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# MODELLING AND ANALYSIS OF INTERMODAL PASSENGER OPERATIONS IN A CRUISE TERMINAL

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## ABSTRACT

In this paper we present a discrete event simulation model of a cruise terminal for decision support and strategic planning. The main objective is to provide an analysis tool for systems with high capacity constraints, heterogeneous subsystems, time-dependent demand and stochastic passenger transfer and travel times. Cruise terminals are connected by bus to a transport interchange or intermobility center where passengers are transferred to taxis. All terminals are affected by capacity constraints such as the number of bus platforms for passenger pick-up and drop-off and the limited queuing capacity for taxis and passengers. Passenger arrivals are time-dependent and cruise-type-dependent. The purpose of this model is to support the strategic decision-making process through what-if-scenarios. Decisions involve determining the required number of bus platforms, taxi buffer sizes and passenger distribution policies, among other factors. The results identified and proposed the solution of bottlenecks and enabled a sensitivity analysis to be performed.

## 1 INTRODUCTION

A Port Authority currently operates 4 cruise terminals. During high season, normal operation entails the boarding and disembarking of between 15,000 and 28,000 passengers every day. Disembarking passengers are mainly transferred to the airport or the city using the public taxi service, requiring the Port Authority to oversee the movement of approximately 2,300 taxis between 8:00 and 10:30 am. Current operations management routes taxis to the different terminals depending on the queuing capacity at each terminal and the number of passengers waiting. Terminals are inside the port area, and the combination of taxis and normal port traffic causes the infrastructure to reach near-saturation, making it difficult for taxis to reach the terminals and potentially leading to long waiting times for passengers.

Since the prospects are for continuous growth over the next decade, the Port Authority is working to expand the dock, adding 2 new cruise terminals to the 4 currently operating. Since this will increase demand for taxis by more than 50%, the service level is likely to suffer, and the Port Authority has launched several studies to analyze alternatives that will help to overcome the problem of taxi traffic congestion. The alternative presented in this paper consists of transferring passengers to a new intermobility center (IC) via shuttle buses. At the IC, passengers will be able to take a taxi, rent a car, or rent a bicycle (for those that do not finish their cruise). The simulation study will allow us to determine the capacitated resource sizes, such as the number of bus berths in the cruise terminals, the width of the sidewalks to access bus queues in the terminal, the number of bus berths in the IC, the size of the sidewalks in the bus area, the width of the sidewalks to access the taxi stand in the IC, and the size of the IC itself. The simulation study also takes into account strategic decision-making: how the Port Authority should operate the taxi services, how many buses and taxis the system requires at a given moment, how the buses should to be dispatched, how passengers should access taxis, how different taxi types should be operated, how many taxi loading spots are necessary at a given time, and how they should be operated, etc.

The paper is structured as follows: Section 2 describes the logistic simulation problem, Sections 3 and 4 describe the macro- and micro-logistic simulation approach and methodology, and Section 5 presents the study conclusions.

## 2 PROBLEM STATEMENT

The Port Authority is interested in analyzing the logistics potential of a future IC as a logistics hub for the different mobility services available to cruise passengers (pax). Total passenger operations on certain critical days are between 15,000 and 28,000, requiring around 2,300 taxis for disembarking passengers and a similar number for boarding passengers. Taxi operations for boarding passengers are carried out throughout the day, whereas operations for disembarking passengers occur mainly between 8:00 and 10:30 am. Figure 1 shows a model scenario where 6,970 passengers require a taxi across 6 cruise terminals. The total number of passengers requiring taxis are shown for each 10-min period.

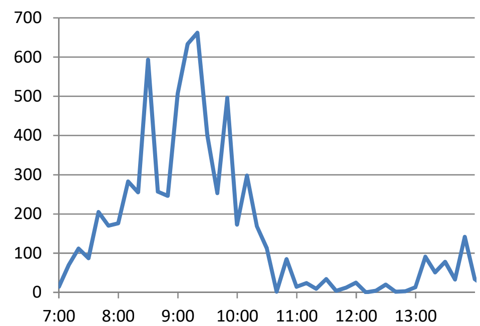


Figure 1: Averaged passengers requiring taxis, per 10-min period.

The Port Authority operates 4 cruise terminals, while the 5th and 6th terminals are under construction. Passenger (pax) numbers are expected to increase once construction of the new terminals has been completed. The type of passenger, volume of luggage, and distance between cruise terminals and the airport or city center make taxis the preferred mode of transport for those passengers starting or ending their cruise in the port.

The high volume of passengers can lead to long queues and high traffic flow. All vehicle traffic must pass through a single-lane gate with recorded peak flows of 410 taxis per hour and 127 taxis per 10 minutes (Figure 2). Taxis share the road with buses, coaches, supply trucks, and regular container trucks. By creating the new IC outside the dock area it will be possible to house a taxi buffer, to manage taxi loading operations, and to manage shuttle buses between the IC and the terminals. The IC will also reduce traffic ongestion in the dock area and should, therefore, reduce queues and waiting times.

