PEDESTRIAN MODELLING IN SOUTH AFRICA: A RECENT CASE STUDY

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ABSTRACT

The introduction of intermodal facilities has brought about a complex interaction between various modes of transport and land uses. Traditionally, evaluation of the movement within rail station facilities has been based on static analysis using the guidelines recommended in an outdated Norms, Guidelines and Standards[1] (NGS) document (SARCC, 1997). Little or no evaluation has been undertaken to assess the synergy or interaction of the various separate static components in a real-time environment. To date, most of the analysis conducted in micro-simulation has focused on the vehicular movements in and around station precincts with little consideration of pedestrian activities. The fact that pedestrians are a mode of transport and that every journey has a pedestrian component is often overlooked.

Public transport (PT) services and facilities are provided primarily for people and not vehicles. It is therefore of paramount importance that the PT user/pedestrian is well accommodated in the movement systems of the facility and its surrounds. The pedestrian system, vis-á-vis the local environment and treatment of routes to a facility, is critical towards contributing to an efficient, attractive and safe operating environment. The accommodation of mobility-impaired users is also crucial to the provision of a holistic system solution of each interchange location. According to research on the different categories of mobility-impairment, planning must address the specific needs of each group within the interchange area.

Pedestrian modeling is used extensively in developed countries as a modern design tool to test complex design options. In the past, this technique has found limited use in South Africa. It nevertheless has vast potential to aid planners and designers in the future. This paper describes a recent case study (Bridge City) in Durban, South Africa which demonstrates the use and value of pedestrian modeling in the design of complex modal interchanges such as Bridge City and for stations throughout the country.

The paper begins by explaining what and why pedestrian micro-simulation is considered an appropriate tool in engineering projects involving people. This is followed by evaluating several software packages considered for the analysis of the Bridge City project, followed by Assessment scenarios considered for analysis. Model inputs and assumptions are then defined after which the outputs of the model in terms of assessment criteria are presented. The paper concludes by summarizing the two main but significant findings that the pedestrian modeling has provided in this project.

INTRODUCTION

What is Micro-Simulation?

Micro-Simulation is the analysis of a vehicle(s) (car, bus, taxi, heavy goods vehicle, pedestrian, etc) travelling through a transportation network (road, sidewalks etc), where the movements of individual vehicles within the networks are determined by using simple vehicle-following, lane-changing and gap-acceptance rules. Although static analysis has its place in determining network configurations; the real value of micro-simulation however lies in its ability to evaluate networks as a system in a real-time environment. Typical station related queries suitable for micro-simulation applications, include for e.g. how a ticketing booth or a turnstile queue affects the flow in a

[1] *Note that portions of the NGS Guideline documentation are currently under revision*

concourse area, or how boom control generates vehicular queues, which in turn affects the flow of traffic on the adjacent road if the queue extends into the adjacent road.

Micro-simulation is an often misunderstood and misrepresented evaluation technique. The science and research behind the algorithms that drive the model behaviour have evolved over many years. Modeled behaviour can now be accepted as an accurate representation of what occurs in reality (provided that the data is inputted correctly). Regression analyses and other means can also be used to check that the correct volumes are being used in the model. In simple terms, the aim is to attain input volumes that are as close as possible to the actual volumes. Queue length analysis should be used in conjunction with the above to validate a model.

Problem Statement

Bridge City Intermodal Interchange, located in Durban, South Africa, is a multimodal public transport facility that has been incorporated into a retail and housing development. There are a number of aspects which make this facility unique in terms of its functionality. The key aspects which have a major bearing on the operational characteristics are listed below:

1. The **pedestrian volumes** to be accommodated in the intermodal interchange: Figure 1.1 shows the peak hour matrix that was determined for the interchange through various transportation planning exercises. The estimated number of pedestrian trips to be accommodated in the interchange is approximately 17,000 passengers (pax) per hour.
2. As the interchange is a multimodal interchange, there is a need to evaluate **modal integration**. Approximately 1,200 Minibus-taxi's, 200 Busses and 4 trains are required to move 17,000 pedestrians between their origins and destinations.
3. The **multiple modes** in conjunction with **multiple land uses** in a single development.
4. The **complex integration** and **functionality** of operational areas.

