Designing a Bayesian Urgency Assessment Tool for Search and Rescue in the Canadian Arctic

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ABSTRACT

Effective urgency assessment is critical for search and rescue (SAR) operations, particularly in remote regions such as the Canadian Arctic. Vast distances, severe weather, and limited resources present significant challenges in Nunavut and Nunavik. Existing urgency assessment frameworks, while effective in other contexts, are often unsuitable for Arctic ground SAR. This paper reviews existing urgency assessment frameworks, including SAR-specific systems and Bayesian network (BN) approaches, assessing their applicability to the Arctic context. It further explores the potential for developing a BN-based urgency assessment tool tailored to ground SAR in Nunavut and Nunavik. We discuss key factors that such a model might incorporate—such as environmental conditions, shelter availability, and local knowledge—and highlight the benefits of probabilistic reasoning in supporting decision-making and optimising resource allocation. While a fully realised prototype is not yet presented, this research outlines the conceptual groundwork for future development. The ultimate aim is to improve decision support for SAR coordinators, risk communication, and the overall effectiveness of Arctic SAR efforts.

Keywords

Decision Support, Risk Communication, Resource Allocation, Probabilistic Modeling

INTRODUCTION

Effective search and rescue urgency assessment (assessing the relative urgency of a missing person case and determining the appropriate response (OPP, *n.d*)) could benefit ground Search and Rescue (SAR) operations in remote environments like the Canadian Arctic, where vast distances, severe weather, and limited resources pose significant challenges (Clark et al., 2016; Kikkert & Lackenbauer, 2021; Kikkert et al., 2023). The isolation of communities and harsh Arctic conditions often delay SAR responses (Kikkert et al., 2023; Kikkert et al., 2024), highlighting the need for adaptive, responsive planning. Further, the number of community, government, and private sectors actors often involved in Arctic SAR responses also increases the need for the rapid generation of shared situational awareness – a requirement met by a shared approach to urgency analysis. We suggest that no

existing urgency assessment tool fully meets the unique operational needs of the Canadian Arctic. Therefore, we assess current systems used for SAR for two key reasons: (1) to demonstrate that existing publicly available systems do not fit our criteria, and (2) to identify relevant components from these systems that could inform the development of a Canadian-Arctic-specific tool. Our approach begins broadly by examining SAR-specific urgency assessment systems and non-SAR-specific urgency assessment systems that use Bayesian Networks (BNs) (a probabilistic framework that captures complex dependencies and uncertainties; Jensen, 2009), and finally, the intersection of SAR and BN-based urgency assessment, with the intent of using BNs to enhance our proposed urgency assessment tool.

SAR operations in Nunavut and Nunavik - the specific areas within the Canadian Arctic where this study takes place - involve a multi-layered network of federal, territorial/provincial, regional and community-based entities, including local volunteers, the Royal Canadian Air Force and Canadian Coast Guard (Arctic Office, Accessed 2025; Kikkert et al., 2024). While this collaborative approach provides valuable resources, deployment delays often strain local responders who have limited formal training, equipment, and funding (Nunavut Search and Rescue (NSAR) Project: Arctic Office, Accessed 2025).

The Nunavut-Nunavik SAR (NNSAR) project was created with the aim of strengthening SAR operations in the Nunavut and Nunavik regions of Canada. This has been achieved by improving ties between SAR stakeholders/rightsholders, and by modelling SAR operations to provide actionable insights for these stakeholders/rightsholders. The development of a successful urgency assessment system for use in the Arctic is a key demonstration of how these two project activities can tie together to improve the effectiveness of SAR in the regions. Due to fundamental differences between the three core types of SAR found in the Canadian Arctic (ground, marine, air) it would be difficult for an urgency assessment tool to be broad enough to cover all three types of SAR operations whilst focused enough to capture the intricacies of the challenges faced in the Canadian Arctic, as a result the proposed tool focusses only on ground SAR, therefore the approach taken by some agencies such as the Coast Guard are not considered in this study.

