Designing Efficient Taxi Pickup Operations at Airports

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This paper provides a practical procedure for designing efficient taxi pickup operations at airports. How to do this effectively is an open question. Solutions are not available, and practices vary. They reflect different approaches to and lack of research on the subject. The solutions are often unsatisfactory. At many airports, passengers routinely suffer long waits outdoors, exposed to the elements, after a tiring journey. Such disagreeable experiences are avoidable. Designing efficient taxi pickup operations at airports is problematic. The peculiarities of the process preclude easy solutions. First, the process involves queuing, so system performance is a nonlinear function of the loads. Second, it features unstable transient situations, since travelers typically arrive in bulk over short periods. Third, traffic is significantly differentiated and consists of a wide variety of groups implying different service characteristics. Standard results from queuing theory thus do not have a useful application to this problem. The design process uses simulation that is based on detailed observation of local practices. It involves four steps: (a) detailed local measurements of the arrival of both travelers and taxis, and the service rates provided by taxis in different queuing positions; (b) creation and validation of a simulation model sufficiently detailed to account for these realities; (c) exploration of design alternatives to estimate the characteristics of the service they would provide; and (d) selection of a preferred design that properly balances efforts to minimize average and extreme wait times. The paper demonstrates the procedure through application to Lisbon International Airport, Portugal.

Taxi pickup operations at airports are sources of frequent complaints. Passengers seeking taxis to complete their journeys routinely have long waits outdoors, exposed to the elements, after a tiring journey. For example, international passengers arriving in Boston, Massachusetts, wait outside, perhaps in rain, wind, or snow, for taxis to arrive sporadically from a lot about 2 km away. Even when taxis are available, travelers cannot board them rapidly because of the design of the boarding area. Similarly, passengers arriving in Lisbon, Portugal, can easily queue for 20 min even though the taxi pool is full and only 100 m away.

The problem of designing efficient taxi pickup operations is important at airports where taxis service a significant fraction of the arriving passengers. Taxi operations are most important for airports close to their cities, particularly where public transit is either minimally available or provides poor service to travelers with bags, as La Croix et al. (1) and Cardon (2) have documented. Boston and Lisbon are good examples of this situation, along with Bangkok, Thailand; Chicago, Illinois; Delhi, India; New York; Paris; Singapore; Sydney, Australia; Toronto, Canada; and many others. Figure 1 illustrates the importance of taxi operations at selected airports.

No coherent guidance is available on the design of efficient taxi pickup operations at airports, despite the prevalence of the issue. Essentially no information is available on the topic. As a practical matter, the international standard design manual (4) and major textbooks (3, 5–8) do not address the efficient design of taxi service, passenger waiting areas, or their interface.

This paper proposes a coherent, practical approach for designing efficient taxi operations. It deals with the entire problem: collection of data, analysis, and meaningful presentation of results to airport decision makers. It consistently deals with the reality of transient queuing processes. As demonstrated by the applications, the method is practical. Specifically, the method provides a process for

• Gathering the data needed for characterizing taxi pickup operations,
• Calibrating the data to peculiarities of the local situation,
• Extrapolating this reality to alternative designs, and
• Presenting the impacts of alternative designs by using a range of metrics (such as average and maximal wait times and the reliability of the process).

The proposed method provides airport managers with the kind of information they need for making informed decisions about how to design their taxi operations for local conditions.

CURRENT PRACTICE

Given the lack of detailed guidance, it is not surprising that airports have adopted a hodgepodge of designs and practices for taxi operations. Airports variously line taxis up in single, dual, or even triple files for queues in front of passengers (Figure 1). Single-file arrangements are most common. Dual files, as at Ronald Reagan Washington National Airport (Virginia) and Lisbon, have the advantage of offering the waiting passengers more taxis close to the head of their queue. Some airports, such as Singapore or Paris Charles de Gaulle Terminal 1, use parallel loading, which permits taxis to exit their queue when they are ready without waiting for other taxis to complete their loading process.

Airport practices also differ in how they treat the passengers waiting for taxis. Some allow passengers to board from multiple points;
others force them to pass through a single point of access. Some airports let passengers go directly to available taxis as they arrive, and others, such as Boston’s airport, constrain passengers to wait behind a barrier until a new batch of taxis is in place.

In short, there is no agreement on how to design and operate taxi pickup operations. While different solutions may be preferable for different situations, it is safe to say that prevailing practices typically are historical legacies rather than the result of conscious analysis and consideration.

