Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

TRAIN STATION PASSENGER FLOW STUDY

Janice P. Li

Booz•Allen & Hamilton
Three Gateway Center, Suite 1625
Newark, NJ 07102, U.S.A.

ABSTRACT

With the increasing demand for public transportation due to congested highways, trains have become one of the most viable alternatives, especially for daily commuting. While transit agencies are excited with the increasing ridership, they are also challenged with a higher volume of passenger flow and longer queuing lines at the existing stations. To improve the current situation and plan for the future, transit agencies are using simulation tools to help evaluate station design, queue management, fare equipment design and fare policy impacts.

1 INTRODUCTION

When traveling by train, the station is the first and last encounter a passenger experiences. Every passenger must access the station before boarding the train and must exit the station upon arrival at the final destination. While at the station, a passenger often travels on escalators or stairs, purchases a ticket, and goes through the fare collection gates before and after a train ride. For transit agencies, it is important to include all these encounters into the evaluation of total passenger travel times when developing service improvements at the stations

With increasing highway traffic in many metropolitan cities, more commuters are taking the trains to work. Beside the need to evaluate station capacity to accommodate the weekday peak period ridership, agencies are also evaluating new fare collection equipment to replace aging units. With a complex environment, agencies are using simulation to optimize operations and service quality.

2 APPLICATION

In light of each transit agency having its own operating policies and each train station having a unique design and layout, agencies share similar challenges in handling passenger flow. Figure 1 showed a general passenger flow chart with listing of key station activities and their relationships. The time required to complete each activity is a function of fare structures, fare collection policies, station layout, equipment design, operating policies and system capacity. Agency staffs often are available only at major terminal stations and their job functions are assisting passengers at information booth, selling train tickets, and guarding the areas.

In the past, transit agencies have used simulation to help addressed the following train station passenger flow related issues:

- Fare Equipment Type Mix Optimization – There are various types of fare equipment; such as ticket vending machines, ticket collecting turnstiles, exit only turnstiles and cash dispensing turnstiles. Agencies need to determine an optimal combination of these equipment. An example would be determining the numbers of bi-directional versus one-way fare gates to mitigate the impediments between passengers entering and exiting the various machines at the same time.
- Fare Policy Change – When there is a proposed fare increase or introduction of a new ticket type, it often increases the time spent purchasing a ticket with cash from a ticket vending machines. Since a passenger may need to put more bill(s) or coin(s) into a machine. Therefore, agencies may need to install additional machines or relocate currently underutilized machines to areas with higher projected traffic volume.
- Fare Equipment Performance – Agencies use simulation for assessment of fare equipment performance criteria. This is often done during procurement of new fare equipment as there is need to determine equipment transaction speed and user interface screen numbers. These factors drive the amount of time a passenger would spend at the machine.
- Train Scheduling – Many train stations offer transfers between rail lines. The transfer often required passenger to go through fare gates and escalators/stairs. To determine the passenger arrival rates and walking patterns at stairways,