The simulation study is divided into two main steps. First, a macro simulation model determines the main behavior of the system. In this step the number of bus berths in each terminal, the number of bus berths in the IC, the number of shuttles, the shuttle dispatch policies, and the number of taxi loading bays are determined. Second, a micro simulation model processes passenger movements, passenger group typologies, luggage typologies, and taxi loading operations. In this second step, the IC layout, taxi batch sizes, taxi dispatch policies, and passenger-to-taxi routing policies are determined.

The final objective of the project is to reduce the total time of passengers inside the harbor facilities. The current system setup, with direct taxi access to the cruise terminals, generates maximum waiting times of 1 hour 30 minutes. Passengers exit the terminal with their luggage and access the taxi pick-up area directly, so the entire pick-up time is waiting time. The proposed design – combined shuttle buses and an

IC with multiple transport services – targets a maximum lead time of 30 minutes for 85% of passenger groups requiring a taxi, with a hypothetical total of around 7,000 passengers leaving the port by taxi.

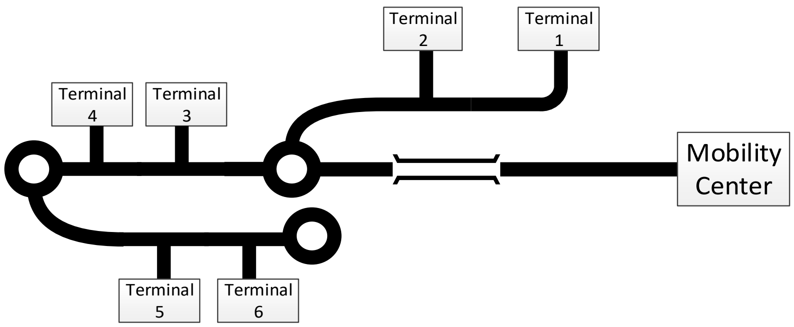


Figure 2: Schematic road layout, one lane in each direction.

Cruise passengers can be distinguished from passengers of other forms of transportation for the following reasons:

- All passengers are tourists: there is no passenger type mix because a cruise is a tourist activity.
- Most passengers travel in groups, and almost 50% in groups of three or more people. Groups of five or six people are not unusual.
- Many passengers carry many items of luggage, most of which are very large. As cruises offer a wide range of activities, luggage can contain casual clothes, several formal outfits, sports clothing, and children's toys (Figure 3).
- Many passengers are in a hurry when leaving a ship since they have to connect with an onward journey by plane or train. Other tourists are more likely to use their last few hours or days in the city for sightseeing. Final destinations are not taken into account for this study.

These specific characteristics increase the difficulty of input data acquisition and analysis. Some data have been obtained through direct measurements taken at the cruise dock, but other important data were derived from other systems and considered a candidate parameter for sensitivity analysis.

Figures 3 and 4 show the distribution of number of bags per taxi and the distribution of taxi loading time, corroborating the above statements.

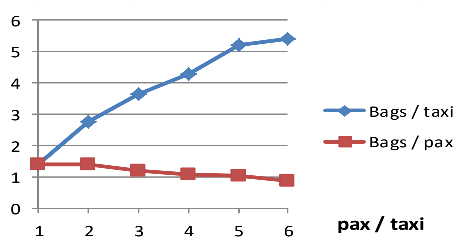


Figure 3: Number of bags as a function of the number of pax per taxi.

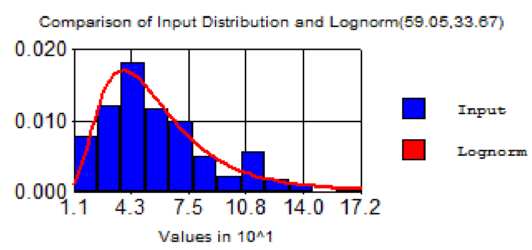


Figure 4: Taxi loading time, empirical and fitted distribution.

## 3 MACRO-LEVEL MODELLING & SIMULATION

The macro simulation model was developed to provide a first study of the dynamics of the IC solution proposed by the Port Authority. The macro simulation model will enable resource dimensioning to achieve the objective of a maximum 30-minute lead time for 85% of passengers.

Figure 5 shows a flow diagram of the proposed process. Fully or partially loaded buses transfer passengers to the IC; after unloading, buses return to their assigned cruise terminal to load new passengers. Buses can be reassigned to other terminals if needed. If there are enough passengers to fill a bus, the bus leaves the cruise terminal full; if the bus is not full, it will wait for a few more minutes and then leave for the IC.

