Tackling Uncertainty Through Probabilistic Modelling of Proportionality in Military Operations

Clara Maathuis[1] and Sabarathinam Chockalingam[2]
[1]Open University of the Netherlands, Heerlen, Netherlands
[2]Institute for Energy Technology, Halden, Norway

clara.maathuis@ou.nl
sabarathinam.chockalingam@ife.no

Abstract: Just as every neuron in a biological neural network is a reinforcement learning agent, thus a component of a large and advanced structure is de facto a model, the two main components forming the principle of proportionality in military operations can be seen and are as a matter of fact two different entities and models. These are collateral damage depicting the unintentional effects affecting civilians and civilian objects, and military advantage symbolizing the intentional effects contributing to achieving the military objectives defined for military operation conducted. These two entities are complex processes relying on available information, projection on time to the moment of target engagement through estimation and are strongly dependent of common-sense reasoning and decision making. As a deduction, these two components and the proportionality decision result are processes surrounded by various sources and types of uncertainty. However, the existing academic and practitioner efforts in understanding the meaning, dimensions, and implications of the proportionality principle are considering military-legal and ethical lenses, and less technical ones. Accordingly, this research calls for a movement from the existing vision of interpreting proportionality in a possibilistic way to a probabilistic way. Henceforth, this research aims to build two probabilistic Machine Learning models based on Bayesian Belief Networks for assessing proportionality in military operations. The first model embeds a binary classification approach assessing if the engagement is proportional or disproportional, and the second model that extends this perspective based on previous research to perform multi-class classification for assessing degrees of proportionality. To accomplish this objective, this research follows the Design Science Research methodology and conducts an extensive literature for building and demonstrating the model proposed. Finally, this research intends to contribute to designing and developing explainable and responsible intelligent solutions that support human-based military targeting decision-making processes involved when building and conducting military operations.

Keywords: Machine Learning, Bayesian Networks, Military Operations, Cyber Operations, Targeting, Proportionality.

1. Introduction

"*Peace cannot be kept by force. It can only be achieved by understanding*." (Albert Einstein)

Ongoing wars demonstrate that although significant technological developments have been made in all societal domains as well as in the military domain, still preventing, limiting, or containing the unintended effects on civilian and civilian objects while achieving military goals, is difficult. This happens due to various sources and types of uncertainty surrounding entities like the context, enemy, target and corresponding intelligence information, and environment plus the multiple dimensions characterizing (in one way or another) the humans involved, e.g., brittleness, bias, unintelligibility, and subjectivity (Margulies, 2020; Morgan et al., 2020). At the core of this phenomenon (i.e., war) is the military targeting process which implies selecting, prioritizing, and matching targets with means and methods for achieving goals and projecting force on the enemy (US Army, 2013; NATO, 2016). A central feature characterizing this process is the proportionality principle directly expressed through the proportionality assessment when conducting military operations (Crow, 2019). In this assessment, two critical and antagonist components (Henderson & Reece, 2018) representing the two parts behind the wall: the anticipated military advantage as intended effects that contribute to achieving military objectives and the estimated collateral damage as unintended effects on civilians and civilian objects (Maathuis, Pieters & van den Berg, 2018b), are brought together so that the military Commander can determine and make sure that collateral damage would not be excessive in relation to military advantage. The proportionality assessment process is in fact a collective decision-making process where multiple agents are involved and advise the military Commander through their input and expertise, for establishing and making proper and legal targeting decisions (Holland, 2002; Colonomos, 2017; Bartneck et al., 2021).

A large body of academic and practitioner studies exist with respect to understanding and applying different perspectives on important concepts that represent a key element when planning, conducting, and assessing military operations, e.g., attack, military objective, target identification, and proportionality. Whereas research on capturing and representing such knowledge for modelling and simulating them using intelligent techniques is in its infancy. To this end, this research aims to capture, represent, and model the components involved when conducting the proportionality assessment in military operations by designing and developing two probabilistic Machine Learning models using Bayesian Belief Networks. On this, Morgan et al., (2020) and Boury-Brisset & Berger (2020) emphasize the benefits of building and using Artificial Intelligence / Machine Learning models for military decision-making support. Accordingly, to the best of our knowledge, these models represent the first attempt in this sense in the existing body of knowledge to move from the possibilistic approach to the probabilistic approach and aim to directly support military targeting decision-making processes. On these grounds, a Design Science Research methodological approach (Peffers, Tuunanen & Niehaves, 2018) is considered and followed to reach the stated goal while having the following contributions:

- Awareness and support to military decision makers such as military Commanders, military-technical, and military-legal experts involved when planning and executing military operations when dealing with different uncertainty dimensions, sources, and entities characterizing the proportionality assessment process.
- A direct call for future research in AI-based and gaming-based modelling and simulation for military targeting decision-making support based on multidisciplinary perspectives, methods, techniques, and technologies for building efficient, effective, trustable, and accountable military operations.