**NATURE OF THE PROBLEM**

The design of efficient taxi pickup operations at airports is technically challenging. The analysis is conceptually difficult, and the problem does not allow for closed-form solutions. These facts help explain why general solutions are not available. Understanding these difficulties points the way to development of an effective procedure for defining efficient designs.

The analysis of taxi pickup operations is conceptually difficult because it involves queuing. That is, people arrive looking for service (to board a taxi), they queue up where service is offered, and exit the process (when they leave in a taxi). The essential difficulty with a queuing problem is that its performance depends significantly and nonlinearly on the state of the system.

First, the level of delays and the length of the queues depend on the relative load on the system. Both the delays and the unreliability of the system in steady state increase rapidly as the rate of arrivals nears its nominal capacity (Figure 2a). Furthermore, the nonlinearity increases as the rate of arrivals at the point of service becomes more irregular (Figure 2b), as Equations 1 and 2 define for a Poisson arrivals process.

An expression for this nonlinearity in steady state is as follows:

\[
W_s = \frac{\lambda \left[ \frac{1}{\mu} + \sigma^2 \right]}{2(1 - \rho)} = \frac{\lambda \left[ E(t) + \sigma^2 \right]}{2(1 - \rho)}
\]

\[\text{(1)}\]
where
\[ W_q = \text{expected waiting time in queue}, \]
\[ \lambda = \text{average rate of arrivals}, \] and
\[ \mu = \text{average rate of service}, \] that is, the nominal capacity of the system.

Therefore \((1/\mu)\) is the expected value of the service time, \(E(t)\).

In addition, \(\sigma_t\) is the standard deviation of the service time. Finally, 
\(\rho\) is the utilization ratio:

\[ \rho = \frac{\lambda}{\mu} = \frac{\text{average rate of arrivals}}{\text{nominal capacity of system}} \quad (2) \]

As Equation 1 shows, when the rate of arrivals approaches the nominal capacity of the system, so that \(\rho\) comes close to 1, \((1 - \rho)\) comes close to zero, and delays increase rapidly.

This phenomenon leads counterintuitively to the fact that the “practical capacity” of the system—that is, the quantity of arrivals that can be served within acceptable delays and levels of reliability—is substantially less than the nominal capacity. Specialists understand this phenomenon, which provided the basis for the old definition of the capacity of runways as their ability to handle arrivals with less than a stated number of minutes of delay \((10)\). Yet managers often miss this reality since they wrongly assume that a service system will operate satisfactorily up to its nominal capacity. The designers of the automated baggage system for Denver International Airport, Colorado, failed to account for this and were dismayed that their system became too unreliable—and thus effectively at practical capacity—whenever loads exceeded about 40% of its rated capacity \((11)\).

The analysis of taxi pickup operations is further complicated because it involves transient loads, that is, a fluctuating rate of arrivals for service. The rate at which travelers arrive at taxi stands varies significantly over the course of a day as flights arrive. Periods of intense demand follow long slack periods. The resulting queuing process is thus rarely in a steady state. There is then no closed-form description of the queuing process of the kind provided in Equation 1. Theoretical queuing analysis is thus not useful.

Finally, the analysis is difficult because the stream of passengers arriving for taxi service is highly differentiated. Customers arrive in groups of various sizes and capabilities of dealing with the taxi boarding process. A single business traveler may hop into a taxi and move on quickly. However, a family of foreigners on vacation will require much more time to load their bags and try to direct the driver. Thus, the taxi pickup system provides service for different groups at varying rates. Queues for taxi operations are distinct from other queuing operations in airports in which travelers come in groups but are processed as individuals, for example at security checkpoints.

In addition, the rate at which taxis can provide service depends on their position in the queue. Specifically, the rate at which a taxi in a line can complete service (as by leaving the queue) usually depends on the speed at which the taxis ahead of it provide service. This point is particularly important for the design of taxi pickup operations.

In summary, the nature of taxi pickup operations at airports precludes theoretical analytic solutions. Furthermore, since the processing rate of the operation depends both on the kind of passenger group being served and the position of a taxi in the queue, an analysis method that is sensitive to such details is needed. A general, all-purpose model will not do. Analysts therefore depend on some form of detailed simulation calibrated to the realities of a specific situation. That is the approach presented in this paper.

