Valuation of Military Training Benefit: A Contingent Valuation Method Approach

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Abstract

Military training constitutes a significant portion of military spending. However, the valuation of such non-market goods remains an under-researched area. This paper addresses this gap by proposing an economic approach to quantify the operational output of military training. To place monetary values on this activity, a dichotomous choice parametric model is developed to derive an average willingness-to-pay (WTP) from the perspective of the potential user. This stated-preference estimation technique is a survey-based method with a closed-ended-question. The WTP is statistically inferred from the choices made instead of being directly stated by respondents. The paper mathematically derives the model along with detailed sensitivity analysis to assess the impact of marginal changes to key parameters of the model. The model developed in this paper is expected to help managers compare and prioritize different training projects as well as allocate scarce training resources among competing demands.

Résumé

L'instruction compte pour une importante part des dépenses militaires. Toutefois, peu de recherches portent sur la valeur de ce type de produit non marchand. Le présent document vient combler cette lacune en proposant une approche économique pour quantifier le rendement opérationnel de l'instruction militaire. Afin d'attribuer des valeurs monétaires à cette activité, on développe un modèle paramétrique de choix dichotomique pour déterminer le montant qu'un utilisateur potentiel serait prêt à payer (disposition à payer). Cette technique d'estimation est fondée sur les préférences déclarées. La disposition à payer est statistiquement inférée à partir des choix faits par les répondants plutôt qu'en fonction de réponses directes formulées par ceux-ci. Le document établit le modèle mathématique utilisé, ainsi qu'une analyse de sensibilité visant à évaluer l'incidence de modifications marginales des principaux paramètres du modèle sur les résultats. Le modèle élaboré dans ce document devrait aider les gestionnaires à comparer divers projets d'instruction et à leur allouer les rares ressources sur une base économique.

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Executive summary

Valuation of military training benefit: a contingent valuation method approach

Abderrahmane Sokri; DRDC CORA TM: 2012-166; Defence R&D Canada – CORA, July 2012.

Military training constitutes a major portion of military spending. However, the valuation of such non-market goods remains an under-researched area. This paper addresses this gap by developing an economic approach to quantify the operational output of military training.

Specifically this paper provides a comprehensive review of the literature on the Contingent Valuation Method (CVM) and presents its economic foundations. CVM is an appropriate tool of analysis because military training is not bought or sold in the marketplace. To place monetary values on this activity, a dichotomous choice parametric model is developed to derive an average willingness-to-pay (WTP) from the perspective of the trainee. This stated-preference estimation technique is a survey-based method with a closed-ended-question. The adjective “contingent” is descriptive of this methodology because the valuation is contingent on an imagined, rather than real, situation [27] (the individual does not actually pay money, nor is there a change in her/his training).

Answering surveys may be hypothetical, but no more than buying unfamiliar or infrequent commodities [7]. This approach is used around the world to value a wider variety of non-market goods and services, including transportation, health, education, and environment. The respondent is required to answer “yes” or “no” when asked if she/he is willing to pay (or accept, if a loss) a given amount (bid) for a change in quantity or quality (or both) of a specific training. The bid amount varies across respondents and the only information obtained from each individual is whether her/his maximum WTP is above or below the bid offered. The WTP is statistically inferred from the choices made instead of being directly stated by respondents.

In this elicitation method, military personnel (all ranks) are the principal decision-making unit and therefore the unit of analysis in this approach. A stratified sample of military respondents is randomly selected and interviewed. Information on socio-economic characteristics of respondents includes age, education, and military rank.

Subsequently, the paper mathematically derives the model discussed above, along with detailed sensitivity analysis to assess the impact of marginal changes to key parameters of the model. The model developed in this paper is expected to help managers compare and prioritize different training projects as well as allocate scarce training resources among competing demands.

Sommaire

Valuation of military training benefit: a contingent valuation method approach

Abderrahmane Sokri; DRDC CORA TM: 2012-166; R&D pour la défense Canada – CORA, juillet 2012.

L'instruction constitue une importante part des dépenses militaires. Toutefois, peu de recherches portent sur la valeur de ce type de produit non marchand. Le présent document vient combler cette lacune en proposant une approche économique pour quantifier le rendement opérationnel de l'instruction militaire.

Plus particulièrement, ce document présente un examen exhaustif des ouvrages portant sur la Méthode d'Évaluation Contingente (MEC) et sur les bases économiques de celle-ci. La MEC est un outil d'analyse approprié parce que l'instruction militaire ne s'achète, ni ne se vend sur le marché. Pour attribuer des valeurs monétaires à cette activité, on développe un modèle paramétrique de choix dichotomique pour déterminer le montant qu'un utilisateur potentiel serait prêt à payer (disposition à payer). Cette technique d'estimation fondée sur les préférences déclarées est une méthode de sondage comportant une question fermée. Cette l'évaluation est contingente parce que l'évaluation dépend d'une situation [27] imaginaire, fictive (la personne ne paye pas vraiment et son instruction ne change pas non plus).

