

Initial Estimation of the Number of Urban Air Mobility Operations at Aerodromes to Assess Operational Limits

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Community acceptance and aerodrome throughput are important operational limits for Urban Air Mobility (UAM) that must be addressed to attain widespread use for transportation. This paper presents an approach, leveraging previous work that identifies potential UAM trips based on travel data for a metropolitan area, to estimate, without requiring detailed airspace simulations, the number of operations at aerodromes and inform initial assessments of community acceptance and aerodrome throughput issues. Operators, regulators, and infrastructure planners stand to benefit from more accurate assessments of touchdown and lift-off (TLOF) pad and gate requirements to support high-frequency, ridesharing-enabled UAM services. We develop a continuous, temporal-based throughput model that couples a ridesharing-aware scheduling framework with spatially constrained estimates of TLOF pads and gates at candidate sites for a notional UAM network in the Chicago, IL metropolitan area. By building upon previous research, we estimate a plausible number of TLOF pads and gates across nine different aerodromes. Using these hypothesized facilities, we estimate the effects of aerodrome infrastructure on a possible UAM network. The application of the model reveals notable variability in capacity drivers. Some aerodromes are limited by TLOF pad availability whereas others are limited by gate availability. Although ridesharing can reduce the number of aircraft to meet a specified demand, the potential cost savings from ridesharing can stimulate additional demand that intensifies aerodrome bottlenecks. Preliminary network-level estimates—assuming independent aerodrome operations—suggest that throughput reductions of 63% and 69% (considering different inter-arrival times) are plausible solely due to aerodrome infrastructure limits. Although these figures do not account for inter-aerodrome feedback effects, they establish an early upper-bound that underscores the critical role of ground-side capacity in UAM network viability.

Nomenclature

G_{FT}	Gate Free Time
G_{NT}	Gate Needed Time
P_{FT}	Pad Free Time
P_{NT}	Pad Needed Time

I. Introduction

URBAN air mobility (UAM) is envisioned as a means of integrating aerial transport within intra-urban transportation. UAM is a subset of advanced air mobility (AAM), which proposes leveraging novel technologies to provide air

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mobility for local and intraregional missions [1]. Although there is no formally accepted definition of what constitutes a UAM trip, in this work, we consider intra-urban distances of less than 50 miles to be prime candidates for replacement with UAM. UAM is generally expected to be served by electric vertical take-off and landing (eVTOL) aircraft. The VTOL capabilities of such aircraft are expected to enable them to take off and land in dense urban areas, making UAM suitable in metro areas with space constraints. Such aircraft are expected to operate out of specially designated facilities, which many call vertiports, equipped with touchdown and lift-off (TLOF) pads, gates, terminals, etc., to serve passengers. These facilities may include existing airports, helipads, seaports, or even refurbished parking garages (as envisioned by Uber [2], [3]). These have been called by various names, such as helipads, seaports, vertiports, etc., but in this work, we refer to such facilities as “aerodromes” to encompass all facilities that can serve UAM aircraft.

As currently envisioned, potential passengers would travel to a nearby aerodrome using some form of surface-based transportation (such as cars, trains, subways, buses, bikes, etc.) or by walking. Once at the “origin aerodrome,” they would board an aircraft flying to an aerodrome nearest to their intended final destination. Finally, from this “destination aerodrome,” they would again use surface-based transport to reach their final destination. Thus, UAM is envisioned as multimodal transport, wherein the first- and last-mile segments rely on non-aerial modes of transportation.

Urban Air Mobility (UAM) promises to significantly reduce travel times by leveraging the third dimension of airspace—an advantage especially relevant in cities like New York and Chicago, where road congestion led to estimated productivity losses of approximately 9.1 and 6.1 billion USD, respectively, in 2023 [4]. By bypassing surface-level congestion and potentially challenging terrain, UAM enables faster and more direct connections across urban and suburban regions. In terms of vehicle performance, emerging electric and hybrid-electric aircraft architectures offer increased powertrain efficiency compared to internal combustion engines and novel configurations leveraging distributed propulsion, potentially lowering operational energy costs. Some proponents also suggest that UAM could reduce surface traffic congestion; however, this benefit remains to be demonstrated at scale and may depend heavily on integration strategies and adoption rates.

As a point-to-point transportation network, UAM may require less dedicated infrastructure than some path-based systems like rail, which often involve extensive track construction and right-of-way acquisition. UAM operations can potentially leverage a smaller physical footprint through strategically placed aerodromes, particularly in areas where existing infrastructure (e.g., rooftops or parking garages) can be repurposed. Although the development or adaptation of vertiports entails upfront capital costs, these may still be lower than the costs associated with laying new rail lines or building major highways. However, compared to bus systems that utilize existing roadways, the infrastructural advantages of UAM are less pronounced.

UAM faces numerous challenges and regulatory hurdles. Given the novelty of the proposed technologies, many policies and regulations are still being developed. Electric VTOL aircraft have not yet received certification for commercial operations in the United States. The design of eVTOL aircraft is a complex technological challenge that integrates multiple disciplines. Electric aviation, still in its early stages, faces significant challenges related to battery chemistry, energy density, and other unique architectural challenges. For instance, UAM eVTOL aircraft often leverage distributed electric propulsion (DEP). DEP requires multiple rotors operating together creating complex aeroelastic and wake-interaction challenges. For UAM to succeed as a viable mode of transport, collaboration among stakeholders—including UAM operators, government regulators, aircraft designers, and air traffic controllers—is essential.

Community acceptance remains a critical challenge for UAM deployment. Among the most immediate concerns is noise—frequent eVTOL operations must be quiet enough to avoid disturbing communities. Electrified powertrains and novel rotor configurations are expected to help mitigate acoustic impact. However, other factors may also shape public reception, including concerns over privacy, especially in densely populated areas where low-altitude flights could raise surveillance fears. Visual pollution, perceived safety, and changes to neighborhood character may also influence acceptance. Addressing these issues, which are outside the scope of this work, through thoughtful design, regulation, and community engagement will be essential for widespread adoption.

Despite these challenges, significant progress over the past decade has brought this vision closer to reality. Advances in battery chemistry, materials science, and aerodynamics have been critical in moving UAM forward, although several active research areas remain. In this paper, we focus on one such operational aspect: aerodromes. As the primary infrastructure for UAM, aerodromes play a vital role in the cadence of operations, which will largely depend on their throughput capacity. Studying aerodrome throughput capacity is important as it can guide operators on the possible scale of UAM operations.

In our previous work [5] on the hypothetical implementation of ridesharing in an unconstrained* UAM network, we

*In this work, the term “unconstrained” is used to refer to the upper limit of possible operations as investigated using the computational framework

observed a significant increase in passenger ridership. This surge resulted from a reduction in per-passenger costs due to shared vehicle expenses, which led to a substantial increase in projected demand. Although this demonstrates the appeal of ridesharing, it also raises significant feasibility concerns. An unconstrained analysis—one that assumes unlimited infrastructure and airspace capacity—can overlook critical real-world limitations. In practice, accommodating such a large number of flights could overwhelm multiple components of the UAM ecosystem, including vertiport throughput, vehicle availability, and air traffic management systems, especially in dense urban environments. Although our analysis focuses specifically on vertiport capacity as a key constraint, a comprehensive evaluation must consider these broader operational challenges to assess whether the network can realistically support the projected demand.

This paper seeks to investigate the relation between ground infrastructural resources and throughput for UAM operations, by assessing locations in Chicago that can theoretically support expected UAM operations. We present a throughput model that uses an existing ridesharing framework [7] to generate hypothetical schedules for various locales. We also present the frequency of operations based on time of day and the location of the aerodrome, with an assumed number of gates and pads per location. From a community acceptance perspective, the number of operations could be converted to a noise footprint near the aerodrome. From a throughput perspective, the estimated demand for UAM trips might require more operations than the aerodrome can handle; this work can make an initial assessment of how significant the aerodrome throughput might be as an operational limit. A key feature of the approach here is that there is no attempt to provide a full airspace simulation in order to provide computational efficiency that enables relatively quick “what-if” studies.

This paper is organized as follows. Section II delves into other methods that have provided estimates of aerodrome throughput and the number of operations at the aerodrome. It also provides an overview of our previous work, which has been refined in this study. In Section III we explain the methodology we utilize to estimate aerodrome throughput capacities, number of flights, and ridership considering a basic aerodrome topology. Finally, in Section IV, we highlight the results from our analysis. Section V includes conclusions and recommendations for future work.

II. Background and Previous Research

The concept of using aerial transport for intra-urban transportation has been around for a long time. Helicopter airlines, which existed in the 1960s and 70s in metropolitan areas such as Chicago, New York, Los Angeles, and San Francisco [8, 9] can be considered an early precursor. In and around 1975, helicopter airlines went bankrupt due to several factors, such as the withdrawal of government subsidies, rising fuel costs, noise issues, and a series of high-profile accidents [10] that impacted traveler confidence. Recent technological advances have made the concept of UAM viable again.

UAM operations are expected to be heavily based on the aerodrome infrastructure, particularly the availability, location, topology, and throughput capacity of the aerodromes. The spatial distribution and operational limits of these facilities will play a critical role in determining how effectively the network can serve passenger demand. Numerous studies [11–18] have investigated different aspects of aerodrome constraints on UAM operations. These aspects included scheduled versus on-demand operations, network sizes and types, and aerodrome (or vertiport) topologies.

A. External Studies and Related Literature

Sato [11] explored demand capacity balancing (DCB) in cooperative and non-cooperative frameworks using a multi-agent simulation. The study shows that cooperative environments fare better in avoiding DCB violations; however, excessive information exchange hinders scalability. Although the DCB method differs from the first-come-first-served (FCFS) scheme introduced in this work, it presents an alternative framework for assessing aerodrome throughput. This highlights the need to consider trade-offs between coordination complexity and system scalability, which is central to our analysis of operational schemes under constrained conditions.

Kang et al. [12] applied a k-medoids clustering algorithm to construct a hub-and-spoke UAM network. They evaluated operational performance using metrics such as waiting times, rates of unfulfilled trips, passenger delays, vehicle utilization, load factor, and seat capacity. Their results demonstrated the advantages of scheduled services with passenger reservations in improving utilization and reducing delays. Similarly, Preis [13] introduced the *Vertiport Sizing Method*, which aids in selecting optimal vertiport locations and estimating throughput under various processing times, vehicle sizes, and layout configurations. This method integrates geographic data and urban infrastructure to

[6]. The term is meant to acknowledge the fact that constraints such as those related to aerodrome capacity, airspace limitations, weather effects, aircraft availability, infrastructure, etc. have not been accounted for.

inform vertiport layout planning. Although both works focus on bespoke vertiport design to meet forecasted demand, our approach diverges by assessing how existing public-use facilities can support hypothesized demand. This alternative perspective emphasizes operational feasibility using current infrastructure, rather than idealized or newly constructed layouts.

Preis' more recent work [18] offers a deeper investigation into aerodrome topologies and throughput. It introduces a novel metric—hourly passenger throughput per unit area—to evaluate how efficiently space can be utilized to maximize operational capacity. Using a mixed-integer programming framework, the study explores four distinct aerodrome topologies aimed at optimizing this metric. It also provides planners with tools to estimate land use requirements based on different aircraft sizes. Although this work employs similar TLOF pad constraints to those used in our study, it does not account for the actual facility and space availability in specific metropolitan areas (such as Chicago in our current study). Furthermore, our work incorporates real-world commuter travel data, capturing the temporal dynamics of peak and slack demand, which adds greater realism to the potential aerodrome utilization and throughput capacity.

Vascik et al. [14] conducted a comparative analysis of UAM operations in Los Angeles, Boston, and Dallas, identifying community acceptance, TLOF pad availability, and air traffic control (ATC) scalability as key constraints. Follow-up studies [15] explored how sector capacity depends on airspace design, separation minima, and controller workload, whereas vertiport throughput was influenced by location-specific regulations and processing bottlenecks. These findings underscore the importance of both social and physical infrastructure constraints in determining system capacity. In our work, these insights inform critical model parameters such as the number of available gates and TLOF pads, allowing us to test system throughput under realistic physical constraints.