**REVIEW OF LITERATURE**

This section reviews the elements relevant to the design of taxi pickup operations at airports:

1. Analyses of taxi pickup operations,
2. Practical guidance about managing queues,
3. Approaches to dealing with transient queues, and
4. Pertinent topics in simulation.

**Analyses of Taxi Pickup Operations**

None of the standard airport design textbooks or manuals analyzes taxi operations. There appear to be only four reports on the subject within the open domain:

1. Lee \((12)\) presented a detailed analysis of the West London Air Terminal. His work stresses the necessity of carefully examining the behavior of arrivals and service time, in particular the distribution of groups of passengers that translate into single taxi hires and trips.

2. Curry et al. \((13)\) modeled the transient buildup and dissipation of taxi and bus queues at Dallas–Fort Worth International Airport, Texas. They approximated the transient arrivals as a series of steady-state cases and used them to calculate expected wait times and other measures of performance. They did not suggest a procedure for analyzing alternative ways of designing taxi operations.

3. Costa \((14)\) analyzed taxi operations in detail at Lisbon International Airport. This paper reports on these results, as extended by his subsequent work as an employee of ANA—Aeroportos de Portugal, SA, the Portuguese airport operator.

4. On the basis of Costa’s work, Ferreira et al. \((15)\) tested a proposed alternative design of taxi operations at Lisbon International Airport though closed-form formulaic approximations for important system characteristics.

**Practical Guidance About Managing Queues**

For the design of taxi pickup operations, perhaps the most important guidance from queuing theory is the idea that operators can improve overall service by providing differentiated service to customers with distinct service times. This is the principle behind express lanes for customers who can be served quickly at checkout counters, as at grocery stores. Fast lanes expedite service and shorten overall wait time and queue length.

Operators can provide better service where they can implement the equivalent of fast lanes. At airports with heavy traffic, they can sensibly have multiple pickup points that separate destinations, for example, between central business areas and suburban destinations. This approach is common practice for regional bus service in many hub airports, notably at Narita International Airport, Tokyo, and Incheon International Airport, Seoul, South Korea. In these cases, passengers queue in different positions along the curb, each assigned to specific regional destinations.

Analysts often forget that seemingly trivial changes in processing arrangements can have substantial effects on overall performance. Saving 15 s per operation might appear insignificant, but when these operations take 2 to 3 min to execute—as is the case for many airport services and, specifically, taxi pickups—such savings can increase total capacity by about 10%.
Positioning customers from a long queue in front of the place where they receive service is particularly relevant. At busy airports, the U.S. immigration services thus now direct international arrivals from a single snake queue into secondary queues just in front of the kiosk of the examining officer. This practice minimizes the time between one customer exiting service and the next appearing. It contrasts with the more general situation, as at check-in counters, where customers may not leave the head of the snake queue until they notice that one of the service channels is open. When the open channel is 10 m or more away, as easily happens at busy airports, customers will take time both to notice that the service is available and to move to the service agent. As a result, the agent has more time between customers and provides lower capacity, and the performance of the entire service process is less than it could be. The lesson is that the design of taxi operations should pay close attention to details that can expedite service and improve performance.

Newell’s Approach to Dealing with Transient Queues

Newell (16) developed a practical way to estimate the service quality provided by service systems under transient loads. His approach assumes that as traffic builds up, it is served without delay until arriving traffic equals the prevailing capacity of the service system. Further traffic is served at the rate of this capacity, and customers in excess of this capacity accumulate in a queue and are eventually served as the number of customers arriving for service becomes less than the prevailing service capacity of the system. The concept leads to a simple graphical analysis. Figure 3 illustrates the approach on the basis of Costa’s data from Lisbon. As indicated, the vertical distance between the arrivals and the service defines the queue length, and the horizontal distance approximates the wait time.

Newell’s approach is quick and convenient. It provides a means of estimating the effect of changing service rates, for example by opening or closing check-in counters or security inspection lanes. Its drawback is that it only works with a specific scenario. It does not provide guidance on the distribution of wait times or the unreliability of the system. This approach thus does not help managers understand the practical capacity of a particular design of a service system, nor does it give information about the frequency of unsatisfactory service, which may define the overall acceptability of a design.