Les réponses aux sondages peuvent être hypothétiques, mais pas plus que les achats de biens inhabituels [7]. Cette approche est utilisée dans le monde entier pour évaluer une grande variété de biens et de services non marchands, notamment le transport, la santé, l'éducation et l'environnement. Les répondants doivent répondre par « oui » ou par « non » lorsqu'on leur demande s'ils seraient prêts à payer (ou accepter, s'il s'agit d'une perte) un montant donné (offre) pour une modification de la quantité ou de la qualité (ou les deux) d'une formation en particulier. Le montant de l'offre varie selon les répondants et la seule information que fournit chaque personne est si le montant maximal qu'elle serait prête à payer est supérieur ou inférieur au montant offert. La volonté de payer est déterminée de façon statistique à partir des choix faits par les répondants plutôt qu'en fonction de réponses directes formulées par ceux-ci.

Selon cette méthode de sollicitation de renseignements, les militaires (tous grades) constituent la principale unité décisionnelle et, par conséquent, l'unité d'analyse de cette approche. On sélectionne au hasard un échantillon stratifié de répondants militaires à qui l'on pose des questions. Les renseignements sur les caractéristiques socio-économiques des répondants recueillis sont : leur âge, leur niveau d'études et leur grade militaire.

Le modèle mathématique dont il est question ci-dessus est établi et une analyse de sensibilité détaillée est présentée. Ce modèle devrait aider les gestionnaires à comparer divers projets d'instruction et à leur allouer les ressources sur une base économique.

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1. Introduction

1.1 Background

The global economy is going through the deepest and worst financial and economic crisis since the 1930s. Balanced budgets and low levels of public debt seem to be well-founded measures to respond to this global crisis that broke in 2008 [1]. Many governments began to slow the rise of their military spending. With few exceptions, reductions in government spending are resulting in defence budget cuts, which in turn are resulting in transformation that will affect how military training is to be delivered in the future. For example, in 2010, the global increase in military spending registered its slowest annual rate of increase since 2001 (1.3% compared to 5.1% between 2001 and 2009). In Europe, military spending fell by 2.8 per cent in 2010. In the United States, the annual rate of increase in military spending slowed to 2.8% compared to 7.4% between 2001 and 2009 [2]. In Canada, the Department of National Defence will not escape this belt-tightening. Starting in 2012-2013, the federal government will cut between 5 and 10 per cent of its budget.

Figure 1: Military Training

Within the defence budgets, cuts affected all areas to a different degree including military training. In many cases, military training is being cancelled as a cost-saving measure in reaction to the global economic crisis. For instance, due to cost-cutting, military training exercises were cut by half in the United Kingdom. Similarly, in Canada, Exercise Maple Flag (a six-week international air combat exercise held annually) was temporarily cancelled in 2008 and 2009 [3], and reduced to four weeks in 2010 [4].

In recent years valuing military training as a non-market good has become a major area of concern due to an increased recognition of its weight in military spending. The average cost of all training in Canada is estimated at roughly $1.7 billion in constant year dollars of 2005-2006. This cost includes approximately $700 million for Common Training, $500 for Land Training, and $250 for Sea and Air Training [5].

As military forces don't operate with the intent of making a profit, balancing the cost of training with an acceptable level of readiness is a challenging analysis area. Estimating the output side of this training, for instance, requires a technique that utilizes non-price (non-market) data. Such a technique should be able to translate military training benefit into economic benefit in order to design socially optimal training policies. This issue has been an ongoing challenge for military forces for decades.

To address this concern, the NATO Research and Technology Board approved in 2011 the establishment of a Research Task Group (NATO SAS-095 RTG) to examine the broad and complex issue of cost-benefit analysis of military training. The aim of this group, as stated in the SAS-095 Terms of Reference, was to provide NATO nations with theoretical models and practical case studies to ensure that the training benefit is worth the invested cost.

1.2 Aim

So far a comprehensive methodology to evaluate the cost and benefit of military training is missing.[1] The goal of this study is to address this gap by developing an economic approach to quantify the operational output of military training. If the economic value of military training benefit is netted out from the corresponding economic cost, the final result would allow senior decision-makers to compare and prioritize competing training projects.

1.3 Methodology

Assessing the economic value of non-market goods and services can be done by estimating how much purchasing power people would be willing to give up to acquire those outputs if they were forced to make a choice [6]. Military training is not bought or sold in the marketplace. To place monetary values on this activity, a stated-preference estimation technique known as the dichotomous choice-contingent valuation method (DC-CVM), a variant of the contingent valuation method (CVM) is utilized to estimate the total willingness-to-pay (WTP) of military personnel for military training. This elicitation method is a survey-based method with a closed-ended-question (see Annex C). The respondent is required to answer "Yes" or "No" when asked if she/he is willing to pay a given amount (bid) for additional training. The bid amount varied across respondents and the only information obtained from each individual is whether her/his maximum WTP is above or below the bid offered. A dichotomous choice parametric model (Logistic regression technique) is used to derive an average WTP/person.

The potential users of military training are the unit of analysis in this approach. A stratified and randomly selected sample of military ranks from the lowest to highest is used to take into account the multiple dimensions benefits from training.