The remainder of this article is structured as follows. In Section 2, the context of this research is discussed together with related studies. In Section 3, the research methodology pursuit to achieve the goal of this research is tackled. In Section 4, the design of the two models proposed is presented together with important design components and choices. In Section 5, the evaluation mechanism considered is elaborated through demonstration on two military operations scenarios and comparison with another relevant state-of-the-art AI model in this field. At the end, in Section 6, reflection, concluding remarks, and future ideas are discussed.

2. Background and Related Research

To postulate the background of this research, it is important to mention the existence of three theoretical visions in relation to war: *jus ad bellum* that refers to the principles governing the justice of going to war, *jus in bello* that refers to the ones governing the conduct of warfare, and just *post bellum* that refers to the ones after war (Stahn, 2006; Pavlischek, 2010). Given the fact that this research positions itself in time of war it means that it finds itself under the *jus in bello* principles of conducting war, specifically referring to targeting in both international and non-international conflicts (Boothby & Schmitt, 2012; Tallinn Manual, 2017). The core of this setting is the conduct of military operations for influencing targets in different ways, e.g., communication disruption or alter the behaviour of an audience, captured in the military targeting process which implies the selection, prioritization, and match of targets to corresponding responses while considering operational requirements and capabilities, e.g., ROEs (Rules of Engagement) (NATO, 2016; US Army, 2013). To conduct such operations, agents (i.e., state/non-state actors) use means and methods of warfare that “are indispensable” (Downey, 1953) to obtain military advantage against their adversaries and achieve their aim (principle of military necessity). For this, the agents need to make a clear distinction between “those who may be lawfully attacked and those who must be respected and protected” (Boothby & Schmitt, 2012), in other words, between combatants and military objects, and civilian objects and humans, respectively (principle of distinction). For this, multiple aspects are established, and decisions are taken considering (i) if the intended target is a human or an object, and (ii) in respect to different criteria, deciding if the human or object is a lawful target that contributes to the achievement of military aims (Whittemore, 2015). Hence, military necessity shows the attempt to realize the aim through the gain of military advantage that must make an effective contribution to the military action and be concrete and perceptible (Harutyunyan, 2019). At the same time humanitarian considerations aim to minimize human suffering and physical destruction (Wallace & Reeves, 2019). This represents the basis for assessing that an attack that can “cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated” is disproportional, thus forbidden (AP I Art.51(5)(b), 1977, principle of proportionality). In its essence, the principle of proportionality brings in balance two antagonistic concepts (Maathuis, C., Pieters, W., & van den Berg, 2018a), based on “timely, accurate, and reliable information” available at that time (US Army, 2013). Nevertheless, this process is surrounded by different sources of uncertainty regarding aspects such as (i) relative values to be assigned to the two concepts, (ii) what can be included and excluded when summing the two concepts, (iii) which time and space measurement standard should be used, and (iv) how much should be the military forces conducting the operation exposed for limiting civilian casualties or damage to civilian objects (Holland, 2002). Shortly, Colonomos (2017) refers to it as being “a compromise between political constraints, military necessities, legal claims, and ethical aspirations”.

Crow (2019) discusses three distinct approaches for understanding proportionality: as a legal principle, as a goal of government, and a particular structured approach to judicial review. Accordingly, the first and third approaches combined result into a legal obligation conducted in a structured approach characterized by aspects such as legitimacy or suitability, reasonableness or rationality, necessity, and balancing. Particularly, reasonableness represents "an objective standard for reasonability" which implies that a set of constructed values and norms are projected and applied during the assessment. Moreover, Henderson & Reece (2018) analyze what the 'reasonable military Commander' means and implies in the context of proportionality assessment in military operations. In this sense, the assessment is compared to a general assessment that can be seen as subjective (the person believes), objective but unqualified (the person reasonably believes), or objective but qualified (the doctor, i.e., expert, reasonably believes). For realizing a proper assessment, they stress the importance of military training and active participation in military exercises.

