A Multi-Methodology Framework for Modelling Opponent Organisations in the Operational Context

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ABSTRACT

The hyper connectivity of global, regional and local societies has increased the dynamics and volatility of conflicts. Conflicts are no longer contained by borders and ideologies and call for an integrated approach that takes into consideration the involved opponent organisations.

However, limited modelling tools are available to provide insight into the effect of interventions on (human) opponent behaviour and in particular on opponent organisation resilience. To achieve this goal, it is important to not only consider the modus operandi and chain of actions that lead to a violent attack, but also the opponent organisation, its social networks as well as the society and physical environment in which it takes place, as all these aspects may influence each other and the effectiveness of interventions.

Therefore, we introduce a generic multi-methodology framework combining Agent-Based Modelling (ABM) and System Dynamics (SD) that can be tailored for a specific opponent context. The framework distinguishes three levels of modelling: the macro-level contains the context and environment, the meso-level models organisations and networks, and the micro-level models individual behaviour. This multi-methodology framework allows to combine detailed modelling, e.g. for the opponent organisation, with high-level models, for example economic developments.

This framework has been explored for a case study based on an opponent insurgent organisation active in a nation and region. In this area there is a single opponent insurgent organisation trying to enlarge their span of control. This opponent insurgent organisation can actively recruit new members and setup violent actions as well as acquire funding for their activities. On the other hand, a government with policing and intelligence capabilities tries to counter this insurgent group. Using this case study we will show how the modelling framework enables modelling of different opponent organisation structures and government interventions, and shows some promising results in terms of modelling the resilience dynamics of the opponent organisation over time.

1. INTRODUCTION

The hyper connectivity of global, regional and local societies yields on one hand, an increased awareness about

existing conflicts and, on the other hand, an increase of the dynamics and volatility of conflicts as these are no longer contained by borders and ideologies and involve more than ever new and quickly evolving threats. It is therefore not surprising that several analysis have been performed on the nature of conflicts from a complex systems perspective. For instance, Richardson (1948) analysed different conflicts between 1820 and 1945 and showed that for both wars and small-scale homicides in this time period, the frequency of an event scales as an inverse power of the event's number of casualties. Similarly, Clauset et al (2007) analysed the frequency and severity of terrorist attacks worldwide since 1968 and showed that these events are also uniformly characterized by the same phenomenon, i.e. the frequency scales as an inverse power of the severity (in terms of causalities). Although this research sheds light on the general dynamics of conflicts it does not provide insights on the more operational and tactical aspects of conflicts, and in particular on the behaviour of the opponent organisations. Therefore, understanding opponent behaviour reinforces Sun Tzu writings of the 5th Century BC "If you know your enemies and know yourself, you will not be imperilled in a hundred battles" (The Art of War). However, limited modelling exists that provides insight into different opponent organisations and their behaviour in reaction to interventions to counter or contain their effect. For instance, Anderson (2011) introduced a system dynamic model of insurgencies based on the U.S. Army and Marine Counterinsurgency Manual (FM 3-24). The aim of this model is to analyse the dynamic implications of insurgency to the local society and their reaction to interventions by a counterinsurgency force. Atkinson and Kress (2012) introduced an insurgent violence model based on dynamic, differential equations to analyse the impact of three interventions on the popular behaviour in insurgency conflicts. Their analysis of eight cases focused on the levels of violence intensities of the regime and the insurgents, the targeting accuracy of each side, and the response pattern to these acts of violence by the civilian population. Recently, Duijn et al. (2014) have modelled a criminal organisation in terms of its social network and value chain. They show that this approach provides insight into the resilience of an opponent group and also suggest interventions that can mitigate their behaviour. However, they do not consider the environment where the criminal organisation is embedded in. Finally, and as stressed by McKiernan et al. (2015), in order to better understand opponent organisations and their dynamics it is essential to understand the opponents financial structure as opponent activities need financing.

This overview underlines that most of the research has been conducted in a stovepipe manner and that holistic modelling approaches to explicitly incorporate (opponent) behaviour into operational analysis and training models are lacking. To facilitate a more holistic approach, taking into account different modelling paradigms, this paper explores the combination of agent-based modelling and system dynamics to derive a generic multi-methodology framework for modelling opponent behaviour that can provide insights into the dynamics and resilience of the opponent organisation, similar to the approach proposed by Martin & Schlüter (2015) to model social-ecological interactions between humans and ecosystems to analyse their implications for sustainable management of social-ecological systems.

The proposed multi-methodology framework combines three different levels of modelling: macro, meso and micro-level. The micro-level focuses on modelling different types of opponent behaviour at the individual level encompassing interpersonal relationships and direct interactions with immediate surroundings, while the macro-level models the environment where the opponent group is inserted, and associated factors like socio-economic reasons for radicalisation and becoming member of an opponent organisation. Finally, the meso-level modelling covers the opponent group organisation inherent phenomena and interactions that play a role in describing the organisation.

Using this approach scenarios can be tailored for specific opponent organisations ranging from insurgent organisations to organised criminality gangs in a civil context. Applications of this multi-methodology framework are foreseen during the intelligence preparation of the environment within military missions as well as in security research investigation. Applying this framework will enable exploration of possible future

developments and actions of an opponent group, as well as development of effective interventions to counter (individual and collective) opponent behaviour. Moreover, it will also enable the development of training.

The structure of the paper is as follows. In Section 2 the new multi-methodology modelling framework is introduced. In order to illustrate the potential of this framework a case study has been developed and analysed in Section 3. Finally in Section 4 conclusions from our work and suggestions for further research are presented.

2. MODELLING APPROACH

In order to analyse the resilience of an opposing organisation and the effect of direct interventions targeted both to this organisation and to its environment (society where organisation is active) a modelling framework with an adequate granularity is required. Moreover, such a modelling framework should be able to deal with the mentioned three levels of modelling, micro, meso and macro-level.

An Agent-Based Modelling (ABM) approach is powerful to model individual behaviour of model elements their interactions, and emergent behaviour. However, in the context of this paper a single methodology approach would require modelling an extremely large numbers of agents. Moreover, using such a modelling approach would imply that government policies, popular support, investments, taxes et cetera would have to be derived from interactions between agents and model parameters. A System Dynamics (SD) approach seems to be more appropriate to model the interacting policies, spending, support, reaction of large parts of the general population (i.e. migration), et cetera. Finally, and as the coordination of the opponent organisation and its strategy is an essential modelling element, agent-based domain several rule-based approaches for organisational coordination that are based on formal logic, e.g., Opera (Dignum, 2004) and Moise+ (Hübner, 2007) appear to provide a good modelling approach. Therefore, the model framework that better fits our goals should combine ABM to model micro-level behaviour, organisational modelling for meso-level, and SD to model macro-level behaviour. Our modelling approach is, as such, of a hybrid nature, in the sense of Lättilä et al. (2010) and Swinerd and McNaught (2012).

