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ASSESSING THE NATO CLINICAL TIMELINES IN MEDICAL EVACUATION: A SIMULATION WITH OPEN-ACCESS DATA

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ABSTRACT

NATO allies are preparing for Large-Scale Combat Operations (LSCOs) against peer or near-peer adversaries. Although a significant increase in casualties with life-threatening injuries is expected, western military personnel lack experience with the medical requirements of LSCOs. We propose the use of simulation to conduct necessary research, estimate the resources required, and adapt the doctrine. We therefore present a scenario for assessing NATO's clinical timelines based on open-access data, showing that a shortage of surgical capacity is likely to occur.

1 INTRODUCTION

The Russian invasion of Ukraine in 2022 triggered the largest armed conflict in Europe since World War II (Epstein et al. 2023). This prompted NATO to shift its focus to national and alliance defense in Large-Scale Combat Operations (LSCOs) against peer or near-peer adversaries (NATO 2022). Future LSCOs are expected to result in a significant increase of casualties with life-threatening injuries, unprecedented in recent decades (Remondelli et al. 2023). A retrospective study conducted by Shackelford et al. (2024) highlights the importance of prompt treatment of those patients, showing that mortality increases significantly when treatment is delayed. To ensure timely, life-saving treatment, NATO has established the medical evacuation chain, comprising Casualty Collection Points (CCP) and four distinct roles, namely Role 1 to Role 4 (NATO 2019). Along this chain, patients are evacuated through a series of Medical Treatment Facilities (MTFs) with varying capabilities, such as surgery and advanced diagnostics. The established clinical timelines define the time-critical treatment benchmarks (NATO 2018). It encompasses the evacuation from the CCP to Role 2 and the associated medical treatment, which is, therefore, the focus of this paper. The interaction between the evacuation chain and the timelines is visualized in Figure 1.

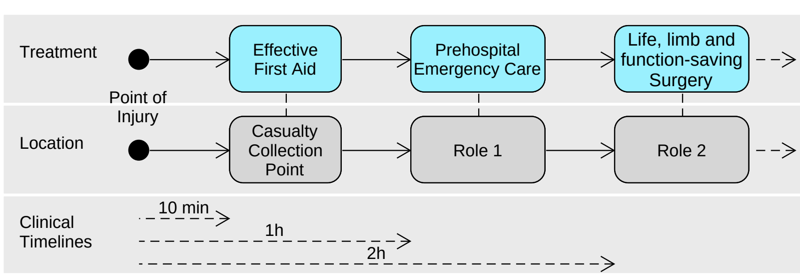

Figure 1: NATO defines clinical timelines (dashed arrows) for different treatment steps (blue). For each step, the corresponding location within the medical evacuation chain (gray) is shown.

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Within the first ten minutes, casualties must be gathered at the CCP, where non-medical personnel provide first aid (United States Department of the Army 2019). Once transferred to medical personnel at the CCP, the patients are transported to Role 1 MTFs, where Prehospital Emergency Care, including Damage Control Resuscitation (DCR), must begin within one hour. The final step defined by the timelines is life, limb, and function-saving surgery in a Role 2 MTF. This treatment must begin within two hours of injury and is in the following referred to as Damage Control Surgery (DCS).

As a result of the counterinsurgency paradigm of recent decades, many military personnel lack experience with the medical requirements of LSCOs (Fandre 2020). Additionally, the current medical evacuation planning process heavily relies on expert assumptions due to limited data and a lack of real-world experience (NATO 2019). We have shown that current static planning approaches fail to capture the highly dynamic nature of combat scenarios and medical evacuation, while also recommending simulation as a valuable support tool to enhance planning efforts (Meisner et al. 2023).

Given the limited data and experience with medical support of LSCOs and the current political situation, we have shown that further research on this complex system is urgently needed (Meisner et al. 2023). However, the fact that military doctrines and capabilities are generally not publicly available hampers scientific exchanges between researchers and NATO members. To address this challenge, we focus on also defining simulation scenarios with open-access data. This way, we aim to facilitate research and enhance collaboration among academia and NATO. Through this effort, we seek to increase the understanding and improvements of military medical evacuation systems. As the first step, we collect data for assessing the medical evacuation, with a particular focus on the NATO clinical timelines from CCP to Role 2 as this phase has the highest impact on mortality (Dilday et al. 2024). Based on this data, we build a scenario and utilize our simulator "*mecos*" (Meisner et al. 2025) to conduct experiments. We develop the scenario by describing the general military context and presenting how patients are modeled. Next, the MTFs as well as the treatment process are presented, followed by the description of the transporter resources and evacuation procedure. Next, we present and discuss our simulation results to assess the clinical timelines. Finally, we conclude our paper and give a brief outlook.