Pertinent References in Simulation

Simulation is now widely invoked as a means of studying and improving landside and airside airport operations. Analysts commonly use it to study bottlenecks in airport terminals, both in advance of construction and afterwards, once problems have arisen. Common applications include check-in processes and security inspection stations. Mumayiz and Schonfeld (17) provide a collection of applications,
which include those of Bender and Chang (18) and Hathaway (19) for roadway operations. Generic computer-based simulations are easy to code, and many versions are available. They are not generally of much use in analyzing operations, however. This is because the output of plain vanilla simulations can be difficult to understand or appreciate. Providers of simulation services thus spend considerable time in preparing attractive visual images, typically in a video, to illustrate their simulation. These graphical capabilities differentiate the simulations in the marketplace. They are proprietary and unavailable for public discussion. Good graphics help sell simulations to customers. However, they do not in themselves make the simulation analytically valuable.

The fundamental difficulty in applying simulations to people lies in describing the flows correctly. Understanding how the flows occur is important. They are typically complicated. People are not like parts in an assembly line that flow in straight paths from entry to exit. People wander around between processes. Between check-in and the security inspection, they may buy a magazine or say goodbye to loved ones, for example. Understanding the complexity of these flows is crucial in creating effective simulations. Simulations prepared by persons who are not deeply familiar with airport operations can easily be misleading, because they are naive about how flows actually occur.

Complementarily, truly effective simulations depend on having good data about the details of the arrivals. As Lee (12) stressed long ago, many processes are affected by how customers arrive in groups. Are they single or with family or friends? Are they frequent fliers who know their way around and proceed expeditiously, or are they encumbered or proceeding with difficulty? These factors can significantly affect the overall process. For this reason, aggregate data about the number of customers per hour or the distribution of arrival times are not sufficient for defining effective simulations of airport operations. This fact motivates the proposed process for analyzing taxi operations.

PROPOSED PROCESS

The proposed process for analyzing taxi operations has four steps:

1. Detailed measurement of arrivals (size and number of groups, interarrival times) and of service characteristics (the way loading times and exits from queue depend on configuration of service and relative position);
2. Creation and calibration of the simulation model to the specifics of the operation;
3. Exploration of alternatives by applying the calibrated model to alternative designs; and
4. Choice of the preferred design, which is a choice between alternative distributions that involves multiple criteria—one that considers possible extremes as well as average wait time.

Step 1. Detailed Measurement of Arrivals and Service Characteristics

Passengers arrive at the taxi pickup points singly and in groups. Furthermore, the groups do not arrive regularly but are spread out over time. An obvious first step is to observe the sequence of persons arriving at the taxi stand. The distribution of groups is almost certain to be different from that of groups in other operations, such as security checkpoints, because people self-select for taxi service. For example, groups may prefer taxis because the cost per person is low relative to that of individual travelers, which makes taxi service a more attractive value proposition for groups.

The taxi arrivals process must also be observed carefully. It decisively influences the availability of service, which significantly affects passenger queuing times and queue lengths. The replenishment of taxis at the service area might be based on a group distribution or subject to a time lag as taxis drive from central holding lots to the specific terminal on a demand-driven basis. Taxis might also arrive in large numbers and cause traffic congestion on curb-side roadways by forming long queues of vehicles exceeding the capacity of the waiting areas. Measurement of the arrival times and sizes of groups at the taxi stand, both for passengers and for taxis, is necessary.

Obtaining good data on the service process is more complicated because each position in a queue of taxis picking up passengers typically has its own service characteristics. They depend (a) on the distance between the taxi’s position in the queue and the head of the queue of passengers, which influences the time required for boarding its passengers, and (b) on its position in the queue, which determines how long it must wait for the taxis ahead of it to leave and thus permit it to complete the pickup service. Furthermore, the service time depends on details of how the taxis locate themselves in the queue, the way the lanes are marked off, the pattern of police or other enforcement, and so on. In general, the process of collecting data on the taxi pickup process requires two phases. The first is a period of observation to identify the local particularities of the process to know what one should be measuring. That done, analysts can devise an effective plan for measuring the service process, which should consider simultaneous observation of interarrival times and service times during any given period for better estimation of queue lengths and in-queue waiting times.

Step 2. Creation and Calibration of Simulation Model

Any simulation model is an assembly of basic modules, such as those depicting arrivals of customers for service in a queue, the service process, and departures from service either to a holding area or to another queue. Creation of a suitable simulation model for taxi pickup operations depends on having a good understanding of the nature of the flows at this location. This understanding is obtained through Step 1. Once analysts have it, the creation of the simulation model is obvious.