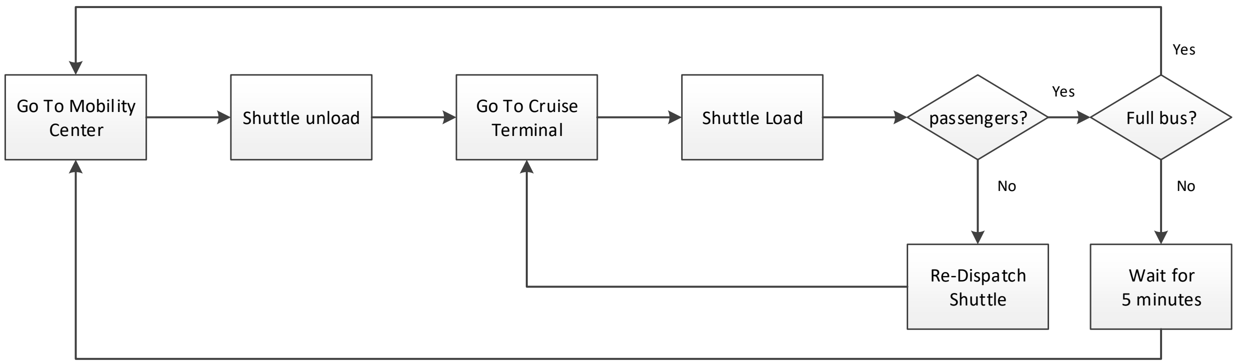


Figure 5: Macro-level flow diagram.

At the macro level, the averaged data required to determine the general system behavior can be divided into three groups: data pertaining to the IC, data pertaining to the cruise terminal, and data pertaining to the shuttles. The data for the macro model were collected by an external contractor before this study. For the micro-level, full probability distributions for critical parameters were fitted using collected data within the study. For the IC, the following data were available:

- The average shuttle unloading time at maximum capacity. This is the time from opening the shuttle doors until all passengers and luggage have left the bus. It has a direct impact on the number of shuttle bus berths in the IC and the number of buses required. This information could not be derived from data collection in the harbor and was collected by an external contractor from bus operations carrying passengers with similar characteristics prior to this study.
- The taxi batch loading time and the taxi batch replacement time. If the taxi operation flow is discretized in batches, the time to load and time to replace a batch determine the total cycle time. In the macro model, an hypothesis was formulated using measurements of taxi cycle times at the cruise terminals.
- The type and size of cruise ships and disembarkation rate. There are two main types of cruises: full-transit and partial transit. Full-transit cruise passengers generally use organized excursions and do not require taxis; they carry small bags since they return to the ship in the afternoon. Partial-transit cruises generate greater use of taxis since many passengers carry all of their luggage; their main destinations are airports, main train stations, and city hotels. The total number of passengers depends on the ship size. Different shipping companies or even different ships implement different methods and schedules for disembarking passenger passengers and luggage, which are staggered to different degrees.

For the cruise terminals, the following data were required:

- The shuttle bus loading time. Supposing that there are enough passengers in the queue to fill the bus, this is the time between the opening and closing of the bus doors. This time has a direct impact on the number of berths in the cruise terminal.

For the shuttles, the following data were required:

- The number of passengers considered to fill a shuttle. This value may be lower than usual because of the number and size of luggage items, as explained in Section 2.
- The transport time. This is the journey time between each terminal and the new IC. As the IC will reduce traffic congestion inside the terminal area and on adjacent roads, real times can be less than actual travel times.

The number and layout of bus berths in the IC and the terminals are are major parameters of the system. However, the concept of effective berth shown in Table 1, depending on layout, is described in (Levinson and Jacques 1998). For example, a linear off-line with two-bus capacity, with two buses occupying the berths, limits the entry of a new bus until both buses have left their berths (Figure 6), regardless of which bus leaves first.

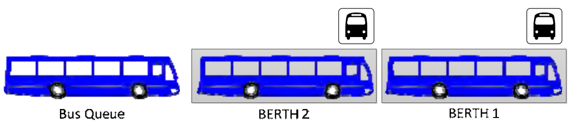


Figure 6: Linear bus berths.

Table 1: Linear berth effectiveness.

| Berth no. | Efficiency | Effective Berths |
|---|---|---|
| 1 | 100 | 1.00 |
| 2 | 85 | 1.85 |
| 3 | 75 | 2.60 |
| 4 | 65 | 3.25 |
| 5 | 50 | 3.75 |

From the static capacity model we can calculate the number of berths required in the IC. Taking reference values of 2,950 pax/hour, 30 pax/bus and a measured unloading time of 1.85 minutes with a bus maneuvering penalty of 10 seconds, 4 berths are required in the IC. Also from basic queuing theory we can determine the average length and time of the queue, which will be 4 shuttles queuing for 6 minutes. The shuttle queue at the IC entrance is a potential problem as it could cause traffic congestion. Therefore, full buses must remain at the cruise terminal until space is available at the IC. Consequently, journey time between the cruise terminals and the IC should be taken into account when calculating the number of berths required at the IC. Taking a mean journey time of 242.5 seconds, 4 berths plus 6 queuing positions or additional berths in the IC are required. This theoretical number of berths can be reduced by using a shuttle dispatcher. The same study can be performed to determine the number of berths required at each of the cruise terminals. Assuming a reference value corresponding to a peak time for a large cruise ship of 925 pax/hour and a measured loading time of 5 minutes with the same shuttle capacity, 3 berths are required. Taking into account the queuing restrictions described above, 3 berths plus 2 additional berths or queuing positions are required. This is the required number of effective berths, so the real number may be higher depending on the layout.