Gillard (2018) emphasizes the importance of understanding the elements involved as well as the underlying aspects contributing to the proportionality assessment. On this behalf, the author stresses firstly the relation between *causation* and *foreseeability*, i.e., the expected effects caused by the attack and the fact that the assessment itself is *ex ante*, i.e., conducted before the attack takes place. In addition to these terms, Gillard (2018) refers to "reasonable foreseeability, i.e., what should have been foreseen by the party responsible at the time of the act" implying that "what can reasonably be foreseen depends on the circumstances in which the attack is planned, decided, or launched". Secondly, the author emphasizes and relates the expectancy of effects to likelihood which means the probability that such effects will occur. And thirdly, the author discusses the weighting perspective, i.e., "once the incidental harm to be considered in a proportionality assessment has been identified, a value or weight must be assigned to it" and the *excessive* element. Mathematically, this can be directly translated to a weight parameter assigned with different values to the concepts involved in this equation to describe the proportionality function or as a weight parameter assigned again with different values while searching to balance the participating components in this equation.

In addition to the uncertainty sources identified above, Katzir (2018) and Morgan et al. (2020) add the subjectivity of the proportionality assessment process. At the same time, Morgan et al. (2020) considers the proportionality assessment to be "an evaluative, qualitative, and ethical assessment [done] by a human weighting and comparing complex values". Moreover, other sources of uncertainty can be added based on heuristics and biases surrounding this process (Whittemore, 2015) born from facts like limitations imposed to cognitive capacities (e.g., time, space, and cost), complexity of the environment, and decision-making impediments due to perceived irrationality. These sources could not only increase the complexity and duration of the assessment but could also lead to an improper decision. In case of disproportionality, military Commanders are tried either because civilians instead of combatants were targeted or because the force applied led to an excessive collateral damage (Maathuis, C., Pieters & van den Berg, J. (2021).

As the background and related studies show, significant attention is provided on understanding the elements involved in the principle of proportionality in the body of knowledge while a limited number of studies is dedicated to designing and developing solutions to model it by capturing various sources and/or types of uncertainty. To this end, it is the aim of this article to capture and represent uncertainty in a probabilistic way building from scratch two BBN-based Machine Learning models as described in the following sections of this article.

3. Research Methodology

This research aims to capture and represent uncertainty present when conducting the proportionality assessment in military operations by means of building two Bayesian Belief Network models for providing decision support when targeting in military operations. Accordingly, this research intends to answer the following research questions:

- How to represent uncertainty surrounding the components involved in the proportionality assessment in military operations?
- How to build probabilistic models that captures uncertainty surrounding the components involved in the proportionality assessment in military operations?

To this end, a multidisciplinary stance is considered taking a Design Science Research methodological approach in an explanatory, predictive, and probabilistic way pursuing the following research activities (Kuechler & Vaishnavi, 2012; Peffers, Tuunanen & Niehaves, 2018):

In Phase I, *Problem statement and aim definition*, the background, disciplines, and dimensions involved and characterizing this research are established. Furthermore, taking into consideration the fact that in general a subjective possibilistic approach is considered when assessing proportionality in military operations and the fact that as the literature and field experts suggest, that it is a process surrounded by uncertainty, this research considers a probabilistic approach for the proportionality assessment building on previous work by (Maathuis, Pieters & van den Berg, 2018b; Maathuis, Pieters & van den Berg, 2021; Maathuis & Chockalingam, 2023). This represents to the best of our knowledge the first research effort in this direction. The review of relevant research studies is conducted using different combinations of keywords like ‘proportionality’, ‘test’, ‘assessment’, ‘military targeting’, and ‘military operations’ for querying scientific databases such as IEEE Xplore, ACM Digital Library, Scopus, and Google Scholar.

In Phase II, *Solution development*, the design of the models proposed is established as follows: the first model captures a direct probabilistic approach considering that the engagement of a specific target can be either proportional or disproportional together with associated probabilities, and the first model captures an extended probabilistic approach by introducing different levels of proportionality when engaging a specific target, on other words, from very low disproportional to proportional. Once the variables, states, and rules of the models are designed, they are further implemented as Bayesian Belief Networks.

In Phase III, *Solution evaluation and Communication*, the models proposed are evaluated considering synthetical military operations scenarios published in dedicated venues in this domain. Specifically, the evaluation is conducted through exemplification, i.e., both models proposed are exemplified on two military operations scenarios. Furthermore, the research conducted, models proposed, and results obtained are communicated through this article as well as corresponding presentations in different scientific settings.