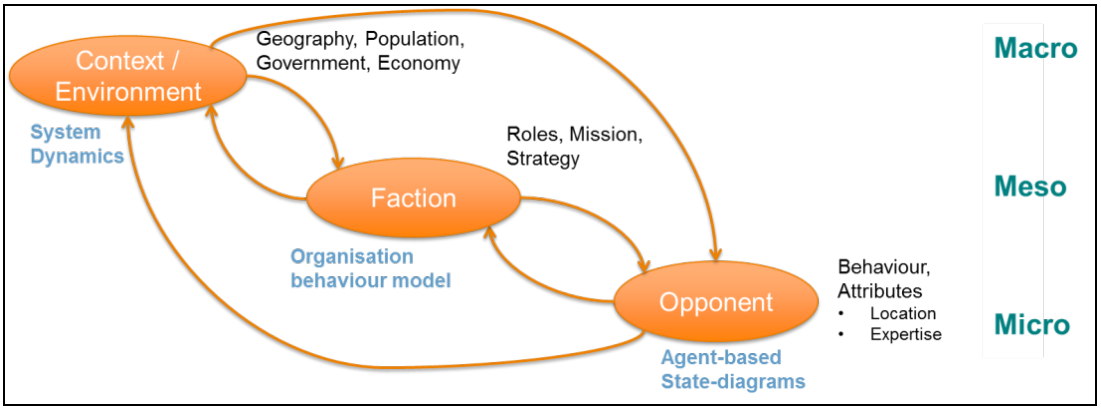


Figure 1: Schematic representation of multi-level framework.

As the Figure 1 shows, all three modelling levels interact with each other. At the micro-level ABM is used to model the (potential) members of the opponent organisation and their complex behaviour including learning and adaptation and their (change of) organisation role. The agent behaviour is influenced by the environment (macro-level) and the organisation (meso-level) in which the agents act. The environment represents for instance

government actions (macro-level attributes) while effect of the organisation is represented by its financial situation (meso-level attributes). At the macro-level the general population is represented by a stock. If a new member is recruited (from the general population), a new agent at the micro-level is created. These agents will evolve in the simulation, by acquiring training and playing their role in the opponent organisation (for instance, perform violent actions, etc), or becoming a leader. State machines are used to model the roles and actions of the agents. The challenge is to include the opponent organisation dynamics in the SD model. The number of opponent members is therefore included as a stock in the SD model which is filled and depleted depending on the total number in the ABM model. As a result, a dynamic environment has been created by an SD model in which the opponent agents act and interact. The modelling framework is setup so it can in the take regional/geographical differences into account (geological properties, population, logistical and environmental features, governmental policies, etcetera). The opponent organisation has a financial cash flow and a financial resource strategy which will be modelled with an SD model.

This modelling framework has been experimentally implemented in AnyLogic, see Borshchev and Filippov (2004). In Anylogic a simulation model can consists of a mixture of system dynamic, agent based, time stepped, and discrete event (state machines) models. These different types of models can interact by exchanging values of their model parameters. For an initial introduction or watch the educational videos on the AnyLogic website[1]. In the next sections the different modelling levels will be introduced in more detail.

2.1. Macro-level modelling

As mentioned before, the modelling approached used at the macro-level is System Dynamics (SD) and is based on an adapted SD model from Anderson (2011). The Anderson-model can be described as a traditional counter-insurgency model in which the population can be drawn to become an insurgent due to dissatisfaction with government ruling. On the other hand, the government can perform combat patrols in order to counter the insurgence activity. This model is well known within the military and scientific literature and has been verified and validated. As such it provides a good basis for our macro-level modelling approach.

The core of the Andersen model is a stock named "*active insurgents*". This stock can increase by potential insurgents becoming active and decrease by retirement, elimination or insurgents leaving service. Retirement is a function of the average serving age of insurgents (i.e. retirement age – joining age). Elimination is defined by the government combat patrols, their efficacy and the density of insurgents in the area. The increase and decrease of insurgents – apart from the elimination and retirement flows – is based on a variable named indicated insurgents. The number of indicated insurgents is calculated based on the variables "*potential insurgents"* and the "*recruitable fraction"*. "*Potential insurgents*" is a number that is based on the population size, the number of persons in the population in a specific age group, the number of males in the population – since a vast majority of many insurgent groups are young males, see e.g. Metz (2009) – and the fraction potentially sympathetic to insurgency. The latter is a value for the part of the population that might be prone to supporting or actively taking part in the insurgency. All these values are scenario-specific and need to be adapted to fit the scenario.

The Anderson model contains a number of important dynamics that are illustrative for insurgencies and terrorist organisations and their behaviour in response to government and population reactions. These dynamics are to a large extent caused by insurgent activities and the government's response:

1. Suppression loop: the government can, in the event of insurgent activities, start combat actions. The number of combat actions by the government multiplied by the *combat efficacy* determines the *detention and elimination of Insurgents*, which decreases the number of active insurgents

[1] http://www.anylogic.com/resources/educational-videos/

2. Blowback loop A: combat actions by the government have an effect on the population (e.g. due to collateral damage and interference of the government in daily life). This leads to lower *indicated popular support for the government*. Eventually, lower popular support can increase the *potential insurgent fraction activated* and the number of insurgents. This is substantiated by Anderson (2011) and the FM-manual:
   a. Protection of the population from external and internal threats
   b. Government leaders are selected in a manner considered just by the populace
   c. High level of participation or support for government processes
   d. Culturally acceptable level of corruption
   e. Culturally acceptable level of development
   f. Acceptance of the regime by major social institutions
3. Law & order loop A: an increase in insurgent violent attacks will yield that the population will feel less safe. Consequently the government will be blamed for not ensuring a secure environment (see also the list of government legitimacy determinants). This will cause the popular support to the government to decrease
4. Intelligence loop: the government can increase its combat efficacy by gathering intelligence, by deploying intelligence patrols. Increasing the number of intelligence patrols will lead to an increase of situational awareness intelligence, which leads to higher combat efficacy. This will give the government the ability to initiate combat actions with less collateral damage and interference on the society daily life. As such it results in relatively more detentions and elimination of insurgents compared to the losses in popular support
5. Law & order loop B: the occurrence of insurgent violent attacks will lead to intimidation of the population, which will lead to less intelligence sharing with the government
6. Insurgent experience loop: as the government initiates more combat patrols, the insurgents will, with a delay, increase their violent attacks (the so-called effect of recent combat on violent attacks)
7. Deterrence Loop: when government combat patrol levels rise above a certain threshold, the insurgents tend to decrease their activity and hide (waiting for “better days”)

Anderson (2011) showed that blowback, intelligence gathering, and population security are important aspects of an insurgency’s dynamics. However, Anderson also identified the model’s shortcomings: the lack of government propaganda and economic effects. Moreover, this System Dynamics modelling approach lacks the desired granularity in terms of opponent organisation behaviour. In fact, the emergent behaviour of an organisation, as the result of the actions of its individual members and leadership structure, is not captured. In order to deal with these findings, we propose a number of adaptations to the Anderson (2011) model.

