colchester East Hants District Health Authority
CDPC	Communicable Disease Prevention and Control
CDPCN	Communicable Disease Prevention and Control Nurse
CBA	Cost-Benefit Analysis
CRS	Congenital rubella syndrome
CEA	Cost-Effectiveness Analysis
CER	Cost-Effectiveness Ratios
COI	Cost-of-Illness
DOH	Department of Health
DOHPP	Department of Health Promotion and Protection
DHA	District Health Authorities
EOC	Emergency Operation Center
E. coli	Escherichia coli 0157
HCW	Health Care Workers
HSEM	Health Services Emergency Management
HAI	Hospital-Acquired Infections
IC	Infectious Control
ICN	Infectious Control Nurse
LPN	Licence Practical Nurses
MSI	Medical Services Insurance
MSU	Medical Service Unit Value
MMR	Mumps, Measles and Rubella
NIE	New Institutional Economics
NS	Nova Scotia
OH	Occupational Health
OHN	Occupational Health Nurse
PRA	Probability Risk Assessments
PHAC	Public Health Agency of Canada
PHN	Public Health Nurse
RN	Registered Nurse
SP	Sulfadoxine-Pyrimethamine
TMN	Treated Mosquito Nets
UTI	Urinary Tract Infections
VON	Victorian Order of Nurses
WTP	Willingness to Pay

## **CHAPTER 1 INTRODUCTION**

Economic burden studies are the oldest forms of economic evaluations used in the health field and are still one of the most common used today (Tarricone, 2006). These studies aim to illustrate the magnitude of a disease in dollar terms to society. Having a better understanding of the economic impact an infectious disease can have on society provides policy makers with the justification for intervention programs, helps determine the optimal use of resources, provides a basis for policy and planning, and supports the development of an economic framework for further evaluations (Kumaranayake et al., 2000; Rice, 2000).

### **1.1 Motivation for the Research**

In 2007, Nova Scotia (NS) experienced the largest mumps outbreak the province has seen since instituting routine mumps immunization in children. The source of the outbreak was traced back to a few infected individuals from New Brunswick attending a nightclub in Halifax, with the first index case reported on February 22, 2007 (Nova Scotia Health Promotion and Protection). Shortly following this index case were the St. Patrick's Day and the Easter long weekends, which facilitated a rapid spread of the disease due to large-scale gatherings and students returning home for the long-weekends (Watson-Creed, 2007). During the costing period between February 22 to October 31, 2007, there were 706 mumps cases reported, compared to the average of 1 – 2 mumps cases previously reported per year in NS.

This mumps outbreak has shed light on the issues around the immunization for mumps, measles and rubella (MMR) for Nova Scotians born between 1970 and 1992 (Public Health Agency of Canada). Individuals born within 1970 – 1992 were identified as the cohort most at risk of becoming infected with mumps. According to the literature, persons born before the licensure of the mumps vaccine (1970) are likely to have natural immunity from being previously infected with the wild virus (Public Health Agency of Canada, 2010). After implementing a one-dose MMR immunization program, it became evident that it was not sufficient to eliminate outbreaks completely, resulting in a second-dose of MMR being introduced into the immunization programs (refer to Chapter 3 for more detail) (Public Health Agency of Canada, 2010; Watson-Creed et al., 2006).

The 2007 mumps outbreak provides an opportunity to examine the economic implications of an infectious disease outbreak, and draws attention to the need to include potential outbreak costs into evaluation frameworks for all immunization programs. The next section will briefly discuss the policy implications this research intends to explore.

## **1.2 Policy Implications of Research**

In Canada, healthcare costs have been steadily rising and the need for economic evaluations to guide policy decisions that maximize the limited resources available is increasing as well. Coupled with this, there is a growing concern with influenza pandemics and the need for healthcare providers to have the necessary measures in place to respond efficiently and effectively. Understanding the full implications of an outbreak, such as the drain on resources and the surge in demand for relevant healthcare services,

can assist governments in preparing for more potentially costly and threatening outbreaks in the future. According to the literature on economic evaluations of MMR immunization programs, outbreak control costs have rarely been included due to the lack of available data (Pelletier et al., 1998). Gaining a better understanding of the economic implications of an outbreak can improve the quality of economic evaluations of immunization programs. A costing analysis can aid in policy development to address issues around response and prevention measures of an outbreak by healthcare providers; specifically, some of the questions this costing analysis can aid in answering are:

- How much funding was required from each cost component?
- How many personnel and other resources were needed to contain the outbreak?
- Was there surge capacity in each of the costing components to handle the resources needed to contain the outbreak?

There are limitations of this costing analysis with regard to policy implications. In particular, the applicability of this study from one country or disease to another is difficult due to different healthcare systems and resources needed to contain an outbreak (e.g., some outbreaks require large amounts of hospital care and others minimal). These limitations are tied to the epidemiology of the diseases themselves. This includes estimations of the number of infected individuals, implications of becoming infected, and the effectiveness of treatments, given that pathogens can become resistant, mutate and re-emerge. The next section will discuss the overall goals and objectives for the costing analysis.

### **1.3 Goals and Objectives of the Thesis**

The purpose of this study is to provide a costing framework to capture the economic burden of the 2007 NS mumps outbreak, providing new research into the costs associated with infectious disease outbreaks. Specifically, the goal of the thesis is to develop a costing framework that captures the economic burden of the NS mumps outbreak from the perspective of the healthcare system, during the period of February 22, 2007 to October 31, 2007.

In order to achieve the goal of the thesis, the following objectives have been identified:

- I. to provide an overview of the economic theory of infectious diseases and a review of the literature on the economics regarding mumps vaccines and vaccinations;
- II. to develop a costing framework that captures the economic burden of the NS mumps outbreak from the perspective of the healthcare system;
- III. to undertake an economic analysis of the NS mumps outbreak; and
- IV. to provide an estimate of the economic burden of the NS mumps outbreak.

The following chapters will deliver on the goals and objectives as follows. Chapter 2 will provide a summary of the economic theory of infectious disease; it will explore some of the key terms and concepts used to produce the costing framework. Chapter 3 will discuss the mumps virus and vaccine, followed by a summary of economic evaluations of the MMR vaccine effectiveness, costs and immunization programs. Chapter 4 provides a theoretical approach to costing and a summary of the costing framework components. Chapter 5 discusses methods for a detailed cost collection; in particular, the objective of

the analysis, components of the framework, and summary of input data collection. Chapter 6 will provide the results of the research findings. This will be followed by the conclusion chapter, which will summarize the main findings of the study and comment on the policy implications of the research.



## CHAPTER 2 ECONOMIC THEORY OF INFECTIOUS DISEASE

### 2.1 Assessing the Economic Burden of Infectious Disease

Assessing the economic burden of an infectious disease involves identifying the economic costs associated with a disease. Economic costs are also referred to as opportunity costs, i.e. costs related to forgone resources and loss in productivity due to an illness (Hodgson and Meiners, 1982). Economic burden of illness studies can be conceptualized as a partial economic evaluation, whereby only economic costs and not consequences (effectiveness, benefits) related to the illness are examined. The detail and depth of an economic burden study also varies depending on the perspective of the study, i.e. whether it is from the perspective of the health care system or society as a whole. As previously noted, economic burden studies can be a useful policy tool in understanding the magnitude of an illness in dollar terms, providing a justification for intervention, the allocation of monies to specific diseases, and providing a framework for policy and planning or evaluations (Rice, 2000).

One formalized method of undergoing an economic burden analysis is a cost-of-illness (COI) study, which was the first type of economic evaluation used in the health field (Tarricone, 2006). There are three types of COI studies: prevalence versus incidence-based; top-down versus bottom-up approaches; and prospective versus retrospective. R. Tarricone (2006) describes each of these types as follows.

### **Prevalence Versus Incidence Based**

In a prevalence-based COI study, the cases in a predetermined time period (usually a year) are identified, along with the direct costs and productivity losses as a result of the disease of interest. The incidence-based COI study takes into account the number of new cases within a specific time period and calculates the lifetime costs based on the onset in a given period. The strength of undergoing a prevalence-based COI study is to draw attention to the costs of an illness which are to be largely underestimated, while an incidence-based COI study sheds light on costs of new cases which can help to determine the best policy to take for prevention.

### **Top-down versus bottom-up approaches**

Given the two types of COI studies noted above (prevalence and incidence), there are two approaches used to perform the analysis. A prevalence-based COI study requires a top-down approach, which takes into account the allocation of total budget expenditures according to major diagnostic categories. For an incidence-based COI study, a bottom-up approach is used, whereby the quantity of health inputs used are multiplied by the unit costs. Such an approach requires very detailed information and is more comprehensive than a top-down approach.

### **Prospective versus retrospective studies**

A COI study can be conducted either prospectively or retrospectively, depending on whether the data are collected before or as all relevant events occurred or after.

Prospective studies would follow-up with patients or patient records as the events unfold, compared to a retrospective study which requires data collection to come from records kept of past events. A prevalence or incidence-based study can be done both prospectively or retrospectively; each has its own benefits. Retrospective studies are less expensive and time consuming than prospective studies given that all relevant events have taken place when the study is initiated. This is particularly the case when the life span of relevant events takes place over a relatively long period of time. Prospective studies offer more flexibility with regard to the template of the analysis and have more influence over the data collection process, compared to a retrospective study, which has to rely on the data available. This is particularly important with non-healthcare costs which are increasingly more difficult to calculate (such as transportation costs to and from the hospital for patients).

Once a study has been categorized based on the different approaches mentioned above, then the method in which the costs collected are organized is another important step in the analysis. Typically they are organized by three types of costs: direct, indirect and intangible costs (Hodgson and Meiners, 1982).

### **Direct Costs**

Direct costs have two components, which are composed of both medical and non-medical costs. Medical costs are payments made and resources consumed due to treatment, continuing and terminal care, rehabilitation, drug expenditures, physician care expenditures, medical research, and training of staff (Hodgson and Meiners, 1982;

Tarricone, 2006; Health Canada, 2002). Non-medical costs include items such as “home modifications, vocational rehabilitation, auto and health insurance” (Rice, 2000).

### **Indirect Costs**

Indirect costs are costs that stem from non-health care resources and are often referred to as productivity loss. Some of the indirect costs that can result for the patient are transportation costs, costs of relocating if regular treatment or supervision is needed, property losses, legal and court cases, informal care by family or friends, and volunteer time (Hodgson and Meiners, 1982; Tarricone, 2006). Another component of indirect costs is the productivity loss as a result of morbidity and mortality. Calculating productivity loss that involves morbidity or mortality is done by applying various specific techniques and requires a great deal more work and detail. One method of calculating the loss of productivity due to morbidity or mortality is by employing the human capital approach. This approach takes into account that an individual will be producing a stream of output throughout life and attempts to capture the loss due to production being cut short, and is calculated based on market earnings (Rice, 2000). This approach has been criticized in the literature as over- and underestimating costs. Specifically, this approach is noted as overestimating when labour is easily replaced in the market and there is not a great deal of lost productivity from a societal point of view (Rice, 2000). In contrast, the approach is noted as underestimating in so far it can undervalue life, since labour market conditions are imperfect, and wages often do not equal the marginal product of labour (Rice, 2000). Additionally, psychological costs are omitted from this approach, which include pain and suffering that stem from the burden of an illness.

Though every study is unique and varies in some respect due to limitations, such as available data, time or resources, there has been much criticism since there are no universal standard approaches to COI studies or to assessing the economic burden of illness. This makes it difficult for comparisons among different illnesses to be assessed based on their impact on the healthcare system or society. Furthermore, it makes comparisons from one jurisdiction or country to another difficult. Based on this, there have been attempts to provide standards in COI studies to mitigate these issues.

## **2.2 Economic Theory of Infectious Disease**

The study of economics concerns itself with the allocation of scarce resources based on the relative valuations of those resources by individuals and firms in the market. Economic theories are developed to provide a modeling framework, which helps to decide how to allocate these resources most efficiently. This next section will elaborate on the role economic theory has in the field of infectious disease and highlight limitations of economic modeling in this context.