4. Models Design

The process of preparing and executing the proportionality assessment can be reduced to identifying the target, outlining the anticipated military advantage, and expected collateral damage, further indicating that the military Commander has determined that under the law engaging the target would be proportional or disproportional, and further requesting final advice in case that other aspects should be considered as well (Henderson & Reece, 2018). Accordingly, two perspectives are considered when modelling the principle of proportionality considering its two main components:

In the first perspective (direct) that corresponds to the first model, the two input variables military advantage (MA) and collateral damage (CD) contain three states: Low (L), Medium (M), and High (H), while the target variable is the proportionality assessment (PA) which has two states: Proportional (P) and Disproportional (DP). To exemplify, the logic behind the first model is captured in equation (1):

If CD is Low AND MA is High, THEN PA is Proportional
If CD is High AND MA is Medium, THEN PA is Disproportional (1)

In the second perspective (extended) that corresponds to the second model, the two input variables military advantage (MA) and collateral damage (CD) contain five states: Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH), while the target variable is the proportionality assessment (PA) which has four states: Very High Disproportional (VHDP), High Disproportional (HDP), Low Disproportional (LDP), and Proportional (P). As exemplification, the logic behind the second model is presented in equation (2):

If CD is Very Low AND MA is High, THEN PA is Proportional
If CD is High AND MA is Low, THEN PA is Very High Disproportional (2)

Furthermore, the design of both models are implemented using Bayesian Belief Networks seeing their capacity to model complex systems, processes, and activities under uncertainty in different societal domains (Kahn Jr et al., 1997; Marcot & Penman, 2019). Accordingly, both models contain two main components. The first component is qualitative and is represented by a Directed Acyclic Graph (DAG) as shown in Figure 1 and Figure 2. that embodies the variables (input and target) and their corresponding states. And the second component is quantitative, which is represented by the Conditional Probabilities (CPTs) of variables containing the conditional probabilities of all combinations that are possible for child-parent variable states, as depicted in Figure 1 and Figure 2. In case that a variable does not have a parent variable, its CPT contains the priori marginal probabilities of the corresponding variable. Moreover, the reasoning considered in this research is predictive being done from cause (upper layer) to effect (lower layer) (Maathuis & Chockalingam, 2023) and the values illustrated in Figure 1 and Figure 2 are without evidence provided, i.e., for showing the use of the models which are further evaluated through demonstration in Section 5.