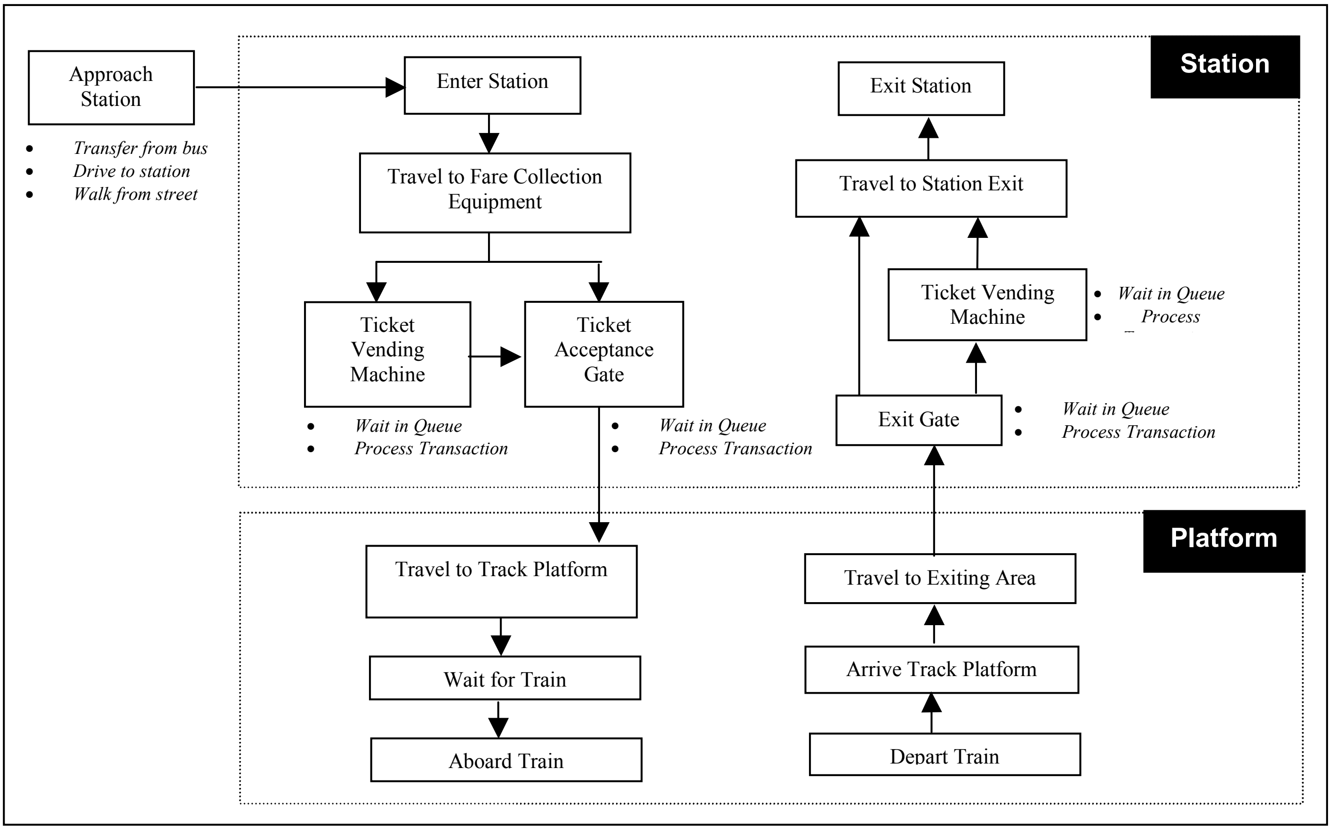

Figure 1: Train Station Passenger Flow Chart

transfer gates and exiting turnstiles, it is important to evaluate frequency of train arrival and the numbers of passengers getting off the train.

- Equipment Maintenance Schedule – Besides planning for normal operations, agencies also developed station operations back up plans for scheduled and unscheduled equipment downtime due to failure or maintenance. The equipment could be the fare collection equipment or the ingress and egress media – stairs, escalators and elevators.
- Station Layout – To minimize passenger travel time and frustration, ingress and egress media, fare equipment, main station entry/exit points, train boarding/exiting points on platform should be strategically layout.
- Ingress and Egress Safety Compliance – Agencies also use simulation models to evaluate the quantity and capacity of stairs, escalators and elevators in the station. Train stations must be designed with adequate ingress and egress media for efficient passenger evacuation during emergencies.

3 MODELING EFFORT

This section discusses the approach and effort used for developing a typical train station simulation model.

3.1 Input Requirements

In most cases, simulation model input data includes both the average behavior (such as ridership, number of trains per hour, time to purchase a ticket using a credit card and escalator speed) and the distribution of the population behaviors (such as passenger arrival rate at the fare gate, types of ticket payment method by cash, credit or debit, varies walking speed, and choice of ingress/egress media.) Figure 2 shows a sample of input data used for the passenger flow study at the proposed Newark Northeast Corridor (NEC) Monorail Station. Input data could be historical data provided by the agencies, data from field observations, or design specification provided by the manufacturers.

Different statistical distribution functions are often used for simulating various passenger arrival patterns at a station. In general, a passenger will get to a station by one of the following transportation modes:

- Foot - walking
- Taxi
- Car
- Subway/Train transfer
- Bus transfer

SIMULATION INPUT	Distribution (%)		unit
Rail Station Ridership			
Headway		2	min
Number of trains per hour		30	train per hour
Number of passenger per train		78	count
Monorail Station Ridership			
Headway		2	min
Number of trains per hour		30	train per hour
Number of passenger per train		78	count
Number of Fare Gates		7	**gates**
Number of TVM	3 at NEC Rail	4 at NEC Monorail	
Rider Type			
Airline Passenger	80%		
Employee	20%		
Airline Passenger TVM Usage			
User	15%		
Non-user	85%		
Employee TVM Usage			
User	5%		
Non-user	95%		
TVM Payment Method		Transaction Time	
Local pax - cash	40%	30	sec
Local pax - credit card	15%	45	sec
Local pax - debit	20%	45	sec
Foreign pax - cash	15%	45	sec
Foreign pax - credit card	10%	60	sec
Fare Gate Usage		Transaction Time	
Local pax w/o baggage	25%	3.2	sec
Local pax w/baggage	60%	5	sec
Foreign pax w/baggage	15%	6	sec
Passenger's Choice of Station Traffic Mode			
Escalator	80%		
Stair	18%		
Elevator	2%		
NEC Rail Station Escalators			
Number of escalator paths	(Maximum)	4	escalator paths
Number of steps per paths	(Maximum)	55	steps
Monorail Station Escalator			
Number of escalator paths	(Maximum)	2	escalator paths
Number of steps per paths	(Maximum)	32	steps
Number of Skywalk path (# of walking speeds)		5	skywalk paths

Figure 2: Sample of Input Data

Arrival rates of Train and bus transfers are driven by their scheduled arrival time and each arrival will bring a large volume of passengers. When simulating these passenger arrival rates, use either the scheduled arrival time or the Poisson distribution which will depend on the type of data available. Use the scheduled arrival time if the train/bus often has on-time arrival.