The average number of shuttles required can be calculated using static capacity models with the cycle time of 12.4 minutes and a passenger number of 2,950 pax/hour, giving a total of 21 shuttle buses. Finally, the same calculations can be performed for taxis to determine the number of loading bays required. Assuming that the recorded mean number of passengers per taxi is 3 pax, and the recorded average taxi batch cycle time is 3 minutes, the system requires an average of 49 taxi bays to service all passengers.

Since the new IC has to be designed from scratch, this initial study has provided a feasible starting point for civil engineers and architects. From this starting point, the Port Authority has drafted a first map of road connections, the IC layout, shuttle circuits and taxi routes, using figures deduced from the geometry such as the shuttle maneuvering time at the IC and at each terminal.

A sensitivity analysis using the above data revealed that an increase of 1 minute in the shuttle unloading time would require an additional 1.5 berths in the IC; that an increase of 1 minute in the shuttle loading time at each cruise terminal would require an additional 0.6 berths in the terminal, and that an increase of 1 minute in the shuttle cycle time would require an additional shuttle.

Conceptual modelling is an important process carried out by all simulation modelers, whether formally or otherwise (Robinson 2010). A conceptual model of the process described here was built using Colored Petri nets (CPN), and the equivalent simulation model was developed in Arena© (Kelton et al. 2009). Colored Petri nets are a successful tool for modelling logistics systems due to several advantages such as the conciseness with which they embody both the static structure and the dynamics, the availability of mathematical analysis techniques, and their graphical nature (Jensen et al. 2007, Gehlot and Nigro 2010). Furthermore, CPN are very suitable for modelling and visualizing patterns of behavior that comprise concurrency, synchronization, and resource sharing, which are key factors in optimizing the performance of logistics or manufacturing systems. Colored Petri nets allow for higher-level modelling, using colors to represent the entity attributes of commercial simulation software packages. Additionally, CPN specification allows for direct mapping between Arena© simulation elements and CPN structures (Guasch et al. 2013, Figueras et al. 2014). The ability to deal with transporters, pedestrians, and flow control has guided the authors to use the general purpose industrial simulation tool Arena over other more pedestrian- or traffic-oriented tools like Pathfinder, Incontrol, MassMotion, Aimsun or Vissim.

Figure 7 shows the CPN of the of the process. The color T is an integer value from 1 to 6 associated with the cruise terminal number. Passenger arrival (transition T1) is modeled using measured date from cruises of different sizes and types (full-transit and partial transit). A dispatcher routes shuttles entering the gate to the cruise docks to a given cruise terminal (P9) taking into account the passenger queue (P1) at each terminal (T2). After the journey time to the assigned cruise terminal, the passenger loading process begins as soon as the bus has a berth (T4). The loading time, though not shown in the figure, depends on the number of passengers in the queue, since additional waiting time must be factored in if the bus is not full. Buses can leave for the IC if there is space available in the IC (P11). After the journey time to the IC (T6), the passenger unloading process begins as soon as a berth is available (P10). The model, therefore, assumes that the IC may have queuing space for incoming buses (T7). Once the passengers have been unloaded, the bus returns to the entrance of the cruise dock.

The previous, basic static capacity analysis assumed 2,950 pax/hour peak taxi demand. The simulation model, by contrast, works with the real transient data where peak demand is constrained to the period 9:00-10:00 am, during which resource utilization values greater than 1 are accepted since demand is much lower in the immediately next hours. Thus, relatively large queues are accepted in order to avoid oversizing resource requirements as far as 85% of the passengers have a lead time less than 30 minutes (94.5% according to the simulation). Therefore, the number of needed buses has been reduced from 24 in the capacity study to 20 in the macro-simulation model.

Table 2 shows the results of a sensitivity analysis with the following factors: number of shuttle berths at each cruise terminal, number of shuttle buses, number of shuttle berths at the IC and number of taxi loading bays at the IC. For each simulation, the table also shows the number of taxi passengers in each lead time interval (the goal is to have 85% of passengers below the 30-minute lead time). These results are based on the additional assumption of 8 queuing positions for buses at the IC and unlimited queuing positions at each cruise terminal. The IC assumption was made on the basis of an initial design that included queuing positions.

As a result of the sensitivity analysis and additional experiments, the target design point shown in Table 3 was chosen. The required resource capacity is lower than that obtained using queue theory: 20 buses instead of 21, 3 shuttle stops at the IC instead of 4, and 40 taxi loading bays instead of 49.