To address the challenges faced in Arctic Canada, we propose a BN to inform SAR planning dynamically. BNs enable real-time updates to survival assessments by integrating factors such as weather, geographical risks, and survivor health (Norrington et al., 2008; Uusitalo, 2007). An additional benefit of a BN-based approach is that it allows easy integration of Inuit Qaujimajatuqangit (Inuit traditional knowledge), a key tool for Arctic SAR, into a probabilistic framework (Colson & Cooke, 2018; Gondor, 2016). Inuit local responders use their expertise in Arctic survival, weather prediction, and navigation to locate missing individuals—an invaluable strength that could be systematically integrated into SAR frameworks.

Our initial efforts to incorporate search urgency analysis into the toolkits of SAR coordinators in Nunavut were met with interest, but also with constructive feedback from Nunavut SAR stakeholders. While the model we proposed included factors such as time overdue and incident history, it was noted that these were not sufficiently tailored to the unique conditions of Nunavut. SAR coordinators emphasised the need to account for additional region-specific variables, such as ice conditions and more detailed categorisations of equipment, particularly regarding access to shelter. This feedback has guided our approach in refining the tool to better align with the realities of SAR operations in the Canadian Arctic and further reinforced that current urgency assessment methods may provide a suitable foundation but need to be further tailored.

REVIEW OF URGENCY ASSESSMENT METHODOLOGIES

In SAR operations, urgency assessment requires a dynamic response to assess survivors' needs and allocate resources efficiently under constantly evolving conditions (Bazyar et al., 2019; Statheropoulos et al., 2015). To investigate the suitability of different urgency assessment for application in the NNSAR project, we conducted a literature review of select urgency assessment to evaluate their strengths and limitations, identifying key elements that may be adapted or improved to inform the development of a Nunavut-and-Nunavik-specific SAR triage framework. Similar remote coastal regions, such as those in Greenland, Alaska, and southern Chile, face comparable environmental and cultural SAR challenges, and were first identified as having potentially compatible SAR urgency systems. Other urgency assessment systems were identified through investigation of a combination of grey literature and academic journal articles. Academic searches were conducted using the Web of Science platform. A wide range of search terms were used to capture all possible iterations, including "Search and Rescue urgency assessment form," as well as various forms and combinations of "SAR," "search and rescue," "urgency," and "form" (e.g., "search urgency form," "SAR assessment," "rescue urgency tool").

One of the most common types of urgency assessment systems is within the emergency medicine sector, known as "triage" - The preliminary assessment of an individual to determine the urgency of their need for resource priority (Christian, 2019; Robertson-Steel, 2006). While effective, their applicability in SAR settings is limited due to differing objectives—medical triage prioritises immediate treatment based on injury severity, whereas SAR urgency assessment focuses on survivability and efficient allocation of resources. As a result, SAR urgency

assessment frameworks will employ distinct indices (such as environment, weather, and location) to assess and categorise individuals accordingly – and therefore medical triages, despite their similarities, will not be discussed.

SAR-Specific Systems

The SAR systems reviewed can be characterised by the factors they consider, the benefits they offer in relation to our proposed tool, and the reasons why these existing methods could not be adopted directly. These aspects are summarised in Table 1, which also helps to inform the development of our urgency assessment tool. Although our focus is on ground SAR, we have included a range of SAR operation types in the review, as they may still offer valuable insights. It is worth noting that many of the urgency assessment frameworks presented in Table 1 are not clearly described or documented in the existing literature. However, several iterations of the same form appear in this study that are well defined (e.g., Illinois SAR, 2024; OPP, n.d.; NZSAR, 2024). This form, seeming to originate from (National Park SAR, 2005), has been translated to a variety of contexts and regions, making it one of the most widely used urgency assessment systems to date. As such these similar forms have been grouped together as one from here on in.

The work to create an urgency assessment tool remains in progress, and we aim to expand it in several keyways. An important consideration is whether these models account for the impact of intervention—distinguishing between scenarios where the probability of fatality is high, but response options are limited, versus situations where intervention could meaningfully improve outcomes. These aspects, among others, will be explored in greater detail in a forthcoming paper as part of our ongoing research and used to inform our completed urgency assessment tool.