The first major adaptation consists in removing the structure and behaviour of the insurgents from the SD model and modelling it as an Agent-Based structure. Here for a number of structures in the Anderson model were modified as follows:

Indicated insurgents (a number of persons that is willing to take up arms against the government troops, e.g. open to being recruited) feeds directly into the ABM.

The number of insurgent activities will be computed directly from the ABM. So any effect of deterrence and insurgent experience gathering is defined in the ABM. The ABM takes into account the effect of government patrols and hostilities on insurgent behaviour. This will lead to a change in the number of insurgent violent attacks, which feeds back into the SD model.

- Combat efficacy is still calculated based on the available intelligence. This variable, combined with the

number of combat patrols, defines how many insurgents are incarcerated or eliminated, feeding back into the ABM.

- The endogenous effect on government actions (combat patrolling) has been removed from the SD model and will be implemented as an intervention in the new approach.

Based on the recommendations of Anderson, two effects have been added to the SD model: the effect of government propaganda and the effect of economic inequality.
Regarding (financial) motives to join an insurgency, Humphreys et al. (2008) mentions:

- Social network/social dynamics/peer pressure: it is easier to activate people when the network is formed from an ideology justifying rebellion (religion, political ideals, social background/ethnicity)
- Benefits received as an insurgent/fighter: the benefits of being an insurgent/criminal (possibly including salary, protection and social services) should outweigh the cost of being an insurgent, i.e. the payment should outweigh the risk

According to Humphreys et al. (2008) the above motives are often interlinked: the first step of an insurgency is to establish an organisation of people from a particular network. After an insurgent group becomes more mature, financial institutions and benefits can be put in place, thus leading to attracting insurgents for a financial motive.
In our modelling framework, the financial motive of insurgents is added to the model as average salary of the population divided by the salary of the insurgents from the financial model.

$$Income\ inequality = \frac{Actual\ average\ wage}{Actual\ wage\ as\ insurgent}$$

This fraction is then added to the model as an effect of income inequality on popular support, i.e. higher relative insurgent wages cause lower popular support, by using an exponential function of the fraction multiplied by an elasticity function as follows:

$$effect\ of\ income\ \ inequality\ on\ popular\ support = e^{-sensitivity\ to\ inequality\ \times\ \frac{reference\ inequality}{income\ inequality}}$$

The sensitivity of the population to economic inequality is a scenario specific parameter (less than or equal to 1). The reference inequality models the income difference between the population and insurgents which is found to be acceptable.

The effect of government propaganda is added to the basic Anderson model as the value of how effective the government is in reinforcing the government's narrative. This value can be positive or negative between (-1, 1) where 1 represents the maximum effectiveness of spreading the government narrative and -1 the opposite.

The resulting model is depicted in Figure 2. A scenario can be modelled by adding the initial values to the scenario specific variables (yellow variables in Figure 2). The red parameters are used by the opponent organisation AB model, while the green parameters are set by the AB model. The orange parameters are obtained from the SD financial model. Pink parameters are parameters related to government policies. More generic parameters (variables in blue) are important for model calibration and can be derived using historic data.

With the purple parameters feedback loops can be switch on or off.