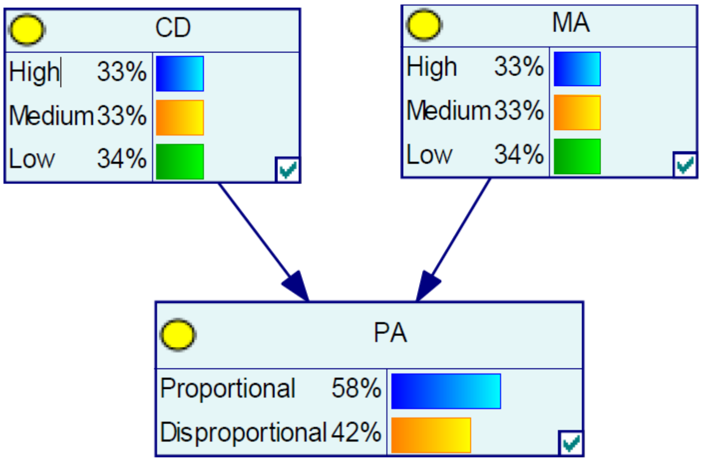

Figure 1. First model

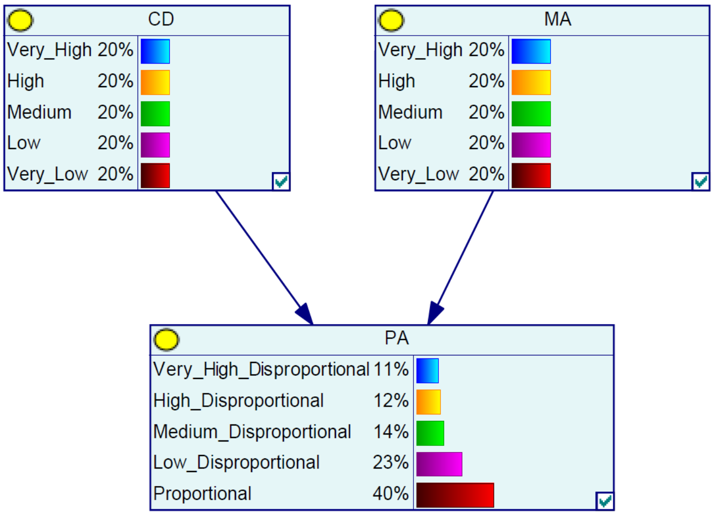

Figure 2. Second model

5. Model Evaluation

The evaluation of the models proposed is done through demonstration based on two military operations scenarios that contain synthetical data used for evaluating a deep multi-layered fuzzy model proposed for proportionality assessment in military Cyber Operations by Maathuis, Pieters & van den Berg (2021). Accordingly, the results of the models proposed in this research are compared with the ones obtained by the multi-layered fuzzy model built in previous work. This comparison is done in order to evaluate the reasoning of the models proposed in this article. Moreover, a short description of the two scenarios is provided together with the demonstration of the models proposed in this research. Hence, the models proposed in this research receive as input for the variables contained in the data from the multi-layered model and the proportionality assessment decision is then compared next to the decision provided by consulted military experts.

In the first scenario, a drone military Cyber Operation is planned to prevent a terrorist attack using a suicide drone/unmanned combat aerial vehicle (UCAV) weaponized with 3 kg explosive munition against the president of a country. For this, the position and speed of the drone is altered in the ground control station. Hence, the proportionality assessment should be conducted regarding executing the corresponding cyber weapon that will do this action. In this case, the multi-layered model estimated a high collateral damage and a medium military advantage. Then, these values are provided as input for the models proposed in this research as depicted in Figure 3 and Figure 4, and further compared in Table 1.

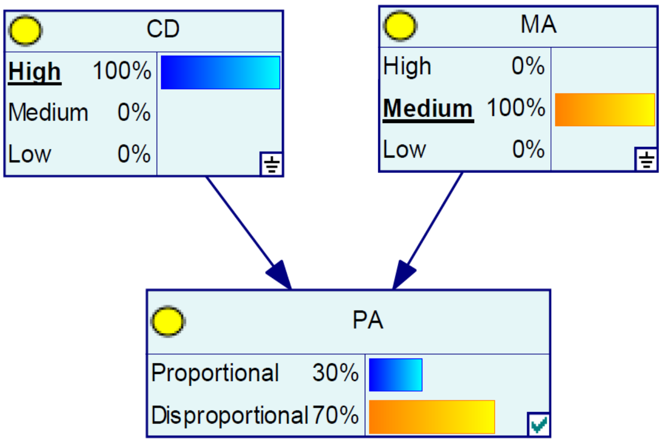

Figure 3. First model demonstration with the first scenario

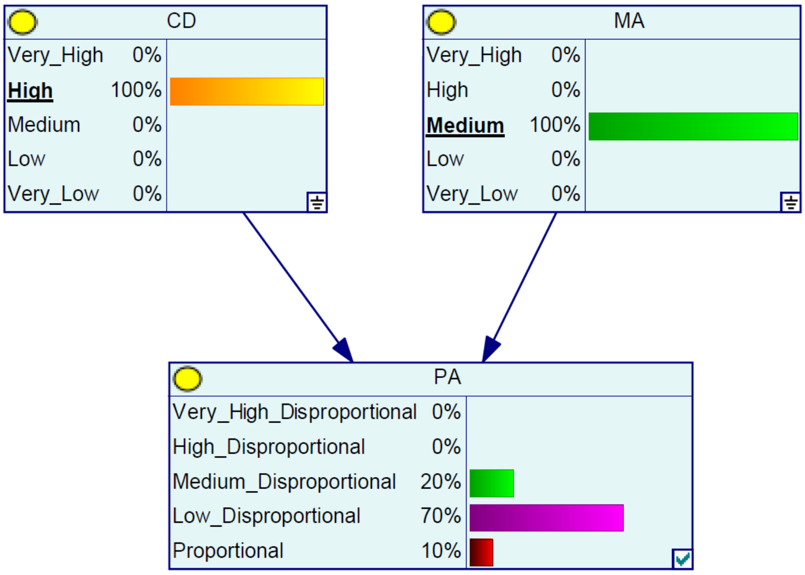

Figure 4. Second model demonstration with the first scenario

In the second scenario, a ship military Cyber Operation is planned to prevent a terrorist attack using a commercial cargo ship weaponized with chemical agents. For this, a protocol-based DDoS is prepared against the pump station by exploiting an unpatched software vulnerability. In this case, the multi-layered model estimated a medium collateral damage and a medium military. Then, these values are provided as input for the models proposed as depicted in Figure 5 and Figure 6.