When applying economic analysis to the health care system, there are different characteristics for some healthcare goods than for non-healthcare goods. For example, some healthcare goods received by the consumer cannot be resold or exchanged, as the good is embodied in the consumer, i.e. if someone becomes infected and seeks a cure or treatment, the cure or treatment cannot be sold or exchanged to another (Roberts, J., 2006). When studying the nature of infectious diseases compared to non-infectious

diseases, there are additional concerns that decision-makers have to deal with. Explicitly, the concern is in not only treating and curing the individual, but the risk of transmitting the infection to others. Due to the growth in resistance of organisms to therapies and antibiotics, some infectious diseases are becoming harder to treat, which can increase the chance of transmission (Roberts, J., 2006). This transmission can lead to infectious disease outbreaks and/or increase difficulty in the prevention of the disease, which may lead to a higher economic burden to society due to increased costs that stem from hospitalizations, expenditure on treatments, decrease in labour productivity, etc. However, as noted, the nature of infectious diseases is complex, as diseases can become resistant to treatments, and even when a treatment is available, other issues that need to be considered are: who should receive or pay for the treatment and what is the scarcity of available resources? These issues are discussed in subsequent sections; however, first, we will examine how economic theory can provide a framework to better understand the complex issues relevant to infectious diseases and how economic theory highlights these concerns.

The concept of externalities in economics helps to explain when a good could be over- or under-produced in a society, based on negative or positive externalities respectively. This concept can be applied when thinking about infectious disease. As mentioned previously, an organism can become resistant to treatment and cause treatments to become ineffective, increasing the risk of transmission and outbreaks. Such incidents could make control and treatment very expensive (developing new drugs, purchasing new drugs, hospitalizations) and could lead to increased morbidity or mortality; this would be an

example of negative externalities produced by infections. On the other hand, when individuals engage in prevention activities, such as vaccinations to protect against a disease, the good could be under-produced, if not enough of the population will engage in this activity to reach the point of herd immunity.

Another aspect of economic theory that can be applied in this setting is the concept of public goods. Public goods can be defined as goods that contain the characteristics of being non-excludable and non-rival. This means there is no effective means to exclude individuals from consuming the good, and the consumption of the good by one individual does not affect other individuals' ability to consume the good. In other words: it is difficult to exclude individuals from benefiting (Roberts, J., 2006). Infection prevention and control activities are said to have some of these characteristics, whereby excluding others from benefiting from an individual who was vaccinated (therefore, can no longer infect others) would be impossible, as would imposing a charge on those who receive this benefit. Further, if there are enough people in the population who are vaccinated to create herd immunity, some members of the society may choose not to be vaccinated and free-ride off those who have chosen to be vaccinated.

Two other important areas of economic theory that are useful in the study of infectious disease are those relating to asymmetry of information and the impact of uncertainty. In economic theory, a necessary component of efficient markets is that the consumer has complete knowledge of the good and all alternatives, allowing for rational choices to be ranked and made. However, often those infected by an infectious disease may not know

the likelihood of becoming infected, the implications of being infected or the effectiveness of different treatments (Roberts, J., 2006). Additionally, there can be a great deal of uncertainty around the epidemiology of emerging or re-emerging infectious diseases (Roberts, J., 2006).

## **2.3 Applying Economic Evaluations to the Field of Infectious Disease**

This next section examines some of the types of economic evaluations that are used when dealing with infectious disease while shedding light on methodological difficulties that can arise.

### **Cost-Effective Analysis**

Cost-effectiveness analysis (CEA) assesses outcomes (cases diverted, disability-adjusted life years, etc.) for an infectious disease, then compares the different treatment options to determine the most efficient method of achieving an outcome. Efficiency can be defined by the least amount of resources used or the least amount of side effects to a drug, and for other dimensions that are then evaluated (Roberts, J., 2006).

As noted by Goodman et al (2006), cost-effectiveness studies are a great way to synthesize data for a wide range of epidemiological behaviours and economic factors; however, they also note some of the difficulties that can stem from employing a CEA.



Goodman et al (2006) examined the Tanzanian government's decision to switch from a first-line drug treating malaria, chloroquine, to another drug, sulfadoxine-pyrimethamine (SP), to demonstrate methodological issues from employing CEAs. The need to explore an alternative treatment option for malaria was due to the drug, chloroquine, reaching a total treatment failure rate of 50 percent, whereas SP, for example, was only 14 percent (Goodman et al., 2006). When only one antimicrobial drug is offered, the disease can have the ability to mutate and become resistant to treatment, leading to high percentages of failure treatment (Laxminarayan, 2006). However, in the case of Tanzania, when the government made the announcement of switching drugs to SP, there was a substantial opposition to this decision by national level stakeholders, which reflects general methodological concerns with CEAs. Those who were reluctant about the change in first-line treatment based their concerns on the validity of data and assumptions embedded within the models to estimate drug resistance of the alternative, SP, and the impact of the drug's resistance on mortality (Goodman et al., 2006). Additionally, there were concerns around the timeframe used and if it was realistic to assume future availability of effective and affordable alternatives to SP (Goodman et al., 2006). Lastly, changing the first-line antimicrobial policy means a great deal of scrutiny from national policy makers, whose level of risk adversity may vary. In other words, they may be concerned that switching to another drug may lead to a high growth rate of resistance to treatment with no viable alternative, thus leading to a catastrophic outcome of an unmanageable outbreak (Goodman et al., 2006). High levels of treatment failure to the first-line drug may be preferable to a possible catastrophic situation from a substitute (Goodman et al., 2006).

### **Cost-Benefit Analysis**

The purpose of a cost-benefit analysis (CBA) is to monetize both the costs and benefits of a prevention strategy or treatment of a disease. Benefits are not restricted to health outcomes as in the CEA, but can incorporate non-health outcomes as well. There are three main approaches to calculating benefits in this regard: human capital approach, observed performance and stated preferences (Bhatia and Fox-Rushby, 2006).

As an example of methodology issues that can arise from undergoing a CBA, a project conducted in Surat India that estimated selected individual willingness to pay (WTP) for treated mosquito nets (TMN) will be examined (Bhatia and Fox-Rushby, 2006). In this study, they surveyed 126 villages and used qualitative data collected through questionnaires to determine how much the head of the household would spend on TMN to protect against malaria. After the study, the participants were revisited to be sold the TMN, providing an opportunity for researchers to test how effective the questionnaire was in estimating a demand for TMN. Some of the main concerns with conducting WTP studies, as noted by Bhatia et al (2006, p. 184), is that they “are prone to various biases, the reliability and validity of the stated WTP estimates are a major concern”. Reliability is a concern due to the lack of being able to retest measurements on the same subjects multiple times to gain a clear estimate of the variability in the data (Bhatia and Fox-Rushby, 2006). The validity issue arises due to not being able to test if the results obtained are truly indicative of what they are attempting to measure (Bhatia and Fox-Rushby, 2006). For the purpose of this study, the researchers did follow-up with the

individuals that took part in the study in order to sell the TMN, “where about 35% of the sample did not act in accordance with their hypothetical preferences” (Bhatia and Fox-Rushby, 2006, p. 195). However, undergoing such a study is vastly time consuming, and multiple follow-ups to verify results is difficult and costly. As well, there is concern about the generalizability of the results in different settings.

### **Cost-Of-Illness Studies**

COI studies are sometimes referred to as partial economic evaluations, where the study’s central tenet is to estimate the costs of a particular illness, taking into account both direct and indirect costs (Plowman, 2006). As noted by Drummond (1992), these studies do not provide insight on allocation of resources, but can provide insight into the economic burden of a disease and assist policy makers in prioritizing their agendas.

As previously noted, COI can be a tool used by policy makers in prioritizing their agendas to address high economic burden diseases. One of the key issues with using these studies is that low economic burden diseases tend to be overlooked, even though they can be easily prevented and have a significant impact on the quality of life if avoided (Plowman, 2006). An example is urinary tract infections (UTI), which have a relatively low cost per case, but in the aggregate, may be one of the most costly hospital-acquired infections (Plowman, 2006).

How to determine the costs and benefits accounted for in a COI can substantially differ from study to study, and this stems from a wide range of factors that can influence the

outcomes of the studies. In addition, these differences can affect the employability of these studies for policy makers. In Graves et. al.'s (2006) study of hospital-acquired infections (HAI), one of the methodological problems referred to in the study was controlling for different types of biases: “selection bias, severity bias, and endogeneity bias” (p. 112). To focus on the first two types, selection and severity bias, there is a trade-off relationship when accounting for the two issues. With severity biases, more variables are needed in the model to take into account the other reasons that may contribute to increases in resources for patients with HAI, compared to patients with no HAI, in order to capture the costs. However, as more variables are introduced into the model, this can eliminate potential candidates that could have been included in the analysis that can no longer be included because they do not match the control variables accounting for the infections, thereby increasing the problem of selection bias in the analysis.

This has been a brief description of the types of economic evaluations that can be used when analysing infectious diseases and the issues a researcher could encounter in their use. In addition, there are a vast number of other issues that should be taken into account when conducting these types of economic studies.

## **2.4 The Role of Risk in the Evaluation & Governance of Infectious Disease**

In economic evaluations involving interventions for infectious diseases, there is a great deal of uncertainty and risk associated with pathogens, which can affect the modeling

process for evaluators. First, in terms of uncertainty and risk, there are no probabilities assigned to uncertainty since it represents unknown events that cannot be predicted, whereas risks are known possible events and probabilities can be assigned to these events.

Using risk assessment techniques can provide essential information in an economic evaluation and there are two different types of methods that can be applied. The first is based on the number of cases of a particular infectious disease, where all known lifetime outcomes are provided along with the number of probable cases assigned that will fall under each category. A disease outcome tree model can be constructed and serve as a useful tool in organizing medical data of infectious disease cases, given the different types of outcomes that can stem from a particular disease and the probabilities which can be assigned to each scenario of the lifetime outcomes. Secondly, risk assessments can be used to calculate the risks of pathogen transmission based on different phases of events. A broad example of this second risk type of assessment is a probability risk assessment (PRA), which allows for estimates of risk-reducing options to be evaluated at each stage of possible contamination or spread of a pathogen (Roberts, T., 2006).

Roberts, T. (2006) provides a concrete example of a disease outcome tree model, involving an escherichia coli 0157 outbreak in the United States. For this outbreak, the Economic Research Service of the United States Department of Agriculture formulated a disease outcome tree model that depicted the full range of acute and chronic disease outcomes and provided the probabilities of all cases for each node. An economist can use

this to calculate the “medical costs, productivity losses, premature deaths and other consequences associated with each node of the disease outcome tree model” (Roberts, T., 2006, p. 240). Economists and policy makers can then determine the most efficient means of mobilizing resources and reducing the incidence of disease as quickly as possible.

In the field of infectious disease relating to food-borne illness, PRAs are a helpful tool in understanding the “... farm-to-fork food production and processing chain...” and all the possible points where contamination can occur (with probabilities assigned to each), thus, allowing for the most risk-reducing options for preventing contaminations to be calculated (Roberts, T., 2006, p. 246). Roberts, T., uses the works of Roberts et al (1999) to illustrate how valuable the PRA is in understanding the impact of beef slaughtering plant practices on process control and contamination of generic *Escherichia coli* 0157 (*E. coli*) (Roberts, T., 2006). For example, when steaming or applying hot water on the carcass before it goes into the chiller, normal practices show a 90% reduction in contamination while improved practices reduce contamination up to 99% (Roberts, T., 2006). Having detailed information on risk assessments for beef slaughtering allows for regulatory bodies to implement efficient practices that protect against contamination of food-borne diseases. As well, given the trade-off between efficiency in production and quality control, it can give government agencies flexibility in deciding how much contamination would be tolerable for different segments of the population. As Roberts, T., (2006) points out, stricter regulations may be needed when dealing with more vulnerable cohorts of the population, such as nursing homes, hospitals, etc.