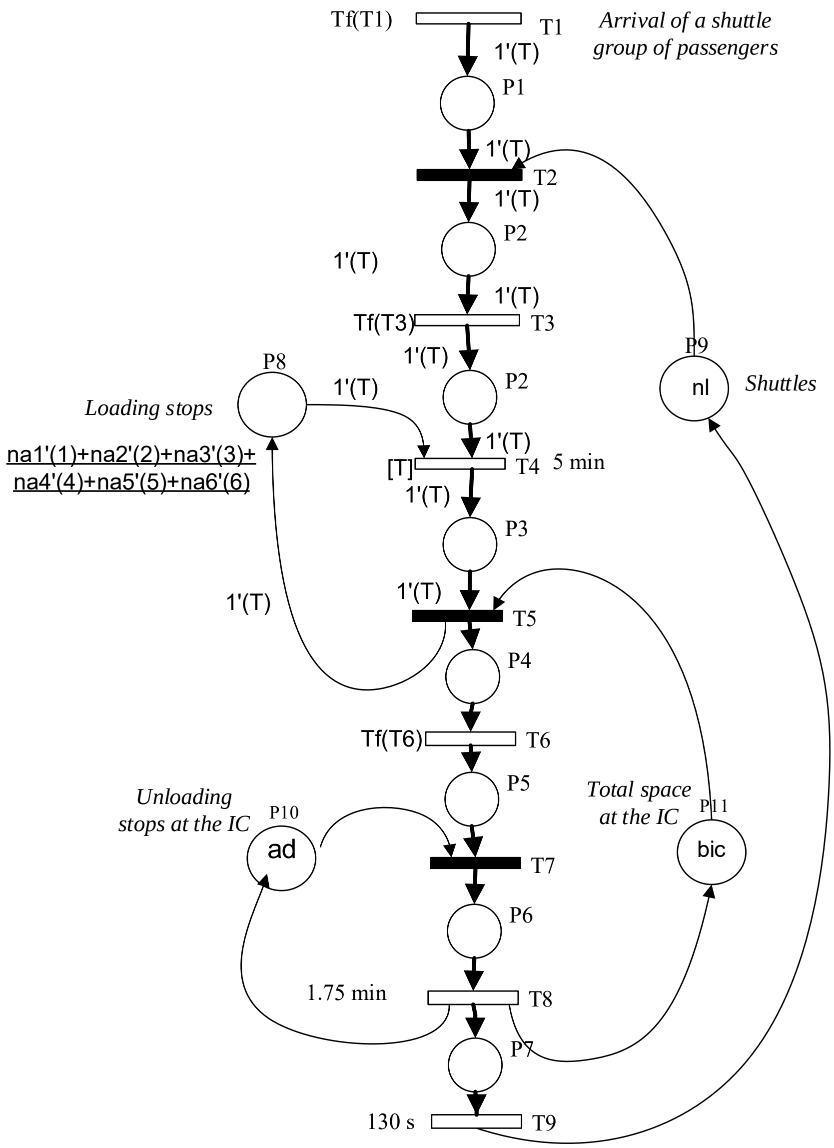


Figure 7: Colored Petri net of the macro-level model.

Table 2: Sensitivity analysis results at the macro level.

| Simulation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Num. of shuttle stops at each cruise terminal | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | **4** | **3** | **2** | **1** |
| Num. of shuttle buses | 30 | 30 | 30 | 30 | **22** | **21** | **20** | **19** | **18** | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| Num. of shuttle stops at the IC | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | **4** | **3** | **2** | **1** | 7 | 7 | 7 | 7 |
| Num. of taxi stops at the intermodality center | **44** | **40** | **36** | **32** | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 |
| Num. of pax with lead time >= 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 59 | 0 | 0 | 443 | 4192 | 0 | 0 | 0 | 2271 |
| Num. of pax with lead time between [45-60] min | 0 | 0 | 0 | 1037 | 0 | 125 | 162 | 252 | 200 | 0 | 9 | 1232 | 501 | 0 | 0 | 32 | 616 |
| Num. of pax with lead time between [30-45] min | 0 | 33 | 1992 | 1625 | 95 | 424 | 584 | 884 | 1529 | 229 | 300 | 1113 | 321 | 162 | 167 | 775 | 881 |
| Num. of pax with lead time between [15-30] min | 2629 | 3189 | 2347 | 2208 | 2777 | 3206 | 3356 | 3109 | 2789 | 2782 | 2870 | 1918 | 683 | 2902 | 2953 | 2962 | 1489 |
| Num. of pax with lead time between [0-15] min | **4223** | **3604** | **2569** | **2030** | **4022** | **3122** | **2867** | **2676** | **2286** | **3766** | **3712** | **2154** | **556** | **3811** | **3681** | **3108** | **1488** |