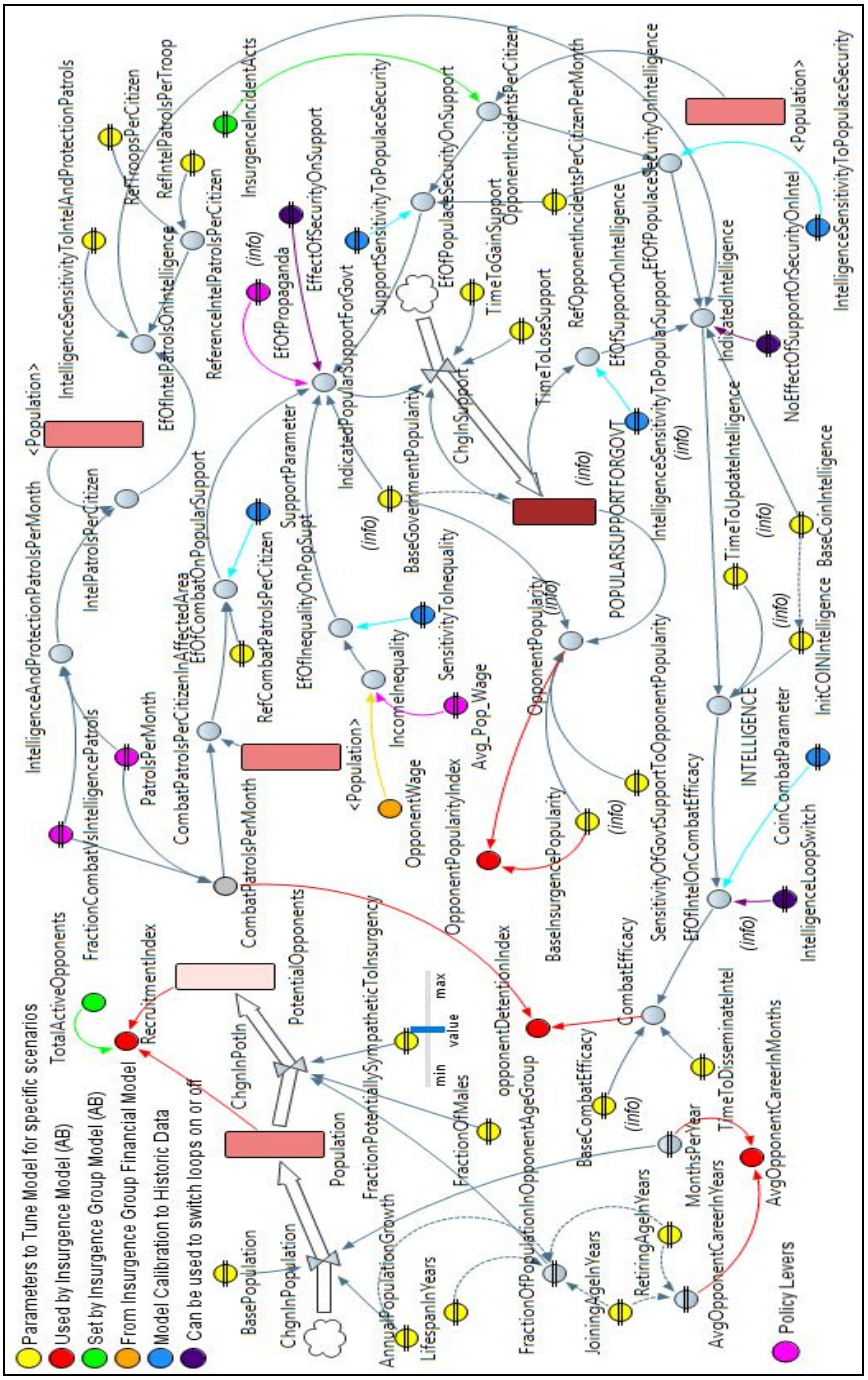


Figure 2: Graphic overview of the Insurgency Dynamics Model, based on Anderson (2011).

2.2. Meso-level modelling

The meso-level modelling approach focuses on two elements: modelling of the opponent organisation structure and the organisation financial structure. For the organisational structure the approach proposed by Moise+ (Hübner et al., 2007) for modelling roles, hierarchy between roles, and organisational tasks was used. The organisational structure imposes constraints on the agent behaviour. As agents take up a role within the organisation, they obtain the corresponding permissions and obligations. The organisational model in the current implementation is simple and consists of four roles in the hierarchy as shown in the figure below. The three roles fighter, financial expert, and recruiter are used to indicate the type of tasks an insurgent can undertake. The forth role corresponds to the leader that, as the name suggests, commands the opponent group by setting up the organisation members to act or not.

Figure 3: Organisational structure

As for the financial structure of the opponent organisation a simple SD model to model the organisation's financial related activities was used. This model is based on McKiernan et al. (2015) and it considers various financing gathering sources (e.g. via fundraising and attacks) as well as organisation spending's necessary for preparing and holding violent attacks, paying wages and pensions of insurgents. The financial subsystem consists of a stock of resources replenished by fundraising activities and is emptied by the payment of insurgent wages as well as the pensions for the families of imprisoned or killed insurgents. A graphic overview of the insurgent organisation financial model is depicted in Figure 4. The green parameters are set by the opponent group AB model. Again, a scenario can be modelled by adding the initial values to the yellow scenario specific variables. The red parameter is used by the AB model.

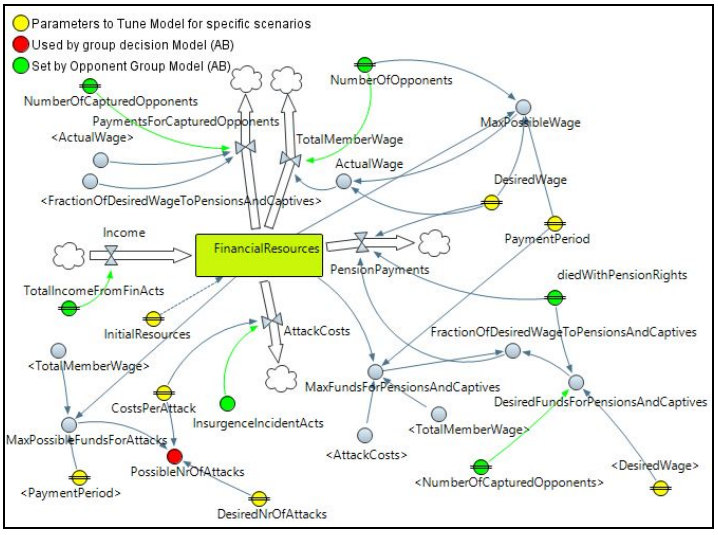


Figure 4: The opponent organisation financial SD model

Wages

In general, most mature organisations are expected to pay their member wages (Humphreys et al. 2008). Multiple sources speak of ISIS members earning as much as $400 per month (McKiernan et al., 2015, The Economist, 2015). But in case of resource decline, these salaries are cut as well (Fox News, 2016). Additionally, in some cases insurgent organisations are expected to also pay for the survivors of the organisation members killed in action (Time Magazine, 2016): *"She was now the wife of a shaheed [martyr] and was being honoured. […] All women, she promised me, were looked after. 'U will still get money each month."* There are also sources stating that terrorist organisations pay salaries to imprisoned organisation members (Jaffer, 2015). The height of the wages in the model is defined as a desired wage given to insurgents. This influences the attractiveness of becoming an insurgent. No sources were found for whether the survivors and prisoners also get the same amount. Similar to the desired wage this will be scenario specific.

Attacks

Setting up insurgent attacks as mentioned in the insurgency dynamics model will require financing: people need to be trained, materials need to be acquired, explosives need to be made, etc. According to the National Commission on Terrorist Attacks Upon the United States (2004), the 9/11 terrorist attacks on the USA cost Al-Qaeda approximately 4-5 hundred thousand US dollars. It is expected that smaller scale attacks will cost relatively less. Therefore, the model contains an average cost per attack variable, which will be different for each insurgent/terrorist/criminal opponent group and modus operandi.

Financial resource distribution

Since the literature does not report detailed sources concerning the financial opponent organisation we made a number of assumptions on how the financial resources are distributed in case of scarcity. The model takes into consideration whether the financial resources are sufficient to pay the insurgent salaries. If that is possible, these salaries will be paid. If the financial resources are insufficient, the insurgents will receive a smaller payment corresponding to the fraction of resources available (i.e. if 80 % of the total desired salary can be paid, all insurgents will receive 80 % of the desired salary) and the resources are empty after paying this amount. The resulting salary payment is taken into account in the insurgency dynamics model.

If insurgents are able to receive their full desired salary, then it is assumed that there is willingness to act to the full extent of the available financial resources. In this case, the model calculates the number of attacks the insurgent organisation can conduct given its current financial situation. If the resources are insufficient, only a fraction of the attacks that can be conducted will be possible. On the other hand, if all the desired attacks can be conducted, the model checks whether there are enough resources left for paying survivors and prisoners families. If only a fraction of the desired resources are available, the survivors and prisoners families receive a fraction of the desired payment. The resources that are not spent will be kept in the resource stock. The variables in green correspond to the Agent-Based Model related variables.