To take another example, in the United States during the 1980s and 1990s, salmonella emerged as a leading food-borne pathogen (Buzby, Spinelli, and Nardinelli, 2006). This outbreak was attributed to raw or undercooked eggs (Buzby, Spinelli, and Nardinelli, 2006). There was a great deal of pressure for the regulatory agency responsible to decrease the level of infections in a short amount of time. A risk assessment was conducted to determine the number of eggs contaminated each year and the amount of illness due to the salmonella. Based on the results, further risk assessments were conducted to determine the proportional decline based on different potential regulations. A CBA was then carried out based on the risk assessment of each potential regulation option. This resulted in the government adopting new regulations for the labelling and refrigeration of shell eggs (Buzby, Spinelli, and Nardinelli, 2006). “[This] demonstrates how a public health agency can use information from risk assessment and a CBA to design a regulation to mitigate an emerging public health problem” (Buzby, Spinelli, and Nardinelli, 2006).

## **2.5 The Role of Transaction Costs in the Contracting & Regulation Related to Infectious Disease**

Transaction costs are part of the relatively new field of economics, referred to as New Institutional Economics (NIE). This field of economics focuses on the role of institutions in the market and sees institutions as a means to mitigate market failures. Institutions can be either formal or informal in nature: family, firms, and contracts to list a few.

Transaction costs are the costs associated with the cost of organizing, communication in bargaining contracts and enforcing/monitoring contracts (Kumaranayake 10, Jan., 2007). As noted by Jamasji-Pavri (2006), any issue that deals with contracting problems, which are a form of institution, should be considered through the lens of transaction costs economics. The objective in examining transaction costs is to choose a form of governance (institution) that best minimizes and mitigates these costs.

Jamasji-Pavri (2006) nicely summarizes the factors to consider when examining transaction costs, in the case of infectious disease case, to include:

**Asset specificity:** human assets that embody essential information and experience that would be difficult to replace or duplicate, and key relationships that are built within an organization to help protect against opportunistic behaviours of individual agents employed by the organization.

**Frequency of similar transaction:** as an organization deals with surveillance and investigation of outbreaks, the more improved is its capacity to handle these tasks through detection and management.

**Complexity and uncertainty surrounding the transaction:** individuals employed need to be flexible in their investigations due to the number of uncertainties surrounding an outbreak, creating difficulties in formulating complete contracts that take into account detailed information on required activities.



**Difficulty of measuring performance in the transaction:** as noted above, due to having multiple individuals involved in an investigation of an outbreak, it can be difficult to attribute weakness to an individual.

**Reliance on other transactions involving other people:** having multiple segments to an investigation system or various government organizations that are involved, entails multiple individuals involved in the process, making cooperation and coordination vital.

To summarize with respect to the prevention and control of infectious disease, during an outbreak there is a heavy reliance on multiple parties to carry out various tasks for controlling and managing the outbreak. It is this web of relationships that can cause great difficulty in attributing weakness of the organization to any one individual or group, and it is these information problems that reflect sources of transaction costs in contracting out to a private operator to manage outbreaks (Jamasji-Pavri, 2006). In addition to the information problems that stem from the web of relationships involved in controlling and managing an outbreak, there is the nature of the pathogen which may entail a great deal of uncertainty, making it difficult to draft a contract to begin with. Due to the high variability and uncertainty of each outbreak in terms of knowing when one will occur, the effects it will have on the population, and the necessary tasks to control and manage it, a difficult situation emerges in setting performance standards and drafting contracts that are all encompassing (complete) (Allen and Croxson, 2006). “The most appropriate form of governance for investigations is the public sector hierarchy”, which is thought to be ideal

to avoid the high transaction costs through contracting when possible (Jamasji-Pavri, 2006).

An example of high transaction costs that stem from contracts and the need for regulation to reduce these costs can be found in Roberts, T., (2006), which looks at the spread of avian flu among poultry. One of the most effective intervention and prevention strategies for avian flu is culling (Roberts, T., 2006). However, there are still many hazards that can stem from this method that are the result of high transaction costs when government contracts this activity out to private contractors or producers of poultry contaminated with the avian flu. Though noted earlier, the government may be the ideal agency to handle outbreaks, but in the case where the outbreak is embodied in an individual type of livestock, controlling and managing becomes more difficult. For example, there could be incentives by those contracted to not destroy all birds; the environment may become contaminated due to culling; and the individuals engaged in culling may not be well protected and become infected (Roberts, T., 2006). In addition, the birds that are culled can be a source of nutrition for other animals and be stolen by other individuals for consumption. Therefore, the monitoring and enforcement costs can be high. The role of efficient regulations for these transaction costs become vital in preventing or mitigating these costs. Providing compensation to encourage contractors to abide by the contract can be used; however, if compensation becomes too high, this may lead to contaminated birds being traded amongst bird producers to qualify for the subsidy. To prevent these activities, harsh legal consequences may be necessary and government surveillance may be needed. Even when the best monitoring system is in place, monitoring such contracts

can be costly and exemplifies the high transaction costs that can occur with respect to infectious disease prevention and control. This example, nonetheless, underline the great importance for government bodies not to overlook transaction costs in the first place, given that the spread and contamination of the disease may become worse otherwise. However, due to the cost of monitoring and controlling such an outbreak, many developing countries may not have the necessary resources to implement the necessary procedures. This may require international organizations to help draft, implement and monitor activities, since the rest of the world could be greatly affected otherwise.

## CHAPTER 3 LITERATURE REVIEW

### 3.1 Mumps Virus and Vaccine

Mumps is an acute infectious disease that originates as an infection of the nose and throat, and the virus spreads by direct contact between people (Gold, 2006). A contributing factor to the difficulty of controlling the spread of mumps is that 20 – 30 percent of mumps cases are asymptomatic and the infectious period can be up to 16 days (Public Health Agency of Canada 2010, 2).

The most common symptoms of mumps are painful swelling of the salivary glands (parotitis), anorexia, fevers, and head and muscle aches (Hviid, Rubin, and Mühlemann, 2008). It affects the reproductive organs of 20-30 percent of post- pubertal males (orchitis) and 5 percent of females (oophoritis), although these complications only rarely result in sterilization (Public Health Agency of Canada, 2006). Mumps is associated with an increase in fetal deaths for women pregnant during their first trimester (Offit and Bell, 1998). An infection to the lining of the brain (meningitis) occurs in roughly one to ten percent of cases, and inflammation of the brain (encephalitis) occurs in approximately zero to one percent of cases; but these do not typically cause permanent brain damage (Hviid, Rubin, and Mühlemann, 2008).

The mumps vaccine is derived from an attenuated mumps virus, whereby the wild virus is injected into a chicken embryo cell and weakened enough so that the body can produce antibodies to combat the virus while preventing actual infection (Offit and Bell, 1998).

The mumps vaccine is produced in monovalent form or in combination with measles and rubella, and there are approximately 11 mumps strains used for vaccine use around the world (Hviid, Rubin, and Mühlemann, 2008). Mumps vaccine was approved in Canada in 1969 as a monovalent vaccine and in 1972 it was replaced by MMR vaccine for a more cost-effective vaccination program (Gemmill, 2006).

### **3.2 Measles-Mumps-Rubella Vaccine Efficacy**

Since the licensure of the mumps vaccine, reported mumps cases have decreased significantly in Canada, the United States and the United Kingdom. In Canada, there was an “average of 34,000 cases reported per year in the early 1950s to under 400 cases per year in the early 1990s” (Public Health Agency of Canada, 2010). Similarly, “in the United States, 906 cases were reported in 1995, representing a 99% decrease from the 185 691 cases reported in 1968” (Caplan, 1999, p. 865). Vaccination against mumps was not introduced in the United Kingdom until the late 1980s; however, “reports of the disease declined 79% in the first year, from 20,713 in 1989 to 4,277 in 1990 (Cohen et al., 2007, p. 12).

Despite the impact the monovalent or combined mumps vaccines have had on the number of annual reported mumps cases, occasional outbreaks have emerged and continue to emerge in these highly vaccinated countries (Conly and Johnston, 2007). The United Kingdom had a large outbreak with more than 56,000 cases reported in 2005 – 2006; the United States and Canada also have experienced major outbreaks since 2000 (Public

Health Agency of Canada, 2010; Conly and Johnston, 2007). The question we address below is, why outbreaks are occurring in highly vaccinated countries. Even though there are explanations provided in the literature, there is no consensus to explain the exact cause for these outbreaks; rather, various probable contributing factors have been identified.

As previously noted, there is no consensus in the literature on MMR vaccine efficacy rates. The reported efficacy of the vaccine varies greatly depending on the type of study conducted, with clinical trial reports showing a higher or equal efficacy rate than reports from field studies. A single dose of the mumps vaccine has been reported in clinical studies to be 95 percent effective, while field study report rates range from 62 to 95 percent (Watson-Creed et al., 2006; Caplan, 1999; Cohen et al., 2007). Higher estimates in clinical studies could be a result of trials being relatively shorted-lived and may not capture secondary vaccine failure (waning immunity over time) (Cohen et al., 2007). Alternatively, lower estimates in field studies could be, inter alia, a result of issues regarding vaccine storage, administration, and inaccurate determination of vaccine status (Watson-Creed et al., 2006; Cohen et al., 2007).

A study done by Cohen et al (2007) calculated MMR efficacy using a different method than clinical or field studies, whereby a strict set of criteria was employed to select cases from a mumps outbreak in England. From the thousands of mumps cases reported in 2004 – 2005, only 312 cases were selected for the study. The criteria used to screen cases were as follows: only mumps cases confirmed by specific oral fluid testing within six

weeks of symptoms onset; those who were eligible for a routine two-dose MMR vaccination; and excluding vaccine related cases (developed symptoms six weeks after vaccine was administered) (Cohen et al., 2007). Once the data were collected, the study calculated the vaccine efficacy by examining the proportion of confirmed mumps cases to the proportion of the populations vaccinated. The study estimated that one-dose of MMR vaccine (mumps component) is 87.5 percent effective and a second-dose is 94.6 percent effective. Furthermore, an important observation was made based on their data and methodology; namely, that secondary vaccine failure (i.e. decreased vaccine effectiveness with age) can occur with either a one or two dose administration of the MMR vaccine (Cohen et al., 2007), indicating that “waning immunity may contribute to mumps outbreaks in older vaccinated populations” (Cohen et al., 2007, p. 12). Other studies suggest that primary vaccine failure (i.e. the body does not produce enough antibodies) is more likely than secondary vaccine failure (Watson-Creed et al., 2006; Caplan, 1999).

Another possible contributing factor to mumps outbreaks is that the MMR vaccination uptakes are too low to create herd immunity. The only country that has been successful in completely eliminating measles, mumps and rubella through immunization programs is Finland (Vandermeulen, Leroux-Roels, and Hoppenbrouwers, 2009). Since the beginning, Finland has taken an aggressive approach to eliminating measles, mumps and rubella. Contrary to other countries that implemented one-dose of MMR initially, in 1982, Finland adopted a two-dose MMR program coupled with a catch-up campaign for at-risk groups. Since 2000, Finland has eliminated measles, mumps and rubella cases; researchers suggest that a high rate of coverage needs to be sustained for decades in order

to prevent future outbreaks (Vandermeulen, Leroux-Roels, and Hoppenbrouwers, 2009; Tischer and Gerike, 2000). Additionally, studies have noted that MMR vaccination coverage needs to be 90 – 95 percent to prevent outbreaks (Vandermeulen, Leroux-Roels, and Hoppenbrouwers, 2009; Tischer and Gerike, 2000). For example, in the United States, coverage rates for a one or two-dose regimen of MMR has ranged from 86 – 87 percent - not high enough to prevent outbreaks (Vandermeulen, Leroux-Roels, and Hoppenbrouwers, 2009). The issue intensifies if efficacy rates are lower than 95 percent; in this case, coverage rates would need to be at a minimum of 95 percent to reach herd immunity (Vandermeulen, Leroux-Roels, and Hoppenbrouwers, 2009).