2 SCENARIO DEVELOPMENT

In this section, we present a scenario for simulating medical evacuation in the context of LSCOs. We focus on assessing the NATO clinical timelines, simulating evacuation from the CCPs up to DCS in a Role 2 MTF. For this purpose, we present the scenario's military context, model the casualties, define the MTFs together with the patient's treatment, and describe the transportation resources.

2.1 General Context

Our scenario is based on the one presented by Kleint et al. (2021) who developed a simulation of the medical evacuation for the Bundeswehr from the CCP to Role 3. While the authors highlight that the scenario itself is fictitious and used primarily for validating the simulation, we consider the underlying scenario to be a plausible approximation in many respects. From this scenario, we can derive key aspects such as the battlefield size, the location of various MTFs, and the patient arrival process.

Since the given scenario covers treatment up to Role 3, which involves a division-level operational context, we modify this scenario to focus solely on treatment up to Role 2 MTFs, therefore excluding the division level. For the remaining areas of command (battalions and brigades), we retain the original sizes presented by the authors, as visualized in Figure 2. We consider three brigades, with three assigned battalions each. The areas of command for each brigade are 30 km by 42 km and 10 km by 8 km for the battalions, respectively. According to Bundeswehr (2025d), each brigade typically oversees about 5600 soldiers, with each battalion commanding up to 1200 soldiers.

In their simulation, Kleint et al. (2021) use more MTFs in the central battalions (Bn_21 to Bn_23), indicating that the primary focus of the battle occurs in these areas. Therefore, we assume that these areas will host the maximum number of soldiers, 1200 per battalion. For Bn_13 and Bn_31, we set the number of soldiers to 1000, while for the remaining we assume a total of 800 soldiers each. The two outer brigades (Bde_1, Bde_3) consist of 3000 soldiers each, which, when combined with the assigned battalions, sum up to the 5600 soldiers indicated by Bundeswehr (2025d). Bde_2 is assigned an additional 1000 soldiers to reflect the assumption that the primary focus of the battle will occur here. As outlined in the later Section 2.2, the number of soldiers in each area corresponds to the Population at Risk (PAR), from which we derive the expected number of casualties.

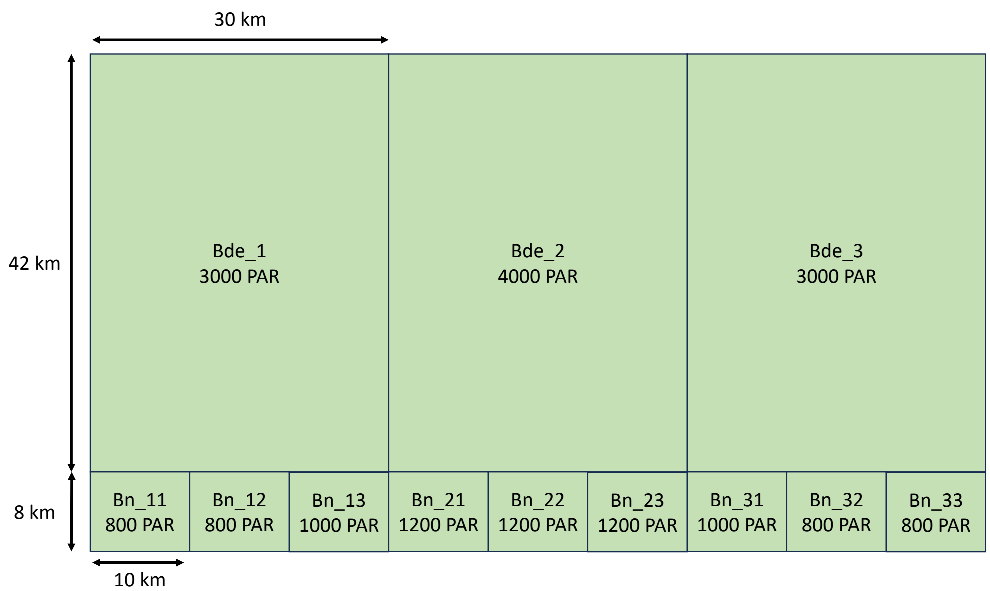


Figure 2: The scenario includes three brigades (Bde) with three assigned Battalions (Bn) each. The Population at Risk (PAR) for each area equals the number of soldiers.

Based on the results presented by Kleint et al. (2021), we observe that seven days of combat are simulated, with casualties arriving daily. It is also apparent that some patients remain in the system on the seventh day. To accommodate for the treatment of these remaining patients, we extend the simulation period to nine days, with seven days dedicated to combat and casualty arrival. The additional two days are included to ensure that no patients are left in the system. For simplification, we assume a static defense scenario, where MTFs do not relocate over time.

