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Team 11: Non-Lethal Weapons in Crowd Confrontation Situations

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INTRODUCTION

Crowd confrontations are a common occurrence. In the Free World, peaceful protest is a human right. However, when a crowd becomes violent, control forces need to step in to restore order. They should do this with minimum but sufficient force. The use of Non-Lethal Weapons has been promoted to ensure a continuum of force between the simple presence of the control forces and the use of lethal weapons. However, the strategy and tactics for the employment of Non-Lethal Weapons is not well developed.

The following study is part of a three-year project by the Centre for Operational Research and Analysis in Defence Research and Development Canada in cooperation with Laval University of Quebec City. The first year of the project was devoted to literature review on the socio-psychological nature of crowd behaviour. The second year of the project was devoted to modeling and simulation using agent-based methods by Laval University and the System Dynamics model by the Centre for Operational Research and Analysis. The project is currently in the third and final year and will concentrate on analysis of modeling results. This paper will discuss the analysis of the System Dynamics model using the Design of Experiments approaches promoted by the SEED (Simulation Experiments and Efficient Designs) Center at the Naval Postgraduate School.

GOALS

The goals of this analysis of the System Dynamics model of Crowd Confrontations and Non-Lethal Weapons are to:

- Determine the most sensitive parameters in the current model in order to potentially simplify the model or at least focus the data collection efforts for future application of the model.
- Develop a robust set of Rules of Engagement for the employment of Non-Lethal Weapons by applying the model to a diverse set of scenarios.

OVERVIEW OF THE MODEL

Following the approach suggested by Coyle [1], the problem statement was developed in some detail. The primary concern of the study was to determine the effective use of Non-Lethal Weapons from the strategic perspective. Namely, there are strategic and tactical decisions concerning both the benefits of controlling a crowd that becomes unruly, and the costs of either making the situation worse by not doing enough or being perceived as using excessive force through the employment of Non-Lethal Weapons.

After recognizing the complex nature of the problem, a qualitative model was developed to understand its important dynamic nature. Figure 1 provides an influence diagram that was generated early in the modeling effort.

The central feature of this diagram is the crowd aggressiveness level. The controllers have an accepted aggressiveness level that they will allow, while the instigator/leaders and the violent crowd members have a desired aggressiveness level that they are wishing to achieve. Based on the discrepancy between the actual crowd aggressiveness and the accepted aggressiveness, the controllers will determine their tactics. Similarly, the instigator/leaders and violent crowd members determine their actions based on the discrepancy between their desired crowd aggressiveness and the actual crowd aggressiveness.

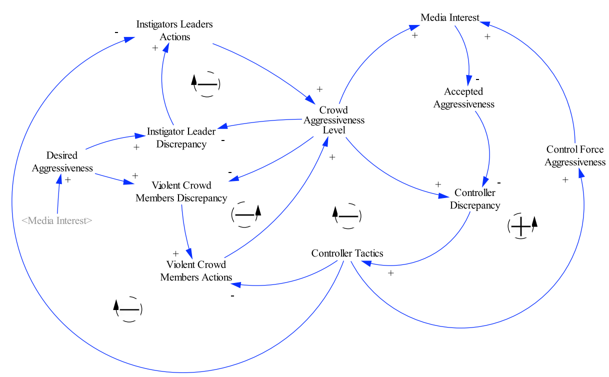

Figure 1: Influence Diagram of Crowd Confrontation Situation

These interactions lead to a series of negative feedback loops. There are also two positive feedback loops that involve the media. Control force tactics and crowd aggressiveness leads to media interest and this influences controller tactics and instigator/leader and violent crowd member actions.

The next step in the modeling process was to develop a series of quantitative models based on System Dynamics

Stocks and Flows. Quantitative models were developed to examine:

- The Crowd Dynamics with Bystanders/Pacifists, Violent Crowd Members, and Instigator/Leaders of various age categories and both genders.
- The Actions of the Violent Crowd Members and the Instigators/Leaders in terms of provocation, violence against property, or violence against the Control Force.
- The Tactics of Controllers with options to use such Non-Lethal Weapons as tear gas, plastic bullets, water cannons, etc.