Affecting high MMR coverage ratings is parents' concerns surrounding the MMR vaccines' adverse reactions. The MMR vaccine (mumps component) first came under public scrutiny when a correlation between the Urabe mumps strain and aseptic meningitis was made in Canada and the United Kingdom (Miller et al., 2007; Bonnet et al., 2006). In the United Kingdom the report brought about an intense investigation using epidemiological, laboratory and hospital data; it concluded that the risk of developing aseptic meningitis following vaccination was 1 in 10,000-15,000 (formerly thought to be 1 in 100,000 vaccinations) when using the Urabe mumps strain in the MMR vaccine (Miller et al., 2007). According to the WHO, some strains are associated with higher rates of aseptic meningitis, including Urabe, the Leningrad-Zagreb and the Leningrad-3 strain vaccines, whereas the Jeryl Lynn mumps strain was not associated with aseptic meningitis or other complications (Watson-Creed et al., 2006; Hamilton-West, 2006). Even though there are risks associated with some of the mumps vaccine strains, the WHO



states that “... the incidence and severity of meningitis following natural mumps infection greatly exceeds that associated with any currently available protective vaccine” (Bonnet et al., 2006, p. 7043). Given this, and to prevent a shortage in MMR vaccines, the WHO encourages manufacturers to continue producing mumps vaccine strains associated with aseptic meningitis in order to meet the international community’s demand for MMR vaccines (Bonnet et al., 2006).

### **3.3 Measles-Mumps-Rubella Immunization Costs**

Since the 1980s, MMR immunization costing analyses have given healthcare providers insight into the true economic burden of mumps. The focus of these analyses has shifted over the decades; initially they examined the economic costs of adopting a one-dose, and then later on, a two-dose MMR immunization program compared with no program.

Two studies conducted in the 1980s were very similar, both analyzing the annual economic costs of a disease(s) in the absence of a MMR immunization program compared to implementing a program in the United States (Koplan and Preblud, 1982; White, Koplan, and Orenstein, 1985). The study by Koplan et al conducted a cost-benefit analysis (CBA) of the MMR vaccine (mumps component only), whereas the study by White et al analyzed the benefit, risks and costs of immunization for measles, mumps and rubella (Koplan and Preblud, 1982; White, Koplan, and Orenstein, 1985). Both studies used similar costing framework; including costs of the immunization program (i.e. vaccine, administration and adverse reactions), and the disease costs that are composed of direct costs (i.e. physician visits, hospitalization, etc.) and indirect costs (i.e. lost

earnings, both present and future, etc.) (Koplan and Preblud, 1982; White, Koplan, and Orenstein, 1985). Though both models were similar, the reported outcomes were vastly different due to the assumptions made within each study.

Koplan et al (1982) reported that, in the absence of an immunization program, the total cost of mumps would have been at \$6,271,764 (direct costs \$1,087,125 and indirect costs \$5,184,639), and with an immunization program in place, the costs were estimated at \$846,827 (direct costs \$16,883 and indirect costs \$79,664) in 1979 dollars. In this study, direct costs are approximately one fifth of indirect costs, with or without an immunization program, and the total costs decreased by 86 percent with an immunization program.

White et al (1985) reported, the total cost of mumps in the absence of an immunization program, to be estimated at \$345,504,782 (direct costs \$6,720,494 and indirect costs \$338,784,288), and with an immunization program in place, the costs were estimated at \$6,049,597 (direct costs \$157,871 and indirect costs \$5,891,726) in 1983 dollars. In this study, direct costs are approximately two to three percent of the indirect costs, and the overall cost decrease is 98 percent with an immunization program implemented (White, Koplan, and Orenstein, 1985).

Again, the reported findings in both studies vary greatly. Though both used similar frameworks to capture the economic costs, the assumptions used were not the same. Some of the more noteworthy differences in assumptions were net cost of lifetime earnings due to mortality: Koplan et al.'s (1982) study estimated \$45,000 and White et

al's (1985) estimated \$62,200. Koplan et al.'s (1982) case study had a cohort of one million, while White et. al.'s (1985) case study is 3.5 times larger at 3.5 million. Lastly, for "moderate" hearing loss, Koplan et al.'s (1982) study estimated costs to be \$2,416 per patient and White et. al.'s (1985) study estimated \$33,600 per patient.

An economic analysis of a two-dose MMR immunization program was conducted in 2004, using a similar framework as the studies mentioned above (Zhou et al., 2004). The study estimated that in the absence of a two-dose MMR immunization program, the total cost of the disease would be 7.8 billion dollars (3.8 billion in direct costs) (Zhou et al., 2004). With a two-dose MMR immunization program, the total cost was estimated at 0.30 billion (0.27 billion in direct costs) (Zhou et al., 2004). Thus, introducing a two-dose MMR immunization program resulted in a 96 percent decrease in total costs. The next section will provide a more detailed economic analysis of MMR immunization programs.

### **3.4 Economic Evaluations on MMR Immunizations**

Economic evaluations greatly assist healthcare providers in their decision-making process through determining the most efficient use of healthcare resources and assisting with the priority setting of healthcare programs. There are various types of economic evaluations that can be employed in the field of healthcare; the most used economic evaluations used are CBAs, CEAs, and COI (refer to Section 2.3 for more detail on the types of economic evaluations). With regard to economic evaluations conducted on MMR immunization programs, the most common evaluations used were CBAs and CEAs. As previously

noted in Section 2.3, CBAs monetize the costs and benefits of a prevention strategy, and CEAs assess based on outcomes (i.e. cases diverted) from to different treatment options to determine the most efficient method of achieving an outcome.

In terms of CBAs, there were four studies conducted of a one-dose MMR immunization program and four studies on a two-dose MMR immunization program. All studies found the MMR immunization programs to be economically beneficial; i.e. the healthcare dollars invested in MMR immunization programs are creating positive and significant savings over time from both the societal and health care providers' perspective. In terms of CEAs, there were two studies conducted. The United States study used three different scenarios; though all used a two-dose MMR immunization program. The European study was more comprehensive, incorporating various types of vaccination strategies. The next section will elaborate in more detail surrounding the study's findings.

### **Cost-Benefit Analysis on MMR Immunization Programs**

The first CBA conducted in 1982 examined only the mumps component of the MMR vaccine (Koplan and Preblud). The study used two different data sets: one with reported mumps cases and one with estimated mumps cases to capture unreported cases. Both methods showed favourable results in implementing a one-dose program compared to no program, with a benefit-cost ratio (BCR) of 7.4:1 for reported mumps cases and 39:1 for estimated number of mumps cases (Koplan and Preblud, 1982). A similar study was conducted in the 1980s, comparing a one-dose immunization program to no program. This study considered the MMR vaccine and the monovalent vaccines for measles,

mumps and rubella (White, Koplan, and Orenstein, 1985). The study reported the BCR for the MMR vaccine to be 14.4:1, and for the monovalent vaccines for measles, mumps and rubella 11.9:1, 7.7:1, and 6.7:1 respectively (White, Koplan, and Orenstein, 1985). The study indicated that roughly 60 million dollars could be realized by switching from the monovalent vaccines to the MMR vaccine (White, Koplan, and Orenstein, 1985). These results are comparable to Koplan et al.'s (1982) findings and both show favourable results in implementing a vaccination program compared to no program.

In a meta-analysis paper that collected economic analyses on the rubella vaccines, there were two studies that included the MMR vaccine (Hinman et al., 2002). One of those studies took place in Norway in the 1980s, and considered the use of either a rubella vaccine or MMR for girls at 15 months of age (Hinman et al., 2002). The BCR for the MMR vaccine was estimated at 5:1 (Hinman et al., 2002). Another study that took place in the United States in the 1990s had an even higher BCR, and included all children with a MMR immunization program at 21.3:1 (Hinman et al., 2002).

A study in 1998 conducted a CBA of a two-dose measles vaccination program in Canada (Pelletier et al., 1998). This was the only study that included outbreak control costs and which included costs associated with a measles outbreak only, due to a lack of data for mumps and rubella (Pelletier et al., 1998). There were four scenarios considered in the study, as follows:

- a second dose of MMR vaccine at 18 months without a mass campaign, or with a mass campaign using the measles and rubella (MR) vaccine for children 18 months to 18 years of age; and
- a second dose of MMR at five years of age without a mass campaign, or with a mass catch-up campaign using the MR vaccine for children five to 18 years of age (Pelletier et al., 1998).

The scenarios that yield the highest BCR were routine second doses at 18 months or five years without a mass catch-up campaign; BCRs were 3.58:1 and 4.31:1 respectively (Pelletier et al., 1998). Provided a second dose is given at 18 months or five years of age with a mass catch-up campaign, the benefits still outweigh the costs; a mass catch-up campaign at 18 months to 18 years of age yields a BCR of 2.61:1 or at five to 18 years of age, a BCR of 2.93:1 (Pelletier et al., 1998). Similar findings were found in a study conducted in Denmark; this study reported a BCR of 3.2:1 for a two-dose MMR vaccination program given at 15 months and at 12 years of age (Hinman et al., 2002).

The study by Pelletier et al (1998) provided both the direct and societal BCRs; this provides policy makers the choice to disregard indirect costs when evaluating different programs with limited healthcare resources. Indirect costs are a large portion of the total costs; on average they compose two-thirds of the total costs for measles, mumps and rubella. Similar to the outcomes reported using societal BCRs, the BCRs were higher with no mass catch-up campaign implemented. The direct BCRs for a second dose of MMR at 18 months was 2.30:1 and for five years of age 2.95:1. With a mass catch-up campaign at 18 months to 18 years of age, the BCR was 1.42:1 and for five to 18 years of

age, 1.78:1 (Pelletier et al., 1998). Even though from a purely economic standpoint a higher BCR is more desirable, the study noted that with a mass catch-up campaign, 29,270 – 58,530 measles cases would be averted and 24-27 prevented deaths (Pelletier et al., 1998).

Another CBA of a two-dose MMR vaccination program in the United States produced significantly higher BCRs than the other two studies noted above. Similar to the Pelletier et al.'s study, both direct and societal BCRs are provided, but additionally, incremental BCR of a two-dose MMR program is also provided. The BCR of a two-dose MMR immunization program compared to no immunization program was 26.0:1 and taking into account direct BCR, 14.2:1 (Zhou et al., 2004). The analysis of an incremental BCA provides more insight into the economic impact of the second-dose of MMR from the first-dose. Based on the study's analysis, a direct and societal incremental BCR of a second-dose of MMR was 0.31:1 and 0.49:1, respectively (Zhou et al., 2004). This analysis does not include the cost of controlling an outbreak, which would have had a significant impact on the results and "the additional cost of the second dose is more than absorbed by the high cost savings of the first-dose program" (Zhou et al., 2004, p. S143)

### **Cost-Effective Analysis on MMR Immunization Programs**

A study in the United States analyzed three different CEAs using a two-dose MMR immunization program compared to no program: cost per case averted; cost per year of life saved; and cost per discounted year of life saved (Zhou et al., 2004). Each scenario was calculated using two methods: the first examined just the program costs (i.e. MMR

immunization program), and the second included direct disease costs averted with the program (Zhou et al., 2004).

The cost-effectiveness ratios (CER), including the program costs only, are:

- to prevent one measles, mumps, rubella and congenital rubella syndrome (CRS) case would cost \$78, \$127, \$149 and \$442,168, respectively;
- to prevent one measles, mumps, or rubella related death would be \$92,253;
- to save one year of life would be \$1,317; and
- to save one discounted year of life would be \$3,684 (Zhou et al., 2004).

The CER including treatment costs and direct disease costs averted were as follows:

- to prevent one measles, mumps, rubella and CRS case would be \$1,023, \$1,676, \$1,969 and \$5,836,977, respectively;
- to prevent one measles, mumps, rubella or CRS related death would be \$1,217,819;
- to save one year of life would be \$17,384; and
- to save one discounted year of life would be \$48,629 (Zhou et al., 2004).

A more in-depth study in Europe examined several vaccination strategies in order to make their analysis as applicable to as many European countries as possible and additionally, used input data from Western European countries to make the data as homogeneous as possible (Beutels and Gay, 2003). This provided healthcare providers in the European countries the opportunity to assess which strategies would be optimal based on historical MMR vaccination coverage (Beutels and Gay, 2003). There were two general scenarios with five strategies for each scenario to consider; the two scenarios were either 70 or 90 percent single-dose MMR vaccination coverage for all one year olds



for the past 15 years (Beutels and Gay, 2003). Depending which scenario a country fit, a 70 or 90 percent MMR vaccination coverage, there were five strategies analysed:

- *Strategy (0)*: status quo of a 70 or 90 percent coverage;
- *Strategy (1)*: a second dose at 5 years of age where the coverage rate is the same as the existing first dose of 70 or 90 percent;
- *Strategy (2)*: the first dose is increased to 95 percent from 70 or 90 percent coverage;
- *Strategy (3)*: strategy 2 plus an additional second dose at 5 years of age at 95 percent coverage; or
- *Strategy (4)*: strategy 3 plus a one-time campaign during the first 12 months for those  $\leq 15$  years of age, reaching 93 percent of the targeted cohort (Beutels and Gay, 2003).

