DEVELOPMENT OF WIND-BASED CRITERIA FOR VERTIPORTS TO SUPPORT DESIGN AND SAFE OPERATIONS

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The design of vertiports - and the proposed use of existing heliports and general aviation (GA) airports as vertiports - warrants a wind assessment to ensure safe vertical take-off and landing (VTOL) operations. The assessment determines if the vertiport can be operated safely and to what extent the built environment may influence wind conditions at the vertiport site. While methods exist to characterize and quantify winds around vertiports , to date there are no design criteria to establish if the vertiport can be operated safely or if design changes and/or operational restrictions are required.

Design Guidelines for Vertiports

At this time, wind-based criteria have not been defined by civil aviation authorities. A number of agencies - including the US Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA), and the Australian Civil Aviation Safety Authority (CASA) - recommend in their guidelines locating the touchdown and lift-off (TLOF) and final approach and take-off (FATO) areas in a way that minimizes turbulence from the surrounding environment. There is no guidance, however, to indicate what level of turbulence from the surrounding environment is acceptable.

The challenge is that design criteria for vertiports goes hand in hand with the performance capabilities of the VTOL aircrafts that will use the vertiports. Performance criteria are currently being defined. Infrastructure needs to be designed and built beforehand so new vertiports and re-purposed heliports are under consideration right now. Therefore, there is an immediate need to fill the gap and establish wind-based design criteria for vertiports that can evolve as VTOL performance capabilities become available. RWDI has filled this gap and taken the first step to develop design criteria based on what is known from aviation regulatory agencies related to wind and VTOL performance and infrastructure requirements using our expertise in the field of wind engineering.

[1] Schajnoha, S., Larose, G.L., Al Labbad M., Barber, H., Wall, A. "The Safety of Advanced Air Mobility and the Effects of Wind in the Urban Canyon," Vertical Flight Society Forum 78. 78-2022-1152. Fort Worth, Texas, May 2022.

What is Known

The FAA and EASA have published controllability requirements for the take-off and landing maneuvers of VTOLs in windy environments. The requirements from the FAA apply to the special airworthiness criteria for the Joby Model JAS4-1 powered-lift aircraft and the Archer Aviation Model M001 power-lift aircraft. The requirements from EASA are set in the Proposed Means of Compliance (MOC) for Special Condition VTOLs. These documents require aircraft to demonstrate control in 17 knots of steady wind from any wind azimuth in thrust-borne operations.

Although the UK Civil Aviation Authority (CAA) does not currently have design guidelines for vertiports, they do provide guidance related to wind conditions for heliports. Specifically, they set a limit for turbulence at heliports that corresponds to pilot workload.

This forms the basis of the criteria RWDI proposes.

Proposed Turbulence Criteria and Turbulence Index

It is expected that VTOL developers will demonstrate compliance with the controllability criteria of 17 knots at an existing airport or heliport during favorable atmospheric conditions in relatively low turbulence. Based on this, RWDI derived the corresponding wind characteristics for flat open terrain to form the proposed turbulence criteria for vertiports as presented in Table 1. If you know, for example, that the gust wind speed above the vertiport is less than 24 knots and the rms of the vertical wind speed is less than 1.7 knots, then the turbulence conditions at the vertiport are less demanding than the conditions at which the controllability of a specific VTOL was demonstrated.

Table 1: Proposed Turbulence Criteria for Vertiports, all azimuth

Wind Characteristics	Value	Notes
Sustained wind speed (10-min mean)	17 knots	8.8 m/s
Gust wind speed (3-s mean)	24 knots	12.5 m/s
Vertical wind speed (rms)	1.7 knots	0.9 m/s
Lateral wind speed (rms)	2.3 knots	1.2 m/s
Wind pitch angle (rms)	5°	
Wind yaw angle (rms)	7.5°	
Cross-correlation coefficient of vertical wind fluctuations	> 0.7	for a 10-m separation

*based on conditions expected in flat open terrain at 10 m above ground.

The criteria in Table 1 were combined with the UK CAA criterion for turbulence at heliports as an upper bound condition to form the Proposed Turbulence Index in Table 2.

Again, taking the example where the gust wind speed above the vertiport is less than 24 knots and the rms of the vertical wind speed is less than 1.7 knots (0.87 m/s), then the turbulence conditions at the vertiport are less demanding than the conditions at which the controllability of a specific VTOL was demonstrated. This equates to a Turbulence Index rating of 2 or “moderate.”