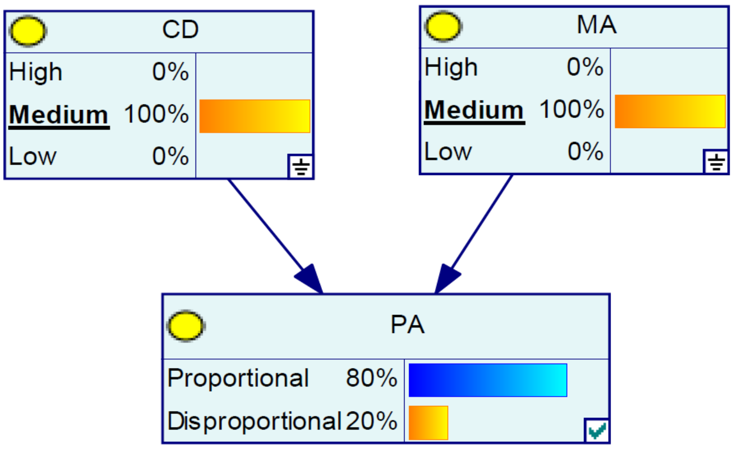

Figure 5. First model demonstration with the second scenario

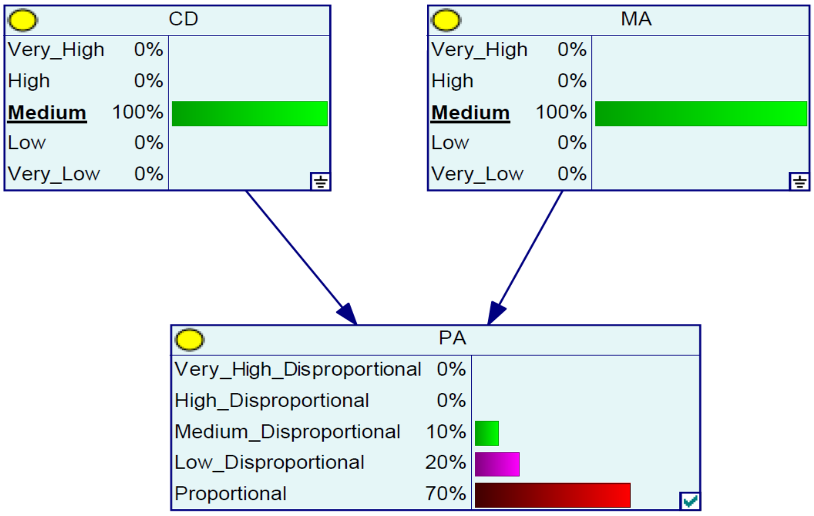

Figure 6. Second model demonstration with the second scenario

Henceforth, the values obtained by the model proposed in this research are compared in Table 1 with the ones obtained by the multi-layered model proposed and evaluated with military experts by Maathuis, Pieters & van den Berg (2021).

Conclusively, the results show that the models proposed in this research provide a probabilistic advancement for the existing model in this domain. Accordingly, the highest probabilities assessed by both models herein match the decision provided by the existing AI model in both cases of military operations examples. Additionally, these assessments match the decisions provided by experts consulted in this field in previous research. Hence, the models proposed are evaluated through comparison and the results of this evaluation show that they represent a realistic solution for capturing and modelling uncertainty dimensions when assessing proportionality in military operations.

Table 1. Comparison of models and assessment of experts

Military Operation Scenario	Proportionality Assessment Expert Decision 1, 2, 3, 4	Multi-layered model Proportionality Assessment	First model Proportionality Assessment	Second model Proportionality Assessment
1	Proportional Disproportional Disproportional Disproportional	Disproportional	30 % Proportional 70 % Disproportional	0 % Very High Disproportional 0 % High Disproportional 20% Medium Disproportional 70 % Low Disproportional 10 % Proportional
2	Proportional Proportional Proportional Proportional	Proportional	80 % Proportional 20 % Disproportional	0 % Very High Disproportional 0 % High Disproportional 10% Medium Disproportional 20 % Low Disproportional 70 % Proportional

6. Conclusions

Wars are a phenomenon characterizing the human existence and experience since the dawn of history (Tabansky, 2011). As they directly represent the planning, execution, and assessment of military operations for reaching (pre)defined goals, important legal, ethical, and social aspects need to be considered for minimizing harm to civilians and protecting combatants based on previous experience. Additionally, the technological development is beneficial (Pfaff, 2016) since it allows building the capacity of (effectively and efficiently) modelling and simulating different activities, actions, and aspects. Among these can be mentioned the achievement of objectives established and the effects produced while providing accurate predictions having different degrees of autonomy for military decision-making support. In this realm, Artificial Intelligence/Machine

Learning techniques and applications such as image recognition, natural language processing, and voice recognition already showed impressive results in target identification and engagement control (Panwar, 2017; Bartneck et al., 2021).