2.2 Patient Arrival and Behavior

The arrival of battle-related casualties (BCAS) is modeled using a discretized nonstationary spatiotemporal Poisson process, as described by Kleint et al. (2021). This approach allows for the simulation of casualties arriving in waves throughout each day, a behavior observed in real combat scenarios. According to (Kuhn 1991), combat situations typically involve pulses of high casualty rates, with significant variability in both the timing and location of these peaks, resulting from factors such as combat intensity, terrain, and enemy actions. To represent this variability, we assign unique patient arrival behaviors to each of the areas of command. To determine the expected casualty rate for each zone, NATO (2019) describes three steps, shown in Figure 3. First, the PAR has to be determined, as done in Section 2.1. Next, the casualty occurrence rate needs to be established. Although NATO and the Bundeswehr do not publish specific rates, the Australian Army offers a publicly accessible casualty rate estimation tool (Army 2003). This tool differentiates between BCAs as well as diseases and non-battle-related injuries (DNBI). For DNBI, a daily rate of 0.13% was observed in real exercises. The casualty rates for BCAS, as provided by the tool, are shown in Table 1.

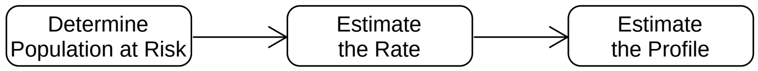


Figure 3: NATO (2019) describes three steps to determine the expected casualty rate.

Table 1: Army (2003) published rates of battle-related casualties for different combat intensities.

Battle Intensity	Battalion / Brigade	Division
Quiet	0.03%	0.01%
Sustainable	0.5%	0.2%
Intense	2.3%	0.9%
Extreme	7.0%	2.2%

The third step is to estimate casualty profiles. NATO (2019) classifies patients into four triage categories: T1 (life-threatening injuries), T2 (severe injuries but not life-threatening condition), T3 (minor injuries), and T4 (expected to die). Using this and the data from Army (2003), we can categorize BCAS and DNBI into different sub-classes, as shown in Figures 4 and 5, respectively. In both cases, the sub-classes are visualized as tree structures, beginning with the total set of BCAS or DNBI and ending with the specific patient types being modeled, with each category color-coded according to the associated NATO triage classification. For BCAS, we first differentiate between Killed in Action (KIA), Missing in Action (MIA), and Wounded in Action (WIA). While KIA and MIA affect the PAR, the specific casualties are not further modeled. WIA is then divided into the three NATO triage categories (T1_BCAS, T2_BCAS, T3_BCAS), with an additional distinction made for patients requiring surgery (T1_BCAS_OP, T2_BCAS_OP, T3_BCAS_OP). For DNBI, the classification follows a similar structure, but without KIA or MIA. The DNBI patients are grouped into the NATO triage categories (T1_DNBI, T2_DNBI, T3_DNBI) and further categorized by whether or not they require surgery (T1_DNBI_OP, T2_DNBI_OP, T3_DNBI_OP).

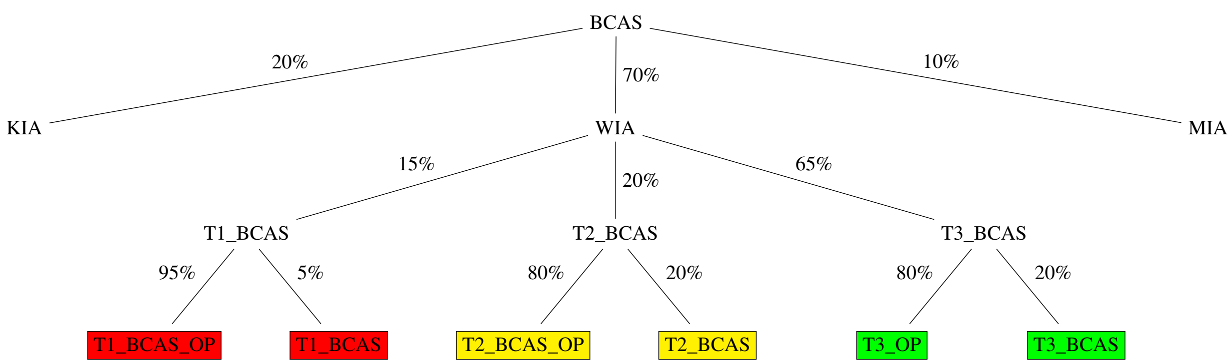


Figure 4: Battle-related casualties (BCAS) are categorized as Killed in Action (KIA), Missing in Action (MIA), or Wounded in Action (WIA). WIAs are further classified into the three NATO triage levels T1, T2, and T3, with a percentage of each requiring surgery (OP), as indicated by the edges. The leaves represent the six types of BCAS modeled, visualized with the corresponding NATO triage colors.

