HUMAN AVALANCHE EXPOSURE: A MISSING LINK IN REAL-TIME AVALANCHE RISK MANAGEMENT

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ABSTRACT: Regional avalanche forecasts and terrain-classification systems describe avalanche conditions and terrain, but they do not explicitly classify the dynamic layer of human involvement: where people are positioned, whether potential involvement is separate or shared, and who remains ready to respond. Human avalanche exposure extends across disciplines, yet activities can create different human-position patterns in the same avalanche environment. This practical paper presents the Motorized Human Avalanche Positioning System (Motorized HAPS), a practitioner-developed system for motorized travel using five descriptive states: None, Single, Separated, Overlapping, and Stacked. The states describe the current human configuration; they are not danger or risk ratings and do not prescribe one acceptable travel state. Motorized HAPS complements avalanche and terrain assessment by making changing human involvement explicit. The Readiness prompt asks who can respond, while rescue capacity is the deeper concept of capable response resources relative to the potential rescue problem. The framework draws on prior motorized travel and rescue work, practitioner experience, literature, and iterative scenario evaluation. It is presented as a motorized system first; transfer to other disciplines should be evaluated rather than assumed. Motorized HAPS remains unvalidated and is offered for field testing, inter-rater evaluation, incident-pattern review, and practitioner refinement.

KEYWORDS: human avalanche exposure; motorized travel; human positioning; avalanche risk management; rescue readiness; decision support

1. INTRODUCTION

Avalanche decision-making already has established systems for avalanche conditions and terrain. In North America, the North American Public Avalanche Danger Scale communicates regional danger through likelihood, expected size, and distribution. European Avalanche Warning Services (EAWS) use snowpack stability, its frequency distribution, and avalanche size (Statham et al., 2010; European Avalanche Warning Services, 2026). The Avalanche Terrain Exposure Scale (ATES) separately describes terrain characteristics and options for reducing exposure (Statham and Campbell, 2025).

Less explicit is where people are within that avalanche situation and terrain. Human avalanche exposure is the broader risk-management concept. Motorized HAPS operationalizes one part of it by classifying potential involvement: whether people could be involved, whether involvement is separate or shared, and who remains ready to respond. Exposure is recognized within avalanche-risk theory (Statham, 2008); the practical gap is common language for the dynamic human picture.

Human avalanche exposure extends beyond one discipline, but activities create different strengths and constraints. Ski and snowboard groups may have more time before a descent commitment to collect local snowpack and instability information, while the descent itself can limit route changes. Motorized users can often bypass steep terrain and cover large areas quickly, creating frequent terrain transitions, intermittent visual contact, and rapid changes in group geometry. Mechanized travel creates another pattern of movement and group positioning. No discipline inherently manages avalanche risk better; the movement, information, commitment, and human-position problems differ.

Motorized travel provides a clear test case. Snowmobile and snow-bike riders can disperse, converge, lose line of sight, move through different avalanche features, assist stuck partners, and regroup quickly. Research has examined the stepwise nature of mountain-snowmobile decisions and GPS-tracked travel in avalanche terrain (Haegeli and Strong-Cvetich, 2020; Hendrikx and Johnson, 2016). Motorized HAPS describes this human-position component without calculating risk or prescribing one acceptable state. Traditional one-at-a-time travel guidance remains foundational, but motorized groups routinely encounter situations—such as stuck-rider assistance, convergence, and regrouping—where more than one person has potential involvement. Motorized HAPS does not replace that guidance; it provides language for describing when involvement remains separate or becomes shared, while keeping rescue readiness visible.

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https://doi.org/10.15788/1790098395

2. ESTABLISHED DECISION CONTEXT AND FIELD VERIFICATION

2.1 Published danger is a forecast

Regional danger ratings are forecasts built from available snowpack, avalanche, and weather information plus expected weather. Uncertainty is inherent because a regional forecast covers an area and future weather has not yet occurred. European guidance states that regional danger should be checked on site; Avalanche Canada likewise notes that regional forecasts can be affected when observed weather differs from forecast weather (European Avalanche Warning Services, 2026; Avalanche Canada, 2026b).

Weather observations are therefore part of the current assessment. A meaningful mismatch in snowfall, wind, temperature, rain, solar input, or signs of instability does not automatically make the forecast wrong; it means confidence in applying it locally may have changed. Forecast confidence, where provided, is another input.