Li et al. [16] evaluated the sensitivity of UAM performance to variations in ground infrastructure and fleet design. They found that although the system is robust to changes in these factors, its performance is highly sensitive to fleet and traffic management policies. This suggests that operational policies may have a more pronounced impact than infrastructure scaling alone. Although our current work does not directly address fleet management strategies, it lays the foundation for incorporating such dynamics in future iterations of our model, particularly in scenarios involving coordinated scheduling or resource prioritization.

Guerreiro et al. [17] implemented an FCFS scheduling algorithm to model vertiport throughput, using TLOF pads and parking space availability as the primary constraints. Their results showed that FCFS can reach up to 80% capacity but suffers from inefficiencies caused by time gaps, especially as the number of resources increases. The study also found that throughput can be limited either by parking availability or pad occupancy, depending on the dwell times. These findings are directly relevant to our work, which employs a similar FCFS-based approach to examine throughput under surge conditions. Although our current model does not incorporate parking space constraints, our framework is extensible to include them[†]. Our model reinforces findings regarding demand surges and space constraints, highlighting the need for designers to strike a balance between over-sizing aerodromes to handle peak loads or accepting reduced throughput during high-demand periods.

B. Purdue Research Efforts

Although existing studies offer valuable methodologies and parameters for analysis of UAM operations, they often lack metro-specific data grounded in real-world locations to accurately estimate throughput constraints. Addressing this gap, a multiyear research effort by Purdue University has focused on quantifying operational limits for UAM operations, with an emphasis on city-specific constraints and operational scenarios. Earlier work in this series has examined factors such as weather [19, 20], economics [6, 21, 22], emissions [23, 24], ridesharing [5, 7, 25] and cargo operations [26]. Our work is built upon the computational framework referenced in these papers. The reader is encouraged to refer to [22, 27–33] for a complete understanding of the computational framework.

This computational framework models how travelers choose between UAM and conventional ground transport. It integrates travel demand, mode choice, and emissions estimation within a systems-level simulation. The framework assigns trips based on effective cost[‡]—which combines monetary cost and Value of Time (VoT)—to determine whether an economically rational traveler opts for UAM or car travel. It models multimodal UAM trips, including first- and last-mile car segments, and incorporates different vehicle types (conventional combustion-powered automobiles, electric ground vehicles, eVTOL) to calculate system-level metrics related to aggregate passenger trips, flight trips, and emissions. The framework also considers network constraints and demand dynamics, enabling assessments of accessibility, equity, and

[†] Constraints related to parking spaces can be implemented using the methodology presented in our paper and future work would consider these.

[‡] The effective cost is a particular, simplified version of the generalized cost, which includes other non-monetary costs other than the value of time, such as the value of comfort and value of convenience.

operational efficiency across different urban scenarios.

Utilizing this computational framework, Sells et al. [32] simulated the operational feasibility of single passenger UAM and RAM trips by routing them through multiscale networks composed of existing aerodrome facilities. Each network scenario—small (3-node), medium (10-node), and large (>10 nodes)—was considered using existing aviation infrastructure such as airports and heliports, as well as designated sites within the metro region (e.g., old runways, seaplane ports) that are underutilized but are physically suitable for UAM operations. For every candidate trip, the model simulated scheduled arrivals and departures under assumed visual flight rules (VFR) or instrument flight rules (IFR) spacing rules and evaluated whether the infrastructure can accommodate the traffic. Trips that exceed available resources—such as TLOF pads, boarding gates, or aircraft—were considered “unfulfilled operations.” This metric captures the extent to which infrastructure constraints limit the realization of AAM demand. The results indicate severe bottlenecks: for instance, in San Francisco, between 81–93% of candidate trips are blocked by pad and gate constraints alone. Similar saturation levels were observed across other metro areas, underscoring the critical role of ground infrastructure availability in scaling AAM services.

However, incorporating ridesharing significantly increases the number of potential UAM operations, as shown in recent studies [5, 7] that account for trip bundling and shared aircraft usage. It is important to note that these studies rely on specific assumptions about demand patterns, passenger willingness to share rides, and vehicle availability, which may not fully capture the operational constraints of real-world implementations. In contrast, Sells et al. [32] did not model ridesharing explicitly, resulting in more “unfulfilled” flights assessed. Furthermore, the UAM analysis conducted assumed a fixed aerodrome topology, which may not reflect the heterogeneity expected in real-world applications. The “unfulfilled operations” metric used in their work was computed using a discrete-time snapshot approach, where every 30 or 90 seconds, the model checked whether scheduled arrivals and departures exceeded pad or gate[§] limits. However, this aggregate binary check does not simulate the continuous evolution of aircraft state on the ground or in the air, nor does it allow for dynamic repositioning, queuing, or sequencing—potentially underestimating achievable throughput.

By contrast, the method introduced in this work employs temporal sequencing of individual aircraft rather than discrete-time snapshots, enabling a more precise resolution of resource allocation conflicts—such as multiple arrivals scheduled to use the same pad within a short time window. This aircraft-centric approach captures the continuous flow of operations and enables more effective sequencing and queuing, allowing the system to accommodate more flights. The approach in this paper also integrates infrastructure-specific characteristics (e.g., gate count, pad availability) derived from location-specific data, avoiding the need for uniform assumptions. This refinement improves the fidelity of the throughput model and better captures the interplay between demand, infrastructure, and assumed concept of operations. At the same time, our approach deliberately avoids using a spatially dynamic airspace simulation that tracks individual aircraft across the entire UAM network. Unlike most airspace studies, this work does not model spatial de-confliction beyond enforcing minimum inter-arrival and inter-departure times. This simplification enables greater computational efficiency, making the approach well suited for rapid trade studies and preliminary estimations of aerodrome-level operations.

This framework does not aim to optimize throughput at individual aerodromes, nor does it capture the interdependencies between aerodromes—such as how congestion or delays at one location may impact others across the network. Similarly, it does not account for real-world operational disruptions, including flight delays, off-nominal events, or temporary airspace closures, which could restrict or free up available slots. With these caveats in mind, this work seeks to answer the following research questions:

- Given plausible, location-specific limits on aerodrome infrastructure, how many operations can be fulfilled at each site, and what proportion of total attempted operations remain unfulfilled?
- How many UAM operations can be realistically fulfilled using the modeled aerodromes, given our assumptions and the underlying commuter demand?
- Which locations across the metro area act as bottlenecks for operations under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR), based on assumptions about separation times and airspace access?
- How does the ratio of gates to takeoff/landing pads influence the number of operations that can be successfully completed within the modeled network?

[§]The term “gate” used here is analogous to gates used in airports. In this context, a gate refers to a space where the aircraft loads or unloads passengers.

III. Methodology

This study focuses on two primary aerodrome-related constraints—gates and TLOF pads—that eVTOL aircraft must interface with in day-to-day operations. The number of gates and TLOF pads are expected to be key constraints that could limit UAM operations due to limited space on the ground for UAM aircraft. This work utilizes the ten aerodrome network for Chicago previously introduced in Ref. [5]. Aerodrome throughput constraints are evaluated considering ridesharing. Considering Chicago, the ten aerodromes have been selected based on the methodology highlighted in Ref. [33]. This leads to Chicago’s ten aerodrome network having eight conventional airports and two heliports.

The first step of this study involves estimating the number of TLOF pads and gates at each aerodrome. These estimates are constrained not only by the physical footprint of each location, but also by current land use and existing site conditions, which may limit the ability to add or expand infrastructure. Satellite imagery and FAA airport diagrams were used to determine a hypothetical number of TLOF pads at each site. Subsequently, the available space at each aerodrome was calculated to accommodate a “plausible” number of TLOF pads. The use of the term “plausible” acknowledges certain limitations of this siting approach. Specifically, the proposed TLOF pad placements may not be operationally feasible, as they could disrupt existing airport activities. Some taxiways may need to be rerouted or removed, and in some cases, remote stands or aprons might have to be repurposed. Although this approach may not reflect actual implementation constraints, it is considered acceptable for the purposes of this study, which aims to identify broad trends rather than provide precise, site-specific planning guidance. With these caveats in mind, every TLOF pad has been located in the aerodromes pursuant to the following rules informed by the FAA Engineering Brief # 105A [34].

- The centers of two adjacent TLOF pads must be at least 200 ft apart pursuant to FAA guidelines to enable simultaneous operations [35].
- The approach and departure vectors for each TLOF pad must be deconflicted and not intersect with flight paths from any other TLOF pad.
- Approach and departure flight paths must be pursuant to FAA guidelines [34]:
 - The angle between approach and departure vectors must be between 135° and 180° .
 - The minimum radius of turns during approach should not be less than 1886 ft
- For active runways the pad must be located at least 500 ft (or 700 ft for runways handling aircraft with MTOW greater than 300,000 lbs.) from the runway centerline and approach thresholds [34].
- Pursuant to FAA design guidelines, each TLOF pad must have the following features [34] (see Fig. 1)
 - The pad must be sized to meet the controlling dimension (D) of the largest expected aircraft. The controlling dimension is the diameter of the smallest circle enclosing the entire VTOL aircraft projection on a horizontal plane, including all possible configurations with rotors/propellers turning.
 - The Final Approach and Take-Off (FATO) area must have a length twice the controlling dimension ($2D$).
 - The safety area must extend up to 2.5 times the controlling dimension ($2.5D$).
- The approach/departure paths must have no obstacles obstructing an 8:1 horizontal units to vertical units surface.

Considering these requirements, pads were placed on all nine[¶] aerodromes studied in Chicago. The location of these pads across all aerodromes are presented in a research repository [36]. Some selected aerodrome locations, Vertiport Chicago Heliport (43IL), Chicago Executive Airport (KPWK), Chicago Midway International Airport (KMDW), Chicago Bolingbrook International Airport (K1C5), and Kenosha Regional Airport (KENW), are shown in Appendix A.

Once the number of TLOF pads at each aerodrome is defined, the number of gates is estimated using a simple heuristic. Specifically, this work assumes a TLOF pad-to-gate ratio of 1:4, loosely based on the 14-gate, 4-pad vertiport layout proposed in Ref. [37]. Although the actual concept of operations—including the relationship between gates, pads, and site-specific operational details—remains an open question and is beyond the scope of this study, this baseline assumption provides a reasonable starting point for modeling capacity. A sensitivity analysis for this estimate is also presented in Section IV. Using this metric, the number of pads and number of gates are presented in Table 1.

A. Pad and Gate Assignment

Once the number of TLOF pads and number of gates are determined, each arriving or departing aircraft is assigned to a pad or gate on a FCFS basis. For departures, each aircraft reserves a TLOF pad for a fixed 30-second window, during which it must enter the pad, take off, and clear the area for the next aircraft. For arrivals, the reservation duration depends on operating rules: 30 seconds under VFR and 90 seconds under IFR. During this period, the aircraft must land and vacate the safety area. The model assumes independent approach and departure paths, allowing any TLOF pad to be used interchangeably for both arrivals and departures.

[¶]As per results from Ref. [5], Chicago Rockford International airport was estimated to not have any simulated trips

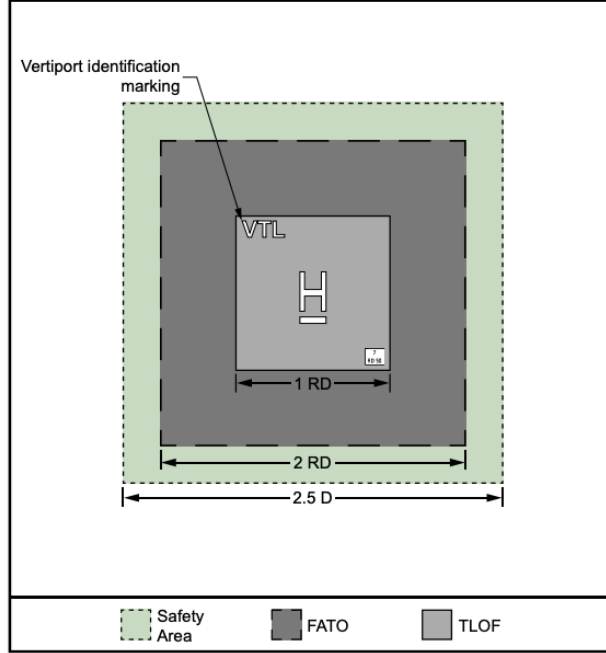


Fig. 1 FAA-prescribed dimensions for aerodrome pads for powered-lift VTOL aircraft [34]. D refers to the controlling dimension in this figure. For the purpose of this work, the rotor diameter (RD) is considered equal to the controlling dimension D .