The calibration of the model is tricky. Since the measurements of the system include the determining elements of the queuing process (the arrivals and service rates), a correctly assembled simulation should reproduce observed results such as the queue lengths. However, this is often not the case. The initial measurements in Step 1 may have missed some factor that caused the distortion. Analysts should determine the cause of such discrepancies by observation and subsequently adjust the simulation until it represents observed behavior reasonably well.

Step 3. Exploration of Alternatives

Given a simulation model satisfactorily calibrated to local behaviors of passengers and taxi operators, the analyst can explore and
compare alternative designs of taxi operations. This evaluation should consider the range of possible inputs and outputs.

The prospective performance of the pickup system should be considered under various levels of loads and patterns of demand. This is because queuing systems are nonlinear, and queue lengths and waiting times are likely to increase much faster than the level of loads (Figure 2). Furthermore, because taxi operations are subject to fluctuating loads, they are rarely in steady state: they are sensitive to the precise pattern of arrivals for service. In short, pickup operations may exhibit widely different performance in terms of queue lengths and wait times for the same average hourly or daily level of traffic, depending on whether arrivals are spread smoothly over the period or are clumped together.

Complementarily, the analysis should recognize that different designs produce different distributions of performance—some will be more reliable (have lower variance) than others. These differences matter. Customers are bothered both by delays and by their unpredictability. Therefore, analysts should consider not only average performances of alternative designs but also the range of performance. Note that the standard deviation in this context is not an especially useful concept, because performance is asymmetric: good performance is limited to zero delays and queues, whereas bad performance can deviate greatly from the average. It is more appropriate to refer to maximum and minimum performances, especially for decision makers who may not appreciate technical terms.

Step 4. Choice of Preferred Design

In the context of uncertain outcomes, such as those resulting from queuing systems, it is generally best to refer to preferred rather than best designs (20). This is because measures of performance and of cost reflect different, incomparable units. While delays and service unreliability can both be considered undesirable, agreement on how to compare these units—let alone give them a monetary value—is unlikely. In the absence of an agreed-on way to weight the various characteristics of any alternative, defining an unambiguous best design is impossible. Reference to preferred designs, those whose combinations of attributes stakeholders prefer, is more appropriate. Furthermore, what constitutes acceptable performance differs from country to country and from airport to airport, and even between terminals at the same airport, as when different airlines desire a higher level of service or cheaper service according to their business models. Therefore, a decision as to service standards is not up to the analyst. Owners and managers of airport facilities set their own goals.

The analysis must recognize that designs that the decision makers prefer may differ substantially from those the analyst favors. Decision makers may be more sensitive to costs, for example, or particularly responsive to unreliable service. This fact implies that analysts should provide decision makers with data on the range of performance for the several alternatives.

CASE APPLICATION: LISBON INTERNATIONAL AIRPORT

Costa (14) developed and applied the proposed process at the Lisbon International Airport in cooperation with the airport operators, ANA. Although conditions differ from airport to airport, this case demonstrates the usefulness of the process and reports on the specific findings.

The analysis included assumptions and modeling options based on local conditions:

- Absence of supply shortage: The supply of taxis was considered to be constant, even during off-peak periods. This was based on observations that the number of available taxis varied negligibly during the day, month, and year. Elsewhere, this is not usually the case. Shortage of taxi supply is a key issue at many large airports and leads to increases in service times and waiting times for passengers.
- Service times were measured per server as the total time elapsed between service availabilities. Service time includes loading time (the interval between a passenger leaving the queue and the time the taxi starts moving) and empty time, when no taxi is available at that position. This allows for the implicit consideration of service position interdependence effects, which often translate into delays caused by blocking vehicles. It also includes the maneuvering and travel times of taxis that come from the back and delays caused by other exogenous factors.
- Zero travel times between the taxi parking lot and the taxi stand: In Lisbon, taxis move sequentially along a segregated lane that provides access to the inner curbside area, transforming it into an extension of the central taxi parking lot. This is not the general rule in most airports, where variations in travel times between taxi pools and terminals can lead to significant delays and passenger queues.