2.3. Micro-level modelling

The opponent organisation, modelled using Moise++, is formed by a given number of members, for instance insurgents. These members are modelled as agents in an Agent-Based Model (ABM). They have individual properties that characterise the member such as role, location, experience, relations, etc. Figure 5 shows the state machine of the agents. Newly recruited members start in a so-called training state. If enough training points have

been collected[2], the agent switches to the *work*-state in which the agent may be tasked to act. Agents in this state correspond to the *active insurgents*. Each agent is attributed a role: recruiting new agents (recruiter-role), collecting money (financial expert-role) and committing violent attacks (fighter-role). Active insurgents can be captured and imprisoned or killed. One of the active insurgents is selected as leader.

For practical reasons a separate state has been created for the leader in which he continuously monitors the organisation performance and gives orders to the other agents. Note that the leader cannot be detained, but can die or leave the organisation. In this case a new leader will be selected based on the experience level of available organisation members. All other agents can be detained, leave the insurgent organisation or die at any time.

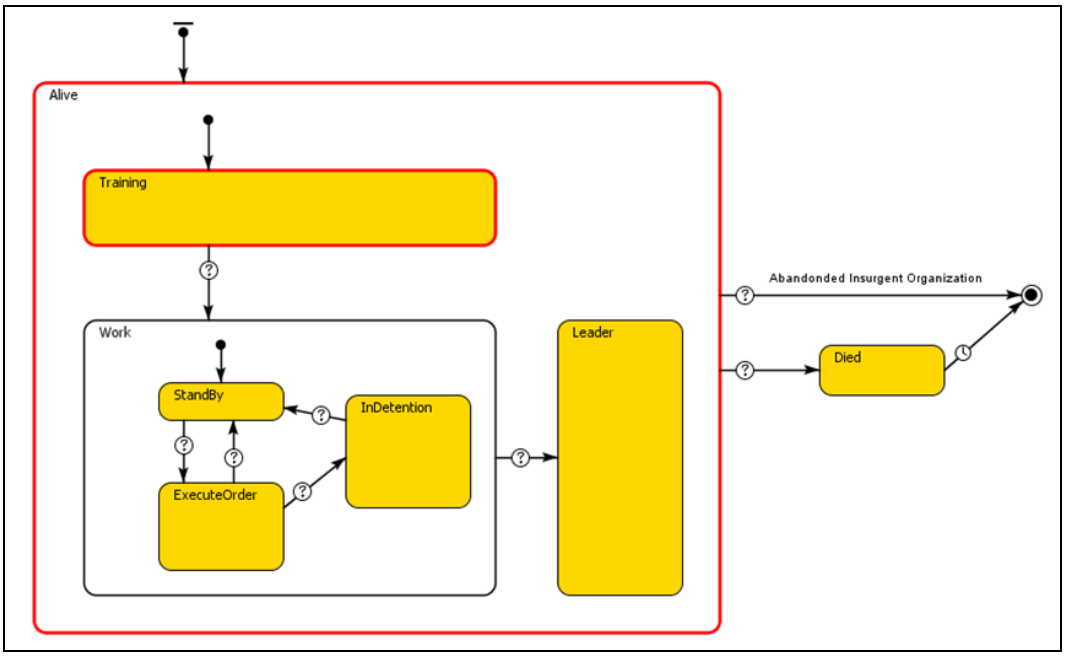


Figure 5: State machine of agent-behaviour

2.4. Interactions between the micro, meso and macro-levels

All modelling levels interact with each other via their attributes. Figure 6 shows some snapshots of these interactions. At the macro-level a subset of the population is attributed as potential insurgents. The number of potential insurgents influences the success rate of a recruitment action that is used at the micro-level. Successful recruitments have effect on the number of members of the insurgent organisation at the meso-level, which in turn, influences the number of potential insurgents.

[2] In the current version of the model the number of points collected by an agent is defined simply by how long it is a member of the organisation. In a future version of the model an agent could also collect additional points by performing successful attacks, successful financial or recruitment actions et cetera.

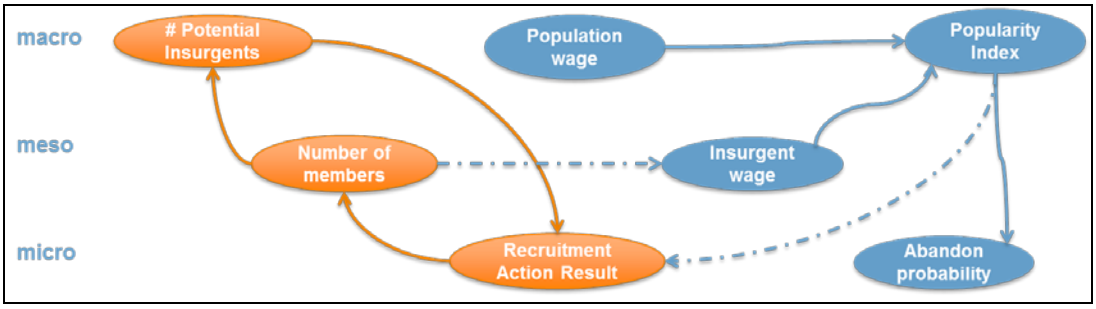


Figure 6: Example of interactions between attributes at the three modelling levels

Economic factors are modelled in simple form. At macro-level the population wage is given. From the organisation model, the insurgent wage is defined. Together these two factors influence the popularity index of the opponent organisation, which is maintained at macro-level. The "abandon" probability of agents leaving the opponent organisation is dependent on this popularity index, which in turn has its effect on the agent behaviour at micro-level.

3. A CASE STUDY

A case study of an insurgent organisation has been developed and modelled in order to explore the potential of the proposed multi-methodology framework. It has been set up with one geographic area with a homogeneous population. In this area one insurgent group fights against an established government which has combat patrolling and intelligence capabilities. This insurgent organisation is capable of violent actions, and financing and recruiting activities.