Table 1 Summary of the plausible number of TLOF pads and gates at each aerodrome in Chicago leveraged for analysis.

Aerodrome	No. of Pads	No. of Gates
Lansing Municipal Airport (KIGQ)	9	36
Tinley Park Heliport (TF8)	2	8
Chicago Bolingbrook International Airport (K1C5)	4	16
Chicago Midway International Airport (KMDW)	4	16
Vertiport Chicago Heliport (43IL)	3	12
DuPage Airport (KDPA)	9	36
Schaumburg Regional Airport (K06C)	3	12
Chicago Executive Airport (KPWK)	6	24
Kenosha Regional Airport (KENW)	8	32

As mentioned, aircraft are assigned using a FCFS scheme. In the FCFS scheme, the computational framework [7] provides the exact arrival or departure time for each aircraft, and all operations are chronologically ordered based on these timestamps. This timestamp is then used to allocate TLOF pads. Depending on the type of operation (arrival or departure) and the flight rules (VFR or IFR), the model calculates the time interval during which a pad is required—denoted as P_{NT} —and the time at which it becomes available for the next use— P_{FT} . The model queries all TLOF pads to find one that is available during the required interval. If such a pad is found, it is marked as occupied between P_{NT} and P_{FT} . If no pad is available, the operation is canceled and recorded as an “unfulfilled operation.” The model then proceeds to allocate the next aircraft based on its timestamp.

Gate allocation follows a similar procedure to pad allocation. For departing flights, it is assumed that fully charged aircraft are readily available from a designated charging area. Likewise, upon arrival, aircraft are assumed to proceed to the charging area after passengers are offloaded at the gate. Since this study does not model individual aircraft

movements or fleet size, the charging area is treated as an idealized system—functioning as both an infinite source and sink of aircraft. However, instead of using the P_{NT} metric for chronological ordering, a separate metric— G_{NT} —is introduced. This timestamp is calculated differently depending on whether the operation is an arrival or a departure. To determine G_{NT} , the following assumptions are made:

- Taxi-time from the gate to the pad or vice-versa is fixed at 120 seconds^{||}.
- During departure, each gate is occupied for seven minutes (420 seconds).
- During arrivals, each gate is occupied for three minutes (180 seconds).

Based on these assumptions, the gates are each queried individually for availability. If a gate is available, the aircraft is allotted to an open gate; if no gate is available, the aircraft is marked as an unfulfilled operation. The gate-allotment calculations are illustrated in Fig. 2.

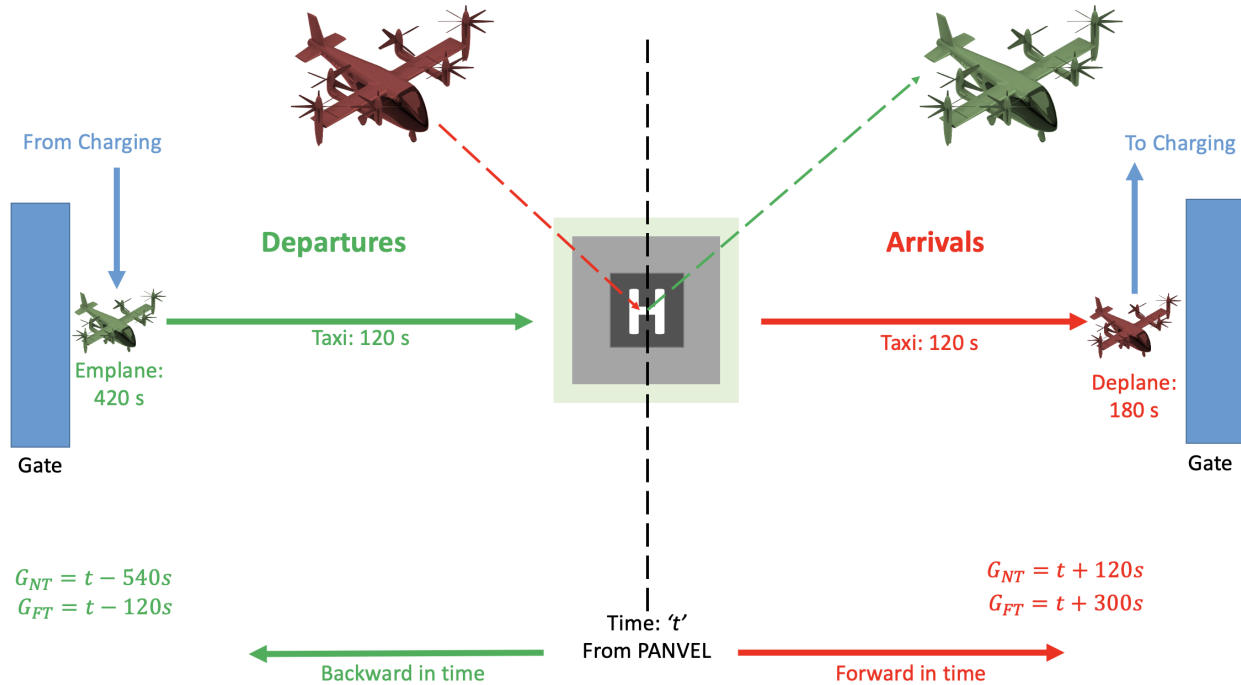


Fig. 2 Hypothesized concept of operations at an aerodrome. Red lines represent arrivals and green indicate departures. Taxi times are assumed to be equal (two minutes) for both. Gates are occupied for three minutes for arrivals or seven minutes for departures. After leaving the gate, aircraft move to a charging area; conversely, departing aircraft arrive from a charging area. Charging time and infrastructure are not modeled—aircraft and charging stands are assumed to be always available.

B. Combined Throughput Analysis

Once the TLOF pad and gate availability constraints are implemented, each constraint is handled independently by two models: the TLOF pad availability model and the gate availability model. Both models process the same dataset, which contains scheduled UAM operations as generated by the computational framework [7]. Each operation in the dataset has a unique trip identifier and is associated with a specific takeoff or landing time, along with other relevant attributes.

The TLOF pad model simulates operations assuming only pad constraints—verifying whether a TLOF pad is available during the required time window for each arrival or departure. Similarly, the gate model checks whether a gate is available during the time the aircraft needs to occupy it, accounting for different dwell times for arrivals and departures. Each model individually identifies which operations can be accommodated, marking them as “fulfilled.”

After both models have been executed, their results are compared. Only those trip identifiers that appear as fulfilled in

^{||} It is assumed that the gates have individual bidirectional taxiways to each TLOF pad

both the pad and gate outputs are considered truly fulfilled—i.e., the operation is only marked as successful if it satisfies both TLOF pad and gate availability constraints. This filtering step ensures that the final list of fulfilled operations represents UAM flights that can be physically and operationally supported by the available ground infrastructure.

The difference between the number of fulfilled operations considering TLOF pad and gate models helps predict if a location is pad constrained or gate constrained. Typically, locations that see a large number of departures in a short interval of time are more gate constrained than those seeing a large number of arrivals. This is mainly due to the fact that the gate dwell time for departures is higher than that for arrivals.

In Section IV, we present various tables and charts that show these characteristics in much more detail for four chosen aerodromes considering both IFR and VFR operations. Complete results for all nine aerodromes are provided in Ref. [36].

IV. Results

In this section, we present the results of aerodrome throughput impact on UAM operations under the VFR and IFR regulations. Figure 3 shows the reduction in departures and arrivals when flight operations are restricted under the TLOF pad constraint and when IFR and VFR regulations are in place. We observe that Tinley Park, Chicago Bolingbrook, Vertiport Chicago Heliport (43IL), and Chicago Executive aerodromes have some of the lowest fulfilled flight operations under both flight conditions given the available travel data.

The number of pads in these aerodromes shown in Table 1 greatly influences the operations fulfilled under TLOF pad constraint. Vertiport Chicago Heliport (43IL), Tinley Park Heliport (TF8), and Chicago Bolingbrook International Airport (K1C5) aerodromes have only two to four pads available, whilst having more than 6,000 flight operations within the day. Despite having six available pads, Chicago Executive Airport (KPWK) cannot handle over 50% of the arrivals and departures under IFR operations based on the number of UAM preferred trips from the computational framework. Furthermore, it cannot handle around 35% of the arrivals and departures from the computational framework under VFR operations. Since most flights were scheduled within similar time frames, bottlenecks at TLOF pads increase. Though a trivial finding, additional TLOF pads at this location may help relieve the bottleneck to service more demand. Under TLOF pad constraints, the Lansing Municipal Airport (KIGQ), Chicago Midway International Airport (KMDW), and Kenosha Regional Airport (KENW) aerodromes are able to service a relatively large proportion of total operations due to the relatively low traffic volumes compared to other aerodromes.

For all aerodromes shown in Figure 4, we observe similar results for flight operations that are sustained when the gate constraint is enforced. As the dwell times at the gates and the taxi times do not depend on IFR or VFR operations, gate throughput is not affected due to changes in flight conditions. Though a trivial finding, the results align with expected trends for locations with fewer gates and high traffic and vice-a-versa.

A. Flight Operations Under IFR Regulations with TLOF pad and Gate Constraints

This subsection contains an analysis of four selected aerodromes that represent different flight operation behaviors and aerodrome characteristics. We selected Vertiport Chicago Heliport (43IL), DuPage Airport (KDPA), Kenosha Regional Airport (KENW), and Tinley Park Heliport (TF8) as our aerodromes of interest. For results of the remaining aerodromes, refer to Ref. [36].

The four selected aerodromes differ notably in terms of available gates and TLOF pads, as well as in the number of flight operations modeled over the chosen day. For each aerodrome, we present two subplots: Sub-figures (a) and (b) visualize aerodrome capacity over time, showing the number of fulfilled arrivals and departures in 10-minute intervals across the 24-hour period (144 intervals from 00:00 to 23:59). Sub-figure (b) provides a three-dimensional perspective of sub-figure (a) also displaying frequency, with both plots color-coded to reflect the time of day.

Figure 5 depicts an overview of the simulated flight operations at Vertiport Chicago Heliport (43IL) aerodrome. A total of 367 arrivals and 613 departures meet both TLOF pad and gate constraints. This translates to roughly 10.15% of arrivals and 9.56% of departures out of the total unconstrained flight operations are fulfilled under IFR. Vertiport Chicago Heliport (43IL) consist of 3 pads and 12 gates and sees the highest amount of flight operations compared to other aerodromes in the network. The aerodrome capacity diagrams shown in Figs. 5a and 5b illustrate the number of flight operations binned into 10-minute intervals during the day. The scatter plot indicates high incoming traffic volume during the early mornings, representing the inflow of individuals commuting to work. Later in the day we see more departures indicating the evening rush hour. This is likely due to the central location of the Vertiport Chicago Heliport (43IL) aerodrome, which is situated within the core of the metropolitan area.