Table 3: Results with the selected design point.

| | |
|---|---|
| **Number of shuttle stops at each cruise terminal** | 3 |
| **Number of shuttle buses** | 20 |
| **Number of shuttle stops at the intermodality center** | 3 |
| **Number of taxi stops at the intermodality center** | 40 |
| **Number of pax with lead time >= 60** | **0** |
| **Number of pax with lead time between [45-60] min** | 24 |
| **Number of pax with lead time between [30-45] min** | 804 |
| **Number of pax with lead time between [15-30] min** | 2928 |
| **Number of pax with lead time between [0-15] min** | **3146** |

## 4 MICRO-LEVEL MODELLING & SIMULATION

The main drawback of the macro model is that the IC operations are simplified. Nevertheless, the macro simulation has been used to obtain starting design values for the IC and the cruise terminals, to validate the feasibility of the implementation, and to determine the need for a dispatcher to control process operations. The main goal of the micro-level model was to provide detailed modeling and simulation of IC shuttle, passenger, and taxi operations.

The design of efficient taxi pick-up operations is important for airports, train stations, and harbors, where taxis service a significant proportion of the arriving passengers. There is no agreement on how these operations should be designed or carried out. While we should expect that different solutions are preferable for different situations, it is safe to say that prevailing practices are typically historical legacies rather than the result of conscious analysis and consideration (Da Costa and De Neufville 2012). Many pick-up operation studies are focused on airports. For example, (Conway et al. 2012) discuss the dispatching policies at John F. Kennedy International Airport and (Passos et al. 2011) propose a simulation methodology for the evaluation of taxi services at airport terminals.

The main constraint in the design of the cruise IC is the availability of physical space in the harbor area close to the cruise dock. Eleven thousand square meters were initially made available for IC operations and taxi staging area. Additional space has been added as a result of the micro-level simulation analysis. Figure 8 shows the current working design of the IC, which has 7 shuttle stops with 15 degree configuration, 4 independent 2-lane taxi pick-up blocks for 18 taxis each, 4 independent 2-lane taxi queues for 18 taxis each, and 4 independent queues for passengers. The current design follows the IATA principles described in (Jenks et al. 2007). The taxi queues are configured as two platform ramps descending from a first-floor staging area with a capacity of about 500 taxis.

In this design the hypothesis of a 3-min time cycle for each pick-up block cannot be assumed. The 3-min time cycle was measured at a cruise terminal where taxis adopt a parallel configuration. Thus, the movement of one taxi is independent of the other taxis in the block. Using the two-lane configuration, the time cycle depends on the taxi with the highest loading time in each block. The time needed to load a taxi depends heavily on the total number of passengers and bags in the group, as can be seen in Table 4. These distributions were obtained from measurements at the cruise terminal. When the group size is equal to or greater than 7 (i.e. 4 passengers and 3 bags), the loading time can be very high.

Most of the groups of size 7 or higher have 3 or more passengers in the group. So, as a first future rule for IC personnel, individual passengers are directed to block B4, groups of 2 passengers to B4 and B3, and groups of 3 and 4 passengers to B3, B2, and B1. Finally, groups of 5 or more passengers are directed to B1 since they need higher capacity taxis (Figure 8). Individual passengers and groups of 2 account for 43% of the total. However, they use only 33% of the available capacity, whereas groups of 3 or 4 passengers use

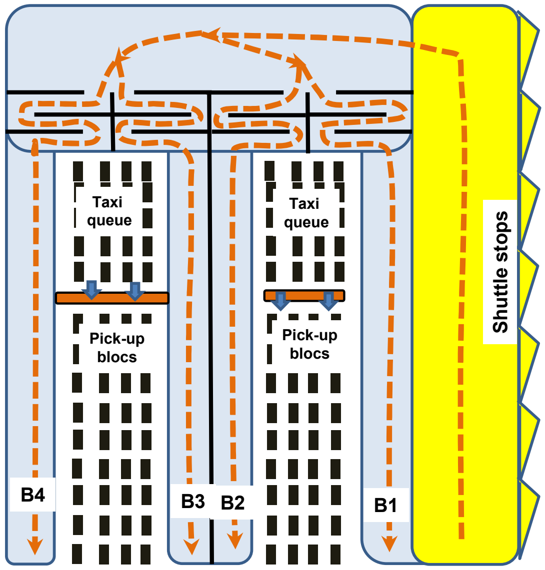


Figure 8: IC layout.

59% of the available capacity. Additionally, IC personnel should direct groups requiring special assistance to B1 and B2. As we will see in the simulation results, random distribution of groups to pick-up blocks significantly penalizes the total number of taxis that can be loaded in the peak period.