Answering surveys may be hypothetical, but no more than buying unfamiliar or infrequent commodities [7]. This approach is used around the world to value a wider variety of non-market goods and services, including transportation, health, education, and environment. This method has been extensively used officially by many Federal and State agencies in the United States such as the US Environmental Protection Agency (EPA), the US Army Corps of Engineers, and the Water Resources Council. It has also been used by many international organisations such as the World Bank and the Food and Agriculture Organization of the United Nations (FAO). [6, 8, 9]. The technique will be discussed in greater detail in follow-on chapters. To our knowledge, this study is the first to explore the issue of military training by using the CVM and the resulting WTP.

1.4 Document structure

This paper is organized into six sections. Following the introduction, Section 2 provides a comprehensive review of literature on the CVM and other methodologies used to evaluate the cost of military training. Section 3 defines the CVM and presents its economic foundations. Section 4 sets up the employed binary model and indicates its mathematical derivations. Section 5 outlines the sampling strategy. The paper concludes in Section 6.

[1] The study assumes that military training is a public good.

2. Literature review

A growing body of literature has begun to recognize contingent valuation as an approved method for measuring benefits and damages of non-market goods. Davis [10] was the first economist to empirically implement a CV study in his Harvard dissertation. The author used questionnaires to estimate the benefits of outdoor recreation in a Maine backwoods area [9]. In 1979, the Water Resources Council included it as a recommended method in project evaluation. In 1986, the U.S. Army Corps of Engineers published the first government handbook on how to undertake contingent valuation studies [11].

Over the next decades many other researchers have contributed on the development of an overall framework and used this approach to value various non-market goods and services. The most influential of the theoretical studies was Hanemann [12] which formulated a logit model that is consistent with utility-maximising choices. Cameron [13] made a significant contribution to CVM and its variant DC-CVM by using a closed-ended survey set to estimate the value of non-market resources. Instead of using an ordinary constant threshold, the author considered bid amounts that varied across respondents.

Work on CVM proceeded fairly rapidly and the range of applications of the CVM has been broad. Kristrom [14], for example, introduced a distribution-free non-parametric estimator for discrete response valuation experiments. The author applied the suggested approach to study the value of preserving a set of virgin forests in Sweden. Ludwig and Cook [15] used the CVM to estimate the benefits of reducing crime. Based on a national survey, the study indicated that the public's WTP to reduce gun assaults by 30% equals $24.5 billion, or around $1.2 million per injury. More recently, Widiyati [16] used a contingent valuation survey to estimate the WTP to avoid the cost of intermittent water supply. The statistical analysis indicates that the mean WTP to obtain a continuous service is equal to a 29.7% surcharge and confirms that family size, children and education determine how much households will be willing to pay, whereas only education accounts for the decision to pay or not to pay anything. Aswad et al. [17] conducted a study to estimate the economic value of a tourist attraction in Malaysia, based on visitors' expressing WTP. The authors used dichotomous choice form of CVM to estimate the relevant values.

The existing cost-benefit literature on military training has primarily focused on the cost and social cost side of this activity. Benefit has not been covered in this literature. Swanson and Sleezer [18], for example, developed a practical Training Effectiveness Evaluation (TEE) system that could be applied to any training programme in industry. They provided tools for planning evaluations, gathering the effectiveness information and reporting the information. Desmier and Thompson [19] examined alternative methods of training to determine the most efficient and economical method of conducting undergraduate pilot training while maintaining the high standards inherent in the previous training system. The study postulated that the suggested streaming would allow achievement of substantial savings. Hunter and Dixson [20] came up with a tool with which one could take a given level of cut in the training ammunition budget, and see what effect such a cut might have on training and combat capability. Solomon and Parai [21] developed an analytical cost-effective framework to analyze options for future pilot training which include consolidation of the pilot training into a single site. The authors provided empirical estimates of the socio-economic impacts of the range of options on the host community. Zegers [22] presented a methodology used to quantify the savings in training cost that result from reduced attrition. In this methodology, the cost or benefit of a retention bonus is determined by comparing cost savings resulting from reduced attrition with the expenditure of paying out a bonus. Woodill [23] used discrete-event simulation to provide a forecast of the training demand, the associated probability distributions and timing of the Canadian artillery demand. The author verified, in particular, whether moving from a comprehensive training program to a functional career path model could reduce training costs, address skill fade problems, and increase job satisfaction for field artillery personnel.

More recently, Giangreco et al. [24] examined trainees' immediate reaction to training by focusing on an analysis of the factors that affect participants' overall satisfaction with training. The results revealed that the perceived usefulness of training was significantly positively related to training satisfaction. Sokri [25] used a Cost-Efficiency Analysis (CEA) to estimate the incremental economic costs of the new Green and Insensitive Ammunitions (GIA) to be used in training exercises. The study indicates that significant potential cost avoidance could be realized if GIA replaced current ammunitions. Bates [26] conducted a Cost-Effectiveness Analysis for the use of the Indoor Simulated Marksmanship Trainer (ISMT). The analysis compared costs of using live-fire training alone, versus using ISMT training. Results provide an estimate of per-person cost of training, logistics savings, and virtual system benefits. The conclusion of the analysis is that a well-sequenced mix of ISMT and live-fire training would maximize cost savings and is as good for overall marksmanship quality as live fire alone.