Figure 5b illustrates both arrival and departure operations along with their time-of-day distribution. This temporal

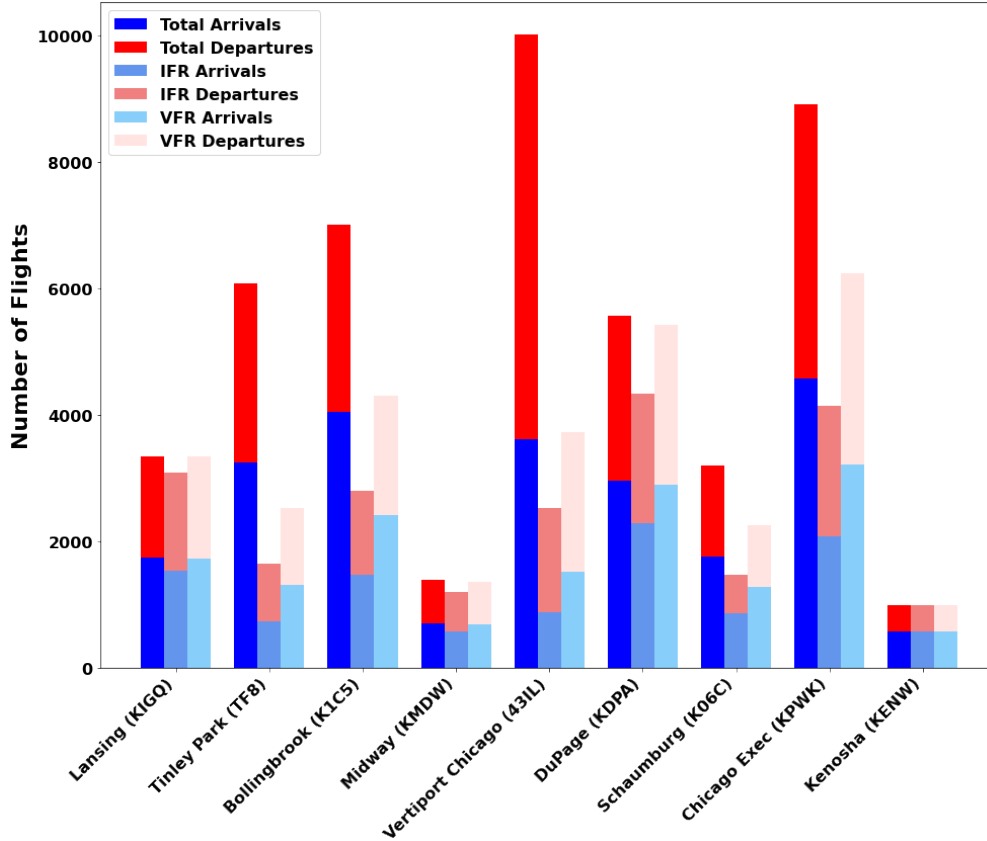


Fig. 3 Flight operations at all nine aerodromes in Chicago under TLOF pad constraint under VFR and IFR regulations showing disparities between the total flight operations and fulfilled arrivals and departures. Total arrivals/departures refer to the total ridesharing enabled operations that are not constrained by flight rules or aerodrome related constraints. We observe significant restrictions at Tinley Park Helistop (TF8), Chicago Bolingbrook International Airport (K1C5), Vertiport Chicago Heliport (43IL), and Chicago Executive Airport (KPWK).

detail is essential for computing community noise metrics, such as Day-Night Average Sound Level (DNL) contours, which are commonly used by acoustics engineers and city planners to evaluate the impact of aircraft noise on surrounding communities. Although our work does not compute these contours directly, it provides the necessary operational inputs to enable such analyses.

Figure 6 illustrates an overview of the simulated flight operations at DuPage Airport (KDPA) aerodrome with TLOF pad and gate constraints under IFR. A total of 1,899 arrivals and 1,639 departures meet both TLOF pad and gate constraints. This translates to roughly 64% of arrivals and 63% of departures out of the total unconstrained flight operations are fulfilled under IFR. Figure 6a and 6b illustrates the frequency distribution of fulfilled arrivals and departures binned into 10-minute intervals, with a peak of roughly 64 flights operations during the early morning occurring at about 08:00 hours. The plot shows a broad spread in the frequency of operations but indicates generally sustained operations throughout the day. These figures also show feasible operations cluster mainly in the early mornings and late afternoon - early evenings. The DuPage Airport (KDPA) aerodrome exhibits a pattern of increased departures in the morning and arrivals in the evening, indicative of commuter travel behavior. Compared to Vertiport Chicago Heliport (43IL), DuPage Airport (KDPA) exhibits increased operational balance between expected flight demand and infrastructure capability, resulting in a higher proportion of fulfilled operations under both TLOF pad and gate constraints for arriving and departing flights. Note that there is a red bar that is obscured by the bar with height of 8, showing two 10-minute intervals with zero arrivals and departures.

Figure 7 shows an overview of simulated flight operations at Kenosha Regional Airport (KENW) aerodrome with TLOF pad and gate constraints under IFR. Kenosha Regional Airport (KENW) sees the least number of simulated flight

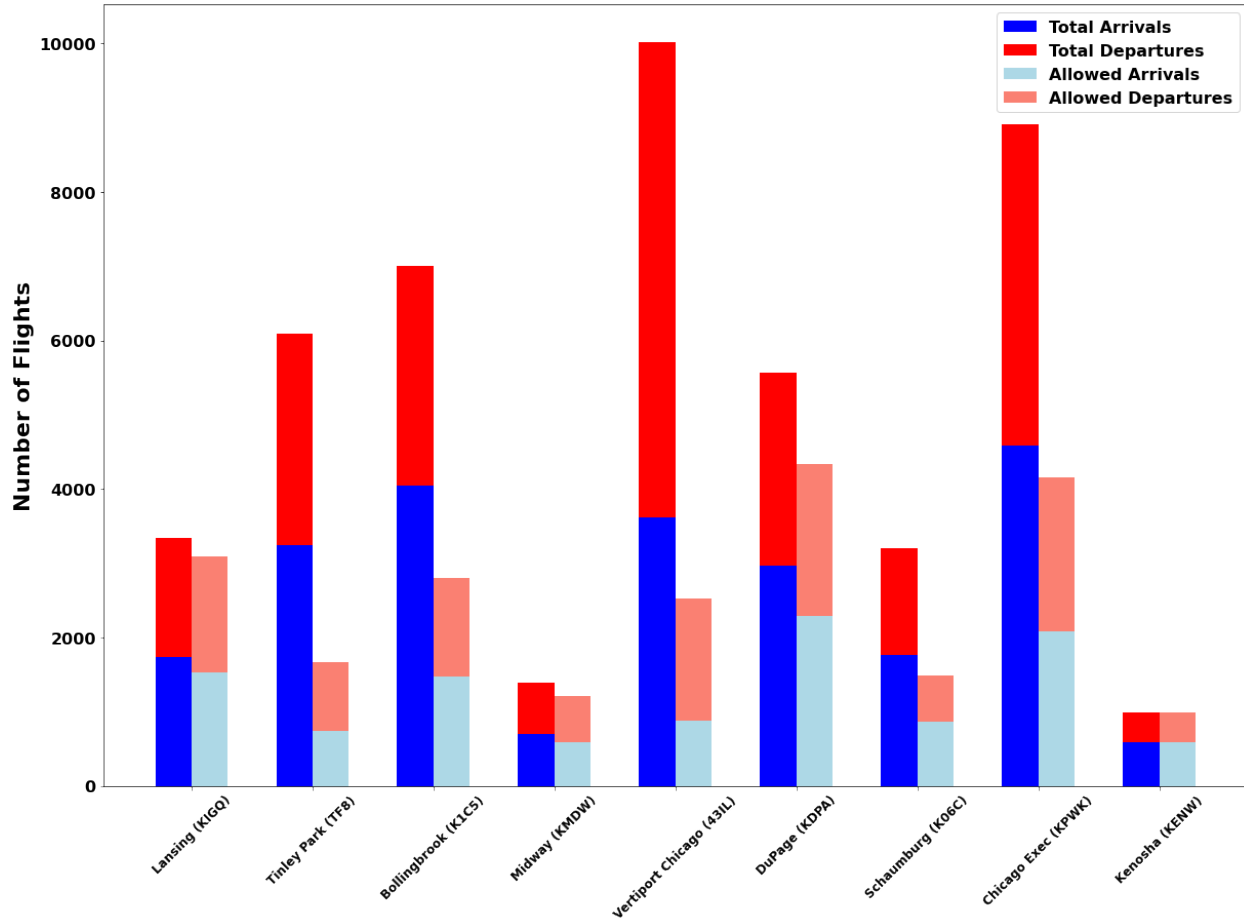
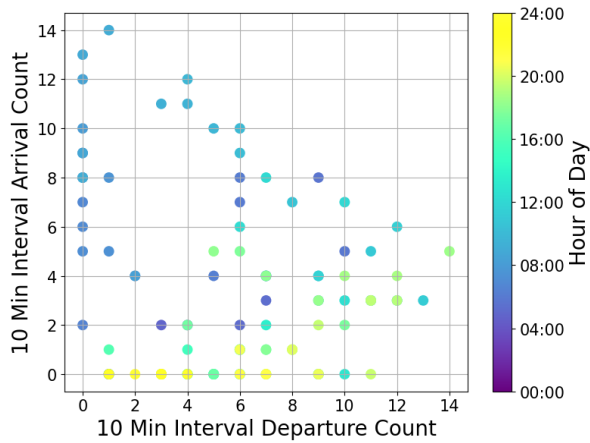


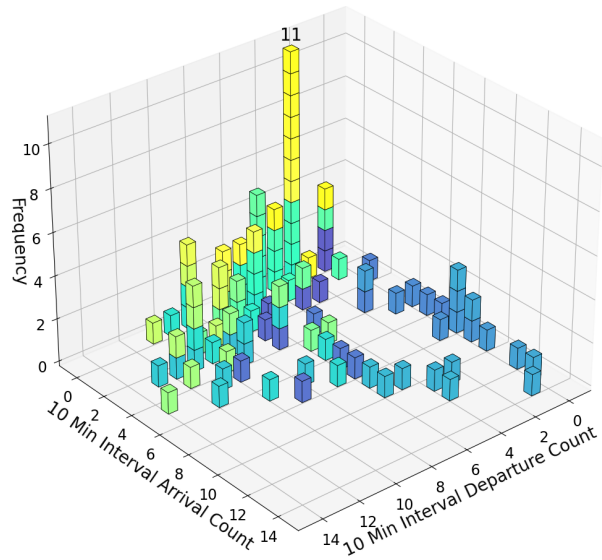
Fig. 4 Similar to the TLOF pad constraint, we observe significant restrictions in Tinley Park Helistop (TF8), Chicago Bolingbrook International Airport (K1C5), Vertiport Chicago Heliport (43IL), and Chicago Executive Airport (KPWK) aerodromes when flight operations are restricted to gate constraints. Gate constraints are independent of IFR or VFR constraints.

operations compared to other aerodromes, while having a large number of TLOF pads and gates—8 TLOF pads and 32 gates. For Kenosha regional (KENW) 587 arrivals and all 406 departures meet both TLOF pad and gate constraints. This translates to roughly 99.8% of arrivals and 100% of departures out of the total unconstrained flight operations are fulfilled under IFR. This aerodrome is able to meet all but one arriving flight within the day, as it has many available TLOF pads and gates to almost completely meet demand throughout the day. Figures 7a and 7b show the frequency and distribution of fulfilled arrivals and departures binned into 10-minute intervals, with a peak of 33 flights during the early evening. The plot shows a broad spread of frequency showing operations throughout the day, with dense operations occurring between 08:00 to 10:00 hours and 15:00 to 17:00 hours, indicative of the commuter traveling pattern to and from work. The results show fulfilled operations cluster mainly in the mornings and late afternoon. Compared to the aforementioned aerodromes, Kenosha Regional Airport (KENW) exhibits more structured and steady throughput activity, as the available gates and TLOF pads are able to maintain operations with only one flight from the UAM preferred trips that cannot be handled during the day. Additionally, in sub-figure (b) the red bar showing 16 10-minute intervals (out of 144 total) during which the aerodrome sees zero arrivals or departures is clearly visible.