URGENCY SYSTEM	OVERVIEW	FACTORS CONSIDERED	STRENGTHS RELEVANT FOR NNSAR URGENCY ASSESMENT.	LIMITATIONS WHEN APPLYING TO NNSAR URGENCY ASSESMENT.
MOUNTAIN RESCUE TRIAGE (*ANNUAL REVIEW MOUNTAIN RESCUE ENGLAND AND WALES*, 2022)	Emphasises survival probability and exposure risks, allocating priority to those in greatest danger.	Survival probability, exposure risk	Focuses on environmental hazards, looks at exposure risks.	No real-time update integration, focusses on scene assessment and causality prioritisation.
WILDERNESS MEDICAL SOCIETY TRIAGE (VAN TILBURG ET AL., 2024)	Assesses injury severity to determine treatment urgency, specifically involving avalanche rescue.	Injury severity	Clear framework for urgency, considers environmental factors.	Assesses injury severity.
REVERSE TRIAGE (GENSWEIN ET AL., 2008)	Prioritises those with the highest survival likelihood.	Survival likelihood	Maximises survival in constrained environments	May deprioritise critically injured
GREENLAND SAR TRIAGE (RESCUE SERVICE, ACCESSED 2025)	Greenland's SAR prioritises resources based on the remoteness of incidents and severity of the environment.	Remoteness, environmental severity	Adapted for Arctic SAR needs, integrates multiple agencies	Limited documentation
ALASKA SAR TRIAGE (AKRCC, ACCESSED 2025)	Combination of local responders and Coast Guard triage protocols.	Local responders, Coast Guard protocols	Blends federal and local resources for efficiency	Dependence on Coast Guard limits inland adaptability. Limited documentation.
SOUTHERN CHILE SAR TRIAGE (SEMINAR ON THE IMPACT OF SEARCH AND RESCUE OPERATIONS ON ANTARCTICA, N.D.)	Local authorities adapt standard SAR protocols to the region's unique coastal and mountainous environments	Extreme weather, coastal/mountainous terrain	Adapts to varied terrain and conditions	Limited documentation.
URGENCY ASSESMENT FORM (ILLINOIS SAR, 2024; OPP, N.D.;NZSAR, 2024)	A standardised form used widely which multiple criteria are scored, with urgency based on the final total.	Age, clothing, experience, terrain, weather.	Good foundation as includes many relevant variables and is designed for SAR.	SAR co-ordinators stated not sufficiently tailored to the unique conditions of Nunavut.

Table 1: Characterisation Table of SAR Triage Systems

Applications of Bayesian Networks in Urgency Assessment Systems

In this section we aim to explore the use of BNs in existing urgency assessment systems – in particular triage systems due to the lack of literature applying BNs to other urgency assessment systems, and apply the insights gained to inform the development of our urgency assessment tool. BNs offer a flexible, probabilistic framework that models complex dependencies and uncertainties, enabling more effective urgency assessment under fluctuating conditions (Jensen, 2009; Sadeghi et al., 2006) which parallels the initial assessment phase in SAR operations.

BNs are particularly advantageous in unpredictable environments such as Nunavut and Nunavik, as they allow SAR coordinators to update probabilities and adapt priorities as new information emerges. For instance, BNs can incorporate local insights—such as Inuit Qaujimajatuqangiton, weather patterns or animal movements—refining search planning with culturally relevant data (Gondor, 2016; Martin et al., 2012). As operations progress, BNs adjust to reflect the latest findings, helping SAR teams make informed, data-driven decisions that enhance survival outcomes.