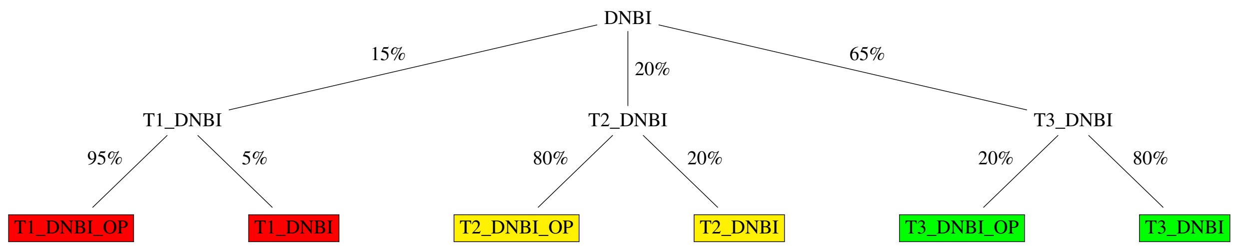


Figure 5: Casualties with diseases and non-battle injuries (DNBI) are classified into the three NATO triage levels T1, T2, and T3, with a percentage of each requiring surgery (OP). Each edge indicates the respective proportions, while the leaves represent the six types of BCAS modeled, visualized with the corresponding NATO triage colors.

Using the provided data, we can model the patient arrival process. We assume an intense fighting scenario with a BCAS rate of 2.3% and a DNBI rate of 0.13%. Following Kleint et al. (2021), we expect three casualty waves per day, each lasting 30 minutes. The PAR is updated after each simulated day. Let r_{BCAS} and r_{DNBI} be the given rates. The total number of casualties on day one is then calculated as:

$$E(\#casualties) = PAR \cdot r_{BCAS} + PAR \cdot r_{DNBI} = 18800 \cdot 0.023 + 18800 \cdot 0.0013 \approx 457. \quad (1)$$

For comparison, Kleint et al. (2021) expect about 550 casualties on the first day, considering an additional division level. Therefore, we conclude that our data is realistic enough to observe plausible effects.

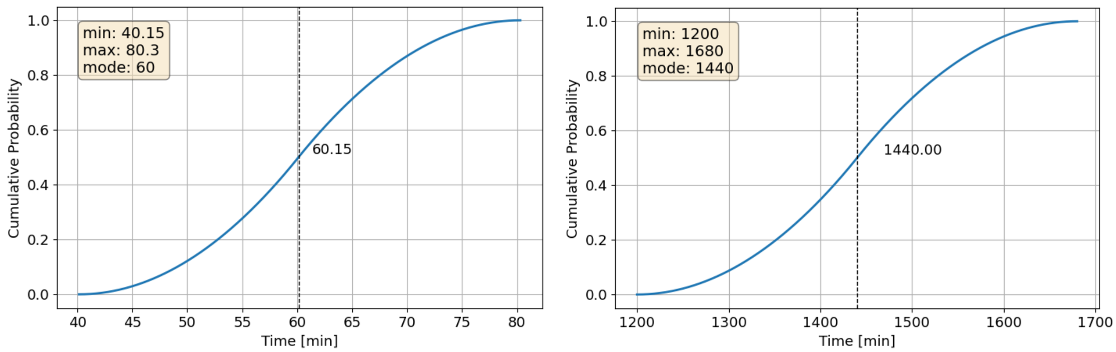
With the casualty arrival process modeled, we now define the patient's behavior. For each treatment step, we establish the maximum survivable wait time. If a patient does not receive the required treatment within the specified time, he/she dies. In the absence of specific data and to introduce more variability into the simulation, we model this time using triangular distributions. Based on the NATO clinical timelines, one might expect a survivable wait time for T1 patients of at least an hour. However, recent research indicates that only about half of these patients would survive the hour without life-saving interventions (Beldowicz, Bellamy, and Modlin 2020). Benhassine et al. (2022) propose an exponential relationship between the Injury Severity Score (ISS) and a patient's survivable time, pointing out that some studies report longer survival times. An analysis conducted by Epstein et al. (2023) shows that the average ISS of patients in Ukraine close to the front exceeds 36. We apply the formula of Benhassine et al. (2022) and an ISS of 36 to calculate the minimal survival time of T1 patients, which is 40.15 minutes. We set the mode to 60, as this is the timeline specified by NATO. The maximum value to 80.3 minutes, leading to a mean time of ~ 60 minutes and half of the T1 patients not surviving the first hour, as reported by Beldowicz, Bellamy, and Modlin (2020). For T2 patients we set the time to 24 ± 4 hours. T3 patients are expected not to die in the considered time frame. The triangular distributions are shown in Figure 6.

2.3 Medical Facilities and Treatment

The treatment process for the different patient types is illustrated in Figure 7. BCAS are assumed to arrive at a CCP, while patients with DNBI directly come to a Role 1 MTF. Since our simulation focuses on the medical aspects of patient evacuation, first aid performed at the CCP is not modeled, as it is performed by non-medical personnel. All patients receive DCS or (T1/T2 patients) Prehospital Emergency Care (T3 patients) at Role 1 before being transported to a Role 2 MTF. For those requiring surgery, DCS is performed at Role 2. Treatment of patients beyond this point in Role 2 is not considered within the scope of this scenario. Once DCS is completed, the patient is considered treated in the simulation.