These sub-models were interrelated by the various decision processes of the individual agents in the model. Thus, the actions of the crowd and the instigator leaders affect the crowd dynamics and the decisions of the controllers. The actions of the controllers affect the crowd dynamics and the actions of the violent crowd members and instigator/leaders.

The detailed documentation of the model is available in [2].

MODELING PARAMETERS

The philosophy of system dynamics is that it is better to have a crude estimate of an important parameter than to ignore the parameter because a good estimate of its value cannot be obtained. By not including a parameter, one is implicitly assuming that its impact is zero. However, in this model 227 parameters have been included and the goal is to determine which of these parameters are most important to the future analysis. There are four types of parameters that are explicitly modeled:

a. Observables – such as number of people in the various groups of various types, and actions carried out by these people of various types.
b. Change rates in the observables – such as number of people joining or departing the groups, the increasing or decreasing rate of actions by the people, the effects of the observables on the rates, etc.
c. Thresholds that determine tactics – such as the level of crowd aggressiveness that will trigger the use of various Non-Lethal Weapons by the Controllers, and the level of crowd aggressiveness that will cause the Instigator/Leaders to take actions.
d. Strategic targets – such as the acceptable level of crowd aggressiveness that the Controllers will allow, and the desired level of crowd aggressiveness that the Instigator/Leaders wish to achieve.

Some of these parameters, such as the number of Bystanders/Pacifists initially in the crowd, are scenario dependent. Some of the parameters are theoretically determined, such as the tactical effects of Non-Lethal Weapons on the crowd behaviour. Some of them are controllable by the agents, such as the Thresholds that determine the tactical use of Non-Lethal Weapons, and the strategic values related to acceptable and desired levels of aggressiveness.

Because of their importance to the understanding of the central feature of the model, namely the aggressiveness levels, Tables 1 and 2 are provided to show how the aggressiveness of the crowd and the controllers are categorized.

Aggressiveness Level	Majority Action Type	Minority Action Types	Description of Crowd
1	Passive	Passive	Passive Crowd
2	Passive	Provocative	Passive Crowd with Isolated Violent Actions
3	Passive	Provocative, Property Damage	
4	Passive	Provocative, Property Damage, Control Force Attack	
5	Provocative	Passive	Agitated Crowd
6	Provocative	Passive, Property Damage	Agitated Crowd with Isolated Violent and or Passive Actions
7	Provocative	Passive, Property Damage, Control Force Attack	
8	Property Damage	Passive, Provocative	Violent Crowd
9	Property Damage	Passive, Provocative, Control Force Attack	
10	Violent Against Control Force	Passive, Provocative, Property Damage	Violent Crowd

Table 1: Crowd Aggressiveness Categorization

Aggressi	Tactical Combinations
0	Presence
1	Communications
2	Defensive Move
3	Tear Gas
4	Defensive Move and Tear Gas
5	Water Cannon
6	Defensive Move and Water Cannon
7	Tear Gas and Water Cannon
8	Defensive Move, Tear Gas and Water Cannon
9	Plastic Bullets
10	Defensive Move and Plastic Bullets
11	Tear Gas and Plastic Bullets
12	Defensive Move, Tear Gas and Plastic Bullets
13	Water Cannon and Plastic Bullets
14	Defensive Move, Water Cannon and Plastic Bullets
15	Tear Gas, Water Cannon and Plastic Bullets
16	Defensive Move, Tear Gas, Water Cannon and Plastic Bullets
17	Offensive Move
18	Tear Gas and Offensive Move
19	Water Cannon and Offensive Move
20	Tear Gas, Water Cannon and Offensive Move
21	Plastic Bullets and Offensive Move
22	Tear Gas, Plastic Bullets and Offensive Move
23	Water Cannon, Plastic Bullets and Offensive Move
24	Tear Gas, Water Cannon, Plastic Bullets and Offensive Move

Table 2: Controller Aggressiveness Categorization

DESIGN OF EXPERIMENTS

To achieve the goals of the team, two experiments were run: one to determine the sensitive parameters in the model; and one to develop a robust set of rules of engagement.

The first experiment involved a two-level fractional factorial design, which required 512 simulation runs.