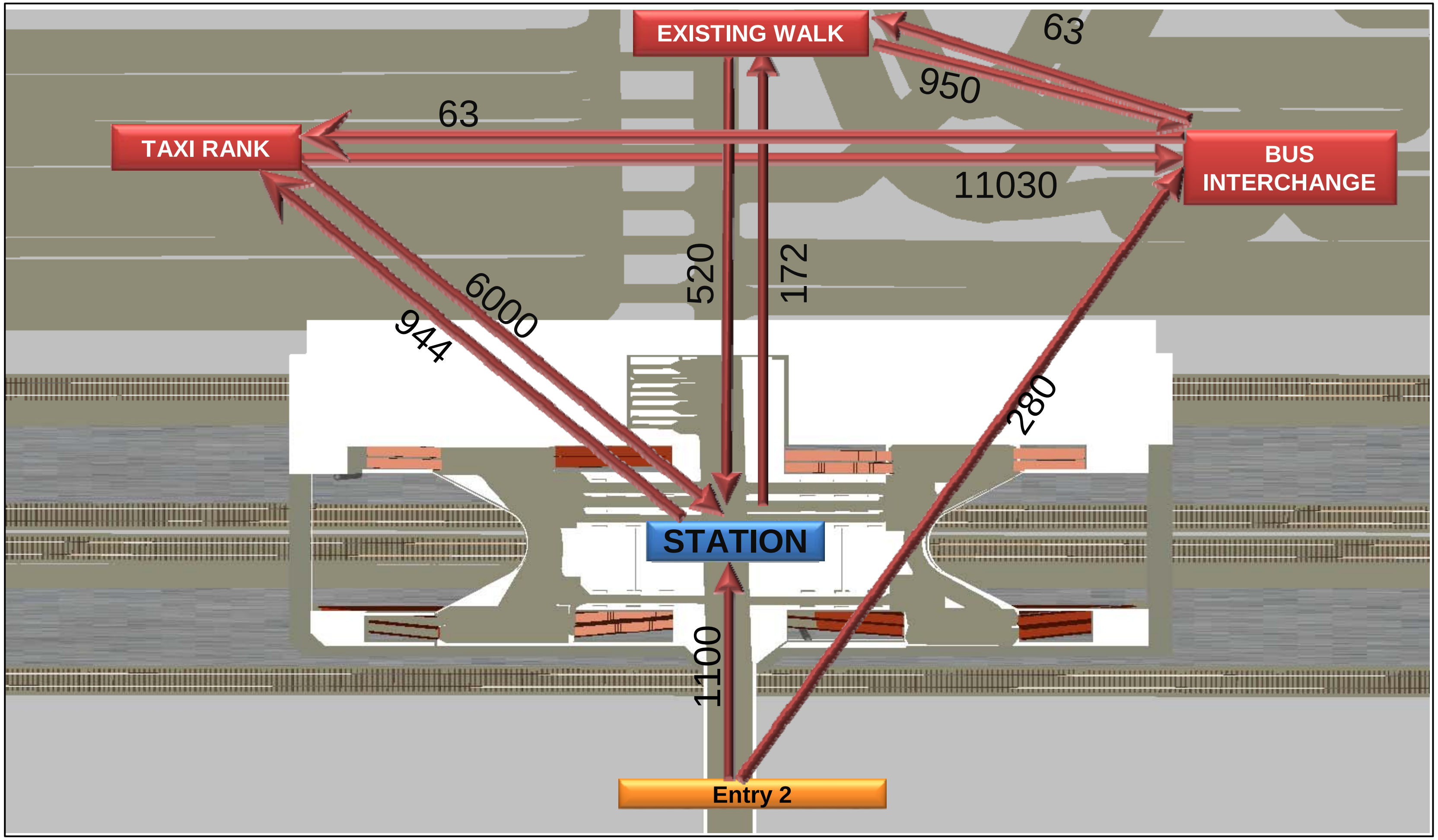


Figure 0-1: Peak Hour Pedestrian Volumes for Bridge City Intermodal Interchange (Source: Refer reference 2)

Analysis Tools

Part of this study entailed the determination of commercially available software packages most suited to undertake the analysis required for the Bridge City intermodal interchange.
Four packages were initially identified for evaluation viz.:

- Steps®
- Legion®
- Vissim®
- Cast®

Each of the packages was evaluated against a set of software parameters for comparative purposes. This comparison is summarised in Table 1-1. *Cast*® was not considered further as this package is geared more towards the analysis of airports.