Based on a casualty evacuation exercise with 200 simulated casualties, Lynch et al. (1997) found that Role 1 treatment took 28 minutes on average. Benhassine et al. (2025) used data from a NATO exercise and similarly found that treatment in a Role 1 MTF took approximately 27 minutes. However, Procházka et al.

(2022) assume that Role 1 treatment takes 15, 10, and 5 minutes for T1, T2, and T3 patients, respectively. Since these durations were estimated by the authors without further explanation, we adhere to the measured durations provided by Lynch et al. (1997) and Benhassine et al. (2025).



(a) Survival time T1 patients (b) Survival time T2 patients

Figure 6: For T1 and T2 patients, triangular distributions are used to randomly generate the maximum survivable wait time before treatment.

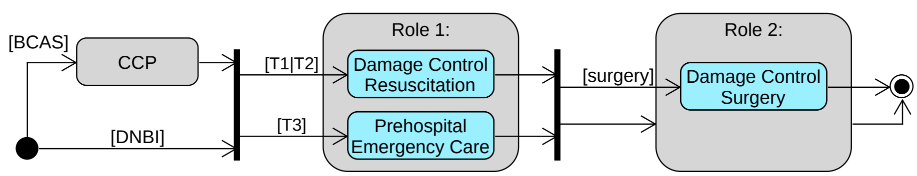


Figure 7: Battle Casualties (BCAS) arrive at Casualty Collection Points (CCP) while patients with Diseases and Non-Battle Injuries (DNBI) go directly to Role 1 (gray boxes). The modeled treatments in Role 1 and Role 2 are represented by blue boxes. Treatment of patients not requiring Role 2 surgery is not modeled.

Hall et al. (2023) provide mean durations for Role 2 surgeries, as summarized in Table 2. The authors classify patients into four categories based on the ISS. While a direct mapping between NATO triage categories and ISS is not available, Epstein et al. (2023) highlight that approximately 70% of Ukrainian combat casualties resulted from artillery and rocket barrages, often leading to severe polytrauma affecting multiple organ systems. Their retrospective analysis of 100 Ukrainian patients revealed an average ISS exceeding 36, placing these cases in the highest severity category defined by Hall et al. (2023). Given the minimal difference between the *Severe* and *Critical* categories, we merge them for simplicity. The rightmost column in Table 2 shows how we assign our patient types to the different ISS categories. For each patient requiring surgery, we model the duration using a normal distribution with the reported mean and standard deviation. After each treatment step, we update the patient's remaining survivable time. To do this, we use the triangular distributions defined in Section 2.2 to determine the time extension and add it to the patient's current remaining time. This approach emphasizes the importance of early treatment in maximizing survival chances.

For the locations of CCPs and MTFs, we adopt those used by Kleint et al. (2021). For each battalion, nine to eleven CCPs and one to two Role 1 MTFs are assigned. The brigades have 16 and 28 CCPs, three to five Role 1 MTFs, and three to four Role 2 MTFs. Further, we use the capacity specifications provided by the Bundeswehr for the MTFs. A Role 1 MTF includes four treatment beds, staffed with seven paramedics and two emergency physicians (Bundeswehr 2025b). Given that emergency physicians are primarily required for T1 and T2 patients, we assume a conceptual capacity allowing for the simultaneous treatment of two T1 and/or T2 patients (requiring DCR) and two T3 patients. A Role 2 MTF, on the other hand, is equipped with two surgical stations (Bundeswehr 2025a).

Table 2: Open-access data showing the mean surgery time in a Role 2 MTF for different Injury Severity Scores (ISS) (Hall et al. 2023). We assigned our patient types requiring surgeries as shown in the right column.

ISS	Duration of Role 2 surgery: mean (std)	Assignment to patient types
Mild (1-9)	93.9 min (41.3)	T3_BCAS_OP, T1_DNBI_OP, T2_DNBI_OP
Moderate (10-15)	142.2 min (90.3)	T1_DNBI_OP
Severe (16-24)	177.4 min (82.4)	T1_BCAS_OP, T2_BCAS_OP
Critical (25-75)	182.9 min (83.9)	

2.4 Transporters and Evacuation

Russia has been targeting medical infrastructure far behind the frontline using cruise missiles and drones (Epstein et al. 2023). Given that our battlefield scenario spans only 50 km in depth, we assume that patient evacuation primarily relies on armored vehicles for protection. The Bundeswehr employs the GTK Boxer for this purpose (Bundeswehr 2025c). The Boxer is available in different configurations, allowing it to transport either (1) seven sitting patients, (2) two lying and three sitting patients, or (3) three lying patients. Since there is no data available on how quickly the vehicle can switch between configurations, we assume a standardized capacity of two lying and three sitting patients. In our scenario, T1 patients need to be transported lying while T2 and T3 patients are transported sitting.