By providing a structured way to assess interconnected variables such as environmental hazards, responder availability, and survivor health, BNs support SAR efforts in ways that traditional urgency assessment systems cannot. We propose that integrating BNs into the NNSAR urgency assessment framework could help optimise resource allocation. Below we explore three papers that make explicit use of BNs for urgency assessment to gain key insights

Paper 1: A Bayesian model for triage decision support (Sadeghi et al., 2006)

Contribution
The paper provides empirical evidence on the effectiveness of automated triage systems in improving sensitivity for hospitalisation decisions while acknowledging trade-offs in specificity, in this context sensitivity refers to the proportion of patients who required admission and were correctly identified as such, while specificity refers to those who were correctly recognised as not requiring admission.. Further, it evaluates the performance of an automated emergency department triage system compared to decisions made by an emergency medicine specialist. The research assesses the sensitivity and specificity of the system in predicting hospitalisation needs and explores its potential as a decision-support tool.

Relevance to the NNSAR Urgency Assessment tool:
While this study focuses on an emergency department setting, its findings are highly relevant to the NNSAR urgency assessment tool model. Beyond their shared reliance on probabilistic reasoning, this study's findings underscore key considerations:

1. **Sensitivity vs. Specificity Trade-offs:** The study highlights that automated triage systems tend to prioritise sensitivity over specificity. In the NNSAR context, where delayed evacuation can be fatal, high sensitivity (ensuring critical cases are not missed) is crucial, even if specificity trade-offs lead to some over-triage (Over-triage refers to cases where patients who do not require hospital admission are incorrectly classified as needing it, potentially leading to unnecessary use of resources).
2. **Adaptability in Resource-Limited Environments:** The automated triage system effectively predicted emergency department (ED) admissions, suggesting its potential for environments where specialist oversight is limited. The NNSAR urgency assessment tool will operate in remote, resource-scarce conditions, making an automated, data-driven decision-support tool highly relevant.
3. **Decision Support Rather than Replacement:** The study suggests that automation complements rather than replaces human judgment. We can leverage BNs as an assistive tool, refining real-time assessments while allowing for expert oversight when available.
4. **Potential for Remote and Self-Triage:** The paper discusses how such technology could be used for telephone or self-triage. In the vast and isolated terrain of Nunavut and Nunavik, integrating a similar approach could empower responders, or even individuals in distress, to make informed decisions before professional assistance arrives.

Paper 2: *Emergency department triaging of admitted stroke patients—A Bayesian Network analysis (Nadathur & Warren, 2011):*

Contribution

The study demonstrates the effectiveness of BNs in modelling and visualising patient journeys based on triage decisions. By using standardised hospital data, it provides a structured overview of triage performance and its

impact on care processes. The research highlights opportunities to refine triage practices, particularly in improving early stroke assessment, and showcases the potential of BNs in healthcare decision analysis. Further, it investigates the relationship between ED triage categories and patient outcomes in a stroke care setting. Using BNs derived from hospital administrative data, it examines how triage urgency affects admission rates and patient expected health trajectories.

Relevance to the NNSAR urgency assessment tool
This study offers several insights applicable to NNSAR urgency assessment tool:

1. **Impact of Triage Categories on Outcomes:** The research shows how urgency levels influence admission and discharge patterns. In NNSAR, where delays can be life-threatening, a BN-based model can dynamically adjust triage levels based on evolving survival probabilities and environmental risks.
2. **Optimisation of Limited Resources:** The study's findings illustrate how triage decisions affect resource allocation, such as prioritising urgent stroke cases for immediate hospitalisation. In the remote setting of Nunavut and Nunavik, where evacuation and medical resources are scarce, Bayesian modelling can similarly guide optimal distribution of assets and personnel.
3. **Integration of Administrative Data for Continuous Refinement:** The research utilises hospital administrative data to refine triage assessment. In NNSAR, a similar approach could integrate historical rescue data, environmental conditions, and search subject outcomes to continuously improve triage effectiveness.

Paper 3: *MemTri: A Memory Forensics Triage Tool Using Bayesian Network and Volatility (Murray, 2016)*

Contribution
MemTri demonstrates that memory artefacts can provide critical insights into criminal investigations. The study highlights the benefits and limitations of its two operational modes—normal mode, which offers higher accuracy for active processes, and scan mode, which maintains stability even after process termination. Further, using BNs, MemTri analyses artefacts from Internet Browsers, Instant Messengers, FTP Clients, and Document Processors to determine whether evidence of illegal activity is present. The research evaluates the tool's accuracy across different operational conditions and explores potential improvements through enhanced search methodologies.