Table 0-1: Comparison between Software Packages

No	**Software Parameter**	**VISSIM**	**STEPS**	**LEGION**
1	Developed by	PTV Germany	Mott MacDonald UK	(Legion International Ltd.)
2	Software Licence Limit	None	None	None
3	Cost	€30k	£3k	£15k pa
4	Published Research	Yes	Yes	No
5	Model Normal Ped Movement	Yes	Yes	Yes
6	Ped Assignment	Flexible Like Traffic	Density Based/Good for Evacuation	Based on least cost path
7	Model Multiple Peds on Path Spaces	Yes	No	Yes
8	Model Familiarity of Peds with Environment	Approximate Ped Categories	Yes	Yes
9	Model Time based Barriers (e.g. Signal Heads)	Yes	+ Lifts, Trains	Yes
10	**Overall Applicability**	**+ve But Modify Driver Behaviour**	**Good but does not incorporate complex Vehicle model**	**Good theory but no publications and no demo software make is difficult for use in research**

Based on the research done, Vissim® was deemed to be the ideal tool to evaluate the intermodal interchange as it has the ability to model the integration of various modes, which is the primary objective of an intermodal interchange.

STUDY AREA AND LOCALITY

Information regarding the development details was obtained from the Bridge City webpage:

"Bridging social divides of the past and creating a new African urban town centre that celebrates diversity, humanity and sustainability - Bridge City is located in the Inanda, Ntuzuma and KwaMashu area collectively known as the INK area, home to over half a million people, in the northern region of the eThekwini Municipality, 17km away from the Durban City Centre.

It is a partnership development between eThekwini Municipality and Tongaat Hulett Developments, the property company of Tongaat-Hulett, which will unlock a 650 000 square metres, high density development on a 60 hectare site.

Bridge City Urban Renewal Project is a dynamic mixed-use town centre that gives meaning to integrated settlements bringing city convenience and social services that create a balanced lifestyle."

(www.bridgecity.co.za - 2007)

The locality of Bridge City is illustrated in Figure 2-1.