Figure 8 shows an overview of simulated flight operations at the Tinley Park Helistop (TF8) aerodrome with TLOF pad and gate constraints under IFR. For Tinley Park (TF8), 344 arrivals and 353 departures meet both TLOF pad and gate constraints. This translates to roughly 10.6% of arrivals and 12.5% of departures out of the total unconstrained flight operations are fulfilled under IFR. Figures 8a and 8b illustrate the frequency and distribution of operations binned into 10-minute intervals for the aerodrome. We observe peak operational activity during the early mornings and late

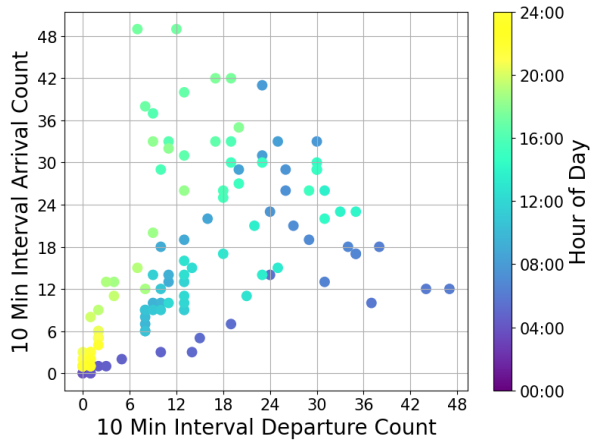


(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under IFR within 10-minute intervals showing dense flight operations during the early mornings and late evenings.

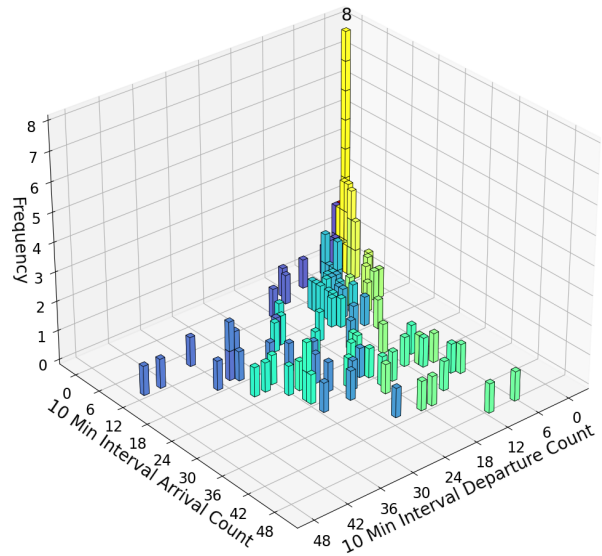


(b) Frequency bar chart visualizing the fulfilled departing and arriving flights in 10-minute intervals that meet both TLOF pad and gate constraints, with most operations occurring during the evening between 16:00 - 23:59 hours.

Fig. 5 Flight operations at the Vertipoint Chicago Heliport (43IL) aerodrome with TLOF pad and gate constraints under IFR.

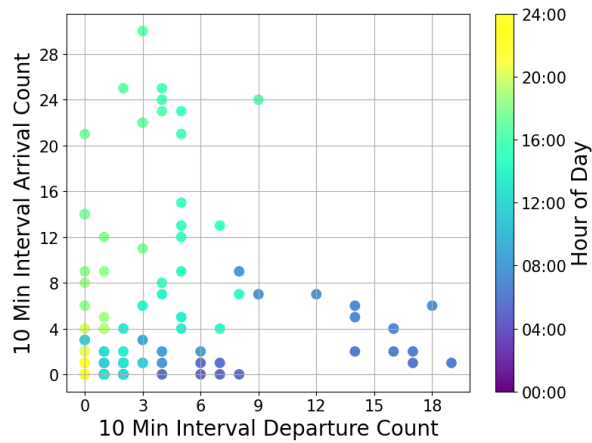


(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under IFR within 10-minute intervals showing dense flight operations during the early morning and late evening.



(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring during the early morning and late evening.

Fig. 6 Flight operations at DuPage Airport (KDPA) aerodrome with TLOF pad and gate constraints under IFR.

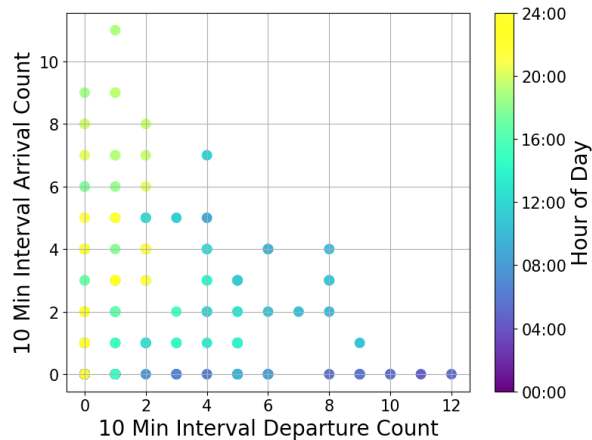


(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under IFR within 10-minute intervals showing dense flight operations during the early morning and late afternoon.

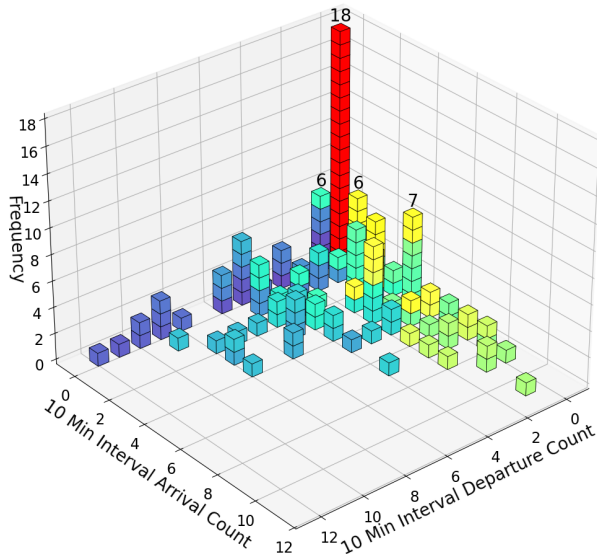


(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring during the early morning and late afternoon. The red bar indicates when there are no flight operations taking place.

Fig. 7 Flight operations at the Kenosha Regional Airport (KENW) aerodrome with TLOF pad and gate constraints under IFR.



(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under IFR within 10-minute intervals, showing lower operational intensity in the early morning.



(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring in the early mornings and mid to late evenings. The red bar indicates when there are no flight operations taking place.

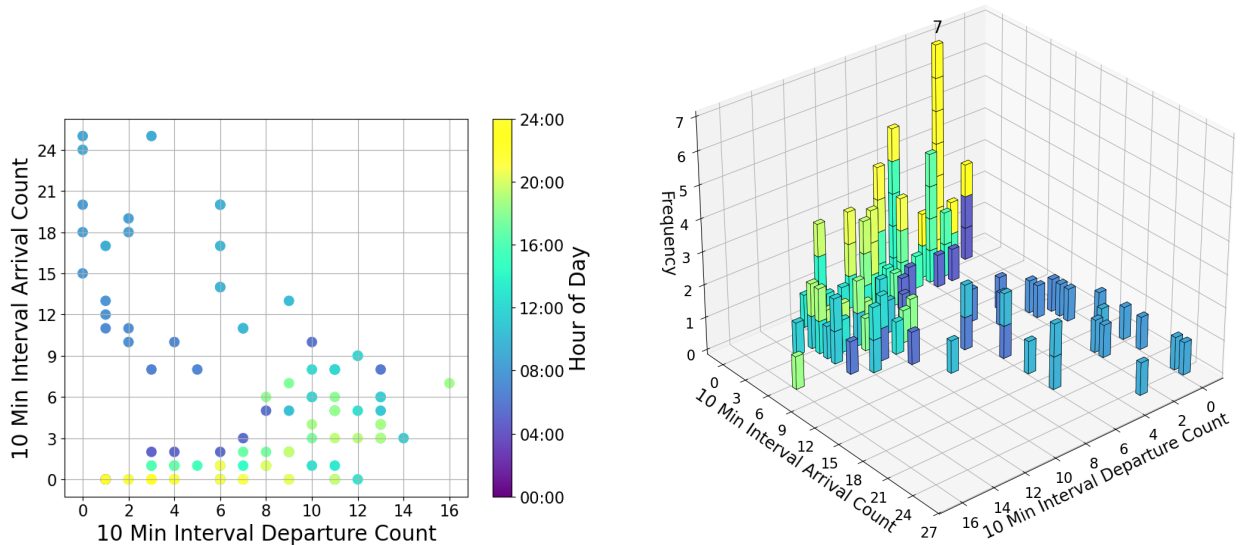
Fig. 8 Flight operations at the Tinley Park Helistop (TF8) aerodrome with TLOF pad and gate constraints under IFR.

evenings, with up to 12 operations taking place within a single interval occurring in the early morning at 04:00 hours and 10:00 hours, and again in the evening at 18:00 hours. The Tinley Park Heliport (TF8) aerodrome exhibits similar commuter travel behavior as observed at the DuPage Airport (KDPA) and the Kenosha Regional Airport (KENW) aerodromes, consistent with the modeled demand.

B. Flight Operations Under VFR Regulations with TLOF pad and Gate Constraints

The previous subsection highlighted results for IFR operations, which had a 90-second inter-arrival time and a 30-second inter-departure time. This subsection presents corresponding VFR operations, which assume 30-second inter-arrival and inter-departure times, for the Vertiport Chicago Heliport (43IL), DuPage Airport (KDPA), Kenosha Regional Airport (KENW), and Tinley Park Heliport (TF8). Note that VFR and IFR definitions used in this effort are based on inter-arrival and inter-departure times from Ref. [24].

Figure 9 shows an overview of simulated flight operations for the Vertiport Chicago Heliport (43IL) aerodrome. Under VFR operations, Vertiport Chicago heliport shows 589 arrivals and 747 departures meet both TLOF pad and gate constraints. This translates to roughly 16.3% of arrivals and 11.7% of departures out of the total unconstrained flight operations are fulfilled under VFR. The aerodrome capacity diagrams shown in Figs. 9a and 9b present the number of flight operations binned into 10-minute intervals during the day. We observe similar frequencies of operations as IFR, but increased operations overall with peak frequencies reaching up to 28 operations within a 10-minute interval. A comparison of fulfilled operations under VFR and IFR shows that VFR resulted in 222 more arrivals and 134 more departures, indicating an increase in operational capacity.

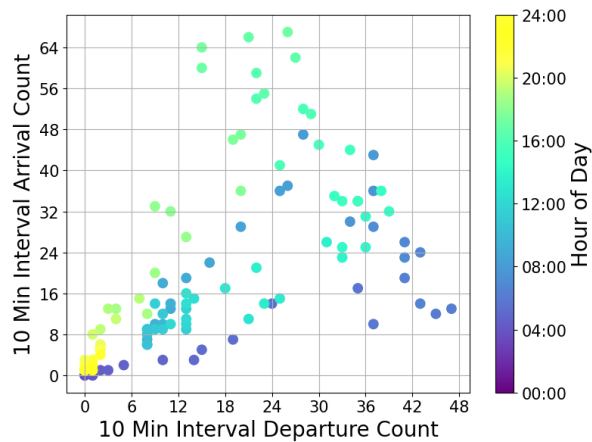


(a) Fulfilled departures and arrivals under TLOF pad constraint and gate constraints under VFR within 10-minute intervals showing dense flight operations during the early mornings and late evenings.

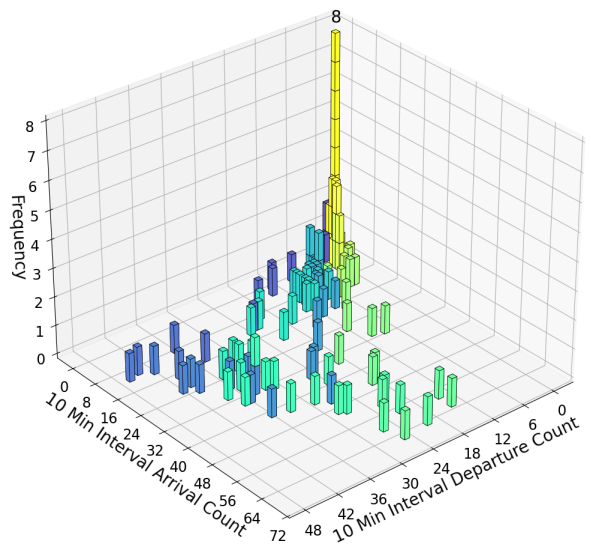
(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring during the evening and morning hours.