Relevance to the NNSAR urgency assessment tool

While MemTri focuses on digital forensics, its methodology and findings provide several key takeaways for the NNSAR BN triage system:

1. **Artefact-Based Decision-Making:** MemTri extracts and analyses artefacts to infer criminal activity, similar to how the NNSAR urgency assessment tool can assess environmental and physiological indicators to predict survival likelihood and prioritise rescues accordingly.
2. **Handling Uncertainty in Data:** The study demonstrates how BNs can infer probabilities even when key information is missing (e.g., terminated processes). In SAR, this principle can help estimate a missing person's survival odds based on incomplete data.
3. **Mode Adaptability for Different Scenarios:** MemTri's normal and scan modes illustrate the importance of flexible triage strategies depending on available data. The NNSAR urgency assessment tool could implement adaptive modes—one for rapid, high-certainty cases where the location is known and another for prolonged rescues with evolving information, the two types of SAR cases currently occurring in Nunavut and Nunavik.
4. **Contextual Understanding:** The NNSAR urgency assessment tool could enhance decision-making by integrating historical survival data, real-time weather conditions, and responder input into its Bayesian framework.

While the three BN-based urgency assessment tools provide valuable insights into structured decision-making under uncertainty, their direct applicability to SAR operations is limited due to their focus on medical and digital forensics contexts. However, the underlying methodologies and probabilistic reasoning frameworks they employ can inform the development of our proposed tool.

Bayesian Networks for Call Triage

Tools reviewed in the previous section show that BNs can be successfully integrated into urgency assessment systems – although none are designed for use within SAR operations. Currently, there is no SAR-specific BN-

based system available for direct implementation. However, "call triage" involves assessing information from emergency calls and using a BN to determine the appropriate level of response (Yunoki et al., 2014), "call triage" offers a foundational framework, which we can reinforce with knowledge gained from speaking with SAR co-ordinators and our insights from other urgency assessment systems.

The Call Triage system (Yunoki et al., 2014) serves as a strong foundation for the NNSAR urgency assessment system because it follows a similar operational structure: assessing incoming emergency information and dispatching an appropriate rescue response. Just as call triage evaluates the urgency of medical cases based on phone-based assessments and then assigns emergency teams accordingly, NNSAR urgency assesment will rely on gathering limited initial information. Both systems must rapidly prioritise cases with incomplete or uncertain data, ensuring that resources are allocated efficiently. The BN approach used in call triage also aligns well with SAR needs, as it allows for probabilistic reasoning when making dispatch decisions. While modifications are necessary to account for Nunavut and Nunavik's unique challenges, such as unreliable communication and extreme environmental conditions, the core decision-making framework of call triage mirrors the fundamental process of SAR operations, making it a valuable starting point for adaptation – Table 2 shows the aspects of Call triage that could be used within the proposed NNSAR urgency assessment system.

ASPECT	APPLICABILITY TO NNSAR URGENCY ASSESSMENT	LIMITATIONS
INFORMATION GATHERING	Structured approach to collecting critical information from callers, aiding initial assessment.	Reliance on phone communication may be challenging in remote areas with limited connectivity.
DECISION SUPPORT	Utilisation of Bayesian Networks to evaluate information and prioritize response aligns with SAR needs.	Original system designed for urban medical emergencies; may not account for environmental factors.
RESOURCE ALLOCATION	Framework assists in dispatching appropriate resources based on assessed urgency.	Does not consider unique SAR resources or logistical challenges in remote regions.

Table 2: Comparison of themes between the Call Triage System and the NNSAR Urgency Assessment Tool

While the call triage system provides a useful starting point, it requires significant adaptation to address the specific demands of SAR operations in the Canadian Arctic. Challenges such as limited communication infrastructure and the need to incorporate environmental and situational variables necessitate a customised approach (Clark et al., 2016; Kikkert et al., 2023). In conclusion, while existing triage methodologies, particularly those employing Bayesian Networks, offer valuable frameworks, developing a Nunavut-and-Nunavik-specific SAR urgency assessment system will require tailored solutions.