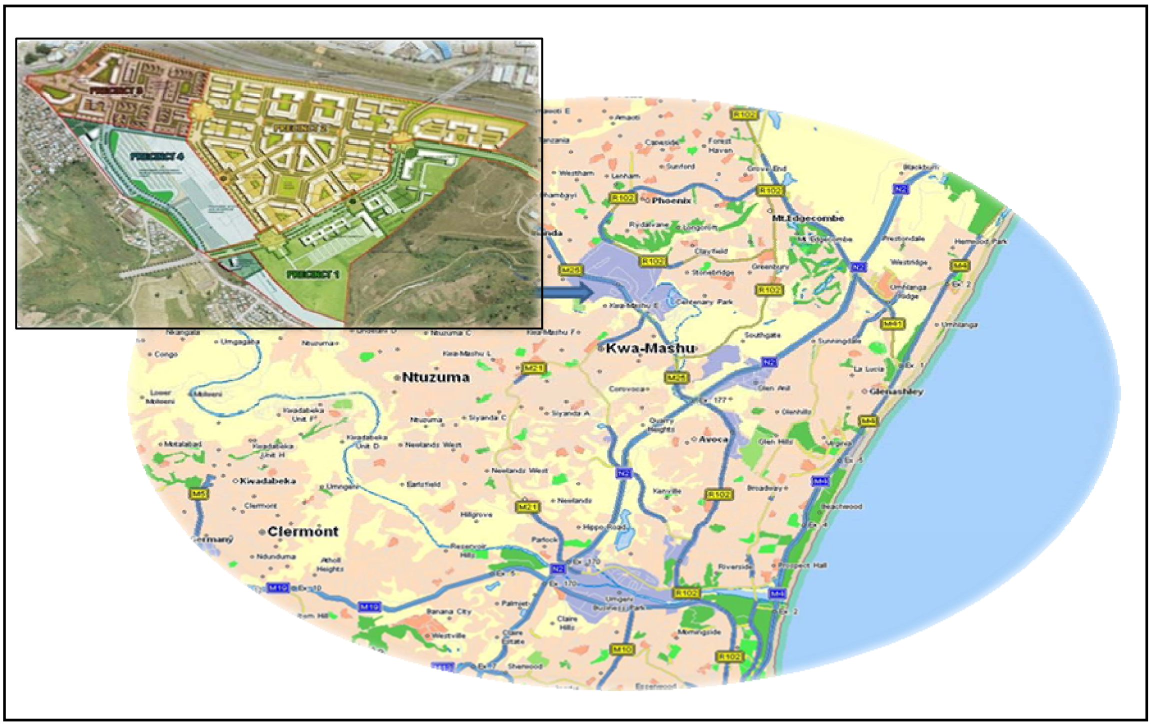


Figure 0-1: Locality and Study Area (inset) (Source: Refer reference 2)

ASSESSMENT SCENARIOS

Two assessment scenarios were developed, based on the proposed phasing of the development. An additional two assessment scenarios were required to determine the number of turnstiles required to achieve acceptable levels of service. The four assessment scenarios are described as follows (refer to figure 4.1) :

Scenario 1: Phase 1

- 4 turnstiles for entry into platforms and 2 turnstiles for exit from platforms
- Using only Phase 1 staircases/escalators for access to and from platforms

Scenario 2: Phase 1 with extra turnstiles

- 6 turnstiles for entry into platforms (4 original & 2 additional) and 2 turnstiles for exit from platforms
- Using only Phase 1 staircases/escalators for access to and from platforms

Scenario 3: Phase 2

- 4 turnstiles for entry into platforms and 2 turnstiles for exit from platforms
- Using both Phase 1 and Phase 2 staircases/escalators for access to and from platforms

Scenario 4: Phase 2 with extra turnstiles

- 6 turnstiles for entry into platforms (4 original and 2 additional) and 2 turnstiles for exit from platforms
- Using both Phase 1 and Phase 2 staircases/escalators for access to and from platforms

MODEL INPUT

A Vissim® pedestrian model was developed to not only evaluate the rail station operational characteristics, but to evaluate the collective operational characteristics of the entire intermodal interchange. A detailed evaluation of the bus and taxi rank is currently been undertaken by Tongaat Hulett Developments and the eThekwini Municipality. This chapter briefly discusses the manner in which the model was developed.

Inputs & Assumptions

1) The model was developed on the proposed design of the intermodal interchange as approved by the SARCC.