2.2 Terrain, current assessment, and discipline-specific application

ATES provides complementary terrain context. In Complex terrain, overlapping avalanche paths and fewer route options can reduce opportunities for group members to maintain separate potential involvement (Statham and Campbell, 2025), while motorized travel may offer opportunities to avoid steep terrain.

Existing tools can support deeper assessment without being absorbed into HAPS. Avalanche Canada's Avaluator, for example, links forecast danger and ATES in trip planning and uses a Slope Evaluator for slope-specific avalanche-condition and terrain assessment (Haegeli et al., 2006; Avalanche Canada, 2026a). These tools remain available for deeper field reassessment when conditions, terrain, or the human picture no longer match the current assessment.

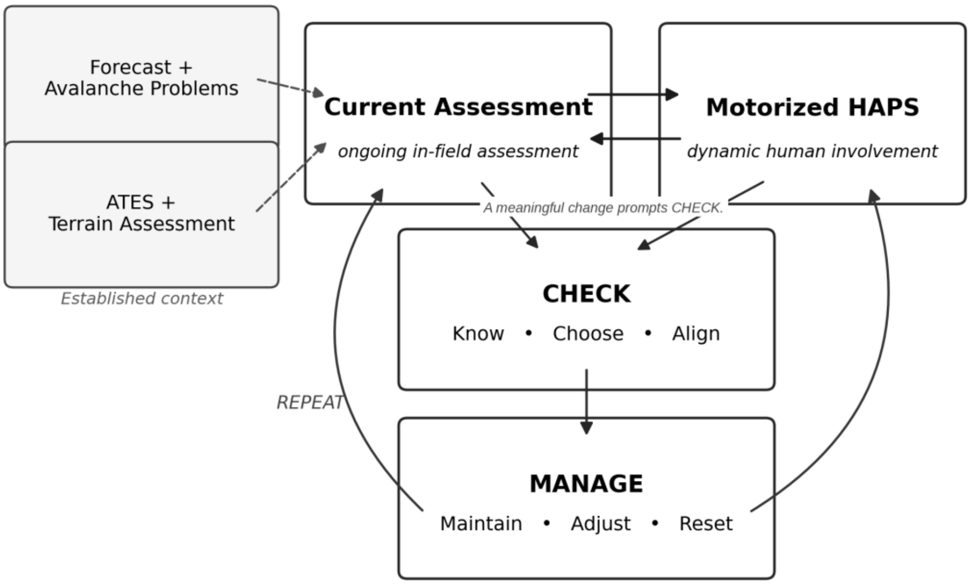


Figure 1. Conceptual relationship between established context, the current assessment, Motorized HAPS, CHECK, and management. Forecast and terrain information establish background context; the current assessment and dynamic human picture are repeatedly updated.

3. DEVELOPMENT BASIS AND SCOPE

Motorized HAPS is practitioner-developed, not derived from a controlled trial. Development draws on motorized avalanche instruction and terrain-travel practice, earlier motorized travel and rescue work, and literature-informed scenario evaluation. The literature constrains terminology and claims; this is not a systematic review.

The framework has lineage in earlier motorized work on spacing, regrouping, line of sight, posting, rolling regroup, stuck riders, and the questions 'What's Above Me?', 'What's Below Me?', and 'What Happens if it slides?' (Hanke and Stewart-Patterson, 2023). Candidate definitions were tested against ambiguous scenarios including lost tracking, stuck-rider assistance, simultaneous shared involvements, changing avalanche information or rescue capacity, external groups, premature regrouping, and an actual avalanche incident. Definitions were revised when classifications became contradictory or unclear. This is iterative scenario evaluation, not validation.

Motorized HAPS is presented as a motorized system first. The underlying human-involvement problem may exist in other disciplines, but transfer should be evaluated rather than assumed.

4. MOTORIZED HUMAN AVALANCHE POSITIONING SYSTEM

4.1 Core vocabulary

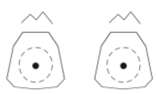
- Potential involvement: A person is positioned where an avalanche could involve them.
- Shared potential involvement: Two or more people have potential involvement that is not being maintained separately.
- Connected avalanche terrain: Avalanche terrain whose spatial relationship allows avalanche release or movement to potentially involve people occupying more than one position. Its operational extent depends on current avalanche conditions.
- Operating group: The people intentionally travelling and making decisions together. HAPS normally classifies this group. An external person becomes relevant to the HAPS state only when their position materially intersects the potential involvement being managed.
- Rescue readiness and rescue capacity: The Readiness prompt asks, 'Who can respond?' and keeps rescue capacity in view: the capable response resources remaining relative to the potential rescue problem. Readiness is not determined by distance alone; a rider may be physically distant and still be ready to respond if their potential involvement remains separate and they remain capable of responding within the operating context. Readiness is simple field language; rescue capacity remains the deeper analytical concept.