In line with operational conditions, we further assume an average speed of 30 km/h in rough terrain. During the transport via a GTK Boxer, patients are accompanied by medical personnel (Bundeswehr 2023). This ensures that patients can potentially survive longer on transport than while lying at a CCP. So far, however, we found no data to quantify this effect. Therefore, we assume the best-case scenario where the patient's health condition does not worsen during transportation. While this may result in a lower observed mortality, we still expect our simulation to reveal realistic bottlenecks.

For evacuations from CCPs to Role 1 MTFs, transporters are stationed at the MTFs. For evacuations from Role 1 to Role 2, they are stationed at Ambulance Exchange Points (AXPs), following the setup used by Kleint et al. (2021). A detailed explanation of AXPs is provided by United States Department of the Army (2019). In our scenario, each brigade has one AXP. Patients from CCPs are evacuated to the nearest Role 1 MTF, while those from Role 1 MTFs are transported to the Role 2 MTF of their assigned brigade, prioritizing the facility with the lowest utilization. There is no publicly available data on the number of GTK Boxers assigned to each MTF or AXP. However, the Bundeswehr currently operates 72 of these transporters (Speer 2024). As an initial estimate, we allocate three GTK Boxers per Role 1 MTF and four per AXP, resulting in a total of 62 transporters.

3 RESULTS AND DISCUSSION

In our experiment, we performed 30 simulation repetitions. For all reported means, we provide the corresponding confidence intervals (CI) at a confidence level greater than 0.95. To improve readability, measures of deviation are not detailed in the text, as they can be inferred from the figures.

Figure 8 illustrates the evolution of various performance indicators over the simulation period. The final casualty wave occurred on day seven, resulting in an average of 2141 casualties (CI: 2121.9-2160.0). Nearly all patients were stabilized in a Role 1 MTF shortly after their occurrence (red line). On average, 1567 patients (CI: 1551.9-1581.9) underwent surgery in a Role 2 MTF. A total of 2009 patients (95% CI: 1990.7-2027.8) exited the system, requiring further treatment not covered by the current simulation. Additionally, an average of 132 (95% CI: 127.9-135.5) patients died.

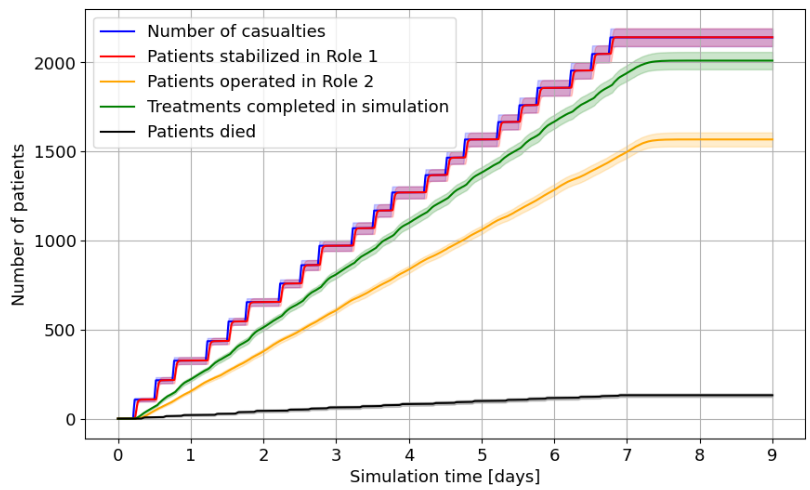
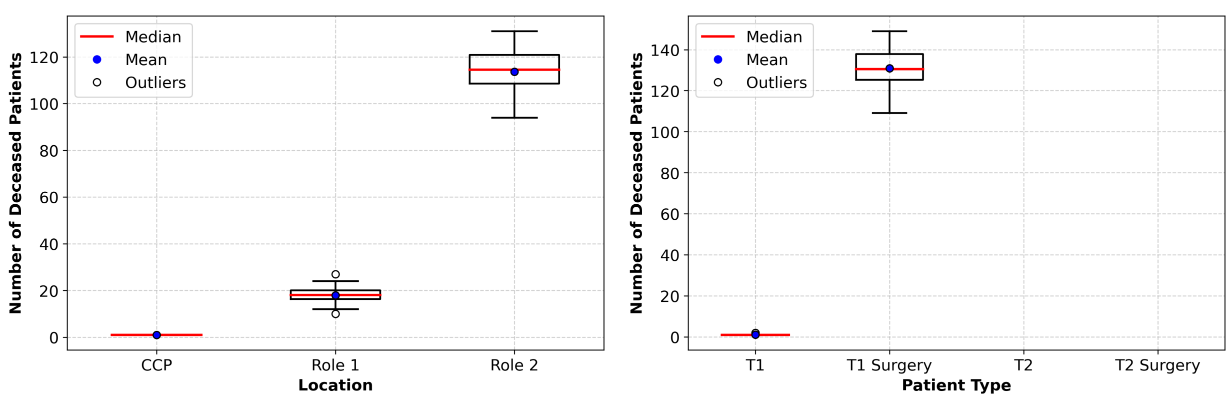


Figure 8: Average number and standard deviation across all runs of patients in different categories: occurred (blue), stabilized (red), operated (yellow), completed treatments (green), and deceased (black). The sum of patients with completed treatments and those deceased corresponds to the total number of casualties.