Fig. 9 Flight operations at the Vertiport Chicago Heliport (43IL) with TLOF pad and gate constraints under VFR.

Figure 10 provides a comprehensive overview of simulated flight operations at DuPage Airport (KDPA) aerodrome with TLOF pad and gate constraints under VFR. Unsurprisingly, DuPage (KDPA) also sees an increase in the number of fulfilled operations (when compared against IFR operations), having 2,290 arrivals and 1,937 departures that meet both TLOF pad and gate constraints. This translates to roughly 77.2% of arrivals and 74.4% of departures out of the total unconstrained flight operations are fulfilled under VFR. Figure 10a shows fulfilled operations cluster mainly in the early mornings and late afternoon. Under VFR, the DuPage Airport (KDPA) aerodrome is able to fulfill 391 more arrivals and 298 more departures throughout the day. Furthermore, we observe the additional flight operations shifts the scatter



(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under VFR within 10-minute intervals showing dense flight operations during the early morning and late evening.



(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring during the early morning and late evening.

Fig. 10 Flight operations at the DuPage Airport (KDPA) aerodrome with TLOF pad and gate constraints under VFR.

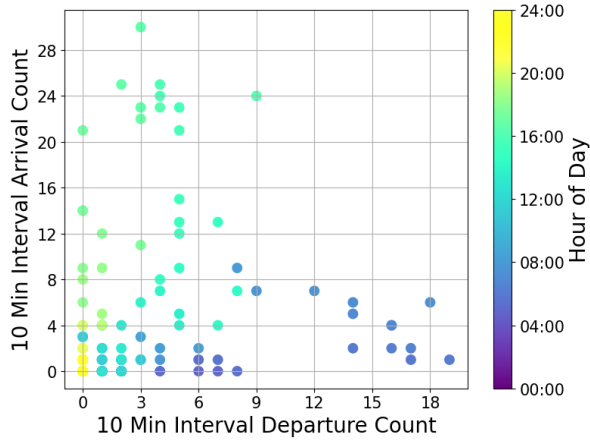
plots up-right, which is explained by the increase in operational capacity to fulfill the morning and evening rush hour commuting patterns. Figure 10b illustrates the frequency distribution of fulfilled arrivals and departures binned into 10-minute intervals, with eight instances of two arrivals and four departures during the late evening. The plot shows a broad spread of frequency showing sustained operations throughout the day. Similar to IFR operations, DuPage Airport (KDPA) shows a greater proportion of fulfilled operations than Vertiport Chicago Heliport (43IL), owing to more TLOF pads and gates.

Figure 11 shows an overview of flight operations at Kenosha Regional Airport (KENW) aerodrome with TLOF pad and gate constraints under VFR. At Kenosha Regional Airport (KENW), all 588 arrivals and 406 departures under VFR are accommodated within existing TLOF pad and gate constraints. This mirrors IFR operations, where only a single arrival was “unfulfilled” due to gate limitations. The distribution of flight operations within 10-minute intervals under VFR closely resembles that of IFR, indicating consistent traffic patterns.

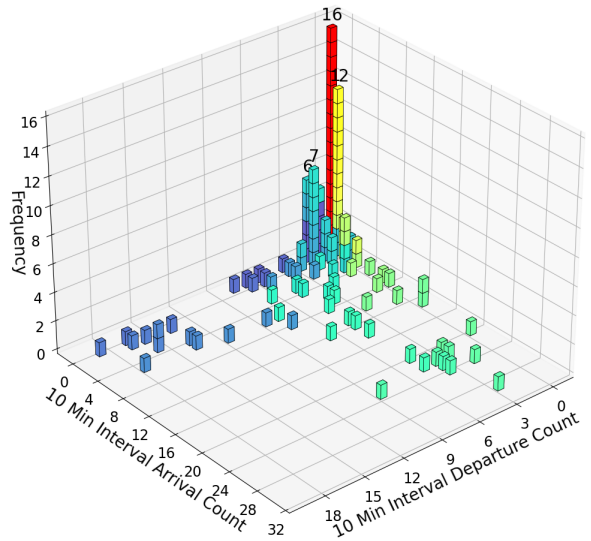
Kenosha Regional Airport (KENW) experiences pronounced peaks in arrival and departure activity during the early morning and evening hours, consistent with commuter behavior. Off-peak traffic is considerably lower, likely due to the aerodrome’s distance from the city center. Despite these fluctuations, all 588 arrivals and 406 departures under VFR are accommodated within existing TLOF pad and gate constraints, thanks to the airport’s sufficient infrastructure.

Figures 11a and 11b illustrate the frequency and distribution of fulfilled arrivals and departures in 10-minute intervals, with a peak of 33 flights during the early evening. These results highlight the concentration of operations around commuting hours and underscore the importance of infrastructure capacity during peak periods.

Figure 12 shows an overview of simulated flight operations at Tinley Park Heliport (TF8) aerodrome with TLOF pad and gate constraints under VFR. Under VFR operations, 516 arrivals and 447 departures meet both TLOF pad and gate constraints. This translates to roughly 15.88% of arrivals and 15.76% of departures out of the total unconstrained flight operations are fulfilled under VFR. Under VFR, the Tinley Park Heliport (TF8) is able to fulfill 172 more arrivals and 94 more departures during the day, compared to IFR. The increase in fulfilled operations occurs during the early morning and evening, indicating an increase in operational capacity to accommodate peak-hour demands. Figures 12a and 12b illustrate the frequency and distribution of operations binned into 10-minute intervals. We observe similar trends to those seen under IFR, such that peak operational activity occurs during the early mornings and late evenings, with up to 17 operations taking place within a single interval occurring in the evening.

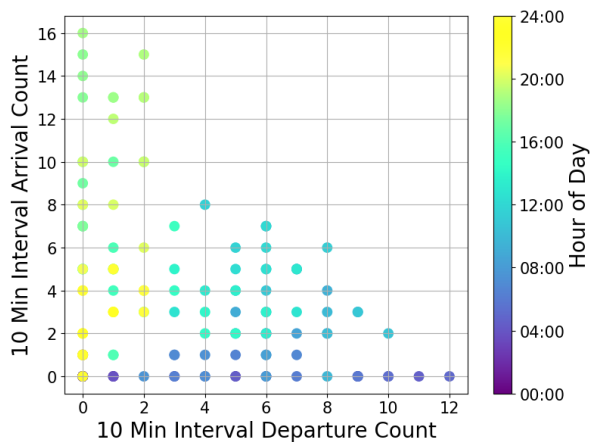


(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under VFR within 10-minute intervals showing dense flight operations during the early morning and late afternoon.

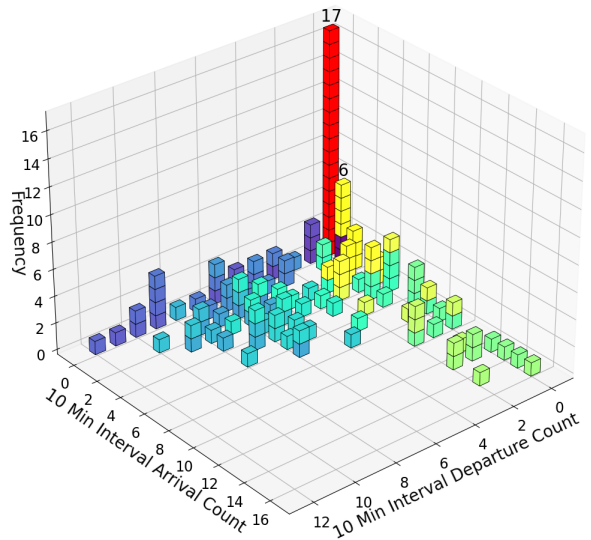


(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring during the early morning and late afternoon. The red bar indicates when there are no flight operations taking place.

Fig. 11 Flight operations at the Kenosha Regional Airport (KENW) aerodrome with TLOF pad and gate constraints under VFR.



(a) Fulfilled departures and arrivals under TLOF pad and gate constraints under VFR within 10-minute intervals, showing lower operational intensity in the late evening.



(b) Frequency bar chart visualizing the fulfilled departing and arriving flights that meet both TLOF pad and gate constraints, with most operations occurring in the early mornings and mid to late evenings. The red bar indicates when there are no flight operations taking place.

Fig. 12 Flight operations at the Tinley Park Heliport (TF8) aerodrome with TLOF pad and gate constraints under VFR regulations.

Table 2 Median, average, and peak flight operations (arrivals + departures) observed at different aerodromes in a ten-minute interval. There is a direct correlation between the number of TLOF pads and peak operations. Aside from Kenosha Regional (KENW), all other aerodrome locations reach saturation during peak congestion intervals.

Location	TLOF Pads	VFR			IFR		
		Median	Average	Peak	Median	Average	Peak
Lansing (KIGQ)	9	17	26	90	21	27	65
Tinley Park (TF8)	2	7	8	17	5	5	12
Bollingbrook (K1C5)	4	20	18	39	14	14	26
Midway (KMDW)	4	8	12	36	8	11	26
Vertiport Chicago (43IL)	3	12	12	28	9	9	19
DuPage (KDPA)	9	26	35	93	26	29	64
Schaumburg (K06C)	3	11	12	30	9	9	19
Chicago Exec. (KPWK)	6	31	27	65	21	20	42
Kenosha Regional (KENW)	8	4	8	33	4	8	33

Unsurprisingly, we see more fulfilled flight operations with both TLOF pad and gate constraints under VFR than under IFR. This is due to the inter-arrival time duration being 60 seconds less than IFR, enabling increased throughput activity during the day. As a result, the aerodromes have the capacity to handle more flights. The difference in inter-arrival time becomes highly influential during specific times of high-demand, allowing the aerodrome to accept more flights.

An example of increased capacity under VFR can be seen by comparing Figs. 8a and 12a for the DuPage Airport, where peak flight operations within the 10 minute interval decrease from 17 (two departures and 15 arrivals) under VFR to 12 (one departure and 11 eleven arrivals) during IFR, both seen during the evening (shown in light green). Similarly, under IFR, the Dupage Airport (KDPA) aerodrome has a peak operational capacity of roughly 64 flights, whereas under VFR, approximately 93 flights can operate within a 10-minute interval. All of this leads to the finding that when transitioning from IFR to VFR, more operations can be handled at aerodromes, which implies that an increased volume of operations are possible in the UAM transportation network. Another interesting result is that all aerodromes see a roughly 30% (actual values ranging between 28% and 36%) increase in “fulfilled” operations under VFR when compared to IFR operations**.

Table 2 summarizes the median, average, and peak number of operations per ten-minute interval for each of the nine aerodromes under study. The data reveal that peak activity at most sites is typically two to four times higher than the median or average throughput. This pattern reflects pronounced demand surges during specific periods of the day—particularly during morning and evening commuter peaks. As a result, aerodromes may need to be intentionally “oversized” to accommodate these short but intense bursts in activity.

Additionally, Table 2 provides some insights into the potential community impacts of UAM operations in this notional network. For the busiest aerodromes, Lansing and DuPage, there may be UAM aircraft taking off or landing nearly constantly during peak demand periods.†† These frequent operations may cause notable visual and audial disturbances to nearby businesses or residents that planners should consider when designing UAM networks. Additionally, the ground traffic around the aerodrome is likely to be impacted by many travelers arriving to the aerodrome in the peak demand times. Again taking Lansing and DuPage as examples, there may be up to approximately 370 individuals desiring to arrive at and traverse through the aerodrome in the same ten minute span, which is on average approximately one passenger every 1.6 sec. The design of the pick-up and drop-off locations as well as the aerodrome buildings themselves should consider these peak demand periods to allow for UAM passengers to easily and quickly transition between air- and ground-based modes without creating congestion on roads or in the aerodrome buildings.