The definitions intentionally avoid fixed distance thresholds. Riders can be far apart and still share potential involvement, or occupy avalanche terrain simultaneously while keeping involvements separate. Distance remains useful operationally, but it is not the classification.

4.2 Five positioning states

Motorized HAPS uses five descriptive states: None, Single, Separated, Overlapping, and Stacked. They describe the current human configuration, not a safe-to-dangerous progression. None does not mean no avalanche hazard, and Stacked is not automatically unacceptable. The same state may be evaluated differently as conditions, expected size, terrain consequence, or rescue capacity change.

Table 1. Motorized HAPS positioning states. The states describe human-position configurations; they are not an ordinal danger scale.

State	Schematic	Field meaning	Core definition	Rescue readiness
None		No one could currently be involved.	No current potential involvement.	Current potential involvement does not reduce rescue readiness.
Single		One person could be involved.	One person has potential involvement.	Who remains ready to respond?
Separated		Multiple people could be involved, but not together.	Multiple potential involvements exist and remain separate.	Who can respond to each potential incident?
Overlapping		One pair could be involved together.	One pair has shared potential involvement; others remain separate.	Who remains outside the shared involvement?
Stacked		Shared involvement has expanded beyond one pair.	Three or more people participate in shared potential involvement, or more than one overlapping pair exists simultaneously.	Who remains ready as potential rescue demand increases?

Stacked is a group-level loss-of-separation condition. Two simultaneous Overlapping pairs in different terrain are Stacked even if one avalanche could not involve both pairs. Stacked intentionally describes group-level loss of separation beyond one pair; rescue readiness and rescue capacity distinguish the different operational consequences that may exist within that state.

4.3 Consequence, rescue readiness, and rescue capacity

Human positioning can change consequence without changing avalanche hazard. More shared potential involvement can increase potential rescue demand while reducing those available to respond. Rescue readiness therefore belongs beside the HAPS classification, not inside the state definition. For field communication, the HAPS state should be paired with the Readiness answer—for example, 'Overlapping—Riders C and D ready,' or 'Separated—no one ready.'

Time pressure is substantial. In a Swiss cohort of 1,643 critically buried avalanche victims, survival probability was about 91% at 10 min and 31% at 30 min (Rauch et al., 2024). The 2024 Wilderness Medical Society guideline cites manikin work requiring about 10 min to locate, excavate from 1 m depth, and initiate CPR, while noting that real avalanche rescue may take longer (Van Tilburg et al., 2024).

Multiple-burial literature also shows why available rescuers matter. AvaLife uses 'two or more rescuers per remaining buried subject' as one criterion in a limited-resource multiple-burial algorithm (Genswein et al., 2022). HAPS does not use that value as a travel rule or score; it supports the narrower point that preserving capable responders can materially change the rescue problem.

5. REAL-TIME FIELD APPLICATION

The practitioner-facing loop is LOOK -> TRACK -> CHECK -> MANAGE -> REPEAT. The loop stays active in the background while the group moves; it is not a verbal checklist for every terrain transition. LOOK reads the terrain picture, TRACK describes the human picture, CHECK evaluates it against knowledge and terrain, and MANAGE identifies what to do next.

Table 2. Motorized HAPS field loop.

Step	Field prompt	Primary function
LOOK	Above • Below • If It Goes	Read the immediate terrain picture and possible outcome.
TRACK	Me • Them • Readiness	Account for human position, classify HAPS, and maintain awareness of rescue readiness.
CHECK	Know • Choose • Align	Check knowledge and confidence, terrain fit, and whether the group remains appropriately situated.
MANAGE	Maintain • Adjust • Reset	Maintain the current approach, make an adjustment, or reset.
REPEAT	Continuous	Run the loop again as conditions, terrain, people, tracking, or readiness change.

5.1 LOOK - Above • Below • If It Goes

LOOK establishes the immediate terrain picture. Above asks what type of terrain is above, what size of avalanche could reach the position, and whether overhead threat, connected terrain, or another user could affect it. Below identifies runout, terrain traps, and escape limitations. If It Goes asks where an avalanche could travel, who could be involved, and the possible consequence. Apply the same questions to teammates.