To our knowledge, no study exists applying the CVM to the valuation of military training. Despite the existing literature, the valuation of military training remains an under-researched area. This paper addresses this gap by developing, for the first time, an economic approach based on the CVM to derive an average WTP from the perspective of the user.

3. Contingent Valuation Method

In general, economists use direct revealed preference information (information on market demand) or indirect revealed preference information (information on surrogate markets) in estimating project benefits. In a situation where there is no market, this information is not available. In such a situation, economists are confined to use of CEA or a stated-preference estimation technique, to estimate benefits. The CVM is one of the few methods used to estimate the value of a non-market good or service to a person by asking a hypothetical question about its value (see Annex C). This technique directly questions respondents as to how much they would be willing to pay (or accept, if a loss) for a change in quantity or quality (or both) of a specific commodity. A military member might be asked, for instance, how much she/he would pay to have an additional day of military training. The adjective “contingent” is descriptive of this methodology because the valuation is contingent on an imagined, rather than a real, situation [27] (the individual does not actually pay money, nor does she/he actually have an additional hour of training).

3.1 Dichotomous Choice Contingent Valuation Method

The DC-CVM is a variation of the CVM. Like the CVM, the DC-CVM is used to estimate economic values for a wide range of non-market goods and services [28]. This approach is differentiated from the CVM by the indirect reference to WTP in a hypothetical choice scenario. The WTP is statistically inferred from the choices made instead of being directly stated by respondents. Its format may take the form of a bidding procedure or a referendum-style approach. In this format, respondents are randomly provided with a set of bids and each respondent is asked whether she/he would be willing to pay the given bid amount for a specific good or service. A “Yes” answer will be given if the true WTP is in excess of the stated monetary value and “No” for otherwise. To obtain mean WTP, a binary choice econometric model is set up by assigning 1 for “Yes” and 0 for “No” answers. A set of relevant independent variables and the bid values are subsequently incorporated. The resulting data are then analyzed statistically and extrapolated to the population that the sample represents.

Due to its simplicity and flexibility, this method of eliciting values has become the most popular technique for the valuation of non-market goods and services. It has been widely applied in many areas including environment, health, transport and culture. Numerous related papers, reports, and books have been published, and ongoing research continues to offer new applications and improvements to the method [29].

3.2 The Economic foundations of WTP

Improving one’s well-being is the underlying goal of individuals. People express their well-being and preferences through their choices and tradeoffs [30]. Individual preference for one state over another is measured using WTP (increase in value) or willingness-to-accept (WTA) (decrease in value). WTP is the amount that an individual is willing to give up for a particular good or service. It is the amount that must be taken away from the agent’s income while keeping his utility constant. WTA is appropriate if the person faces a potential loss of the good. It is the amount that a person is willing to accept to forego a particular good or service [6]. In the context of non-market goods and services, both measures may be relevant depending on the property rights regime in place [31].

To understand the concept of willingness to pay and how it can be used in a military context, assume that the military person wants to maximize her/his utility function subject to a budget constraint. This can be given in the form:

$$\underset{X,T}{Max}\ U(x,t,s)$$
$$Subject\ to\ xp_x + tp_t \leq y, \tag{1}$$

where x is a set of all goods other than military training, t is military training, p_x and p_t are the prices of x and t, y is income and s is a set of socioeconomic and demographic characteristics (variables hypothesized to influence WTP). As suggested by Hanemann [12], this procedure explicitly recognizes the utility-maximising choices underlying individual responses. Solving (1) will give the indirect utility function:

$$V_0 = V(p_x, p_t, y; s). \tag{2}$$

This function gives the user's maximal utility in terms of prices and income rather than military training (t) and other goods (x). If the supply decreases, for example, the shift in the supply curve will result in a price increase from p_t to (p_t +d) and the new utility function will be

$$V_1 = V(p_x, p_t + d, y; s). \tag{3}$$

Now, if the military person had to pay any amount (WTP) to get back to the old price, then that amount should not make her/him worse off than would the price increase. That is,

$$V(p_x, p_t, y - WTP; s) \geq V(p_x, p_t + d, y; s) \tag{4}$$

The maximum WTP will set equality in equation (4). Solving (4) (with equality), we obtain

$$WTP = f(p_x, p_t, d, y; s) \tag{5}$$

Assuming p_x and p_t to be constant, we get;

$$WTP = f(d, y; s) \tag{6}$$

The value of d will depend on the shift in the supply curve (as expected by the respondent). Gender, age, and education could be used for s.