In order to explore the potential of the modelling approach to explore the resilience of the insurgent organisation we have defined different government interventions and organisational strategies. Government interventions include:

(i.) intensification or reduction of combat patrols and propaganda. The intensification or reduction of combat patrols (which increases or decreases the probability of capturing insurgents during these patrols) corresponds to the number of patrols deployed per month. An intensification or reduction of government propaganda (that is directly linked to the government popularity and insurgent popularity) will be modelled in the case study as the effect of government propaganda, which can be either positive or negative for the government

(ii.) interventions targeted at insurgents in specific organisational roles. For targeted interventions, a specific role may be selected, increasing the probability of capturing opponent organisation members in specific roles (like recruiters) and decreasing the probability of capturing opponent organisation members in other roles

As for the effect of different organisation strategies we have considered the role distribution between recruiters, financial experts and fighters. Adjusting the distribution between organisation members in the different roles will change the behaviour of the opponent organisation

The case study data used was based mainly on the data used by Anderson (2011) the counterinsurgency scenario of the Anglo-Irish conflict of 1919-1921. The main reason for taking this scenario is that a lot of data on this conflict is available. Different constants of the model (i.e. the responses of the system to certain changes) were

calibrated in order to create behaviour that corresponds to the available historic data. The financial data used was inspired by McKiernan et al. (2015).

In the case study, the insurgency organisation starts initially with 100 members, of which 35 are recruiters, 20 are fighters and 45 are financial experts or fund raisers. One of the members is elected as leader. This number of members and role distribution is called the baseline distribution. Evolution of the number of members of the insurgency organisation and the number of violent insurgent attacks was considered over a period of ten years. All the results presented in the next sections are collected by running each scenario a hundred times. Each run was performed with a new seed for the random number generator. These results illustrate the modelling framework potential. Figure 7 shows the number of attacks in each of the hundred runs. In one run there was over 200 incidences while most had only about 25 incidents or less.

The baseline scenario represents the case that starts with the baseline distribution and where no interventions have been made. In this case, a growth of the insurgency organisation from 100 to 219 members, and an average of 29 violent attacks in a period of 10 years are observed. It should be noted that a large fluctuation in the results is observed. This is due to the dynamics of the systems and its non-linear behaviour. The results show especially a large spread in the resulting number of violent attacks. The width of the main peak is computed used the functionality provided by AnyLogic to compute a standard deviation of an average outcome from a collection of simulation runs. The standard deviation is 30.4. However, one should keep in mind that the results are clearly no Normal distribution as shown in Figure 7. The computed standard deviation only give an indication of the spread of the simulation results. The simulation runs also show that the organisation behaviour may exhibit an increase in violence if some specific requirements are met. Namely, the organisation should have sufficient money to afford the attacks and sufficient members who have the role of fighter.

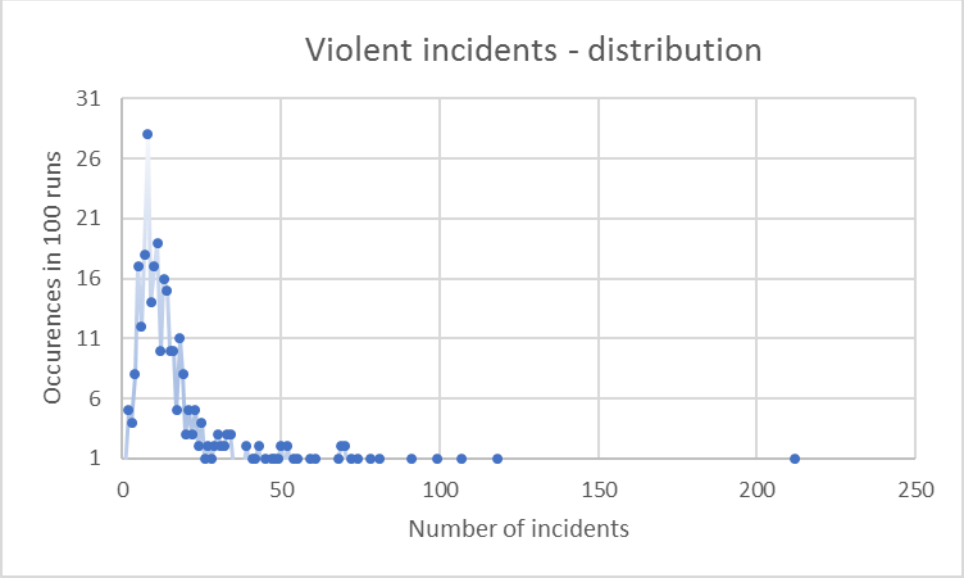
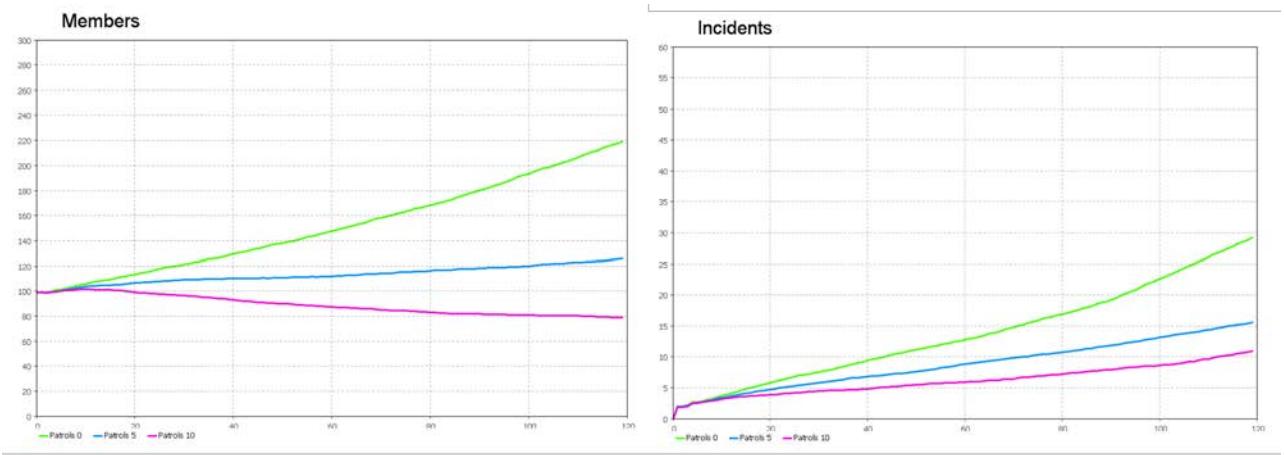