5.2 TRACK - Me • Them • Readiness

TRACK maintains the human picture. Me identifies the rider's potential involvement. Them asks where others are and whether involvement is separate or shared; that produces the current HAPS state. Readiness asks: Who can respond? It keeps rescue capacity in view before an incident.

If a rider's position is unconfirmed, do not assume that their potential involvement remains separate. Keep the position unconfirmed until the human picture is re-established. Position uncertainty is handled within TRACK; it is not a sixth HAPS state. Loss of line of sight, communication, or position certainty should prompt the group to rebuild the human picture while individual riders continue to manage their own potential involvement.

5.3 CHECK - Know • Choose • Align

KNOW. What do I know, and how confident am I? Update the current assessment with the forecast and avalanche problems, weather observations, signs of instability, snowpack observations, appropriate tests, motorized tests, and contradictions with the current assessment. Confidence should change as the evidence changes; no single observation or test proves stability.

CHOOSE. Does the terrain still fit? Consider terrain and ATES context, aspect and elevation, overhead hazard, connected avalanche terrain, runout, terrain traps, expected avalanche behaviour and size, consequence, and simpler alternatives.

ALIGN. Are we all situated for this? Evaluate whether the group's positioning, HAPS state, tracking picture, and rescue readiness remain appropriate to the current assessment. TRACK describes the human picture; ALIGN evaluates it.

A meaningful change may require a quick CHECK or deeper verification. HAPS does not prescribe one method. A recreational skier may use a structured slope tool and/or snowpack assessment tool; a guide may use a professional operating process; a motorized practitioner may combine observations, instability tests, snowpack tests, and motorized tests. HAPS does not prescribe a motorized test protocol.

5.4 MANAGE - Maintain • Adjust • Reset

Maintain. The current approach still fits the current assessment; active management continues.

Adjust. Make an immediate correction to positioning, movement, spacing, sequence, route detail, or another controllable factor. An obvious correction may precede a deeper CHECK.

Reset. Move appropriately to a safe regroup location, rebuild the group picture, communicate the change, integrate new information, and recalibrate. Reset does not automatically mean abandoning the plan.

5.5 Meaningful changes that prompt CHECK

A meaningful change prompts CHECK. Routine changes can often be processed while moving. Significant uncertainty, loss of the group picture, major consequence change, or material deterioration in rescue readiness may justify a reset at the next safe regroup location. A deeper CHECK never means stopping blindly while exposed.

Table 3. Meaningful changes that prompt CHECK.

Change area	Examples	Primary CHECK focus
Avalanche information	Forecast/observation mismatch; weather or loading change; avalanche activity; instability signs; snowpack information or tests; motorized tests.	KNOW
Terrain / consequence	New terrain character or ATES context; overhead hazard; runout; terrain trap; connected avalanche terrain; expected size or consequence change.	CHOOSE
Human picture	HAPS change; compression; stuck rider or assistance; new shared potential involvement; premature regroup.	ALIGN
Tracking integrity	Loss of line of sight, communication, last point seen quality, or position certainty.	TRACK -> ALIGN
Rescue readiness	A person expected to respond is no longer separate, available, or capable; rescue capacity deteriorates.	TRACK -> ALIGN
External users	Another group affects human triggering, terrain use, or materially intersects potential involvement.	KNOW / ALIGN

6. MAINTAINING THE GROUP PICTURE

HAPS depends on reliable positional awareness. When tracking degrades, first manage one's own potential involvement, then LOOK and continue moving appropriately while rebuilding TRACK. Visual contact, radio, last point seen, posting, relay, and rolling regroup can support tracking. If the human picture cannot be restored while moving, progress to a safe regroup location and reset.

A safe regroup location allows the whole group to come together with no current potential involvement: HAPS = None. A rolling regroup restores accountability as the tail catches the front through such a location and spacing is re-established. Compression before the safe location can instead create Overlapping or Stacked. Leader, middle, and tail roles can support tracking; they are not HAPS states.

7. OPERATIONAL SCENARIO EVALUATION

7.1 Simple case: stuck rider and deliberate assistance

Rider A becomes stuck while Single. Before Rider B deliberately enters and creates Overlapping, Rider B uses CHECK to revisit avalanche information and confidence, terrain fit, and whether the group is situated to preserve rescue readiness. Where practicable, the rest of the group is updated before shared involvement increases. HAPS does not declare Rider B's assistance right or wrong; it makes the increased shared potential involvement and changing rescue readiness explicit.