PROPOSED URGENCY ASSESSMENT FRAMEWORK

Bayesian Network Prototype

The proposed SAR urgency assessment tool will use a BN approach. Drawing from various urgency assessment systems, particularly call triage, the system will be derived from a bottom-up approach that integrates user feedback from SAR stakeholders/rightsholders, ensuring the system aligns with operational realities and regional needs. Further, after speaking with stakeholders/rightsholders within Nunavut and Nunavik the tool should also 1) save data to a database for evaluation, allowing continuous refinement of the BN model based on real-world SAR operations and 2) integrate user feedback from Nunavut and Nunavik SAR stakeholders/rightsholders before full implementation, ensuring the system aligns with operational realities and regional needs.

Included factors

Our proposed SAR urgency assessment system is part of a larger research project focused on building a comprehensive BN to support decision-making across a range of SAR risks in the Canadian Arctic. This BN is being developed collaboratively by a dedicated team who have conducted multiple field visits to Nunavut and Nunavik, where they hosted a series of structured workshops with local stakeholders and SAR professionals.

The section presented in this paper isolates one component of that broader BN—specifically, the section related to patient survival time in ground SAR scenarios. The included factors were initially identified through literature review on existing urgency assessment systems, then refined through expert elicitation during Arctic workshops. These included SAR practitioners and community members with deep contextual knowledge. In subsequent workshops, Inuit participants helped to clarify and validate culturally and contextually appropriate risk factors,

and are now contributing to a participatory process of identifying which BN nodes are perceived as most relevant or impactful from a local perspective.

Due to the limited availability of reliable data on Arctic SAR, particularly ground-based operations, expert input is a vital source of knowledge. One of the strengths of BNs is their ability to incorporate such expert knowledge in a structured and probabilistic manner. While the factors presented below are grounded in both literature and stakeholder input, they remain preliminary and open to revision as the network is refined through future workshops and validation exercises. Further work will include fine-tuning variable definitions, testing internal logic, and integrating real-world data as it becomes available.

Shelter (Shelter vs. No Shelter)

Access to shelter significantly impacts survival, particularly in extreme weather conditions. Individuals with proper shelter are at a lower risk of hypothermia and exposure-related conditions, while those without are far more vulnerable, especially in harsh environments.

Survival expertise (High vs. Low)

Survival knowledge and experience on the land play a crucial role in self-preservation. A high survival expertise suggests the person understands navigation, resource conservation, and emergency signals, reducing risk. Conversely, a low survival expertise increases dependency on rescue efforts and raises urgency.

Equipment (≤3 hours, 3–24 hours, >24 hours)

The amount and type of equipment carried can dictate how long an individual can survive without external assistance. Minimal equipment (≤3 hours) implies an immediate need for rescue, while well-prepared individuals (>24 hours) can endure for extended periods.

Clothing (Suitable vs. Not Suitable)

Proper clothing is essential for thermoregulation and protection against the elements. Suitable clothing (e.g., insulated layers, waterproof outerwear) increases survival time, whereas inadequate clothing accelerates the risk of hypothermia, particularly in cold climates.

Air Temperature (<-20°C vs. >-20°C)

Temperature plays a vital role in survival chances. Below -20°C, frostbite and hypothermia become immediate concerns, increasing the urgency of a rescue. In milder conditions, the risk is lower, though still dependent on other factors such as wind and precipitation.

Wind Conditions (Favourable, Unfavourable, No-Go)

Wind exposure affects both the individual's survival and the feasibility of a rescue operation. Favourable conditions mean a lower windchill effect and better aerial support options. Unfavourable winds increase heat loss, and "No-Go" conditions indicate extreme hazards that prevent immediate rescue operations.

AN EXAMPLE OF TWO SAR OPERATIONS WITHIN THE CANADIAN ARCTIC

To illustrate how the above factors manifest in real-world scenarios, we now examine two detailed fictive SAR operations in the Canadian Arctic, highlighting the challenges and decision-making processes involved.