Based on the first scenario of 70 percent past coverage rates, strategies 1 and 2 were not efficient options to consider; however, strategies 3 and 4 saved the greatest total costs of all strategies (Beutels and Gay, 2003). “At €6313 and €6863 per discounted life-year gained, strategies 4 and 3, respectively ... the most cost-effective option is to accompany the introduction of high coverage two-dose vaccination with a campaign targeted at susceptible youngsters” (Beutels and Gay, 2003, p. 277). Strategy 4 is the most efficient strategy from both the healthcare provider (direct costs) and societal perspective (Beutels and Gay, 2003).

As for past coverage at 90 percent; there was no dominating strategy from a healthcare provider’s perspective (Beutels and Gay, 2003) However, from the societal perspective,

all strategies were shown to be cost-saving with strategy 3 yielding the most savings, \$1,209 per discounted life-year gained (Beutels and Gay, 2003).

## **CHAPTER 4 THEORETICAL APPROACH TO COSTING**

This chapter will explore the differences between economic and accounting cost analysis, and explain why an incremental cost analysis was used instead of a full costing study. As well, a description of the ingredients-based and activity-based approaches used to collect cost data, and the limitations to a retrospective costing analysis, are discussed.

### **4.1 Economic versus Financial Costs**

This study uses accounting principles to carry out the costing analysis; however, the analysis goes beyond collecting strictly financial costs to include economic costs. If the study only considered financial costs, then only costs explicitly spent on the containment of the outbreak would have been considered. Economic costs are more comprehensive and take into consideration the “opportunity costs” of providing goods and services. To elaborate, the concept of opportunity costs refers to “...the value of the forgone benefits because the resource is not available for its best alternative use...” (Drummond et al. 2005). The basis behind adopting the concept of ‘opportunity costs’ is to capture the real market value of all inputs and provide policy makers the true costs of the outbreak (or programs and services), which can then assist with long-run sustainability planning. To illustrate, at the beginning of the outbreak, Capital District Health Authority (CDHA) delegated some of their routine program work (non-mumps related) to Colchester East Hants District Health Authority (CEHDHA), given a shortage of available resources to carry out these routine tasks at CDHA as a result of the outbreak. The time CEHDHA spent assisting CDHA was included in this study, since there exists an opportunity cost for assisting with these tasks and forgone resources were consumed that could not be

used for their best alternative use. Provided another outbreak occurs, it should not be assumed that work can be delegated, as circumstances may not permit it at that time. Nevertheless, if it is delegated, it becomes part of the cost of the outbreak and if it cannot be delegated, then the cost of postponing this work should be included.

#### **4.2 Incremental versus Full Cost Analysis**

A full costing analysis would take into account all of the resources used in producing services or programs, whereas an incremental study only takes into account resources that would not. In the context of the mumps outbreak, a full costing analysis would take into account the office space used by employees working on outbreak activities, whereas an incremental study would not take into account the office space existing in the absence of the outbreak – in other words, the day-to-day overhead. As such, incremental analysis only takes into account “new” resources being consumed by the outbreak, i.e. the costs of additional activities undertaken to contain the outbreak, such as employees’ time dedicated to mumps-related activities only, as opposed to the full cost of personnel.

#### **4.3 Ingredients-Based Approach**

This approach to data collection has the total costs broken down by each input, or *ingredient*, used to contain the outbreak. These inputs can include personnel, supplies, and capital and equipment costs. With the cost profiles organized in this fashion, costs can be presented in several ways, such as fixed versus variable, recurrent versus capital, and by cost components.

“In reporting as well as calculating the costs it is important to show the units of each input and their prices separately (the “ingredients” approach). This facilitates comparisons, the generalization of results across settings, and the extrapolation of historical experience to new settings or new combinations of prices and quantities” (World Health Organization, 2003). Since the study was conducted from the NS healthcare system perspective, all healthcare systems resources used for the outbreak had a corresponding “unit cost”, so inputs were identified and multiplied by their respective prices (refer to Appendix A for a list of all inputs).

#### **4.4 Activity-Based Approach**

Analogous to the ingredients-based approach is the activity-based approach to costing. Once all the inputs are calculated, organizing the costs based on the key activities (strategies) implemented to contain the outbreak can be very valuable for policy-makers, as it provides a means to prioritize categories based on the largest cost components. As well, this process helps to avoid double counting of cost. This is particularly important given that individuals’ time is divided among various activities.

#### **4.5 Retrospective Time Period**

Retrospective studies always entail collecting data and other important pieces of information from events that occurred in the past. The 2007 mumps outbreak costing analysis was retrospective, and took place after the peak of the 2007 NS mumps outbreak occurred. This type of study is different from a prospective study, which includes collecting data as events occur. Prospective studies are typically more time consuming

and costly than retrospective studies; however, retrospective studies have to rely on what data are available and have no influence on the original data collection process.

## **CHAPTER 5 METHODS FOR DETAILED COST DATA COLLECTION**

One of the key findings in Chapter 3 was the lack of economic burden studies conducted on infectious disease outbreaks (Pelletier et al., 1998). As discussed, outbreaks have an element of uncertainty that make it difficult to predict the magnitude and outcomes, such as the number of cases and resources required to contain the outbreak. Despite this uncertainty, without any consideration of a potential outbreak and the economic implications for healthcare resources, the benefits and costs of implementing an immunization program can be under-valued. Each type of infectious disease requires its own unique set of resources; in the case of mumps, there is minimal hospital care required, but individuals had to self-isolate for nine days.

This chapter provides a detailed summary of the data collection method used to capture the economic burden of the NS mumps outbreak. Although each outbreak is unique, this research can still aid in the development of related research for future outbreaks. The next sections will briefly outline the objectives of the costing analysis, mumps cases included in the study, components of the framework, and details regarding the collection of input costs.

### **5.1 Objective of the Economic Analysis**

The objective of the framework is to capture the economic burden of the NS 2007 mumps outbreak from the perspective of the health care provider, which in this case is the Government of Nova Scotia.

## **5.2 Mumps Cases included in Costing Analysis**

The framework collected cost data for the period February 22 – October 31, 2007, which included the peak period of the outbreak. With a total of 706 mumps cases in this approximate eight month period. The framework only includes four of the nine district health authorities (DHA) in Nova Scotia:

- CDHA
- Annapolis Valley District Health Authority (AVDHA)
- Cape Breton District Health Authority (CBDHA)
- CEHDHA

The reason only four DHAs are included is due to time and resource constraints; however, even with including only four DHAs, the analysis is able to capture 94 percent of the total mumps cases reported (661 of 706) for the study period. Since the study does not include any patient level data, not incorporating the costs from the rest of the province has a minimal effect on the study's results. The impact on the healthcare sector for these five excluded DHAs is relatively minimal compared to the four examined; the DHAs with universities and colleges were the most affected and the areas of most interest for the purpose of this analysis. Figure 5.2.1 provides a map of the NS DHAs.



**Figure 5.2.1 Map of Nova Scotia District Health Authorities**



Source: Nova Scotia Department of Health website

### **5.3 Components of the Framework**

In order to identify all the resources used during the outbreak, a macro and micro perspective is used. For example, the macro perspective identifies all the major components (activities) and the micro perspective all the inputs used for each activity. The framework incorporates provincial and DHA level activities, which includes two immunization programs, case management, laboratory, emergency management, surveillance, and communication activities.

#### **5.3.1 Immunizations Programs**

There were two immunization programs implemented: the first was for healthcare workers (HCWs) and the second for post-secondary and grade 12 students. The HCW immunization program was intended to reduce the risk of HCWs becoming infected with mumps and infecting patients and to prevent future outbreaks of measles, mumps and

rubella (Nova Scotia Health Promotion and Protection). The immunization costs associated with the HCW program are comprehensive and include the following items:

- Occupational health (OH) costs - generated from a wide variety of sources including:
  - OH nurses collecting vaccine history and blood samples, administering HCW immunizations; and
  - OH physicians assessing HCW for potential mumps infection (to determine if a HCW should self-isolate or return to work) and conducting some HCW immunizations;
- Infection control (IC) costs - includes HCW mumps related absences, and implementing IC measures such as posters to make staff aware of appropriate steps to follow to prevent further spread of mumps. Costs also extend beyond activities strictly related to IC measures. The majority of these costs stem from IC nurses (ICN) assisting in the immunization of HCWs. It should be noted that costs collected in this latter category were in a lump sum format and could not be separated into OH and IC related activities.

The second immunization program implemented was for students. Students had the option to be vaccinated through the offices of their family physicians or at school clinics. The following is a list of student vaccinations included in the study (refer to Section 6.4.2 for more detail):

- Grade 12 students: 4966 immunized by CDHA school clinic or physician visits;
- College students: 1,459 immunized by the Victorian Order of Nurses (VONs); and

- University students: 11,460 immunized by their respective university health services office or family physician.

### 5.3.2 Case Management

The activities associated with case management includes collecting demographic, clinical, and vaccine history information. Individuals infected with mumps were asked to self-isolate for nine days after the on-set of symptoms. Follow-up lists were created of infected individuals' household members and other potential contacts.

### 5.3.3 Laboratory Costs

Laboratory costs were collected from CDHA, CBDHA, CEHDHA and AVDHA laboratories. Specimens were collected at local hospitals and sent to the CDHA laboratory for testing (refer to Section 6.3 for more detail).

### 5.3.4 Emergency Management

There are two main components of emergency management in the costing framework. The first component includes Health Services Emergency Management (HSEM) personnel costs. This organization is a shared resource for the NS Department of Health (DOH) and Health Promotion and Protection (HPP). The second component of costs is associated with activating the Emergency Operation Center (EOC) that includes, inter alia, professional and clerical services, inventory consumption, and telecommunications.

### 5.3.5 Surveillance

The surveillance component of the outbreak refers to the overall management of the outbreak. The management of the outbreak was initially the responsibility of CDHA, due to the outbreak being initially confined within that DHA. As the outbreak spread to other DHAs, the responsibility was taken over by NS HPP. There were daily and weekly

meetings that involved government departments at the national, provincial and DHA levels to facilitate communication between all key stakeholders. These meetings provided a venue to develop strategies to control the outbreak in order to implement prevention measures.

### **5.3.6 Communication**

At both the provincial and CDHA level, there were personnel that provided regular mumps updates to the media, the public (via a website) and physicians. This included developing media campaigns, and the supplies used to deliver these media campaigns (e.g. posters, ads, etc.).

## **5.4 Summary of Input Data Collection**

The data collected for the thesis was gathered during an internship at HPP, which commenced in June 2007. During this time, I assisted the department in capturing the true cost of the outbreak that extended beyond the cost centers previously established by CDHA, DOHPP and DOH. There was a significant amount of costs not included in these cost centers, such as, the time spent on mumps related activities by management personnel.

### **5.4.1 Personnel Costs**

The personnel data collection can be organized and summarized into three phases: compiling lists of personnel, calculating personnel time and analyzing the personnel data.

## Phase 1: Compiling Lists of Personnel

One of the crucial first steps in developing the costing framework was to become familiar with the management of the outbreak. In order to achieve this, I joined the outbreak management team at HPP and attended all of the meetings facilitated by the department. In addition to these meeting, I reviewed all routine documents collected by HPP regarding the mumps outbreak - for example: meeting minutes, information packages developed for the public and physicians, and DHA cost centers developed for the mumps outbreak.

Based on the meetings I attended and the routine documentation, a list of all government personnel involved in the mumps outbreak at the provincial and district level, as well as the Public Health Agency of Canada (PHAC) employees dedicated to assisting the province during the outbreak was compiled. Once lists of names were compiled, these were reviewed with key individuals in HPP and DHA management, to ensure all individuals were included (refer to Appendix A for a full list of personnel by positions).