Figure 7: Occurrences of number of violence attacks in 100 runs

3.1. Intensification and reduction of security patrols and government propaganda

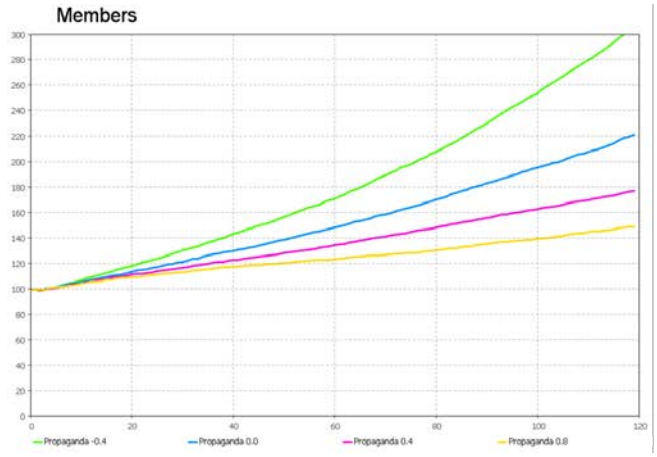
Security patrols and government propaganda are typical government interventions that can be evaluated in SD counter insurgency models. In our case study government interventions have be added to the baseline scenario in which there are no patrols. The results in Figure 8 show the scenarios where the government has deployed 5 (blue line) and 10 patrols per month (purple line). As can be expected, patrolling has the effect on average of lowering the number of members and violent attacks. Moreover, more patrols appear to have a stronger countering effect both on the number of insurgents as of violent attacks.



# Patrols / month	# Members average	# Members stddev	# Incidents average	# Incidents stddev
0	219	49.6	29	30.4
5	126	28.2	16	13.4
10	79	19.4	11	7.0

Figure 8: Scenario: effect of government patrols on members and incidents. No patrols (green line), 5 patrols per month (blue), and 10 patrols per month (purple).

Another type of intervention is government propaganda. Effective government propaganda (positive value) yields a positive effect for the government, while ineffective propaganda (negative value) should yield the opposite effect. The simulation results show that when government propaganda is added to the baseline scenario in which the propaganda effectiveness is zero, these effects are observed. Moreover, **Error! Reference source not found.** shows that the effect of ineffective propaganda is larger than of effective propaganda. It should be noticed, than on average, the overall effect of propaganda is smaller than the effect of patrolling.



Propaganda (government perspective)	# Members average	# Members stddev
-0.4	306	76.9
0.0	221	42.6
0.4	176	35.6
0.8	149	35.2

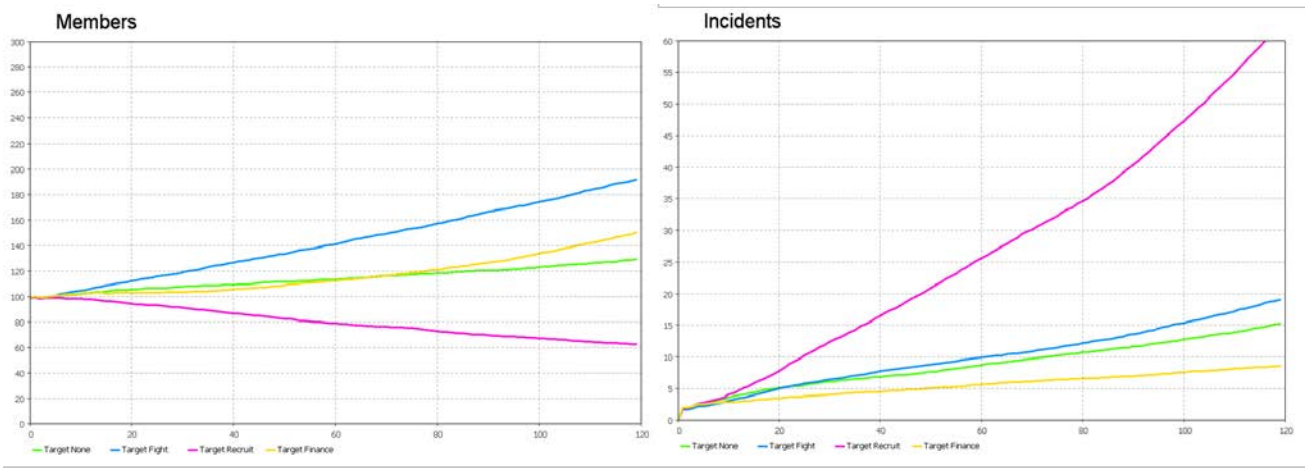
Figure 9: Effect of propaganda from a government perspective. Propaganda with a negative effect (green line), propaganda without effect (blue), propaganda with a moderate effect (purple) and propaganda effective of limiting the growth of the opponent organization (yellow).

These results show that the model exhibits the behaviour expected from the model when a parameter is changed individually in the SD model but their impact can be different in strength. These results show that the framework can be used to explore effects of interventions and to suggest combinations for policies if one would include the cost of interventions because patrolling might be more expensive than propaganda for instance.

3.2. Interventions targeted at specific opponent organisational roles

The multi-methodology framework also enables extra analysis possibilities, in terms of the effect of government interventions targeted to certain opponent organisation roles. In fact we can analyse the possible effect of patrols targeted at a specific role of the organisation, for example targeting fighters or recruiters. In the SD counterinsurgency models such a distinction was not possible. For targeted interventions, a specific role may be set, increasing the probability of capturing insurgents with that specific role by a factor of five and decreasing the probability for group members in the other roles of being detained. The effect is that the composition of the organisation will dynamically change.

Figure 10 shows the evolution of opponent organisation over ten years that start with the baseline distribution. Interventions are performed with five patrols per month. The number of members and incidents in the scenario in which the interventions are not role specific is shown by the green lines. Results from the scenarios where the patrols are targeted at fighters, recruiters and financial experts are shown by the blue, purple and yellow lines. There is a clear distinct effect in targeting the different roles. Targeting recruiters (purple) shows, on average, a strong decrease in the member growth, whereas targeting financial experts (yellow) has a minor effect on the number of members and targeting fighters (blue) even leads to an increase of members. At the same time, the effect on violent attacks is totally different. Namely, targeting recruiters (purple) results, on average, in a strong increase of the number of violent attacks, while targeting fighters (blue) has a small effect and targeting financial experts (yellow) seems most effective to decrease the number of violent attacks. This can explained by the organisational behaviour model. The organisation first spends its money to pay insurgent wages and only if there is money left, violent attacks will be financed. Therefore, a rich organisation with relatively few members, of which enough fighters, has the potential to become very violent. This combination of factors is achieved when targeting recruiters.



Targeted patrols (5 / month)	# Members average	# Members stddev	# Incidents average	# Incidents stddev
None	129	27.0	15	12.1
Fighters	191	36.5	19	14.5
Recruiters	63	14.2	63	44.8
Financial Experts	150	48.3	9	3.2

Figure 10: The effect of 5 government patrol interventions per month targeted at members with specific roles. For the blue line the interventions were not role specific. Result from the scenario in which the fighters, recruiters and financial experts are targeted are shown by the blue, purple and yellow lines. The table shows the averages and standard deviations of the 100 runs per scenario at the end of the simulation runs (10 years).