3.3 Estimation of mean WTP

To explain the theory behind the estimation of mean WTP in the context of a dichotomous closed-ended question, consider the following military person's indirect utility function

$$V = V(j, y; s) + \varepsilon_j, \tag{7}$$

The systematic portion of the indirect utility function, $V(j,y;s)$, depends on income (y) along with individual characteristics (s) that affect the satisfaction obtained from the training. Let $j = 0$ represent no access to the additional training and $j = 1$ represents access when the respondent must pay the stated bid amount, d (the amount posed to respondents in the WTP question). Random elements that influence utility are denoted by ε_j. When faced with an increased bid amount to access the additional training, the respondent will pay the amount only if the utility gain is positive:

$$V(1, y-d; s) + \varepsilon_1 \geq V(0, y; s) + \varepsilon_0. \quad (8)$$

The random elements ε_1 and ε_0 are assumed to be independent and identically distributed random variables with zero means. The "Yes" or "No" response depends on the difference in indirect utility functions, that is

$$\Delta V = V(1, y-d; s) - V(0, y; s) + (\varepsilon_1 - \varepsilon_0). \quad (9)$$

Each individual's "Yes" or "No" response indicates whether the true difference in indirect utility function exceeds or is less than zero. To compute the mean WTP, let $s = (s_1, s_2, \ldots s_k)$ denote the vector of socioeconomic and demographic characteristics, and ε a random component following a normal distribution with mean zero and standard deviation σ [12, 13]. Then, the regression model to be estimated is:

$$\Delta V = \beta_0 + \beta_1 d + \beta_2 y + \beta_3 s_1 \ldots + \beta_{k+2} s_k + \varepsilon. \quad (10)$$

The true difference in indirect utility of each respondent is not directly observable. It is modeled as a function of exogenous variables such as the bid amount (d), the respondent's income (y), and socioeconomic characteristics (s) that affect the satisfaction obtained from the training. It has a deterministic component and a stochastic one (ε) [32]. Taking the expectation of both sides of equation (10) we get:

$$E(\Delta V) = \beta_0 + \beta_1 E(d) + \beta_2 E(y) + \beta_3 E(s_1) + \ldots + \beta_{k+2} E(s_k) + E(\varepsilon). \quad (11)$$

In answering the CVM question, the respondent maintains the same level of utility by giving up an amount of money equal to WTP and acquires the (added) service. The maximum WTP will set equality between the two indirect utilities and therefore the true difference $E(\Delta V)$ is zero:

$$0 = \beta_0 + \beta_1 E(d) + \beta_2 E(y) + \beta_3 E(s_1) + \ldots + \beta_{k+2} E(s_k), \quad (12)$$

or

$$E(d) = -\frac{\beta_0 + \beta_2 E(y) + \beta_3 E(s_1) + \ldots + \beta_{k+2} E(s_k)}{\beta_1}. \quad (13)$$

Therefore, the average WTP is found by multiplying each regression coefficient by the mean value of the corresponding explanatory variable (excluding the bid) and summing up. The resultant value is then divided by the negative of the bid's coefficient. The same procedure can be used to calculate the WTP for each respondent.

4. The binary choice model

In statistics, a binary response model is a type of regression where the dependent variable is binary. It can take only two possible values which are generally denoted as 1 and 0. This section sets up the employed binary model and presents its mathematical derivations.

4.1 The Model

The probability that the response of the i^{th} respondent (R_i) takes a particular value can be expressed by the following indicator function:

$$R_i = \begin{cases} Yes, & if\ \Delta V_i > 0 \\ No, & otherwise \end{cases}. \tag{14}$$

As in equation (10), the difference in the true indirect utility function ΔV_i of each respondent is not directly observable. It is modeled as a function of exogenous variables such as the bid amount, the respondent's income, and socioeconomic traits. For the i^{th} respondent, equation (10) could be rewritten as

$$\Delta V_i = Z_i^{'}\beta + \varepsilon_i. \tag{15}$$

Where $Z_i = (1,X)$ is the vector of explanatory variables and the constant unity, 1; β is the vector of the corresponding unknown coefficients and ε_i is an error. This error term is introduced to capture the effects of all omitted factors. If we assume that the error term ε_i is independent of Z_i, then the probability of saying "Yes" to the bid can be obtained as follows:

$$\begin{aligned} P(R_i = 1 | Z_i) &= P(\Delta V_i > 0) \\ &= P(Z_i^{'}\beta + \varepsilon_i > 0) \\ &= P(\varepsilon_i > -Z_i^{'}\beta) \\ &= 1 - P(\varepsilon_i \le -Z_i^{'}\beta) \\ &= 1 - F(-Z_i^{'}\beta), \end{aligned} \tag{16}$$

where $F(.)$ is the cumulative distribution function (cdf) of the error term. If we assume that the error term ε_i has what is known as a logistic distribution, the model is then referred to as the Logit model [13], that is,

$$F(Z_i^{'}\beta) = \frac{e^{Z_i^{'}\beta}}{1 + e^{Z_i^{'}\beta}}. \tag{17}$$

Therefore,

$$\begin{cases} P(\mathrm{R}_i = 1 | Z_i) = F(Z_i^{'}\beta), \\ P(\mathrm{R}_i = 0 | Z_i) = 1 - F(Z_i^{'}\beta). \end{cases} \tag{18}$$

Using equations (15) and (18), the solution consists of estimating the unknown parameters β, in the following binary choice model relating the probability of saying "Yes" to a function of the bid and other socioeconomic variables.