## Phase 2: Calculating Personnel Time

The personnel time capture for the costing framework refers to mumps related activities that were a result of the outbreak only, and time spent on non-mumps related activities that were indirectly related to the mumps outbreak. An example of a non-mumps related activity included in the study is the routine workload that CEHDHA did for CDHA, due to CDHA personnel being occupied with the management of the mumps outbreak.

In order to calculate the personnel cost, there were a variety of methods used depending on the type of employee (permanent or temporary) and the level of government (federal, provincial or district level). For provincial permanent employees, I conducted a series of interviews with the purpose of gathering each individual's time spent on mumps-related activities. Interviews were conducted in person, over the phone and via email. I used information gathered from meetings and other routine documentation to assist individuals in recalling how much time was spent on mumps-related activities. For temporary personnel hired for the purpose of the outbreak only, costs were simply salaries paid.

#### Capital District Health Authority

CDHA cost centers were established to submit financial costs to HPP. The cost centers included mumps-related absences and redeployed staff that assisted with the mumps outbreak; however, they did not always include management and core staff. In order to gather personnel time in addition to the cost center data, site visits were conducted as follows:

- Public Health Services office visits with management for Communicable Disease Prevention and Control (CDPC) personnel costs.
- Central CDHA laboratory personnel data collected through interviewing key staff to gather personnel time spent on mumps-related activities.
- Occupational Health visits with management for both Capital and IWK hospital offices. For Capital, the OH personnel data was collected by conducting interviews for management data and the rest through the mumps cost center. An interview with

management was used to obtain the IWK personnel data, management, OH nurses (OHN), and administrative support data.

- Infection control costs were obtained through visits with management for both Capital and IWK hospital offices. Both Capital and IWK IC personnel data was obtained through interviews with management. However, the IWK ICNs information was estimated based on the amount of time Capital ICN dedicated to mumps-related activities. Since there were records kept only of Capital ICNs time spent on mumps-related activities, i.e. no records were kept and for IWK ICNs. It was noted that both ICNs spent similar amounts of time on mumps-related activities.

Additional costs collected from the mumps cost center included HCW related absences and replacement healthcare professionals that assisted in the mumps outbreak, e.g. data entry, etc. There was one individual included in the study from CDHA Marketing and Communications Department. For this individual, an interview was conducted to discuss activities performed over the course of the outbreak when Capital was initially managing the outbreak alone.

#### Colchester East Hants District Health Authority

In order to gather personnel time for CEHDHA, I conducted a site visit to interview the CDPC manager at the Public Health Office in Truro. The CDPC manager provided personnel time for case management activities, immunization education sessions, and staff that answered calls from the public. As well, during the peak of the outbreak, CDHA's CDPC department was not able to carry out all routine activities due to the

mumps outbreak consuming personnel time; therefore, some of these routine activities were delegated to CEHDHA. The personnel cost associated with these non-mumps related activities was included in the analysis, since CEHDHA would not have done this work in the absence of the mumps outbreak.

During the site visit in Truro, I also met with the OHN to cost OH-related personnel costs. With respect to the HCW MMR immunizations, there were clinics held and immunization office visits. There was one OHN and the rest were public health nurses (PHN) for the HCW MMR clinics, and only one OHN for the walk-in clinics. The number of HCWs immunized during an OH office visit was recorded, but not the amount of time spent with each patient. Therefore, estimations were made based on the average amount of time the OHN would spend collecting a health history, getting the vaccination ready, and vaccinating; this was estimated at 15 minutes in total.

To discuss East Hants Public Health office personnel costs, an interview was conducted via phone with a PHN. There was only one person included from this office who was engaged in mumps-related activities, such as contact tracing follow-up, creating forms, creating a display on mumps, and administrative tasks.

Laboratory personnel data were not provided and estimations were made. CBDHA was the only DHA, of the three DHAs outside of Halifax that provided lab personnel data. Given that there was a similar number of mumps cases reported in these three DHAs, the



number of mumps cases was used as a proxy to estimate costs for CEHDHA and AVDHA, based on the data provided by CBDHA.

#### Annapolis Valley District Health Authority

During a site visit to the Public Health Office in AVDHA, an interview was carried out to estimate personnel time spent on mumps-related activities for the CDPC manager, two nurses and administrative staff. The CDPC manager spent the majority of her time commuting to Yarmouth, Bridgewater and Kentville for educational purposes. Travel costs were also included<sup>1</sup>.

OH personnel data was obtained through phone and email interviews. There were two main types of personnel data collected: OH clinics and office visits to immunize HCWs. Licensed practical nurses (LPN) held the OH clinics, and the total number of clinics, clinic hours and nursing hours was provided. As well, when the immunization of HCWs was done through office visits and provided by an OHN or registered nurse (RN), this data was also collected.

#### Cape Breton District Health Authority

Data for the CDPC manager, three CDPC nurses and laboratory personnel was collected for this DHA. A letter was faxed detailing the purpose of the study and the information required and information was returned to the author via fax.

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<sup>1</sup> 474 kilometres were travelled at a rate of \$0.4051 per kilometre ( $\$0.4051 \times 474 \text{ kilometres} = \$192.02$ )

### Phase 3: Using Personnel Data

In addition to collecting personnel time, salary information was collected or estimated to calculate total cost (refer to Appendix A as an example). The DOH and DOHPP provided annual salaries for provincial employees, federal employees provided an hourly wage, and some of the DHA employees wages were provided, while others were estimated based on similar positions in other DHAs.

#### **5.4.2 Supplies and Equipment Costs**

With the exception of the immunization programs, supplies and equipment costs were obtained through routine financial records. The immunization program costs are explored in more detail in the next section and Section 6.4.

Table 5.4.2.1 is an example of the Microsoft Excel document used to collect and store cost data; refer to Appendix A for more detail.

<b>Table 5.4.2.1 : Costing Framework for the Nova Scotia Mumps Outbreak</b>				
<b>*Activity</b>				
Personnel	Government Department	Total Hours (A)	Hourly Wage (B)	Total Costs (A*B)
Total Personnel Cost				
Supplies	Government Organization	Units (A)	Unit Costs (B)	Total Costs (A*B)
Total Supply Costs				
Type of Equipment	Government Organization	Quantity (Q)	Unit Cost (C)	Total Costs (Q*C)
Total Equipment Costs				
Total Activity Costs				
Total Outbreak Costs				

\*Each activity would have its own personnel, supply and equipment tables (immunization programs, case management, laboratory, emergency management, surveillance and communication).

### 5.4.3 Other Costs

Some of the costs were provided in lump-sum formats, and due to this, could not be separated into input categories. The first example of this is the medical first-responders and some of the students who were immunized at a physician’s office. Physicians in NS are reimbursed for health services through a medical services insurance (MSI) program administered by Medavie Blue Cross on behalf of the NS Government. There is a Medical Service Unit Value (MSU) attached to a particular service rendered and each MSU has an applicable monetary value. The physician’s reimbursement for MMR immunization visits was calculated based on 1.5 MSU for a tray fee and 6 MSUs for the

administration of the vaccine at a MSU rate of \$2.17 (Medavie Blue Cross PowerPoint Presentation, Cost of Administering Vaccines, 2007). Table 5.4.3.1 provides a summary of the type of patient and calculation of costs.

<b>Type of Patient</b>	<b>Number of Patients</b>	<b>Type of Visit</b>	<b>Total MSU</b>	<b>MSU Costs</b>	<b>Total Costs</b>
Post-Secondary Students	6403				\$104,208.83
Grade 12 Students	966				\$15,721.65
Medical First Responders	448				\$7,291.20
Total Costs	7817	MMAR= 6 MSU + Tray Fee = 1.5 MSU	7.5	2.17	\$127,221.68

Source: Department of Health 2008

The OH physician visits were not included in the MSI billing information above. The CDHA OH department provided the OH physician cost data in a lump sum format, not including the number of patient visits. There were various types of nurses that conducted MMR immunization clinics for HCW and one type for CDHA grade 12-school clinics. These types of nurses include OHNs, ICNs, PHNs, and LPNs. Clinic costs were either provided through HPP or estimated. When estimations were used to calculate clinic costs, they were based on the amount of time it took to immunize per patient (15 minutes per patient), the average wage for the type of nurse immunizing, and supplies used to immunize; Table 5.4.3.2 provides a cost summary of the supplies.

<b>Medical Supplies</b>	<b>Costs</b>
Patchettes	\$5.67/100
Sharps Containers	\$6.70 each
Cotton Balls	\$5.10/2000
Alcohol Swabs	\$3.89/200
Syringes	\$12.20/100
#23 Needles	\$7.37/100

The immunization of college students was contracted out to the VON; the costs of using these services is based on the rates provided in Table 5.4.3.3.

<b>Category</b>	<b>Costs</b>
Nursing/Clinic Time	\$72/hour
Travel Time > 1 hour	\$72/hour
Mileage	\$0.39/km
Cancellation fee (<48 hours notice)	\$150

Source: Department of Health Promotion and Protection

The University Health Services Offices immunized their respective students (in addition to physician visits); the cost data were collected based on financial costs submitted to the province.

## **5.5 Data Constraints**

A more general limitation of the study lies in the fact that it only includes the perspective of the NS healthcare system, and not society as a whole. To undergo a societal perspective would require a great deal more resources to carry out. As well, the study is only for the period February 22 – October 31, 2007, capturing the beginning and peak periods of the outbreak. This is in part because an end point needed to be established, and the mumps outbreak could not be declared over until mumps cases reported were back to normal rates, which would take a considerable amount of time. The study left out some of

the student immunization programs as they were not carried out until the following year. Another limitation of the study stems from the unavailability of data, in particular, the number of MMR vaccine shipments from HPP to the DHAs. Only the total number of MMR vaccines sent to the DHAs in aggregate form was provided. As well, there was no record of the amount of vaccine wastage; however, as noted in a study on NS childhood immunization programs, wastage rates have a minimal financial impact and are estimated at 5.1 percent (Michaels, 2007).

One of the major assumptions of the costing analysis rests in the personnel cost component. In order to collect personnel data, the majority of the costs were collected through conducting interviews with key personnel on how much time they and/or their staff spent on mumps-related activities. Some individuals maintained detailed records while others did not, and had to rely on their ability to recall this information. Table 5.5.1 provides a sensitivity analysis on personnel costs that were estimated based on interviews, versus personnel costs that were recorded, by applying a 10 percent increase and decrease to the total personnel cost in question. This information was then applied to the total outbreak costs to compare the overall financial impact this increase or decrease would have. Provided that the total outbreak cost is estimated at \$2,478,500, a 10 percent increase (decrease) in personnel costs would lead to a \$70,716 increase (decrease) or a three percent change in the total costs. In other words, the total outbreak costs are not significantly affected by the 10 percent sensitivity analysis applied to some of the personnel costs estimated.

Level of Government	Personnel Costs Estimated	10% Increase in Personnel Costs	10 % Decrease in Personnel Costs
Provincial	\$344,671	\$379,138	\$310,204
CDHA	\$327,864	\$360,650	\$295,078
CBDHA	\$8,056	\$8,862	\$7,250
CEHDHA	\$9,114	\$10,025	\$8,203
AVDHA	\$17,458	\$19,204	\$15,712
Change in Personnel Costs	\$707,163	\$777,879	\$636,447
New Outbreak Costs	\$2,478,500	\$2,549,216 (3% increase)	\$2,407,784 (3% decrease)

It should also be noted that with an accounting cost analysis, the results depict the costs of production at one point in time. This does not allow for price changes or variation in the number of mumps cases considered.

## **CHAPTER 6 RESULTS**

This chapter will calculate the average and total economic burden of the mumps outbreak, and presents the costs by activity-based, ingredient-based, response and prevention measures.

### **6.1 Total and Average (Unit) Outbreak Costs**

The total incremental cost of the NS 2007 mumps outbreak represents the healthcare systems' total resources utilized to contain the outbreak, from February 22 – October 31, 2007. In total, the mumps outbreak cost the healthcare system - \$2,478,500. The average cost per mumps case is the total economic burden of the mumps outbreak divided by the total number of mumps cases. The average cost per mumps case for the 2007 mumps outbreak is \$3,511. In absence of the immunization programs, the average cost per mumps case would be \$1,761, thus shedding light on the resources used to implement prevention measures (i.e. immunization programs), compared to the total cost of managing the outbreak in general.