Table 4: Taxi loading distributions.

| Pax + bags in taxi | % Pax + bags in taxi | Time | Distribution | Mean taxi loading time | Acc. prob. of used capacity |
|---|---|---|---|---|---|
| 1 a 4 | 23 | | Logn(37,18) | 37 | 0.13 |
| 5 a 6 | 33 | | Logn(52,17) | 52 | 0.39 |
| >= 7 | 33 | <=107 | Logn(70,25) | 70 | 0.75 |
| >= 7 | 11 | >107 | Tria(109,136,321) | 141 | 1 |

Table 5: Number of passengers per taxi and utilization distribution.

| Pax / taxi | % pax/taxu | Mean taxi loading time | Acc. prob. of used capacity | Block |
|---|---|---|---|---|
| 1 | 2.7 | 29 | 0.01 | B4 |
| 2 | 41.1 | 47 | 0.33 | B4-B3 |
| 3 | 23.7 | 67 | 0.59 | B3-B2 |
| 4 | 25 | 74 | 0.92 | B1-B2 |
| 5 | 4.4 | 113 | 0.98 | B1 |
| 6 | 3.1 | 112 | 1 | B1 |

Several subsystems were added to the macro simulation model to increase the level of detail: shuttle stops at the cruise terminals, shuttle stops at the IC, passenger movement in IC queues, staging operations, taxi movement to queues from the staging area, taxi movement to the pick-up areas, and loading before exiting. Figure 9 shows the CPN of taxi movement to pick-up blocks and loading before exiting.

A full queue block of taxis can proceed to the corresponding pick-up block if the pick-up block is free (T8). Note that the guard function [B] in transition T8 means that the value of the color B, which represents the block number, must be equal for both entries in order to activate and fire the transition. In transition T9 a destination position D is assigned to each entering taxi. The destination position is a direct assignment based on the block zone B, column C in the block and row R in the block. Consecutive moving taxis in the same column are 3.5 seconds apart on average (T10). Transition T11 models the movement of each taxi to each destination position D. This movement is handled by transporting instructions in Arena simulation. When a row of two parallel positions in a block is occupied by two taxis (T13), the passenger loading process can start after 4 seconds, which is the time needed for consecutive taxis to occupy the rear positions (T14), so passengers move between taxis only when they are stopped. The taxi loading time (T15) includes the movement of passengers to the taxi and the loading time (Figure 9). When all taxis in the block are loaded, the block is released so that a new block of taxis can enter. Finally, when all taxis in the queue have moved to their corresponding pick-up positions, positions in the queue are available for a new block of taxis (P1).

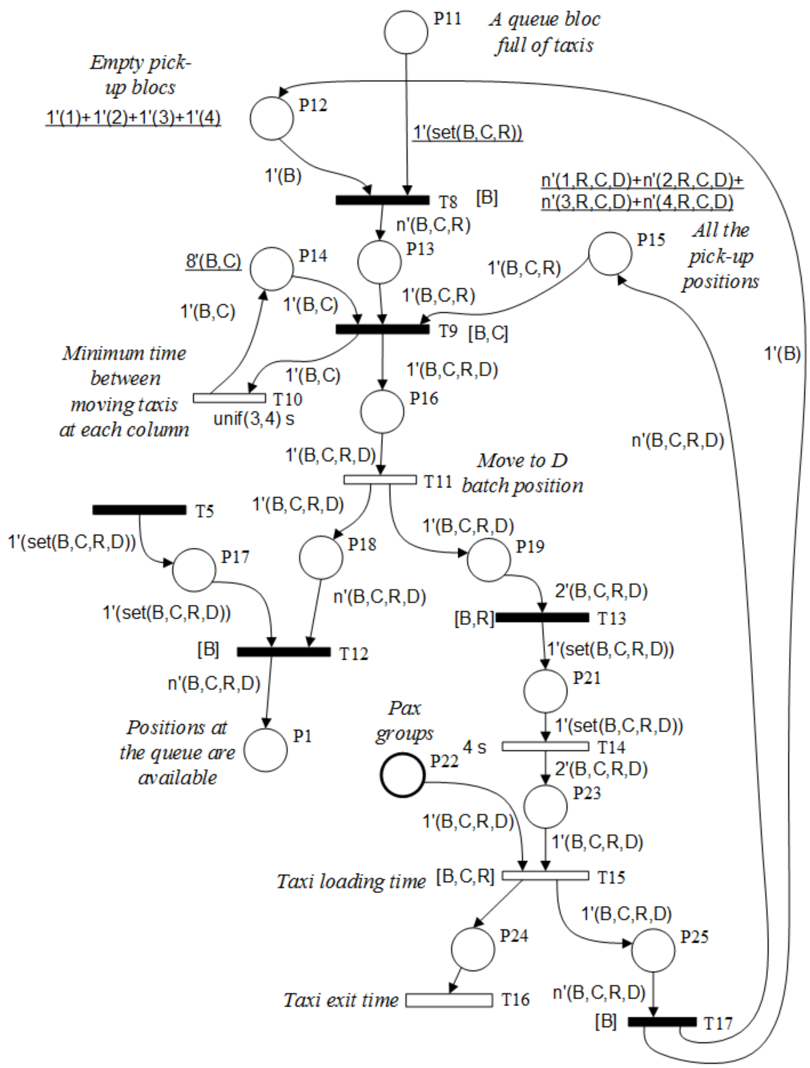


Figure 9: Colored timed Petri net of the taxi block loading positions process.