At the core of this phenomenon is the principle of proportionality. Nevertheless, while a vast number of studies concerning the meaning and applicability of the principle of proportionality in different military operations domains and scenarios are tackled in the existing body of knowledge, a limited number of studies is dedicated to capturing, representing, and modelling the proportionality assessment in military operations. To this end, this research aims to model the proportionality assessment in military operations by capturing and representing its components translated to variables and values taking a probabilistic approach using ML. This is done by building two Bayesian Belief Network models. The first model contains a direct perspective on the proportionality decision while the second model takes an extended perspective on it based on the need expressed both in the literature and by military-technical experts for considering different levels of proportionality. This approach is adopted as it is a well-known approach for tackling uncertainty and to reason in complex, uncertain, ill-defined, and subjective domains, and tasks such as the proportionality assessment. To do this, a multidisciplinary research is conducted merging military, legal, and AI knowledge and expertise following a Design Science Research approach (Peffers, Tuunanen & Niehaves, 2018). Accordingly, the models proposed are further evaluated through demonstration on two military operations scenarios and compared with a previous AI model and proportionality assessment conducted by military experts. The results obtained show the fact that such an approach represents a proper way of capturing, representing, and modelling uncertainty dimensions surrounding different components/dimensions of the principle of proportionality in military operations.

As this research represents the first attempt in the existing body of knowledge to consider a direct probabilistic approach to the principle of proportionality in military operations, it aims to further integrate multiple classes of variables that characterize each of the two components. Further, it can be extended with multiple data sources and multiple clusters of effects while evaluating it using different types of military operations carried out in different domains using both real and synthetical data. In this way, this research paves the way to build explainable, responsible, and trustable intelligent solutions (Chockalingam & Maathuis, 2022; Maathuis, 2022a; Maathuis, 2022b) for supporting planning, execution, and assessment of (digitally prepared) military operations.

References

Additional Protocol I (1977). Art 51(5)(b) – Protection of the civilian population.

Bartneck, C., Lütge, C., Wagner, A., & Welsh, S. (2021). Military Uses of AI. In *An Introduction to Ethics in Robotics and AI* (pp. 93-99). Springer.

Boury-Brisset, A. C., & Berger, J. (2020). Benefits and Challenges of AI/ML in Support of Intelligence and Targeting in Hybrid Military Operations. NATO S&I Organisation.

Boothby, W., H. & Schmitt, M., N. (2012). *The law of targeting*. Oxford University Press. Pavlischek, K. (2010). Proportionality in warfare. *The New Atlantis*, (27), 21-34.

Chockalingam, S., & Maathuis, C. (2022). An Ontology for Effective Security Incident Management. In *International Conference on Cyber Warfare and Security* (Vol. 17, No. 1, pp. 26-35).

Colonomos, A. (2017). Proportionality in Warfare as a Political Norm. *Weighing Lives in Warfare*, 217-240.)

Crow, K. (2019). The Opacity of Proportionality in International Courts: Could Categories Clarify?. *Geo. Wash. Int'l L. Rev.*, *51*, 289.

Downey, W. G. (1953). "The law of war and military necessity." *American Journal of International Law* 47.2: 251-262.

Gillard, E. C. (2018). Proportionality in the conduct of hostilities: the incidental harm side of the assessment.

Henderson, I., & Reece, K. (2018). Proportionality under International Humanitarian Law: The Reasonable Military Commander Standard and Reverberating Effects. *Vand. J. Transnat'l L.*, *51*, 835.

Harutyunyan, A. (2019). Dilemma of Targeting: Dual-Use Objects in Military Operations. *Law of Armed Conflict*.

Holland, J. C. (2002). *Military Objective and Collateral Damage: Their Dynamics and Relationship*. JUDGE ADVOCATE GENERAL'S SCHOOL CHARLOTTESVILLE VA.

Kahn Jr, C. E., Roberts, L. M., Shaffer, K. A., & Haddawy, P. (1997). Construction of a Bayesian network for mammographic diagnosis of breast cancer. Computers in biology and medicine, 27(1), 19-29.