In collaboration with SAR responders and experts from Nunavut and Nunavik, the NNSAR team developed two contrasting scenarios, which represent some of the key challenges faced by SAR operations in Nunavut and Nunavik, as well as illustrating opposite ends of the spectrum in terms of survivor characteristics. Furthermore, these scenarios provide insight into how SAR operations are conducted in the region, highlighting both the strengths and limitations of the current approach.

Scenario 1: The Experienced hunter

At the end of March, an experienced hunter leaves his community to hunt, well-prepared for the conditions and accustomed to spending nights on the land. While he is around 100 kilometres from the community, his snowmobile breaks down. Fortunately, he is uninjured and remains calm, relying on his knowledge of survival techniques.

Environmental and Operational Considerations

- Experience and Knowledge of the Area: Given his deep familiarity with the landscape and traditional survival methods, SAR teams will likely assume he has stayed near his snowmobile, built a shelter, and is conserving energy. This reduces the immediate urgency of the rescue.

- Equipment and Clothing: His preparedness—adequate clothing and fuel—suggests a higher probability of survival while awaiting rescue.
- Communication Capability: If he carries a communication device, SAR teams can confirm his status and location, allowing for a coordinated and efficient retrieval. If no device is present, the search must rely on his expected travel route, common hunting grounds, and weather conditions to determine his likely location.
- Weather Conditions: At this time of year, temperatures drop significantly overnight, which could increase risk over time. However, his ability to build a snow shelter mitigates this risk, allowing SAR teams to delay response if needed due to resource availability.

Scenario 2: The Inexperienced Young Hunter

In contrast, a young hunter—new to the land and unequipped for overnight survival—finds himself in a similar situation. His snowmobile breaks down 100 kilometres from the community, but he has injured his leg and cannot move easily. His anxiety increases as he realises he has not brought his medication for a pre-existing medical condition.

Environmental and Operational Considerations

- Experience and Knowledge of the Area: Lacking familiarity with the terrain and how to survive on the land and SAR best practices, he may not stay near his last known position, potentially complicating the search.
- Age and Health: His injured leg, coupled with a pre-existing medical condition, makes him significantly more vulnerable to extreme cold and stress. This should greatly increase the urgency of the SAR response.
- Equipment and Clothing: His lack of proper survival gear puts him at higher risk of hypothermia, further reducing his ability to survive an extended search effort.
- Communication Capability: If he has a working communication device, SAR teams can assess his condition and direct resources accordingly. If he is unable to communicate, the search area may need to be expanded, delaying response time.
- Weather Conditions: If a storm is approaching, SAR teams must escalate their response to avoid worsening conditions that could threaten his survival.

SAR Response Process

Upon receiving the distress call—either from the hunter himself (if he has a working communication device) or a concerned relative—the SAR coordinator quickly gathers key details, including his medical condition, last known location, and level of preparedness. For the inexperienced, young hunter, given his injury and lack of survival gear, the urgency of the case is likely high, whilst for the experienced hunter, his knowledge and preparedness would likely result in a lower urgency rating.

Nunavut Emergency Management (NEM – responsible for SAR operations within Nunavut) is contacted immediately to issue a tasking number, ensuring insurance coverage for SAR responders. If air resources are available, an aircraft may be dispatched to locate and retrieve him quickly. If air support is unavailable, a ground SAR team must be assembled and deployed as soon as possible. Unlike the experienced hunter’s case, where a delay is manageable, the young hunter's deteriorating condition makes time a critical factor.

The Proposed Urgency Assessment

In our proposed new system, the urgency assessment procedure would be employed by the SAR coordinator, however, in reality, this tool could be accessed and used by multiple SAR practitioners at the community, regional, territorial/provincial, and federal level. The results of this urgency assessment process would guide the coordinator in determining the urgency of air support and strengthen their case when requesting assistance from NEM and the Joint Rescue Coordination Centre (JRCC - responsible for coordinating search and rescue). Additionally, it would help inform decisions on whether to initiate a search under adverse weather conditions or wait until conditions improve.