The deceased patients are categorized in Figure 9. In Figure 9a, these patients are grouped by the location of death, while Figure 9b shows the patient types. 86% of all deaths occurred in Role 2 MTFs. All patients who died were categorized as T1, while 99% of those required surgery.

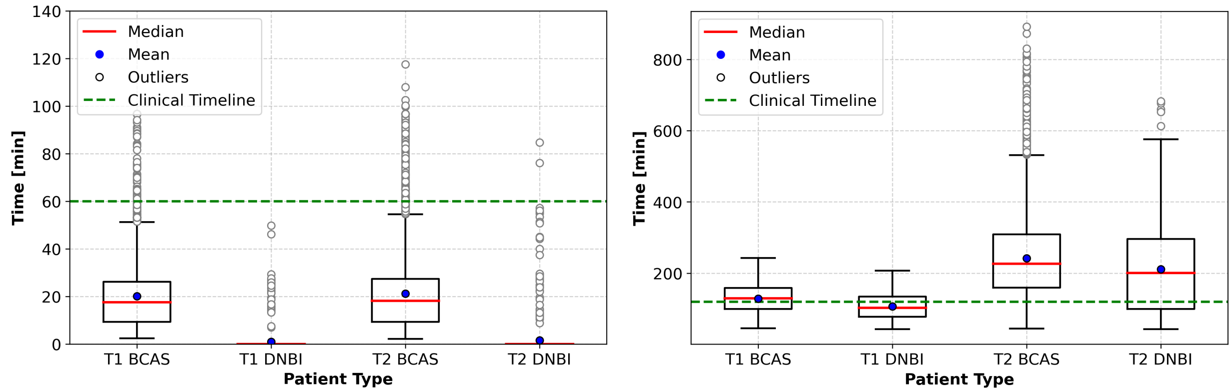


(a) Deceased patients by location

(b) Deceased patients by patient type

Figure 9: Number of deceased patients, categorized by location of death (left) and patient type (right).

The adherence to the NATO clinical timelines for the patients treated is visualized in Figure 10. In this evaluation, we focus on T1 and T2 patients, as T3 patients typically do not require DCR or DCS. Figure 10a illustrates the time until stabilization in a Role 1 MTF, while Figure 10b visualizes the time until surgery in a Role 2 MTF. In both figures, the time from the occurrence at the CCP (for BCAS) or Role 1 (for DNBI) until the initiation of each treatment is considered. The required clinical timelines given by NATO are visualized as a green line in both cases.



(a) Time to Role 1 treatment

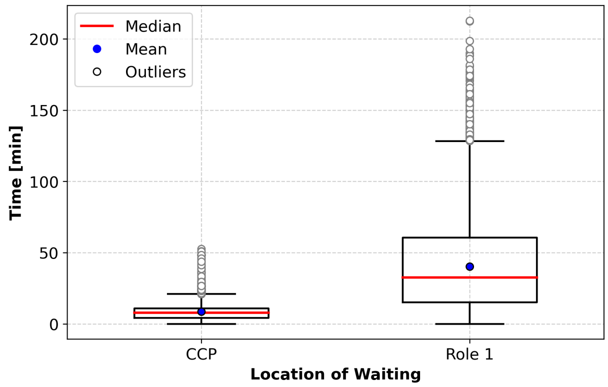
(b) Time to Role 2 surgery

Figure 10: Time from injury occurrence to treatment in Role 1 (left) and Role 2 (right) for battle-related casualties (BCAS) and diseases/non-battle injuries (DNBI). The clinical timelines are visualized in green.