2) Phasing, as indicated in Figure 4-1

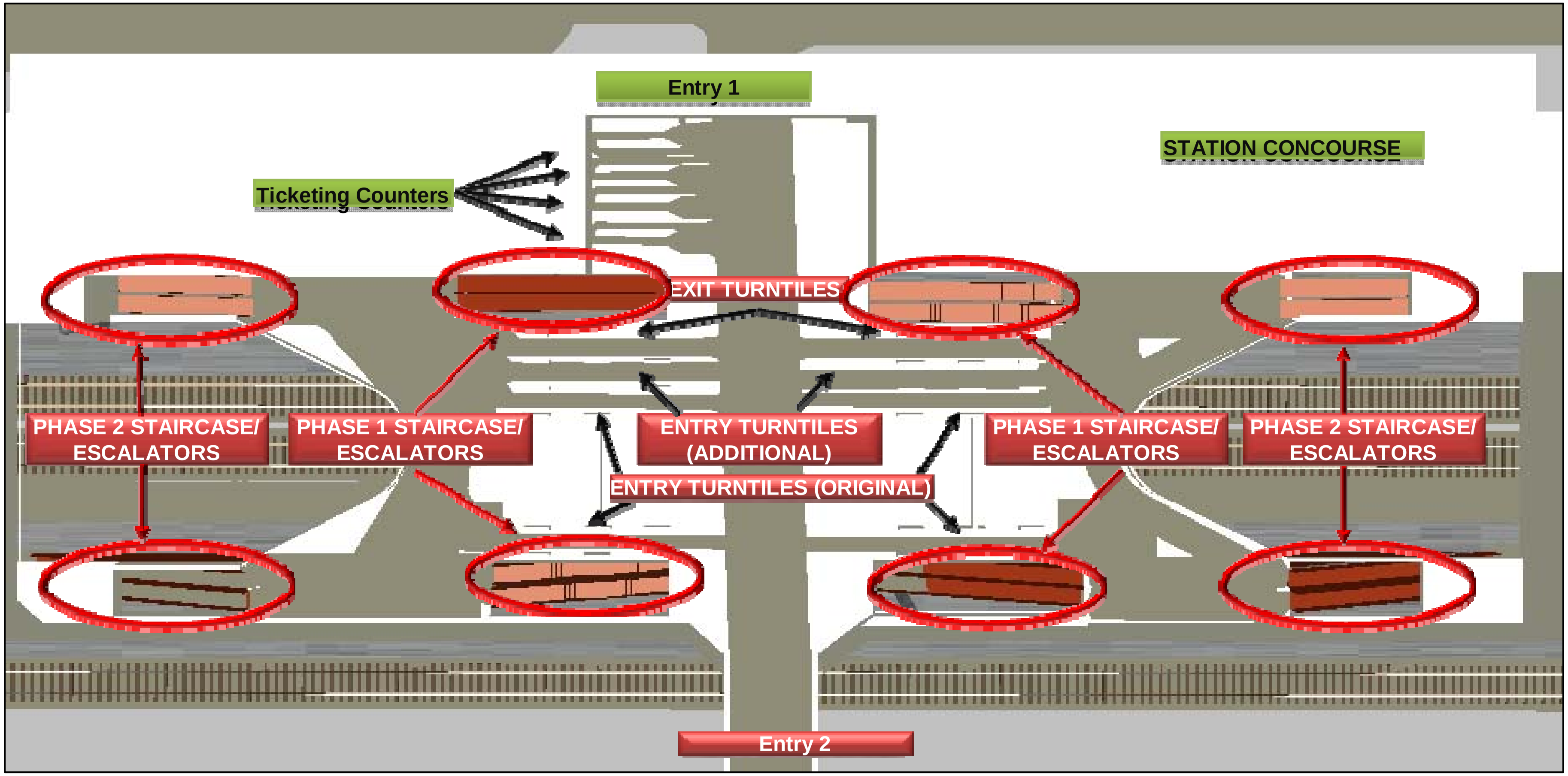


Figure 0-1: Layout and Phasing for Bridge City Intermodal Interchange (Source: Refer reference 2)

3) Composition of Pedestrians:

- 50%: Non-Aggressive Pedestrians
- 49%: Aggressive Pedestrians
- 1%: Disabled Pedestrians

4) Pedestrian Movement within the Station:

- Pedestrians who enter from Entry 1/ Entry 2 and need to buy tickets, would distribute equally amongst the ticketing counters. Once the tickets are purchased, the pedestrians would distribute equally amongst all the entry turnstiles.

- Pedestrians entering from Entry 1/ Entry 2 (and do not need to buy tickets) would distribute equally amongst all the entry turnstiles.

- Once beyond the turnstiles, the pedestrians would distribute equally amongst the staircase/escalators (based on Phase I or Phase II operation). Thus the platforms would service the same number of passengers.

- Once on the platforms, the pedestrians would distribute equally amongst all the coaches of the train.

- The outbound passengers (passengers entering the station via train and alighting at the platform) would be equally distributed amongst all the coaches of the trains and upon alighting, would distribute equally amongst all the escalators/staircases (based on Phase I or Phase II operations).

5) Ticket Purchasing

- 50% Monthly
- 30% Weekly
- 20% Daily

6) Trains

- Service Time: 800 seconds
- Dwell Time at station: 600 seconds (average)

7) Operations within the station

- Delay at ticketing counters: average 15 seconds per person (standard deviation of 5 seconds)
- Delay at turnstiles: 3 seconds per passenger (or 20 persons per minute capacity).