$$R_i = \begin{cases} 1, \; if \; \Delta V_i = Z_i^{'}\beta + \varepsilon_i > 0 \\ 0, otherwise \end{cases}. \tag{19}$$

To estimate the unknown parameters β, the maximum likelihood approach could be used. This method seeks the values of the unknown parameters that are most likely to have generated the data that were observed. To do so, let ($R_1, R_2, \ldots, R_n$) be a random sample of n independent observations (responses), ($X_1, X_2, \ldots, X_n$) the corresponding vectors of explanatory variables, and β the vector of unknown parameters. The likelihood function for the overall set of responses is the product of the individual likelihood functions for each observation in the sample. Taking the logarithm, the log-likelihood function for the sample is the sum of the individual likelihoods:

$$L(\beta) = L(\beta | R_1, \ldots, R_n; X_1, \ldots, X_n) = \sum_{i=1}^{n} \ln P(R_i | X_i; \beta), \tag{20}$$

where $P(R_i | X_i; \beta)$ is the i^{th} individual's response probability. Then the maximum likelihood estimator of β is the solution to the first-order conditions:

$$\frac{\partial L(\beta)}{\partial \beta} = \sum_{i=1}^{n} \frac{\partial \ln P(R_i | X_i; \beta)}{\partial \beta} = 0. \tag{21}$$

In general, these first order conditions are a set of nonlinear equations that require iterative numerical solution techniques [33]. For more details related to this econometric topic see Wooldridge [34].

4.2 Marginal effects / Sensitivity analysis

Using equation (18), it is straightforward to show that the expected response takes the following form:

$$E[R_i | Z_i] = F(Z_i^{'}\beta). \tag{22}$$

In this nonlinear regression model the parameter β is not necessarily equivalent to the familiar marginal effect we are accustomed to analyzing. The partial effect in a binary model is not constant and will vary according to the values of the independent variable. This partial effect is computed by taking the first partial derivative of the expected response with respect to an independent variable. For this problem,

$$\frac{\partial E[R_i | Z_i]}{\partial Z_i} = \frac{dF(Z_i^{'}\beta)}{d(Z_i^{'}\beta)} \beta = f(Z_i^{'}\beta)\beta, \tag{23}$$

where *F(.)* is the cumulative distribution and *f(.)* is the corresponding density function. In expression (23), the marginal effects vary with the values of Z_i. So these effects can be, calculated at the benchmark averages of independent variables including the bid or at any point that holds special interest.

5. Survey design sampling

Standard survey design has many aspects: The problem should be carefully defined, observational units must be selected from the appropriate population, and the sample must be of adequate size and correctly randomized [35]. When rigorous scientific methods are not used, results are subject to numerous types of sampling and non-sampling errors. In this section, we describe the target population and discuss the sampling approach and survey question.

5.1 Description of the target population

The first step in survey implementation is to define the target population. The target population is the population from which we want to gather information. In this study, it consists of military members from the sea, land, and air environments that usually undertake the training in question.

5.2 Sampling method

The target population is usually very large. Doing a census of everyone in this population would be very expensive and time consuming. Sampling method refers to the way that population members are selected to participate in the survey. In this study, a stratified and randomly selected sample of military personnel is recommended. With probability sampling, sampling error can be calculated. Compared to simple random samples, stratified random samples generally provide more precision for an overall sample of the same size [36].

5.3 Sample size

The appropriate sample size leads to results that can adequately be extrapolated to the target population. In addition to the size of the population with which we are dealing, three criteria should be specified to determine the appropriate minimum sample size: the level of precision(r), the level of confidence or risk ($1-\alpha$), and the degree of variability in the characteristics of interest (WTP or income) (S).

The level of precision (r) is the range in which the true value of the population is estimated to be. This closeness is often expressed in percentage points, (e.g., $\pm r$ %). The confidence or risk level ($1-\alpha$) is the probability that the stated range of precision includes the true WTP of the population. Variability is the degree to which the attribute being measured in the survey question (WTP) is distributed within the target population. The more heterogeneous a population, the larger the sample size required to obtain a given level of precision. Precision and confidence are interrelated statistical measures of reliability. Higher precision and confidence levels require larger sample sizes and higher costs to achieve those samples.

Let $\bar{y}$ be the estimated average WTP in the sample, $\bar{Y}$ its expected value (the true average WTP in the population), and z the statistic that defines the desired level of confidence. Assuming a given distribution for the response variable $\bar{y}$, the minimum sample size, n, required to keep the margin of error at or below r, given a significance level no greater than ($1-\alpha$) is given by

$$n = \frac{n_0}{1 + \frac{n_0}{N}}, \text{ where } n_0 = \left(\frac{S}{\bar{Y}}\right)^2 \left(\frac{z_{1-\frac{\alpha}{2}}}{r}\right)^2 \tag{24}$$

Its theoretical derivation is presented in Annex A. Estimates of $\bar{Y}$ and S are generally obtained from pilot surveys, previous surveys, or expert opinion. Defence departments should be able to use the first two options. Results could be presented with the conventional level of confidence of 95% ($z = 1.96$).