Table 2: Proposed Turbulence Index for Evaluation of Vertiports

Turb. Index	Description	Characteristics	Values	Rated Wind Speed
1	Low	Iu; Iv; Iw	< 15%; 12%; 8%	0 -17 knots gusting 23
		Vertical rms	< 0.7 m/s	
		Lateral rms	< 1.0 m/s	
		Cross-correlation	> 0.9	
2	Moderate	Iu; Iv; Iw	15-17%; 12-14%; 8-10%	0 -17 knots gusting 24
		Vertical rms	0.7 - 0.9 m/s	
		Lateral rms	1.0 -1.2 m/s	
		Cross-correlation	> 0.7	
3	Considerable	Iu; Iv; Iw	17-21%; 14-16%; 10-13%	0 -14 knots gusting 22
		Vertical rms	0.9 -1.1 m/s	
		Lateral rms	1.2 -1.4 m/s	
		Cross-correlation	0.4 - 0.7	
4	High	Iu; Iv; Iw	21-32%; 16-26%; 13-20%	0 - 9 knots gusting 16
		Vertical rms	1.1-1.75 m/s	
		Lateral rms	1.4-2.3 m/s	
		Cross-correlation	0.2 - 0.5	
5	Extreme	Iu; Iv; Iw	> 32%; 26%; 20%	< 9 knots
		Vertical rms	> 1.75 m/s	
		Lateral rms	> 2.3 m/s	
		Cross-correlation	< 0.2	

Application of the Turbulence Index to a Vertiport

The Turbulence Index is used to evaluate usability of a vertiport relative to wind conditions. An example of a percentage (%) usability graph for a rooftop vertiport near an urban centre is presented in Figure 1 for turbulence indices varying from 1 to 4. The graph combines the statistics of the local wind climate and winds measured above the landing surface on a scale model of the vertiport and surroundings in one of RWDI's boundary-layer wind tunnels.

The usability of this vertiport relative to wind is in excess of 80% of the time for most wind directions. For vertiports where this is not the case, RWDI works with the vertiport designer and the project architect to develop and validate wind mitigation techniques through wind tunnel testing and consultation. Based on our experience with heliports in urban environments, it is possible to improve from a turbulence index of 4, for example, to a turbulence index of 2. This would result in increased usability of the vertiport. This would improve the economics of the vertiport while reducing both the risk of accidents and electric power demands for VTOL operations. Where wind mitigation techniques are not possible, such as in the case of existing infrastructure, the usability of the vertiport informs operational restrictions and "go, no-go" decisions.

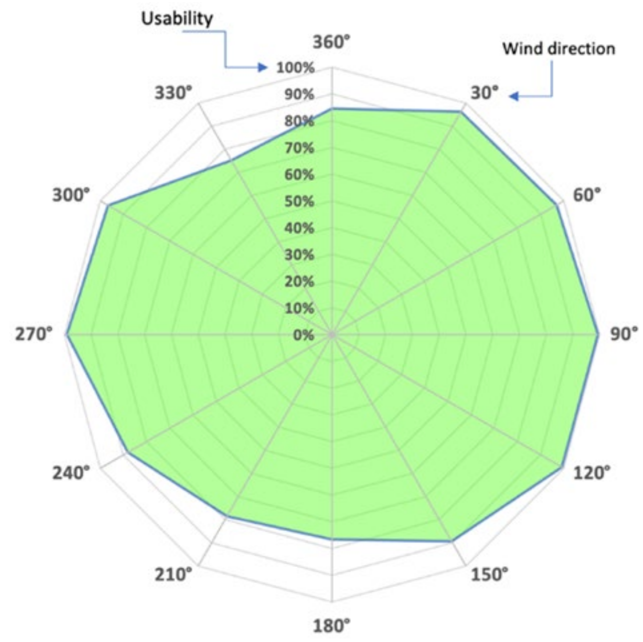

Figure 1. Example of annual % usability analysis of a rooftop vertiport with turbulence index 1 to 4.

This whitepaper features excerpts of a paper presented by Guy Larose, Senior Technical Director and Principal at RWDI, during the AAMForum 80 Conference in May 2024. Vertical Flight Society members can access the full paper here.