### **6.2 Activity-Based Results**

As noted in Chapter 4, the costing framework was developed using an accounting approach to data collection. This involved identifying key activities performed to contain the outbreak. Based on the activities identified for the outbreak, corresponding inputs were used to quantify the total resources. Inputs consist of personnel, supply and equipment costs for each activity.



The most comprehensive activity identified was the immunization programs, which includes both student and HCW programs. This component of the costing study consists of 49.82 percent of the total outbreak cost (refer to Section 6.4 for a more detailed description of the immunization programs). Each of the other activities identified represent approximately 15 percent or less of the total costs, as shown in Table 6.2.1

<b>Table 6.2.1: Activity-Based Results</b>		
<b>Activities</b>	<b>Activity Cost</b>	<b>Percentage of Outbreak Costs</b>
1. Immunization Programs	\$1,234,900	49.82%
2. Laboratories	\$380,900	15.37%
3. Case Management	\$307,800	12.42%
4. Emergency Management	\$235,800	9.51%
5. Surveillance	\$206,600	8.34%
6. Communication	\$112,500	4.54%
Total Outbreak Costs		\$2,478,500

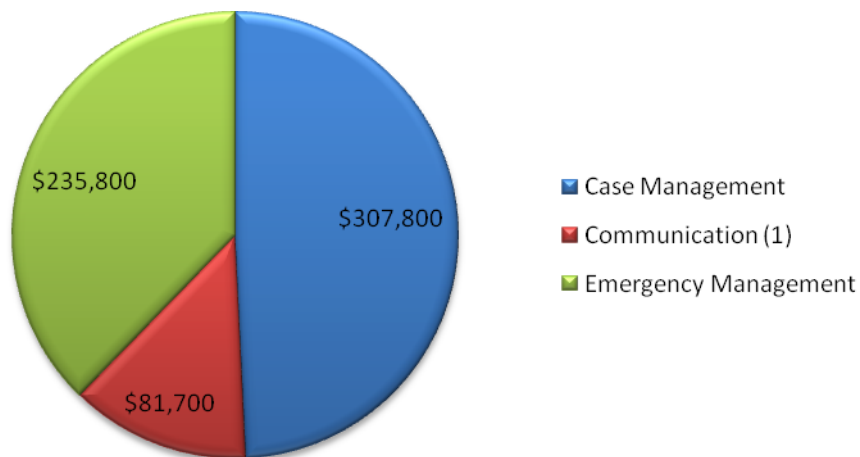
### **6.3 Response and Prevention Measures**

During the outbreak, there were response strategies implemented in order to control and manage the mumps outbreak. These response measures include the following:

- Case management, which involves the collection of demographic and clinical information, as well as vaccine history. Mumps infected individuals were asked to self-isolate for nine days after the on-set of symptoms, and to provide a list of household members and other potential contacts.
- Response communication strategies, which includes time spent on developing information packages for physicians on the diagnosis of mumps and updating the media on the state of the outbreak.
- Emergency management costs, which involves the costs associated with the activation of the EOC and HSEM personnel.

The response measures used to control the outbreak are estimated at \$625,300 which is, approximately 25 percent of the total outbreak costs. Figure 6.3.1 provides a breakdown of the cost components associated with response measures.

**Figure 6.3.1 Outbreak Response Measures**

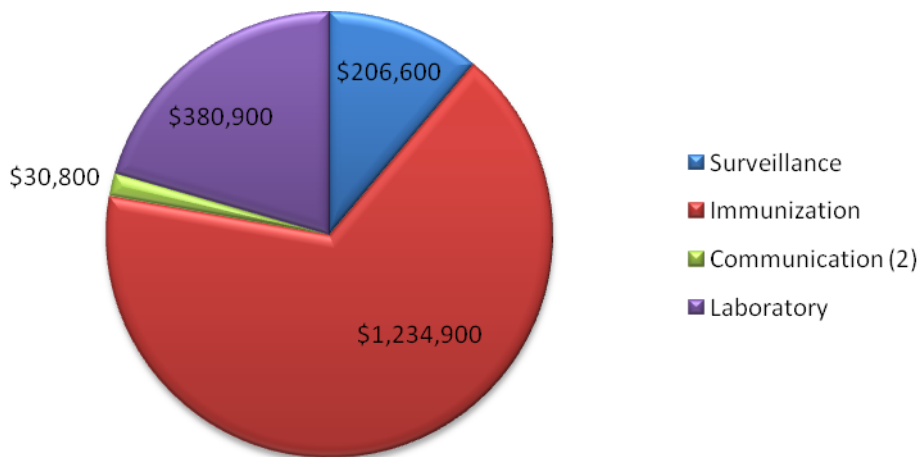


Prevention measures mainly consist of the following cost categories:

- Implementing two immunization programs: the first for HCWs and the second for grade 12 and post-secondary students;
- Communication campaigns, including information ads in bus shelters, newspapers, LCD TV's in waiting rooms, cable TV, etc., to inform the public on how to prevent the spread of the disease and thus, to improve the implementation of the immunization programs.;
- Surveillance measures, consisting of weekly and daily meetings of key stakeholders to oversee the management of the outbreak, and;
- Laboratory testing to confirm a probable mumps case or mumps immunity status.

The prevention measures are estimated at \$1,922,457, which is approximately 76 percent of the total outbreak costs. Figure 6.3.2 provides a breakdown of the various cost components associated with prevention measures.

**Figure 6.3.2 Outbreak Prevention Measures**



## **6.4 Immunization Campaigns**

The immunization programs were the largest cost component of the outbreak and required a wide range of health care services to deliver. The HCW immunization program was implemented in May 2007, followed by the student immunization program in July 2007. The programs consumed 66 percent of the total outbreak costs and are estimated at a total cost of \$1,679,371. Included in these costs are OH/IC, student vaccinations, some laboratory costs and vaccines.

### **6.4.1 Health Care Workers Immunization Campaign**

The HCW immunization program's purpose was to ensure HCW records were up-to-date with a two-dose MMR vaccination or natural immunity to all measles, mumps and rubella. The rationale underlining the programs is that an under-immunized HCW sector results in absences and less available staff to provide healthcare services, and also increases the possibility of spreading the disease to vulnerable groups of the population serviced by HCWs (Nova Scotia Health Promotion and Protection). As well, the 2007 outbreak was the third mumps outbreak in NS since 2005 and vaccination with the MMR would help to prevent future measles, mumps and rubella outbreaks from leading to disruption in the health care system (Nova Scotia Health Promotion and Protection). A number of occupational health and infection control costs are associated with the HCW immunization program.

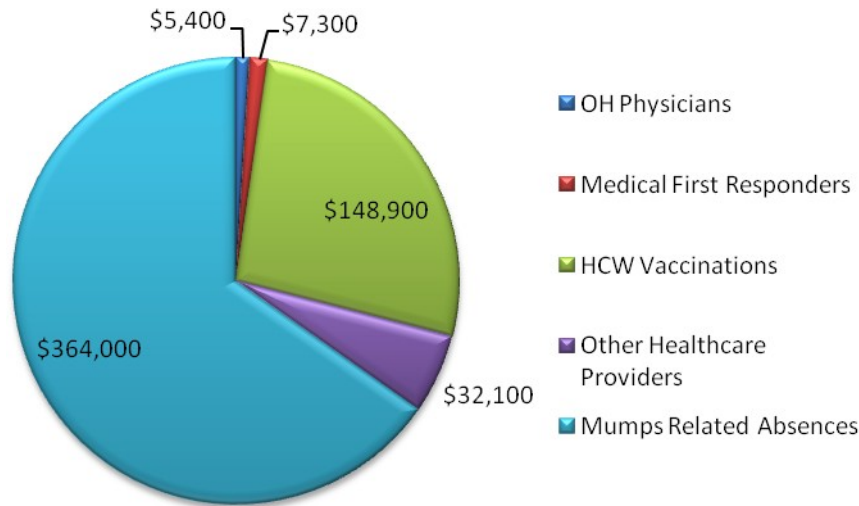
#### Occupational Health Costs

The occupational health costs extended beyond the immunization of HCW, due to the cost data collected including an aggregate amount for time spent working on mumps-related activities. The following is a list of activities collected under the occupational health cost category:

- OH physicians diagnosing HCW for mumps and providing some MMR vaccinations;
- Medical first responders immunized by family physicians;
- Costs associated with various nurses engaging in tasks from developing forms for collecting MMR vaccine histories to collecting blood samples for laboratory testing and costs to hold MMR vaccine clinics as a part of HCW vaccinations;
- Replacement healthcare professionals, referred to as “Other healthcare providers” in Figure 6.4.1.1, that were needed for data entry and other mumps-related activities, and;
- Costs associated with HCWs mumps-related absences.

In total, the OH costs were estimated at \$814,225, with the largest cost component being mumps-related absences. Omitting this cost reduces the total costs to \$450,239. A detailed summary of the costs associated with occupational health is provided in Figure 6.4.1.1.

**Figure 6.4.1.1 Summary of Occupational Health Costs**



Infection Control Costs

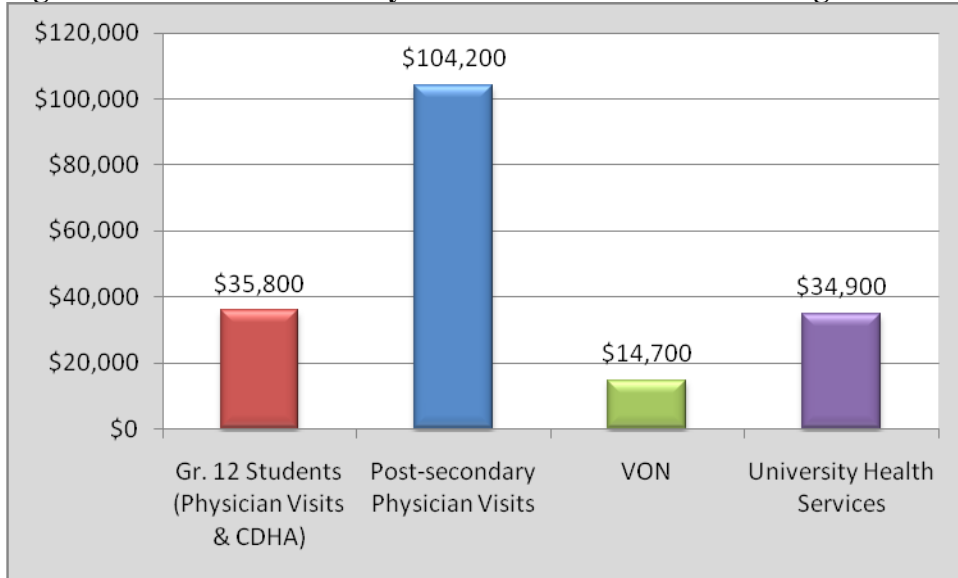
During the mumps outbreak, IC nurses provided assistance in the HCW immunization program, and the majority of the costs incurred stemmed from the immunization program. However, there were also costs associated with developing policies and implementing IC measures, such as, posters in hospitals to remind patients to wash their hands and to wear a mask if they were suspected of having mumps. The total IC costs collected were estimated at \$92,800.

**6.4.2 Student Immunization Program**

The student immunization program consists of students in grade 12 or attending a post-secondary institution. Students had the option of being immunized by their family physician or by their university health services office. During the costing period, there was only one grade 12 school clinic administered by the CDHA; other grade 12 school clinics were held outside of the study period in 2008. The VON held mass clinics for

college students. Family physician visit data was collected through MSI. Figure 6.4.2.1 provides a summary of the cost components for the student immunization program.

**Figure 6.4.2.1 Cost Summary of Student Immunization Program**



### **6.4.3 Measles-Mumps-Rubella Vaccines**

The province spent \$372,300 in purchasing MMR vaccines to be distributed to the DHAs for the MMR vaccination programs. There were personnel costs at the provincial level that were associated with the vaccine coordination that totalled \$22,700.

## **CHAPTER 7 CONCLUSION**

The aim of this research is to estimate the economic burden of the NS mumps outbreak from February 22 – October 31, 2007 from the perspective of the NS government. The research estimated the total economic burden of the outbreak and the average cost per mumps case.