The second experiment involved a cross-design. For the 22 "controllable" tactical and strategic parameters, a nearly orthogonal Latin hypercube was used. This required 129 simulation runs. For the remaining 183 "uncontrollable" parameters, a two-level saturated design was required. This involved 256 simulation runs. Therefore, 129 times 256 or 33,024 simulation runs were required for the entire experiment.

RESULTS AND ANALYSIS

Sensitivity of the Parameters

The 512 runs for the two-level fractional factorial design took only five minutes on a laptop computer because the System Dynamics model is purely deterministic. Therefore, data farming was not required.

The aggressiveness of the crowd and the aggressiveness of the controllers were summed in the model to determine the overall level of aggressiveness that would be minimized in the ideal world. Two types of statistical analysis were conducted on the results of the 512 simulation runs: stepwise regression and a partition tree.

With the stepwise regression, 21 parameters entered the model and were able to account for 30% of the deviation in the results. Eleven of these were considered controllable (i.e., associated with factors influencing control forces strategies). Among them, five are used to determine the tactics of controllers (e.g., tear gas and plastic bullet thresholds). These controllable elements would need to be determined to reduce aggressiveness to a minimum. Ten parameters were considered uncontrollable (i.e., associated with factors influencing the crowd members). For example, the effect of "illegitimacy" is an important factor. The uncontrollable elements would need to be estimated accurately, based on the scenario or the theoretical foundations of the model. As predicted, many of the controllable factors (5 out of 10) made the top 10 list.

With the partition tree, again 21 parameters entered the solution. However, they were a different set of parameters, which included only 6 controllable parameters and 15 uncontrollable parameters. The model was able to account for 50% of the deviation in the results. Some elements, such as the effect of illegitimacy, come later in the order of importance in the partition tree than in the case of stepwise regression. However, one of the uses of the partition tree approach is the ability to develop rules of engagement directly from the results.

Robustness of the Rules of Engagement

The first thing that was done to evaluate the robustness of the rules of engagement was to develop a "loss function." This was not difficult—since the goal was to minimize the total aggressiveness in the scenario, the "loss function" that was chosen was the maximum aggressiveness in the scenario squared.

The mean loss was then determined for each of the 129 controllable parameter runs by averaging all 256 of the uncontrollable parameter runs.

Stepwise regression and a partition tree were applied to the 129 simulation results, with the independent variable being the mean loss.

A stepwise regression was conducted using all 22 main factors, all two- and three-way interactions and all quadratics. Thirty-eight variables entered the model: 15 main effects, 21 interaction effects and 2 quadratic effects. This model accounted for 90% of the deviation in the results. The results confirmed that the thresholds of soft tactics, such as communication and use of cameras, do not have a considerable impact on the aggressiveness of the event. Conversely, the use of plastic bullets and water cannons has a considerable impact. This model could easily be used to determine a robust set of tactical thresholds and strategic goals of the controllers over all possible scenarios that might be faced.

The partition tree results were somewhat less satisfying since only five partitions were possible, even though they represented only 78% of the deviation in the results.

FUTURE WORK

Using this model with an efficient design of experiments, it is hoped that a robust set of rules of engagement can be developed that will minimize aggressiveness of the crowd with minimum force applied by the controllers. There are two approaches that will be examined:

- A set of scenario-independent rules of engagement that can be applied to all possible situations.
- A two-player style measure-counter measure approach that adapts the rules of engagement to the developing dynamics of the situation.

The first set of rules might be useful for doctrinal documentation on Non-Lethal Weapons employment. The second, more dynamic rules, might be useful for training simulations and Red Team/Blue Team gaming.

The 2010 Winter Olympics will be held in Vancouver, British Columbia and the Canadian Forces are currently making plans to support the games with security capabilities. There have already been indications that attempts will be made to disrupt the games by anti-poverty protesters and native groups [3]. With the eyes of the world on Canada through the international media, it will be imperative to handle any disruptions expeditiously, but carefully. Therefore, the optimal use of Non-Lethal Weapons is currently of great interest to the Canadian Forces, and supporting the 2010 Olympic Games planners with doctrine and training could be one of the immediate benefits of this work.

In the longer term, the introduction of design of experiments to verify and validate models in the Centre for Operational Research and Analysis, Defence Research and Development Canada, the Systems Dynamics Society, and the modelling and simulation community through presentations of this work, would be an admirable goal for the Team 11 members.

REFERENCES

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