Summarized results from this work appear in Table 3. This table introduces a new metric, operations per pad (Ops/pad), which represents the unconstrained demand normalized by the number of available TLOF pads. This

**with the notable exception of Kenosha regional airport (KENW), which has nearly no unfulfilled operations under IFR

††If evenly distributed, the 90 and 93 operations in a ten-minute interval would result in an aircraft taking off or landing approximately every 6.5 seconds.

metric enables the classification of the nine aerodromes into three broad categories: light demand (fewer than 400 operations per TLOF pad), moderate demand (up to 2,000 operations per TLOF pad), and dense demand (more than 2,000 operations per TLOF pad).

Table 3 Aggregate results summary showing fulfilled results for both IFR and VFR operations, divided based on arrivals and departures. Total arrivals/departures refer to the unconstrained ridesharing-enabled operations. % Fulfilled refers to the ratio of combined operations (both arrivals and departures) that met TLOF pad and gate constraints

Aerodrome Location	Total Ops/Pad	Arrivals			Departures			% Fulfilled	
		Total	IFR	VFR	Total	IFR	VFR	IFR	VFR
Lansing (KIGQ)	371	1741	1345	1720	1603	1393	1449	81.88%	94.77%
Tinley Park (TF8)	3043	3250	344	516	2836	353	447	11.45%	15.82%
Bolingbrook (K1C5)	1750	4049	914	1264	2954	721	921	23.35%	31.20%
Midway (KMDW)	348	702	546	635	690	576	633	80.60%	91.09%
Vertiport Chicago (43IL)	3341	3614	367	589	6409	613	747	9.78%	13.33%
DuPage (KDPA)	619	2968	1899	2290	2603	1639	1937	63.51%	75.88%
Schaumburg (K06C)	1067	1769	568	770	1433	376	526	29.48%	40.47%
Chicago Exec. (KPWK)	1484	4581	1271	1766	4328	1192	1540	27.65%	37.11%
Kenosha (KENW)	124	588	587	588	406	406	406	99.90%	100.00%

Considering these three families, we can observe a trend. For light demand locations—Kenosha Regional (KENW), Midway (KMDW), and Lansing Municipal (KIGQ)—over 80% and 90% of the operations are fulfilled under IFR and VFR respectively. For moderate demand locations—DuPage (KDPA), Schaumburg (K06C), Chicago Exec. (KPWK), and Chicago Bolingbrook (K1C5)—over 23% and 30% of the demand is met under IFR and VFR operations, respectively. Finally, the dense demand locations—Vertiport Chicago Heliport (43IL) and Tinley Park Heliport (TF8)—are the most constrained, where only about 9% and 13% of the demand is fulfilled under IFR and VFR operations respectively.

Aggregating the net throughput across all modeled aerodromes provides a first-order indication of how ground infrastructure limitations may suppress achievable operations across the full UAM network. In the absence of any aerodrome throughput constraints, our demand modeling indicates a total of 92,739 passenger-trips (also referred to as UAM-preferred trips) on 23,262 flights. These are termed "total flights" in this work.

Given that this study does not incorporate network-level feedback effects and treats each aerodrome independently, a precise estimation of trip fulfillment across the network is beyond the scope and fidelity of this approach. Specifically, this modeling framework does not capture interdependencies between origin and destination aerodromes. For instance, the model may deem a flight from Aerodrome A to B as fulfilled based solely on aerodrome B's ability to accept an arrival, while ignoring the possibility that aerodrome A may lack the availability to dispatch the flight at the corresponding time. In a real-world system, such infeasibilities would trigger dynamic reallocation of resources—potentially allowing another trip to take place instead. However, our model does not resolve such cascading effects, and as a result, the network-level estimates presented here should be interpreted as a simplified, upper-bound scenario.

Despite these limitations, these initial metrics offer valuable insights to at an early planning stage. Our estimation suggests that only approximately 34,310 passenger-trips on 8,606 flights could be fulfilled under VFR operations, and 30,363 passenger-trips on 7,269 flights under IFR operations—representing reductions of 63% and 69%, respectively, due to aerodrome throughput limitations^{‡‡}. These findings highlight that aerodrome throughput can serve as a significant limiting factor on UAM network capacity. Moreover, as the current estimates do not account for additional dynamic or operational constraints, actual realized operations may be lower than the values reported here.

C. Sensitivity of Throughput to Gate Availability

In this work, we adopt the heuristic of four gates per pad to estimate the number of gates available at each location, derived from Ref. [37] as discussed above. Given that the number of pads is typically constrained by available space

^{‡‡}Since the average load factors are comparable across total and fulfilled operations, the percentage reductions apply to both passenger-trips and flights.

and that, at this early stage of UAM design and operations, specific dimensions or design constraints for gates remain undefined, this metric serves as a practical baseline for calculating throughput. However, this simplification does not capture location-specific characteristics and may not be appropriate in all contexts. To address this limitation, we conduct a sensitivity analysis by repeating the throughput calculations using two alternative assumptions: two gates per pad (50% lower than the baseline) and six gates per pad (50% higher). The results of this analysis are presented in Fig. 13.

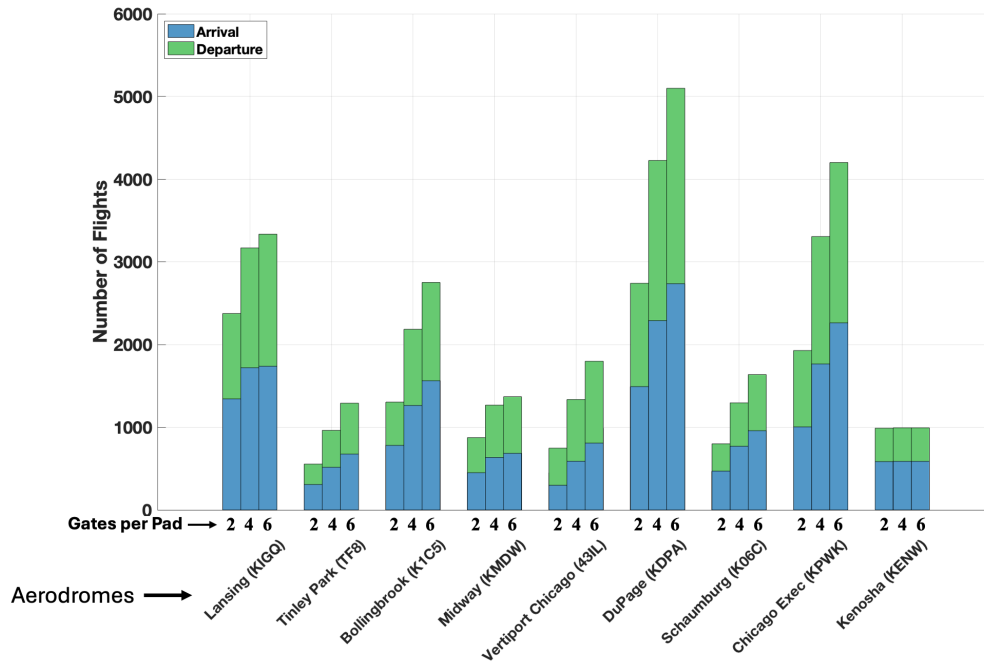


Fig. 13 Bar plot showing the different results from assuming two (left), four (center) or six (right) gates per TLOF pad. The middle bar (four gates per TLOF pad) is the baseline referenced in all the figures shown previously. Note that every aerodrome except Kenosha Regional is gate constrained, so adding more gates can aid throughput.

Figure 13 shows some interesting characteristics. The height of the bars shows the number of fulfilled operations. For instance, at Lansing Municipal Airport (KIGQ), increasing the number of gates per pad from four to six results in a moderate increase in throughput, suggesting that this location is not significantly gate constrained. In contrast, locations such as Tinley Park Heliport (TF8) and Vertipport Chicago Heliport (43IL) experience substantial increases in throughput under the same change, indicating that gate availability is a significantly limiting factor at these sites. These two aerodromes have significant space limitations, which will make increasing the number of pads very difficult; consequently, adding additional gates, which require less physical space than TLOF pads, at these locations may be a viable strategy to improve throughput. Note that the added gates are theoretical if space is not available.

At Chicago Midway International Airport (KMDW), increasing the number of gates per pad yields only a modest improvement in capacity, implying that pad availability—not gate count—is the primary constraint. A similar, albeit less pronounced, pattern is observed at Schaumburg Regional Airport (K06C). Kenosha Regional Airport (KENW) presents a different case: changes in the number of gates per pad have virtually no impact on throughput. This suggests that Kenosha currently has more gates than it requires and could potentially operate efficiently with fewer gates.

These findings also track with our previous discussion on light demand, moderate demand, and dense demand aerodrome locations. We observe that increasing the number of gates per TLOF pad has a marginal impact on light demand locations, but boosts capacity significantly in moderate demand and dense demand locations. This indicates that having more gates in tightly constrained locations could improve throughput significantly. Though these results seem trivial, the data provide quantitative insights to intuition and anecdotes about the relative impact of infrastructure needs on demand and simulated operations.

V. Summary and Conclusions

This analysis estimates the number of operations at an aerodrome based on considerations of site-specific infrastructure and notional visual flight rules (VFR) versus instrument flight rules (IFR). Depending on the layout and demand characteristics, some aerodromes were found to be pad-limited, whereas others were gate-limited. Notably, the results suggest that locations where each TLOF pad is expected to serve no more than 600 to 700 operations per day can still accommodate a significant portion of the total demand.

Ridesharing patterns further shaped operational dynamics by clustering flights into short bursts—typically aligning with commuter travel patterns in the early morning and late afternoon/evening. These concentrated demand peaks intensified bottlenecks at aerodromes. In all modeled cases, throughput constraints prevented any site from fully meeting 100% of the demand under high-frequency scheduling assumptions under IFR.

Flight conditions played a critical role in achievable throughput. Operations under VFR consistently supported higher throughput compared to IFR. The primary contributor was the reduced separation requirement: VFR allowed for 60 seconds shorter spacing between arrivals, effectively increasing capacity by up to 150%. For example, Tinley Park Heliport (TF8) could accommodate up to 12 operations per peak interval under IFR, but up to 17 under VFR—a 142% increase.

Overall, considering gate and TLOF pad constraints, this work provides a first order estimation of network-level metrics across the Chicago ten-aerodrome network. This work estimates that about 63% (VFR) and 69% (IFR) of total operations may remain “unfulfilled” when considering throughput limitations. Although our first-order, independent-site approximation likely overestimates network performance, it highlights the urgency of optimizing TLOF pad-gate combinations and overall aerodrome sizing to avoid severe bottlenecks in future UAM deployments.

We also conducted a bounding study to evaluate the heuristic of allocating four gates per TLOF pad. The results confirmed that this 4:1 ratio was generally appropriate for “light demand” sites (less than 400 operations per TLOF pad). However, for space-constrained, “dense” urban locations—such as Tinley Park (TF8) and Chicago Heliport (43IL)—substantial gains in throughput were achieved by increasing to six gates per pad, indicating that the 4:1 heuristic may underestimate gate requirements in high demand, inner-city environments. Even “moderate demand” locations showed some improvements with increased gate counts, although eventually throughput became limited by pad availability rather than gate count. Thus, although the 4:1 rule serves as a reasonable starting point for suburban aerodromes, it may need to be revised upward for compact or high-traffic sites.

Finally, the temporal distribution of operations revealed sharp disparities between average and peak throughput. Across all sites, most ten-minute intervals experienced only a few operations, punctuated by brief but intense surges. For instance, Kenosha handled 994 flights in a day—an average of approximately 7 operations per 10-minute interval, if spaced uniformly—but reached as high as 33 operations in a single 10-minute interval. Similarly, DuPage’s 4,227 VFR flights average to about 29 operations per interval, if divided equally, but peaked at 64 under VFR conditions. These findings underscore a key planning challenge: designing for average demand may lead to routine overloading during peaks, whereas sizing infrastructure to handle peak loads could leave it underutilized for much of the day. In sum, planners must recognize that short-term demand surges can exceed the average throughput by factors of at least two to four, and these fluctuations must be considered when planning and sizing for vertiport facilities.