Henderson, I., & Reece, K. (2018). Proportionality under International Humanitarian Law: The Reasonable Military Commander Standard and Reverberating Effects. *Vand. J. Transnat'l L.*, *51*, 835.

Holland, J. C. (2002). *Military Objective and Collateral Damage: Their Dynamics and Relationship*. JUDGE ADVOCATE GENERAL'S SCHOOL CHARLOTTESVILLE VA.

Katzir, R. (2018). Four Comments on the Application of Proportionality under the Law of Armed Conflict. *Vand. J. Transnat'l L.*, *51*, 857.

Kuechler, W., & Vaishnavi, V. (2012). A framework for theory development in design science research: multiple perspectives. *Journal of the Association for Information systems*, *13*(6), 3.

Maathuis, C., Pieters, W., & van den Berg, J. (2018a). A knowledge-based model for assessing the effects of cyber warfare. In *Proceedings of the 12th NATO Conference on Operations Research and Analysis*.

Maathuis, C., Pieters, W., & van den Berg, J. (2018b). Developing a cyber operations computational ontology. *Journal of Information Warfare*, *17*(3), 32-49.

Maathuis, C., Pieters, W., & van den Berg, J. (2021). Decision support model for effects estimation and proportionality assessment for targeting in cyber operations. *Defence Technology*, *17*(2), 352-374.

Maathuis, C. (2022a). On the Road to Designing Responsible AI Systems in Military Cyber Operations. In *European Conference on Cyber Warfare and Security* (Vol. 21, No. 1, pp. 170-177).

Maathuis, C. (2022b). An Outlook of Digital Twins in Offensive Military Cyber Operations. In *European Conference on the Impact of Artificial Intelligence and Robotics* (Vol. 4, No. 1, pp. 45-53).

Maathuis, C. & Chockalingam, S. (2023). Modelling the influential factors embedded in the proportionality assessment in military operations. In *International Conference on Cyber Warfare and Security*.

Marcot, B. G., & Penman, T. D. (2019). Advances in Bayesian network modelling: Integration of modelling technologies. *Environmental modelling & software*, *111*, 386-393.

Margulies, P. (2020). Autonomous Cyber Capabilities Below and Above the Use of Force Threshold: Balancing Proportionality and the Need for Speed. *International Law Studies*, *96*(1), 13.

Morgan, F. E., Boudreaux, B., Lohn, A. J., Ashby, M., Curriden, C., Klima, K., & Grossman, D. (2020). *Military applications of artificial intelligence: ethical concerns in an uncertain world*. RAND PROJECT AIR FORCE SANTA MONICA CA SANTA MONICA United States.

NATO (2016). *NATO Standard AJP-3.9 Allied Joint Doctrine for Joint Targeting*. NATO Standardization Office.

Panwar (2017). Artificial Intelligence in Military Operations: an overview – Part I. https://futurewars.rspanwar.net/artificial-intelligence-in-military-operations-an-overview-part-i/

Peffers, K., Tuunanen, T., & Niehaves, B. (2018). Design science research genres: introduction to the special issue on exemplars and criteria for applicable design science research.

Pfaff, C. A. (2016). Five myths about military ethics. *The US Army War College Quarterly: Parameters*, *46*(3), 8.

Schmitt, M. N. (Ed.). (2017). *Tallinn manual 2.0 on the international law applicable to cyber operations*. Cambridge University Press.

Stahn, C. (2006). 'Jus ad bellum','jus in bello'...'jus post bellum'?–Rethinking the Conception of the Law of Armed Force. *The European Journal of International Law*, *17*(5), 921-943.

Tabansky, L. (2011). Basic concepts in cyber warfare. *Military and Strategic Affairs*, *3*(1), 75-92.

United States Army (2013). *Joint Publication 3-60 Joint Targeting*. United States Army.

Wallace, D. A., & Reeves, S. R. (2019). Protecting Critical Infrastructure in Cyber Warfare: Is It Time for States to Reassert Themselves?. *UC Davis L. Rev.*, *53*, 1607.

Whittemore, L. A. (2015). Proportionality Decision Making in Targeting: Heuristics, Cognitive Biases, and the Law. *Harvard National Security Journal*, *7*, 577.

Whittemore, L. A. (2015). Proportionality Decision Making in Targeting: Heuristics, Cognitive Biases, and the Law. *Harv. Nat'l Sec. J.*, *7*, 577.