This approach is not currently utilised by any of the teams we are working with in Nunavut and Nunavik. By facilitating collective sensemaking among SAR teams and potentially the broader community, it has the potential to improve coordination and decision-making. Additionally, it is essential to highlight existing challenges in how

information is communicated between partners during SAR operations in these regions. Implementing an urgency assessment could enhance situational awareness and ensure a more unified response. More fundamentally, it provides a structured framework for assessing survivability, aiding all stakeholders in evaluating risks more effectively.

Key Elements to Include from Existing Urgency Assessment Tool

The following section outlines key factors identified in other established urgency assessment tools that may inform and strengthen the development of our proposed SAR urgency assessment tool.

1. Probabilistic Decision-Making (Call Triage)
The BN model will assess available data (weather, location, distress signal type, past case outcomes) to prioritise cases effectively.

2. Rescue Team Dispatch Logic (Call Triage)
Similar to call triage, the system will assess urgency remotely and match the appropriate response to each case.

3. Environmental Risk Consideration (Mountain & Wilderness Triage)
The system will aAssess exposure risks such as hypothermia, distance from safety, and available shelter when making triage decisions.

4. Data Integration & Continuous Learning (MemTri)
The system will store and analyse past SAR operations to refine future predictions, similar to the way in which how BN models improve with more data.

Evaluation Plan

A larger BN to support SAR decision making has already been developed by our research partners. This BN models a wide range of factors influencing SAR operations in Nunavut and Nunavik. However, by collaborating with our research colleagues, we can isolate a specific section of the network focusing on the chance of survival of the subject, allowing for a more targeted and practical application within our urgency assessment framework. The data underpinning this survival model was gathered through elicitation sessions with local experts and communities in Nunavut and Nunavik, ensuring it reflects real-world conditions. However, this dataset may require further validation. One approach would be to use the saved data from SAR operations to update prior probabilities in the BN, continuously refining its accuracy. Additionally, robust evaluation methods will be essential to confirm that the model performs effectively in real scenarios, ensuring it aligns with the unique challenges of the Northern Canadian environment.

CONCLUSIONS AND FUTURE PLANS

This paper has outlined the foundation for a dynamic, evidence-based SAR urgency assessment framework tailored to the unique challenges of Nunavut and Nunavik. Given the regions' extreme climate, vast terrain, and limited resources, a structured yet adaptable triage system could offer significant potential to improve survival outcomes.

We have explored insights from medical triage, existing SAR-specific approaches, and call triage systems, identifying key elements that can inform SAR in Nunavut and Nunavik. The BN approach stands out as a powerful tool, supporting probabilistic reasoning under uncertainty and enabling real-time decision support. A broader BN model developed by our research collaborators offers a valuable foundation, with a specific subset focused on estimating survival chances, shaped through input from local expertise. This subset will continue to be refined and validated using operational data.

The next steps for this work involve three major strands. First, we will refine the prototype through ongoing engagement with stakeholders and rightsholders. This includes incorporating feedback from SAR teams in Nunavut and Nunavik to ensure the tool is usable and practical, validating key survival-related factors through further expert elicitation, and ensuring adaptability to new information and real-time updates. Engaging with Inuit perspectives on risk will remain central to this process.

Second, we plan to collect and validate more data. Real-world SAR case data will be used to update priors and test model accuracy. We will develop a structured process for continuous data integration and evaluate the outputs against existing triage systems to assess performance.

Finally, implementation and evaluation activities will involve trial runs using both primary data and simulated SAR cases across different triage systems. Through this, we aim to identify operational constraints, refine decision thresholds, and establish a pathway for long-term integration into SAR workflows.

This urgency assessment framework remains a work in progress. However, a probabilistic, mathematically grounded, and dynamic system such as the one presented here could provide enhanced decision support for community coordinators and enable more effective risk communication between communities, emergency management organisations, and the military. The result would be more responsive and efficient SAR operations in Nunavut and Nunavik, and stronger support for SAR responders. Furthermore, this framework could be adapted to suit other SAR contexts involving remote communities and extreme environments. Simply put, this tool has the potential to save lives.

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