Step 1. Detailed Measurement of Arrivals and Service Characteristics

The main taxi pickup operation at Terminal 1 (arrivals) features two rows of taxis, each having two taxis providing service at any time. The rows are located between the main terminal sidewalk and the secondary sidewalk, which separates this space from the bus stops and private vehicle pickup areas. Taxis feed into these rows from a single file constantly replenished from the taxi pool about 100 m away. Customers line up in a snake queue whose head is at the top of the taxi row (see Figure 4).

Data collection involved two observers. One monitored the performance of the taxi service process while the other observed passenger arrivals (group size and interarrival times). Data showed that queues grew rapidly (up to 130 people queuing and 20 min waiting time) despite a constant supply of taxis—this phenomenon stimulated the interest in the issue.

Step 2. Creation and Calibration of Simulation Model

Figure 5 shows the basic configuration of the simulation model created and calibrated from the data collected for the taxi operation. The model includes a separate service module for each taxi position. This contrasts with the naïve alternative of assuming that the service rate for each taxi is the same and that the overall system can reasonably be considered a single queue. Costa implemented the model by using the capabilities of the SIMUL8 package (21).
FIGURE 4  Configuration of Lisbon taxi pickup operations at Terminal 1 (arrivals) and observation points.

FIGURE 5  Configuration of simulation model for taxi pickup operations.
Step 3. Exploration of Alternatives

Four alternative scenarios were built and tested for performance:

- Scenario I enlarged the inner-curbside area to allow three lanes of taxis to serve simultaneously at peak hours, instead of the current two.
- Scenarios IIA and IIB featured an inner service lane, where several taxis at a time (three and four, respectively) could load, and a bypassing lane, which allowed taxis to bypass front colleagues quickly.
- Scenario III explored the possibility of creating a secondary queue (with dedicated road access) near the exit of the inner-curbside road.

Step 4. Choice of Preferred Design

Any coherent evaluation of alternatives must take into account not only the main average indicators of service and queuing but also extreme values as seen in Table 1. The combination of these two evaluation perspectives allows the analyst to weight and show the peak hour system behavior better.

Other interesting indicators can become important, especially in space- or cost-constrained contexts, and decisively influence the final choice of preferred design. In the case of Lisbon, although Scenario I was consistently the best in terms of results, the airport operator perceived it as a less safe, space-demanding, and expensive alternative. Scenario IIB was selected as the preferred design at the time, because it implied better safety and affordability at the cost of only slightly worse performance.

FURTHER APPLICATION: JetBlue TERMINAL AT JOHN F. KENNEDY AIRPORT

On the basis of the successful application in Lisbon, a similar application was developed for the JetBlue Terminal T5 at John F. Kennedy International Airport, New York. Taxi operations at this terminal are different from those at Lisbon. Taxis at Kennedy Airport concentrate in a central taxi hold (CTH) and are dispatched to each terminal according to the estimated demand. The CTH is located approximately 2.4 mi from T5. The taxi stand consists of a taxi waiting area, a service area, and a passenger queue. The waiting area has a theoretical capacity of 18 taxis. The service area has space for seven taxis parked in a parallel and a bypassing lane. The passenger queue exit is located at the head of these service positions. One or two dispatchers oversee the process, request taxis from the CTH according to their perception of demand, and implement processes to speed up loading of passengers into taxis.

The following are the main differences between the New York and Lisbon cases:

- Taxi supply at T5 is not constant, because taxis are called in according to perceived needs and taxi arrivals necessarily take time to get to T5 from the CTH. Moreover, at peak periods there are often no taxis available, and delays at the passenger queue quickly accumulate—this is one of the main issues at T5.
- Taxis arrive in groups, spreading out over short time periods, and taxi requests are demand-driven.
- The service area layout features a bypassing lane, which allows for the approximation that servers are independent when it comes to service times.
- Several dispatching protocols have been observed at T5. Each aims at efficient loading and processing of passengers into taxis. The protocols influence service times in different ways.

The analysis was based on data collected by Kamga et al. (22) adapted to fit the needs of the simulation model. It covers several days of the week during a traditional U.S. holiday season and features detailed information on several indicators. The application of the proposed procedure to T5 was both practical and successful and further demonstrates the value of the approach.

CONCLUSION

This paper proposes and demonstrates a practical solution to a long-standing issue in the design of ground transportation services for airports. It provides airport managers with a means for analyzing taxi operations quantitatively, otherwise unavailable. With this approach, they should be able to investigate alternative designs for taxi pickup sites, identify preferred solutions, and improve operations that so often have been deficient.

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