### **7.1 Economic Theory of Infectious Disease**

The economic theory of infectious disease was explored in Chapter 2, providing the economic foundation of the costing analysis. Cost-of-illness studies (COI) were first discussed as an example of how to conduct an economic burden study. Detail was provided on the three main approaches to carry out this type of costing analysis, including: prevalence versus incidence based; top-down versus bottom-up approaches; and prospective versus retrospective studies. Regardless of the approach used, there are three main cost categories used for data collection: direct, indirect and intangible costs.

COI, cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) were discussed in the context of methodological difficulties when used in the field of infectious disease. Additionally, risk assessments were discussed in terms of being a useful tool in economic evaluations and the concept of transaction costs was explored in the context of contractual agreements and use of regulations in the field of infectious disease control and management.



## **7.2 Literature Review**

The literature review section provided a brief overview on the mumps virus and the mumps vaccine. A summary of the literature on measles, mumps and rubella (MMR) vaccine was summarized concerning vaccine efficacy, costing analysis and economic evaluations; however, there are no published articles that could be identified that explored the economic burden of outbreaks specifically for measles, mumps or rubella.

## **7.3 Methods for Detailed Cost Data Collection**

In order to collect the cost data, a costing framework was developed specifically for the mumps outbreak. The costing analysis used an incremental costing approach compared to a full costing approach. As well, the study employed an accounting approach, specifically, an activity-based costing whereby all the activities conducted throughout the outbreak were identified together with their respective inputs in order to collect the total costs. The study only adopted the perspective of the government and did not take into account the perspective of society.

A number of data constraints were identified, including: issues that stem from conducting the data collection retrospectively with no influence over the format in which the data was received or the availability of data; time constraints, which mean some of the student immunization programs were excluded, and uncertainty about some personnel costs.

## **7.4 Results**

The total economic burden of the NS 2007 mumps outbreak and the average cost per mumps case is estimated at \$2,535,764 and \$3,592, respectively. Overall, the largest cost component of the outbreak is the two immunizations programs implemented for healthcare workers (HCW) and students.

Activity-based results were developed to capture the economic burden of the 2007 mumps outbreak by identifying the main activities (strategies) used to contain the outbreak. Costs were then illustrated by organizing the cost data by response and prevention measures. Response measures include strategies employed to control and manage the outbreak, whereas prevention measures include activities to reduce the transmission of the disease among cohorts at risk.

## **7.5 Policy Implications of the Cost Analysis**

The results of this study demonstrate the large economic burden an infectious disease outbreak can have on the healthcare system. Within less than a year, 706 mumps cases were reported, resulting in 2.5 million healthcare dollars being spent to deal with and contain the mumps outbreak. This underlines the need to include the potential risk of an outbreak (and its cost) in the evaluation framework of immunization programs in general. Otherwise, estimations could be under-valuing the benefits of implementing such programs.

This research attempts to fill part of the void in the literature on the economic implications of infectious disease outbreak, particularly for measles, mumps and rubella. The results of the costing analysis provide new knowledge of the economic burden of infectious disease outbreaks, including:

- I. a costing framework to identify the main cost components of the mumps outbreak;
- II. a general understanding of the cost structure of an outbreak, for the purpose of budgeting and financing options
- III. insight into areas that are relatively costly and identification of potential areas of efficiency improvement;
- IV. evidence on the economic implications of an infectious disease outbreak on the healthcare system; and
- V. insight into the surge capacity within the healthcare system to contain an outbreak.

The costing framework provides decision-makers with a breakdown of the main cost components of the outbreak, which can help guide identification of the best components to evaluate based on costs. For the activity-based results, the immunization programs and laboratory costs are the highest cost components; approximately 50 and 15 percent of the overall costs, respectively. The response and prevention measures divide the cost differently than the costing framework; for the response measures, the largest cost component is the case management activities, and for prevention measures, it is the immunization programs.

The costing framework can assist in the process of developing policies and planning on how government should respond and/or prevent future outbreaks; in particular, the study examines all healthcare resources used to contain the outbreak. Some of these might otherwise be overlooked if relying solely on data on/from the cost centers developed for the mumps outbreak. This is particularly true for the indirect costs of Colchester East Hants District Health Authority, which took on an extra workload from Capital District Health Authority.

With the evidence of this study of the high economic burden of the mumps outbreak, decision-makers have a basis to develop policies to better prepare for future and more extensive infectious disease outbreaks. The mumps disease is a relatively minor infectious disease compared to other diseases (e.g. avian flu or H1N1 flu). The mumps outbreak, despite being a minor infectious disease regarding health outcomes, still had substantial impacts across the healthcare system. This brings to the forefront the issue of surge capacity during an outbreak. The study provides a comprehensive review of all of the healthcare system resources utilized during the outbreak, and provides insight into issues involving asymmetric information that may exist between different healthcare providers regarding the overall impact of an outbreak on the healthcare system. In turn, it can provide a better understanding of the amount of resources used and the degree of surge capacity within each department to cope with the resources utilized during an outbreak

There are, however, limitations to the costing analysis that should be discussed. For example, the study only adopts the perspective of the government and not society as a whole. This leaves out costs involving patients' lost productivity due to self-isolation. The study also did not include all the high school student immunization programs, since the majority were conducted outside the study period.

Another limitation rests in the fact that economic burden studies do not compare costs with outcomes, unlike other forms of economic evaluation. Additionally, the costing results may not be applicable to other jurisdictions or diseases for direct comparison. Since all healthcare systems and vaccine histories vary across jurisdictions, each infectious disease requires a unique set of response and prevention measures. For example, some diseases require a large amount of hospitalization, whereas mumps requires mostly self-isolation.

One of the key issues with a retrospective study is that not all the desired data are available, since the examiner has no influence on past activities, such as the format in which costs were originally recorded and what costs were captured. For this study, some costs were not available, such as vaccine wastage and transportation costs from the Department of Health Promotion and Protection (DOHPP) to the District Health Authorities (DHAs). Therefore, it should be noted that the economic burden estimated in this study is an underestimation of the true economic costs associated with the mumps outbreak.

Areas for future research to build on this study could include projected costs for this (or similar) outbreaks and inclusions of all of the immunization programs that took place. Included in future costing frameworks should be indirect costs, particularly, patient loss in productivity. In the case of the mumps outbreak that mainly affected post-secondary students, a suggestion to cost student loss in productivity could include estimations on the cost per missed class, multiplied by the number of missed days of school. Examining tuition divided by the number of days in school could serve as an estimation for cost per class missed.

Calculating the economic burden of a disease is only the first step of a thorough economic evaluation; more research could be done to compute a cost-benefit or cost-effectiveness analysis for mumps. Specifically, more emphasis could be placed on the immunization programs to determine the most efficient method of delivering the MMR immunization programs.

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## APPENDIX A - COSTING FRAMEWORK

### Output Data Collection Form

Table A.1 is an example of the costing framework developed for the purpose of collecting the economic costs associated with the NS mumps outbreak. In order to collect cost data for each activity, each activity had a personnel, supply and equipment subsection to gather the respective costs as shown below. Some of the personnel and supply costs were provided in a lump-sum format and calculations were not necessary. For a more detailed summary of all inputs included in the study refer to Appendix B.

<b>Table A.1: Costing Framework for the Nova Scotia Mumps Outbreak</b>				
<b>*Activity</b>				
Personnel	Government Department	Total Hours (A)	Hourly Wage (B)	Total Costs (A*B)
Total Personnel Cost				
Supplies	Government Organization	Units (A)	Unit Costs (B)	Total Costs (A*B)
Total Supply Costs				
Type of Equipment	Government Organization	Quantity (Q)	Unit Cost (C)	Total Costs (Q*C)
Total Equipment Costs				
Total Activity Costs				
Total Outbreak Costs				

\*Each activity would have its own personnel, supply and equipment tables (immunization programs, case management, laboratory, emergency management, surveillance and communication).

## Costing Framework Inputs

### Personnel

#### Public Health Agency of Canada

- Field Epidemiologist
- Field Surveillance Officer
- Surveillance Officer

#### Department of Health Promotion & Protection

- Chief Medical Officer of Health
- Deputy Medical Officer of Health/Chief Public Health Officer
- Medical Officer of Health, Central
- Medical Officer of Health, Northern & Eastern
- Medical Officer of Health, Western
- Communicable Disease Coordinator
- Communication Team (2 personnel)
- Infection Control Consultant
- Provincial Epidemiologist
- Biological Coordinator
- Policy Support
- Research & Statistical Officer
- Administrative Assistants (4 personnel)
- Data Entry Secretaries (2 personnel)

#### Department of Health

- Coordinator with the Health Emergency Management Center
- Director of Primary Health Care
- Operational Support
- Planning & Development Officer
- Coordinator of Emergency Planning & Preparedness
- Manager of the Emergency Operation Center

#### Capital District Health Authority

- Communicable Disease Prevention and Control, Manager
- Core Communicable Disease Prevention and Control Staff
- Extra Communicable Disease Prevention and Control Staff
- Occupational Health Nurses
- Replacement Nurses, and Personnel for Data Entry
- Infection Control Nurse, Manager
- Infection Control Nurses
- Communication Personnel
- IWK Infectious Control Nurses
- IWK Occupational Health Manager
- IWK Occupational Health Nurse
- IWK Administration Support
- Laboratory Virology
- Laboratory MICV

- Laboratory MICR
- Laboratory Microbiologist
- Laboratory Media
- Laboratory Supervisor
- Laboratory Secretary
- Mumps-Related Absences of All health Care Workers and Support Staff

Cape Breton District Health Authority

- Communicable Disease Prevention and Control Manager
- Communicable Disease Prevention and Control Nurses

Colchester East Hants District Health Authority

- Communicable Disease Prevention and Control Manager
- Communicable Disease Prevention and Control Nurses
- Occupational Health Nurse (Truro)
- Public Health Nurse (East Hants)
- Personnel Answering Calls
- Laboratory

Annapolis Valley District Health Authority

- Communicable Disease Prevention and Control Manager
- Communicable Disease Prevention and Control Nurses
- Administrative Assistance

**Supply**

Provincial Level Supplies

- 1-800 Mumps Line
- Vaccine Costs
- Bus Shelter Ads
- Daily Weekly Paper Parent Ads
- On Campus LCDs Ads
- Eastlink Cable Ads
- Posters
- Professional Services
- Clerical Services
- Inventory Consumption Supplies
- Promotional Supplies
- Miscellaneous Office Expenses
- Printing & Stationary
- Bulk Printing
- Telecommunications
- Meeting Expenses

Capital District Health Authority

- Infection Control, Occupational health & Communicable Disease Prevention and Control costs were provided in a lump sum format
- Laboratory one time initial setup costs for mumps:
- Laboratory mumps testing supplies

Cape Breton District Health Authority

- Mumps AB IGG

- Mumps AB IGM
- Mumps Virus by PCR

Colchester East-Hants District Health Authority  
Laboratory Supplies

Annapolis Valley District Health Authority

- Communicable Disease Prevention and Control Manager
- Communicable Disease Prevention and Control Nurses
- Administrative Assistance

## **Equipment**

Capital District Health Authority

- Laboratory mumps testing equipment

**Appendix B – Department of Health Promotion and Protection  
Confidentiality Form**

The following form had to be signed in order to proceed with cost data collection on behalf of the Nova Scotia Department of Health Promotion and Protection.



**DECLARATION OF CONFIDENTIALITY**

While working at the Department of Health Promotion and Protection, I may be entrusted with knowledge and confidential information; and I hereby undertake not to divulge any of this knowledge nor to discuss it at any time, or any place, or with any unauthorized person, either during the term of my employment with the Department or thereafter; except in the course of my duties as a member of the staff of the Department.

I also acknowledge that a breach of this undertaking may subject me to disciplinary measures or may result in my not being eligible for future employment with the Department.

Date \_\_\_\_\_ Signature \_\_\_\_\_

I have explained the implications of signing this Declaration of Confidentiality to \_\_\_\_\_, and am fully satisfied he/she is aware of the necessity to hold the affairs of the Department of Health Promotion and Protection in absolute confidence.

Date \_\_\_\_\_ Signature \_\_\_\_\_