Table 6 shows the simulation results when groups are distributed randomly to the queues for the pick-up blocks. There are two working scenarios: in the first, 6,987 passengers take a taxi from the IC (scenario 1); in the second, there are 9,361 passengers (scenario 2). The first scenario corresponds to a standard Saturday during the main cruise season while the second is a scenario in which several large cruise ships disembark passengers. Table 7 shows the results for the same two scenarios but with passenger groups distributed according to number of passengers and bags. The results clearly show that random distribution is undesirable. In the first scenario, 21% of passengers have a lead time greater than 30 minutes while only 12% have a lead time greater than 30 minutes when they passengers are directed to the queues. In the second, more extreme scenario, 30% of passengers have a lead time greater than 45 minutes while only 6% have a lead time greater than 30 minutes when passengers are directed to the queues.

Table 6: Random distribution of pax.

| Simulation | 1 | 2 |
|---|---|---|
| Total number of pax that take the taki | 6987 | 9361 |
| Number of shuttle buses | 23 | 26 |
| Number of pax with lead time >= 60 | 0 | 1207 |
| Number of pax with lead time between [45-60] min | 128 | 1635 |
| Number of pax with lead time between [30-45] min | 1324 | 1826 |
| Number of pax with lead time between [15-30] min | 3716 | 3300 |
| Number of pax with lead time between [0-15] min | 1713 | 1385 |

Table 7: Supervised distribution of pax.

| Simulation | 1 | 1 |
|---|---|---|
| Total number of pax that take a taxi | 6987 | 9361 |
| Number of shuttle buses | 23 | 26 |
| Number of pax with lead time >= 60 | 0 | 4 |
| Number of pax with lead time between [45-60] min | 15 | 530 |
| Number of pax with lead time between [30-45] min | 834 | 2771 |
| Number of pax with lead time between [15-30] min | 4226 | 4415 |
| Number of pax with lead time between [0-15] min | 1850 | 1641 |

As demand exceeds capacity during the peak period, the numbers of passengers at the IC waiting for taxis and at the cruise terminals waiting for shuttle buses rise to maxima of 500 and 300, respectively. It does not make sense to increase the number of shuttle trips to reduce queues at the cruise terminals, as this will simply increase the queue at the IC by the same amount it decreases at the terminals.

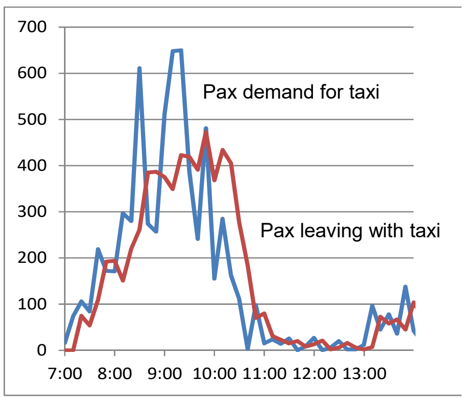


Figure 10: Passengers requiring a taxi and passengers leaving the IC per 10-min period.

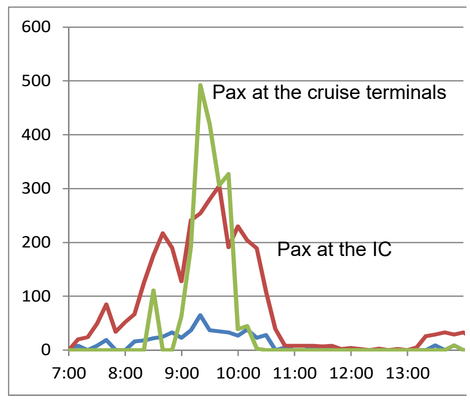


Figure 11: Pax in queues at the cruise terminals and at the IC.

## 5 CONCLUSIONS

This paper describes the methodological approach taken for the simulation analysis of a taxi intermobility center in a cruise harbor. Three models were used: a capacity model to calculate the approximate number of the different resources required, a macro-simulation model to obtain the number of shuttle-related resources required, and a micro-simulation model to analyze the resource requirements of the intermobility center itself. Colored Petri nets were used for conceptual modeling before model coding in the Arena target simulation environment.

Our experiments results indicate that the proposed intermobility center will improve on current procedures. It will lower queuing times, improving quality of service for passengers requiring taxis and providing access to new services. Future studies will have to deal with better luggage handling, how the taxi requirements will impact to the taxi service in the city, and how disabled users will be trated at each terminal. It should be noted that the model validation is not described in this paper, although it constituted an important phase in the simulation study.

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