Arrival rates for traveling by foot, taxi or car are more random and continuous; also, each arrival will bring a smaller amount of passengers. The exponential distribution is often used for simulating continuous arrival patterns.

If a model is designed for evaluating the worst-case scenario, ridership shall be properly adjusted to reflect the busiest travel period. Such as multiplying the average peak period ridership by the following factors:

- Ridership growth rate
- Month of the year adjustment
- Day of the week adjustment
- Other adjustments – special events.

Beside numerical data, the station layout is another key input requirements. A layout shall include, at minimum, the ingress/egress media, fare collection equipment and primary station entry points that are included in the statistical analysis. If using a animated simulation model, the station layout screen could also include real time display of some of the key statistical results while the model is running.

The graphical layout is especially useful for evaluating visual information on bi-directional fare equipment traffic and bottleneck areas. A sample layout of the Newark NEC Monorail Station is shown on Figure 3.

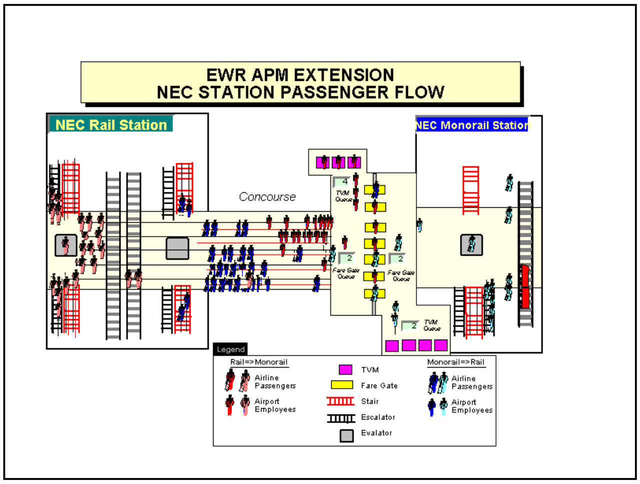

Figure 3: Snap Shot of the Newark NEC Station Simulation Model

3.2 Evaluation Criteria

The primary evaluation criteria for determining an optimal solution are passenger processing time at various check points (such as ticket vending machines, ticket acceptance gates and exit turnstiles) and queue time and queue length at the bottleneck areas (such as fare machines and ingress/egress media.) Figure 4 showed one of the key simulation results – number of passenger waiting in queue – that is often used for evaluating the passenger flow rate. Other criteria could include:

- The number of people missing their first available train due to delays in the queue line.

- Equipment utilization rate.
- Elapsed time between the first and the last passenger passed through a transfer point.

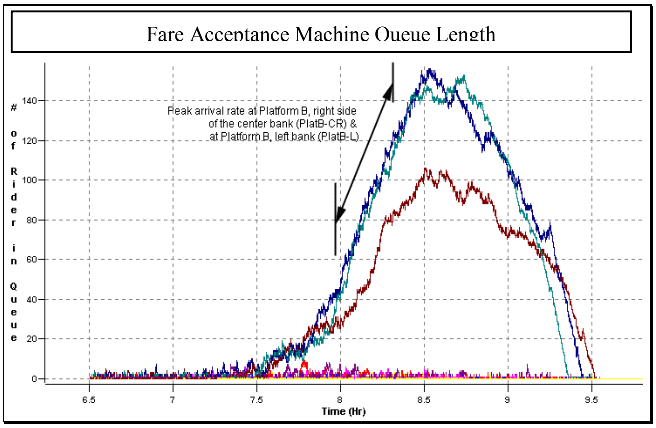

Figure 4: Sample of Simulation Result

3.3 Model Validation

Simulation models are often validated by objective techniques. When evaluating an existing system, a base case model that simulates the current environment often is used for validating the model assumptions and logic. Once the model is calibrated, input requirements are changed for evaluating the "what-if" scenarios.

Since most of the train stations have security cameras installed throughout the station, video observations are useful for comparison with simulation results. Also, results from field observations and interviews with experienced transit agencies are often included in the model validation process.

4 CONCLUSION

Simulation is a powerful tool for train station passenger flow improvement, planning and design analysis. It provides numerical results and graphical animations of activities that take place from the time a passenger enters until departing the station. Transit agencies are integrating lessons learned from simulation into all aspects of passenger flow design/operations. From daily station operations management, scheduled maintenance planning to long term capital planning, simulation has proven to be a tool not only to address today's problem, but it also capable of enabling users to adapt to tomorrow's challenges.

AUTHOR BIOGRAPHY

JANICE P. LI is an Associate with Booz•Allen & Hamilton, Inc. based in Newark, New Jersey. She has nine years of professional transportation experience in project management, operations and maintenance planning, facility design, simulation modeling, and process improvement. Prior to joining Booz•Allen, she has worked and held various positions at Amtrak, including Senior Industrial Engineer, Test Engineer, and Management Associate. She received her Bachelor degree in Industrial Engineering from University of Washington and MBA from University of Delaware. She is a member of IIE and Women's Transportation Seminar. Her email address is `<li_janice@bah.com>`.