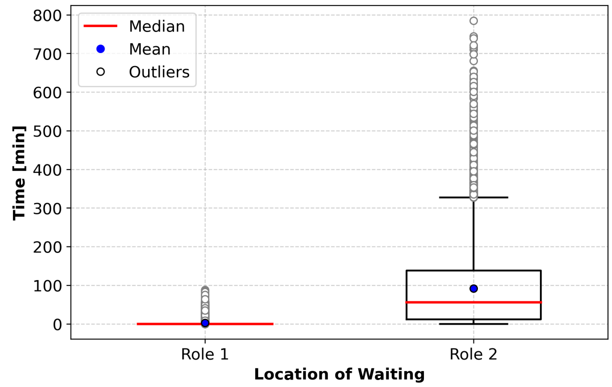
The time to DCR for most patients is under one hour, as shown in Figure 10a. The average time until DCR is 20.1 min (CI: 19.8-20.4 min) for T1 BCAS and 21.2 min (CI: 20.9-21.5 min) for T2 BCAS patients. In both cases, the timeline is adhered to for more than 97% of the patients. For DNBI patients, DCR is administered almost immediately upon arrival at the Role 1 MTF, with a mean waiting time of 1.3 min (CI: 1.0-1.7 min). Figure 10b illustrates, that on average T1 patients undergo surgery after 128.2 min (CI: 127.2-129.3 min) for BCAS and 106.5 min (CI: 103.3-109.8 min) for DNBI, resulting in 42% and 65% of these patients receiving DCS within the recommended time frame. For T2 patients, the average time to surgery is 241.8 min (CI: 239.4-244.1 min) for BCAS and 210.9 min (CI: 201.9-219.9 min) for DNBI, meeting the clinical timeline for 15% and 30% of these patients, respectively.

Figure 11 presents the waiting times for patients. Figure 11a shows the waiting time for transportation. On average, patients waited 8.7 min (CI: 8.6-8.8 min) at the CCP before being loaded onto a transporter. At Role 1 MTFs, the mean waiting time for transport to a Role 2 MTF is 40.2 min (CI: 39.8-40.6). Figure 11b illustrates the waiting time for treatment in Role 1 and Role 2 MTFs, measured from patient arrival at the facility to the start of treatment. At Role 1 MTFs, the average waiting time is 2.9 min (CI: 2.8-3.0 min), while at Role 2 MTFs it is 91.9 min (CI: 90.3-93.6 min).

The simulation results reveal both strengths and weaknesses in the medical evacuation chain. Most patients were successfully stabilized at a Role 1 MTF, with the vast majority receiving treatment within the critical golden hour. However, compliance with the NATO clinical timeline for surgery in Role 2 was significantly lower. Only 42% of T1 BCAS and 65% of T1 DNBI patients received surgery within the required time frame, with even lower rates for T2 patients as they are treated with a lower prioritization. Delays in transport and treatment contributed to this issue, as patients experienced minimal waiting at Role 1 MTFs but faced an average delay of 92 min at Role 2 MTFs. This prolonged waiting time contributed to the high mortality rate in Role 2 MTFs, where 86% of all deaths occurred. These findings suggest that surgical capacity at Role 2 is the primary constraint on meeting NATO timelines, followed by limitations in transport capacity between Role 1 and Role 2.



(a) Waiting time for transport



(b) Waiting time for treatment

Figure 11: Waiting times for treatment once the patient arrives at the required MTF (left) and waiting times for transport (right), categorized by location.

While our model effectively identifies bottlenecks, it lacks the necessary accuracy to fully quantify their impacts. Several factors contribute to this limitation: First, our model simulates a very specific and static scenario with fixed casualty rates. However, real-life combat scenarios are highly dynamic and variable, meaning no two situations will be identical, and human behavior introduces additional unpredictability. Second, accurately modeling patients is highly complex due to the numerous factors influencing a patient's health. We opted for an abstract patient model because our goal is to support high-level capacity planning rather than evaluating outcomes for individual patients. Lastly, we rely on open-source data and make assumptions where data is unavailable. In several instances, we use best-case assumptions. For example, MTFs are assumed to operate 24/7 without breakdowns or supply shortages. Additionally, since each military has different doctrines and capabilities, results may vary depending on the specific context. Despite these limitations, our model provides valuable insights into bottlenecks in the medical evacuation chain and serves as a useful tool for capacity planning, helping to identify critical constraints and areas for potential improvement. In addition, our flexible simulator allows us to simulate a wide range of scenarios. Therefore, our scenario can be easily adjusted and expanded, as new or more accurate data becomes available.

4 CONCLUSION AND OUTLOOK

We proposed a simulation scenario for medical evacuation from CCPs to Role 2 MTFs, laying a foundation for future research and shared discussion. Our analysis revealed that Role 2 surgical capacity and transport from Role 1 to Role 2 are key bottlenecks. Even under best-case assumptions and a moderate 2.3% casualty rate, clinical timelines are missed for about half of T1 patients.

In the future, we aim to increase the scope of our dataset and adjust our scenario as new data becomes available. This way, we want to simulate the medical evacuation on the battlefield up to treatment in Role 3 MTFs or even beyond. As open-access data is limited, we are cooperating with the Bundeswehr to gather data that can be used for research. We further want to encourage the medical and simulation community to reach out and proactively share data wherever possible. By combining the data and knowledge available, we can highly improve research in this field and, in the end, contribute to saving lives.

ACKNOWLEDGMENT

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