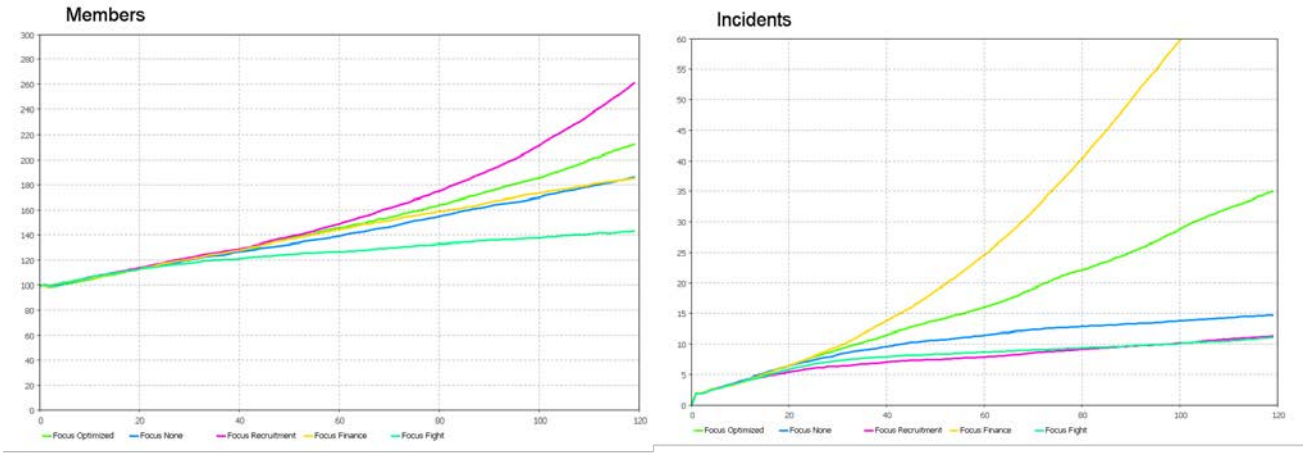
3.3. Influence of opponent organizations on strategy and structure

Because of the explicit definition of the organisational structure and strategies, the effect of different variants of the opponent organisation can be analysed. The organisational strategy is parameterised by its role distribution, i.e. the percentage of recruiters, financial experts and fighters. Table 1 shows the initial distribution of role in organizations with different focus at the start of a simulation and the average probabilities of new members taking up a role. At initialization the organisation adopts the specified distribution. Furthermore, when a new member is recruited, distributions are defined and serve as probability distributions of the new member taking up either of the roles. Therefore, changing the distribution of roles in the organisation will yield different behaviour.

Table 1: Initial role distributions at the start of a simulated scenario of organizations with different focus. These percentages are also the average probabilities of new members taking up a role.

Role Distributions	Focus None	Focus Recruiter	Focus Finance	Focus Fighter	Optimized
Recruiter	3 (33%)	5 (56%)	2 (22%)	2 (22%)	4.5 (45%)
Financial expert	3 (33%)	2 (22%)	5 (56%)	2 (22%)	2 (20%)
Fighter	3 (33%)	2 (22%)	2 (22%)	5 (56%)	3.5 (35%)

Figure 11 shows the effect of different role distributions on the average numbers of number of members and incidents. A 100 simulation runs were performed for each role distribution. An insurgent organisation with a recruitment focus (purple lines) will lead to more organisation members. However, more members lead to higher costs of wages, which will cripple the financial resources of the organisation and its ability to perform violent attacks. Therefore, a balanced distribution between the roles is needed for a healthy organisation on the long term (green lines). Note that the role distribution in these results is fixed. A possible modelling extension would be to adopt a dynamic strategy, where the distribution is varied according to the needs of the organisation.



Organisation strategy & focus	# Members average	# Members stddev	# Incidents average	# Incidents stddev
Optimized	212	40.9	35	33.6
None	186	44.5	15	12.8
Recruiters	261	68.5	11	6.3
Financial Experts	185	40.1	79	56.0
Fighters	143	38.6	11	8.8

Figure 11: The effect of organisation strategy on members and violent attacks: focus on recruiting specialized members. Organisation optimized on number of members and incidents (green lines), no focus (blue lines), focus on recruitment (purple), focus on finance (yellow), and focus on fighters (azure).

These results show that the organization with a focus on members with a financial role who collect financial resources for the organization evolves in the most violent one (yellow line in the right graph of Figure 11) and not the organization with a focus on fighters as one would intuitively expect. The framework allows much more detailed analyses such as the number of incident per member, fighter, the impact of government propaganda, et cetera but as stated above, the example case studies in this paper are intended to illustrate the potential of the developed multi-methodology framework.

4. RESULTS AND FURTHER RESEARCH

In this paper we have shown that using a multi-methodology framework combining agent-based modelling, system dynamics modelling and agent-oriented organisational logic effectively enables modelling opponent

organisation resilience. The case study shows that this framework can model the inherent dynamics of opponent organisations in response to different government interventions, including combat patrols and government propaganda. Moreover, the proposed modelling framework can be easily applied to other types of opponent organisations.

The modelling framework allows also for the inclusion of other facets of opponent organisation dynamics, like the influence of (digital) social networks in recruitment strategies. Also, geographical aspects of area where the opponent organisation is active can be taken into account. Moreover, the framework also allows for the inclusion of multiple competing factions of opponent organisations.

The case study showed the potential of the proposed multi-methodology framework. The case study simulation results show that the interaction between macro, meso and micro-level model enable the modelling of the dynamics in the number of opponent members and violent attacks.

Although this multi-methodology framework shows promising results it does not yet fully model the dynamics of opponent behaviour. Firstly, in the current model, both government and organisation behaviour is static throughout the scenario. Modelling both government and organisation as actors that continuously respond to the situation in a goal-driven manner, would provide more realistic scenarios.

Secondly, the current approach to the micro-level modelling using ABM does not allow yet for fine-grained modelling of the individual psychological processes that play a part in the evolution of the opponent group members and of the group as a whole (splitting of a group due to the development of different goals). For example, the individual recruitment process and the willingness to commit violence are influenced by personal and context factors. The benefits of modelling that in an explicit manner is that new interventions can be included directed at specific target groups (e.g. social classes).

Finally, we believe that this multi-methodology modelling framework is suitable for wargames. In particular, the embedding of such a framework in wargaming would challenge the players to deal with the resilience of opponent organisations.

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