This pattern appears in documented motorized incidents. At Jersey Creek in 2005, two snowmobiles were stuck near each other and both riders were carried when an avalanche released while they were digging out; a third rider in a safer location performed the rescue (Canadian Avalanche Centre, 2005). Similar stuck-rider/assistance mechanisms appear at Gardiner Creek, Alberta, in 2024, and Ant Knolls, Utah, in 2026 (Avalanche Canada, 2024a; Utah Avalanche Center, 2026). These examples illustrate repeated occurrence, not prevalence.

7.2 Real case: Renshaw 2016 - multiple groups and shared involvement

At Renshaw near McBride, British Columbia, in 2016, four separate snowmobile groups converged at a crux decision point in complex terrain. Avalanche Canada's later reconstruction described riders from different groups interacting on the same slope, including stuck riders and people positioned above and below; five people died (Avalanche Canada, 2020; Hanke and Stewart-Patterson, 2023). Viewed through Motorized HAPS, the important feature is that separate social groups did not mean separate potential involvement. Riders from different groups occupied connected avalanche terrain, shared potential involvement expanded across the slope, and potential rescue demand increased accordingly. The case illustrates the compound human-position problem HAPS is intended to make visible; it does not establish that HAPS would have prevented the accident.

8. TRANSITION TO COMPANION RESCUE

If an avalanche occurs, potential involvement becomes actual involvement and companion rescue takes priority. HAPS is no longer the primary management tool, but TRACK information remains useful: who was where, which involvements were separate or shared, last point seen, and who remained ready to respond. These inputs can feed Motorized Avalanche Rescue Procedures (MARP): Assess -> Structure -> Search (Hanke et al., 2026).

9. DISCUSSION, LIMITATIONS, AND FUTURE WORK

Motorized HAPS builds on established motorized travel concepts including limiting simultaneous involvement, communication, visual awareness, safe regroup locations, and preserving response options (Hanke and Stewart-Patterson, 2023). It does not propose a new hazard model; it adds common motorized language for noticing when the human configuration or its context changes.

HAPS is intended to work with other decision methods. Forecast and terrain assessment establish context, field information updates it, and CHECK can reconnect to recreational or professional tools when a deeper look is warranted.

External groups remain a special case. Other users can alter human triggering, terrain use, and the involvement picture, but should not be counted as planned rescue readiness because their competence, equipment, communication, and willingness to respond are unknown. At Sale Mountain in 2024, another group entered to assist a snow-bike rescue and a connected slope released while both groups were working, burying machines from the assisting group (Avalanche Canada, 2024b). Greater standardization of recreational education may improve predictability of baseline competencies in the future, but those competencies should not be assumed today (Hanke and Lee, 2026).

PER-HAPS we aren't travelling well together emerged as practitioner shorthand for the idea that the human arrangement itself may deserve renewed attention; it is not formal terminology.

Motorized HAPS remains unvalidated. It was developed through practitioner iteration and literature-informed scenario evaluation, not controlled study or statistical derivation. HAPS classification is not independent of avalanche assessment: expected avalanche extent and behaviour influence whether positions are considered separate or shared, so uncertainty in the current assessment can also create uncertainty in the HAPS state. Inter-rater reliability is unknown, and the Separated/Overlapping boundary may be difficult when plausible avalanche extent is uncertain. No evidence yet establishes that HAPS changes behaviour or improves outcomes.

Future work should test inter-rater consistency, sufficiency of the five states, cognitive load of the field loop, communication of rescue readiness and rescue capacity, external-user boundaries, and whether motorized incident patterns can be coded reliably. Existing GPS-tracked motorized datasets should also be evaluated to determine whether sufficient terrain and avalanche-context information exists to estimate the frequency of HAPS states during normal, uneventful travel. Cross-disciplinary transfer should be evaluated rather than assumed.

10. CONCLUSION

Avalanche decision-making already has mature systems for regional danger, avalanche problems, terrain, and field assessment. Human avalanche exposure also includes where people are, whether potential involvement is separate or shared, and who remains ready to respond.

Motorized HAPS operationalizes that dynamic human layer with five descriptive states and a simple field process: LOOK -> TRACK -> CHECK -> MANAGE -> REPEAT. It does not assign another colour, danger level, or risk score.

For motorized travel, making the human picture explicit may prompt timely renewed attention. HAPS is offered for testing and refinement, not as a replacement for forecasting, terrain assessment, professional judgement, or companion rescue.

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