A. Appendix

Figures 14 through 18 depict the hypothesized locations of TLOF pads (drawn to scale) across five aerodromes of interest. In each figure, blue squares represent the approximate positions of the TLOF pads and their associated safety areas, each measuring 200 ft by 200 ft—the minimum separation required to support simultaneous VTOL operations [35]. The TLOF pads themselves would be 50 ft by 50 ft squares located in the center of the blue squares. The greyed-out regions indicate exclusion zones near active runways where VTOL operations are prohibited. An exception is made for Vertiport Chicago Heliport, where the greyed-out area reflects unusable space due to height restrictions imposed by a nearby rail viaduct. Approach and departure vectors, indicated by arrows at each TLOF pad, follow FAA regulatory guidance [34]. The aircraft must take off outside the shaded area.

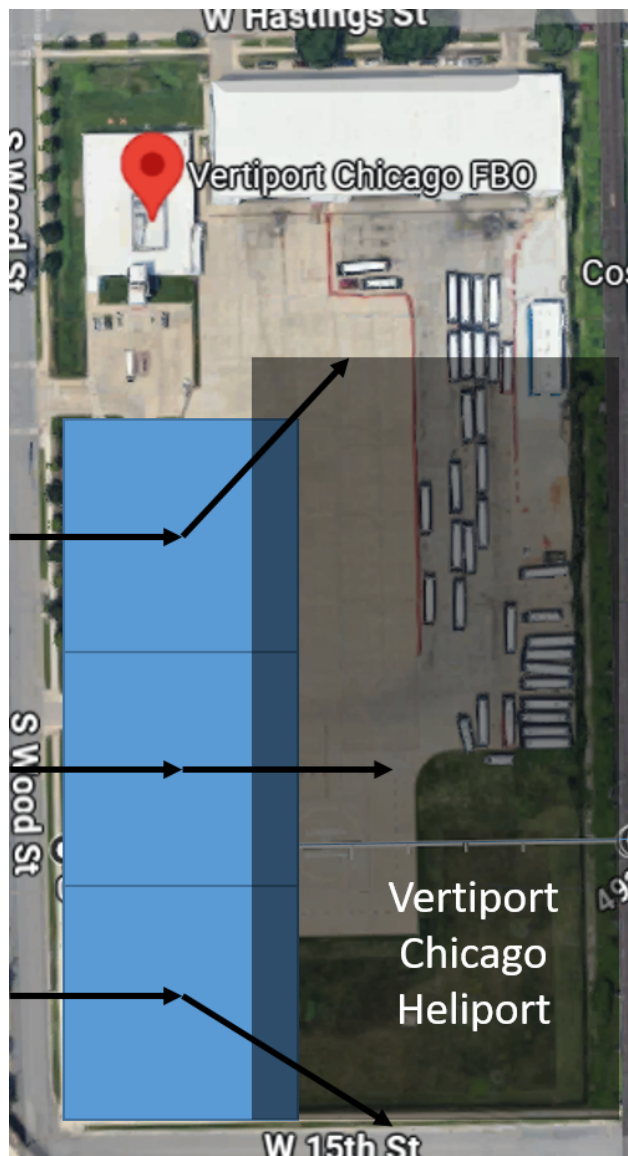


Fig. 14 TLOF pad locations for Vertipoint Chicago Heliport. The black shaded section represents a 400 ft distance from railway tracks (located just outside of the right side of figure). The black shaded area overlaps with the safety area of the TLOF pad. Maps data: Imagery ©2025 Google, Imagery ©2025 Airbus, Maxar Technologies, Map data ©2025



Fig. 15 Chicago Executive airport showing the location of six TLOF pads, each with independent approach and departure vectors. Maps data: Imagery ©2025 Google, Imagery ©2025 Airbus, Maxar Technologies, Map data ©2025

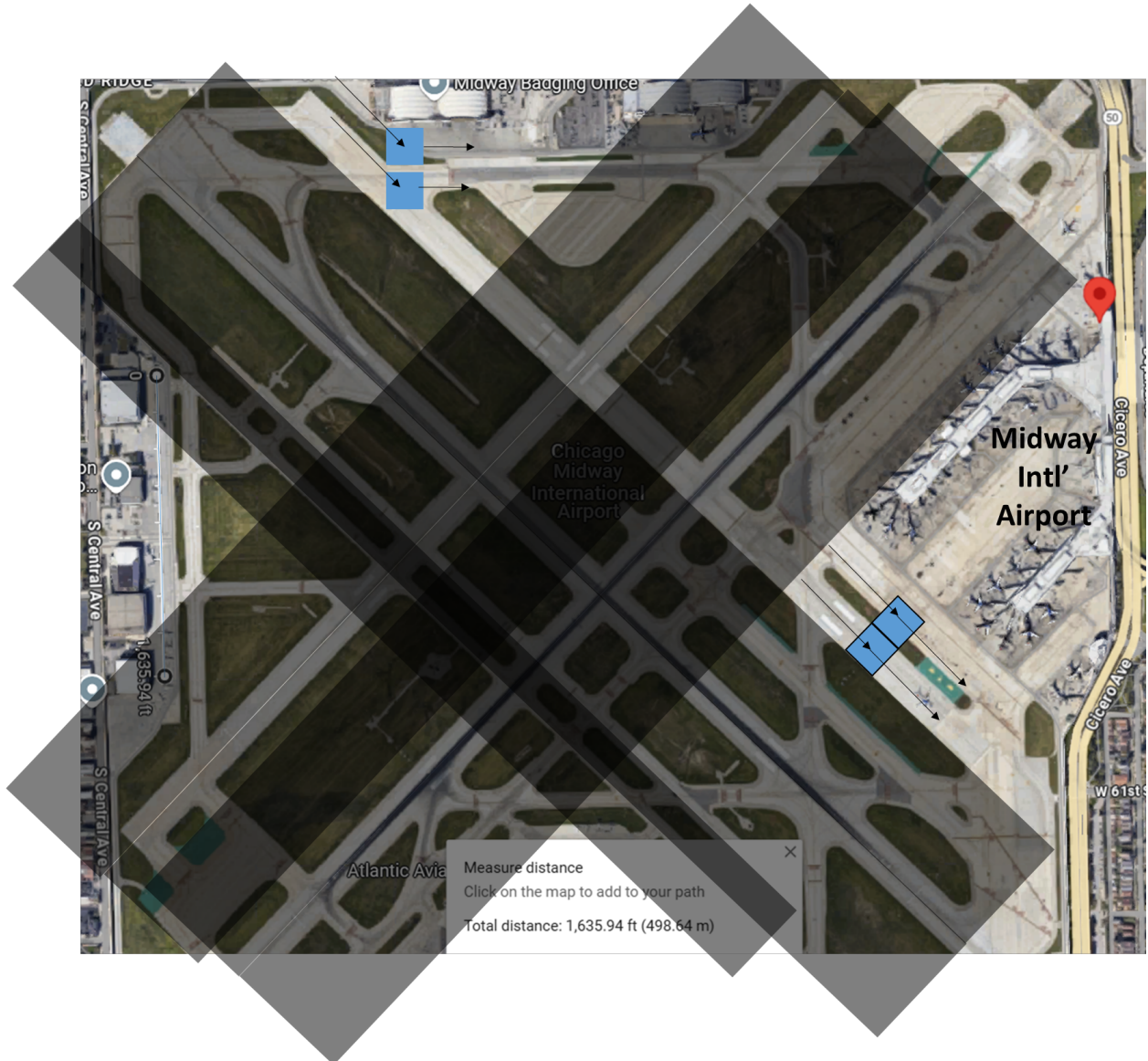


Fig. 16 TLOF pad locations for Midway airport. Despite having a large land area, the runway exclusion zones, and the requirement for independent approach and departure vectors constrain the number of pads. Maps data: Imagery ©2025 Vexcel Imaging US, Inc., Imagery ©2025 Airbus, Maxar Technologies, Vexcel Imaging US, Inc., Map data ©2025

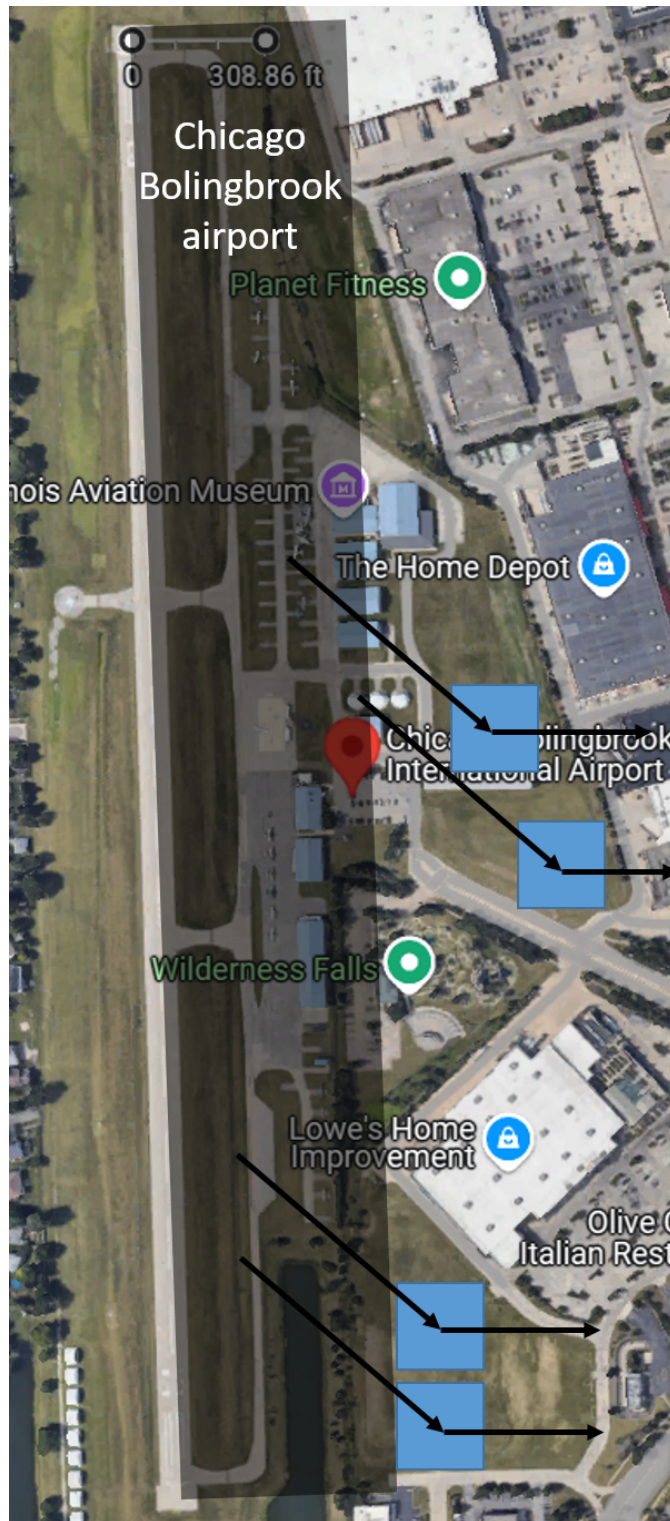


Fig. 17 TLOF pad locations for Chicago Bolingbrook airport. The runway is located quite close to the terminal and the taxiways, which prevents constructing TLOF pads near the airside facilities. Maps data: Imagery ©2025 Vexcel Imaging US, Inc., Imagery ©2025 Airbus, Maxar Technologies, Vexcel Imaging US, Inc., Map data ©2025



Fig. 18 TLOF pad locations for Kenosha Regional airport. The relatively low demand and large number of TLOF pads (eight), result in this aerodrome being relatively unaffected by throughput constraints. Maps data: Imagery ©2025 Google, Imagery ©2025 Airbus, Maxar Technologies, Map data ©2025

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