5.4 Sample size within strata

The strata are generally of different sizes and are expected to respond differently to the survey questions. Assuming that the sample size of each stratum is proportionate to the population size of the stratum, the best sample size for stratum h would be

$$n_h = w_h n, \tag{25}$$

where w_h its weight, and n is the total sample size. The theoretical derivation of this formula is presented in Annex B. Each stratum is sampled separately and sample elements are then selected, independently, from each one.

5.5 Survey question

To increase the response rate and obtain more accurate responses, the survey question should be simple, clear, straightforward, and easy to answer for all respondents. The sample elements would be presented with a hypothetical negative occurrence such as reduction in a given military training. They are then asked if they would be willing to pay an amount of money in order to avoid this negative occurrence and preserve the training at its current level. The posted price should vary across questionnaires. An example of a survey question is provided in Appendix C.

Like any statistical survey, CVM is subject to some biases which include sampling bias, strategic bias, and information bias. Sampling bias, common to any type of survey study, may occur depending on the way the sample was selected. Strategic bias arises when respondents deliberately shape their answers to influence the study's outcome. Information bias may occur depending on the way information on the hypothetical program is presented. Sampling bias is reduced if the sample is correctly randomized, while strategic and information biases will be reduced through good development of the questionnaire. Focus groups should be conducted to set the bid amounts to be used in the final survey. Before discussing the results, a sensitivity analysis should also be conducted to determine the effects of the key parameters on the WTP.

6. Conclusion

The military forces don't seek to make a profit or expand a market share. Assessing the benefits of military training programs has always been a perplexing problem. To address this concern, the NATO Research and Technology Board approved in 2011 the establishment of a Research Task Group (SAS-095) to examine the complex issue of cost-benefit analysis of military training. The aim of this group was to provide NATO nations with theoretical models and practical case studies to ensure that the training benefit is worth the invested cost.

The objective of this study is to show that estimating the economic benefit of military training can be achieved by using the CVM and the resulting WTP. The economic foundation of the CVM is explicitly presented, a binary response model is developed, a broad sampling strategy is offered and a comprehensive review of literature on the used technique is provided.

This study is the first to estimate the economic benefit of military training through the elicitation of respondents' WTP. To design collectively optimal training policies, a theoretical estimation of the economic cost of military training is being developed. These two methodologies will be demonstrated in a use case analysis in a future work.

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Annex A: Sample size

Let $\bar{y}$ be the estimated average WTP in the sample, $\sigma_{\bar{y}}$ its standard deviation, $\bar{Y}$ its expected value (the true average WTP in the population), *r* the desired level of precision, (*1-α*) the desired confidence level, and *z* the statistic that defines the desired level of confidence. Assuming a Normal distribution for the response variable $\bar{y}$, the minimum sample size required to keep the margin of error at or below *r*, given a significance level no greater than (*1-α*) is derived as follows:

$$\Pr\left(\frac{\left|\bar{y}-\bar{Y}\right|}{\bar{Y}} \le r\right) = 1-\alpha \Rightarrow \Pr\left(\frac{\left|\bar{y}-\bar{Y}\right|}{\sigma_{\bar{y}}} \le \frac{r\bar{Y}}{\sigma_{\bar{y}}}\right) = 1-\alpha \Rightarrow \frac{r\bar{Y}}{\sigma_{\bar{y}}} = z_{1-\frac{\alpha}{2}} \Rightarrow r = z_{1-\frac{\alpha}{2}}\left(\frac{\sigma_{\bar{y}}}{\bar{Y}}\right). \quad \text{(A1)}$$

Let *N* be the population size, *n* the desired sample size and S an estimate of the degree of variability within the population. Let *v'* be

$$v' = \frac{r^2}{(z_{1-\frac{\alpha}{2}})^2} = \frac{(N-n)}{\bar{Y}N}\frac{S^2}{\bar{Y}n} = \frac{S^2}{n.(\bar{Y})^2} - \frac{S^2}{N.(\bar{Y})^2}. \quad \text{(A2)}$$

Estimates of $\bar{Y}$ and S^2 are obtained from pilot surveys, previous surveys, or expert opinion. Let n_0 be

$$n_0 = \frac{\left(S/\bar{Y}\right)^2}{v'}, \quad \text{(A3)}$$

then the estimation formula for the desired sample size, *n*, is

$$n = \frac{n_0}{1+\frac{n_0}{N}}. \quad \text{(A4)}$$

n is interpreted as the number of military personnel to be selected.

Annex B: Sample size within strata

Given a fixed budget, how should the sample be selected to get the most precision from a stratified sample? The solution to this problem can be derived from the following problem of optimal allocation:

$$\begin{aligned} &\underset{n_h}{Min} \sum_{h=1}^{T} w_h^2 \sigma^2 (\bar{y}_h) \\ &Subject\ to \\ &c_0 + \sum_{h=1}^{T} c_h n_h = B \end{aligned} \tag{B1}$$

where n_h is the sample size for stratum h, w_h is the weight for stratum h, B is a fixed budget, and c_h is the direct cost to sample an individual element from stratum h, c_0 is a fixed cost of sampling, and T is the number of strata. In this expression,

$$\sigma^2 (\bar{y}_h) = \frac{S_h^2}{n_h} - \frac{S_h^2}{N_h} \tag{B2}$$

is the variance of stratum h, where S_h is the variability within the stratum, n_h its sample size, and N_h its population size. Based on optimal allocation, the best sample size for stratum h would be:

$$n_h = n \frac{w_h S_h \big/ \sqrt{c_h}}{\sum_{h=1}^{T} w_h S_h \big/ \sqrt{c_h}} . \tag{B3}$$

The sample size for stratum h is large when the cost to sample an element from this stratum is low and its variability and population size are large. Assuming that the direct cost to sample an individual element is equal across strata, the best sample size for stratum h would be

$$n_h = n \frac{w_h S_h}{\sum_{h=1}^{T} w_h S_h} \tag{B4}$$

This solution is called Neyman allocation. If we assume that the sample size of each stratum is proportionate to the population size of the stratum, the best sample size for stratum h would be

$$n_h = n \frac{N_h}{N} . \tag{B5}$$

Annex C: Example of survey question[2]

Introduction
Military training is not bought or sold in the marketplace. This study uses an economic approach to quantify or evaluate the operational output of military training. In this approach, you are just required to use the voting buttons (YES/NO) to indicate if you are willing to pay a given amount (bid) for given training. The result is expected to help managers compare and prioritize different training projects as well as allocate scarce training resources among competing demands.

Background
Every new member of the Canadian Forces must complete an intensive 13-week course of basic recruit training. As a part of this course, new recruits take a 23-day course on small arms training. They learn how to use small arms and how to maintain them. This course is designed to help them protect themselves and others in operations. It could also help in closing with and destroying the enemy. Within these 23 days the Regular Force members complete a course on “fire the in-service Pistol” (pseudo code: 119051) which requires 13 training periods or 1.3 day (8 periods in garrison training and 5 periods in field firing).

Situation
Since military training is not bought or sold in the marketplace, it is very difficult to place monetary values on this activity. However, in a situation where there is no market, the valuation of non-market goods and services could be done using a survey-based estimation technique. This technique is used to estimate indirectly the value of a non-market good or service by asking a hypothetical question about its value. This technique questions the potential users as to how much they would be willing to pay for a change in quantity or quality (or both) of a specific commodity. This technique requires the participants, such as yourself, to imagine a scenario or a situation where they have to “pay” for the good or service. For the purpose of this study,

- Consider the “fire the in-service Pistol” course; and
- Suppose that it would be cancelled in the future due to budget cuts.

The questions are listed after the background questionnaire.

Background information

1- Environment: ☐ (1) Army ☐ (2) Navy ☐ (3) Air Force
2- Rank
3- Sex: ☐ (1) Male ☐ (2) Female
4- Age: Years of service:

Questions[3]

1- For new recruits only:

If you (not DND) had to pay for this course, would you be willing to pay the amount of ---- $? ☐ Yes ☐ No

[2] Special thanks to Mr Steve Flemming for his help.
[3] The set of questions are a sub-set of a larger survey that is sent out by DGMPRA (the Your Say survey). DGMPRA will suggest the most appropriate way of incorporating these set of questions into the general survey.

2- For experienced military:

Perspective 1: Imagine that you are required in your current posting to qualify on the "fire the in-service Pistol" course.

If you (not DND) had to pay for this course, would you be willing to pay the amount of ---- $? ☐ Yes ☐ No

Perspective 2: Imagine that you are a new recruit who has just joined the CF.
If you (not DND) had to pay for this course, would you be willing to pay the amount of ---- $? ☐ Yes ☐ No

Thank you very much for your participation and contribution to this survey.

List of abbreviations/acronyms

CVM	Contingent Valuation Method
DC-CVM	Dichotomous Choice- Contingent Valuation Method
WTP	Willingness-To-Pay
WTA	Willingness-To-Accept
NATO	The North Atlantic Treaty Organization
RTO	The NATO Research and Technology Organisation
SAS	System Analysis And Studies
RTG	Research Task Group
FAO	The Food and Agriculture Organization of the United Nations
SC	The US Environmental Protection Agency
CEA	Cost-Efficiency Analysis
GIA	Green and Insensitive Ammunitions
ISMT	Indoor Simulated Marksmanship Trainer
TEE	Training Effectiveness Evaluation

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Military training constitutes a major portion of military spending. However, the valuation of such non-market goods remains an under-researched area. This paper addresses this gap by developing an economic approach to quantify the operational output of military training. To place monetary values on this activity, a dichotomous choice parametric model is developed to derive an average willingness-to-pay (WTP) from the perspective of the trainee. This stated-preference estimation technique is a survey-based method with a closed-ended-question. The WTP is statistically inferred from the choices made instead of being directly stated by respondents. The paper mathematically derives the model along with detailed sensitivity analysis to assess the impact of marginal changes to key parameters of the model. The model developed in this paper is expected to help managers compare and prioritize different training projects as well as allocate scarce training resources among competing demands.

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Military training benefit, Contingent Valuation Method (CVM), Non-market good

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