MODEL OUTPUT

A series of outputs were generated from the four scenarios developed for this study viz.:

i. Average delay per pedestrian.

ii. Journey times from various points of entry.

iii. Comparative queues at turnstiles and ticketing areas.

iv. Highlighted areas of system conflict and congestion.

i. The average delay per pedestrian is a good indication of the overall operating conditions of the system. The output in this format assists in comparatively analysing the four options. Figure 5-1 illustrates the results of this analysis.

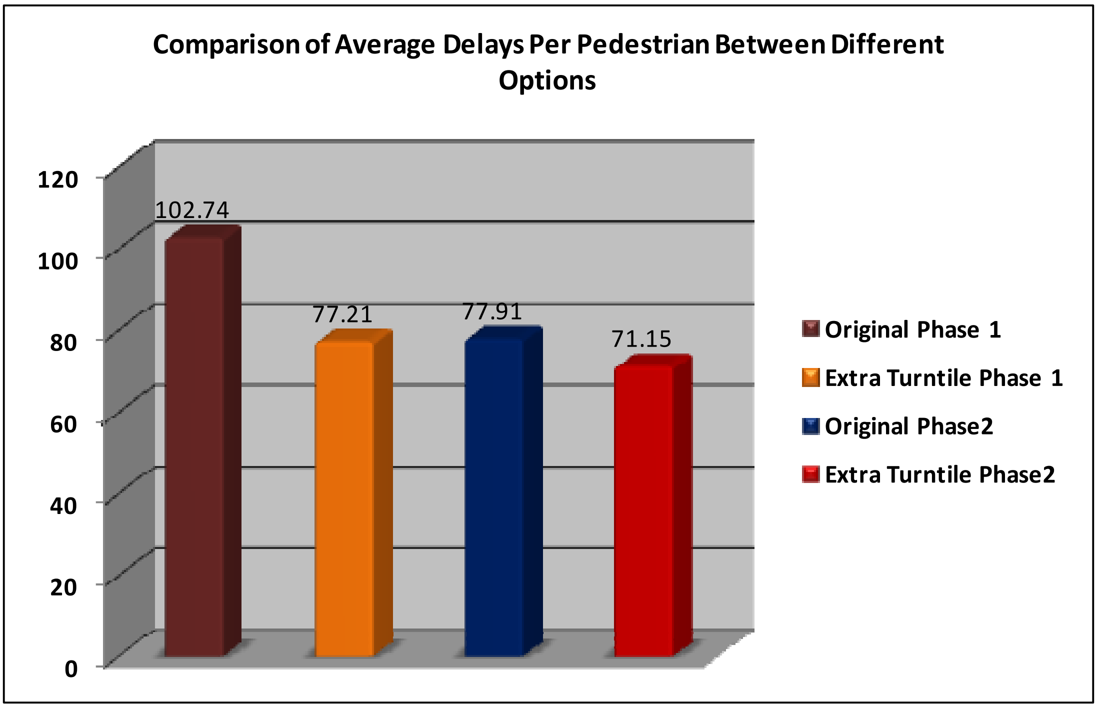


Figure 0-1: Comparison of Average Delays per Pedestrian (Source: Refer reference 2)

ii. The average travel time between various origins and destinations within the station were compared taking into account the various impediments that a pedestrian would encounter en route such as turnstiles, stairs etc. The results are illustrated in Figure 5-2. The benefit of this output is that various scenarios can be evaluated where the direct impact of the pedestrian's journey can be assessed. In this project it was clear that the introduction of additional turnstiles would reduce the pedestrian's travel time within the station by some 20 percent, which is significant. Further benefit of this output lies in the fact that the longest trip (associated with higher pedestrian volumes) can be identified as a 'worst case' evacuation assessment. In this regard, it was ascertained that in an evacuation scenario, the longest journey would take approximately 2-3 minutes for evacuation from the building. This figure can then be compared to standards and mitigating measures can be designed, if required.

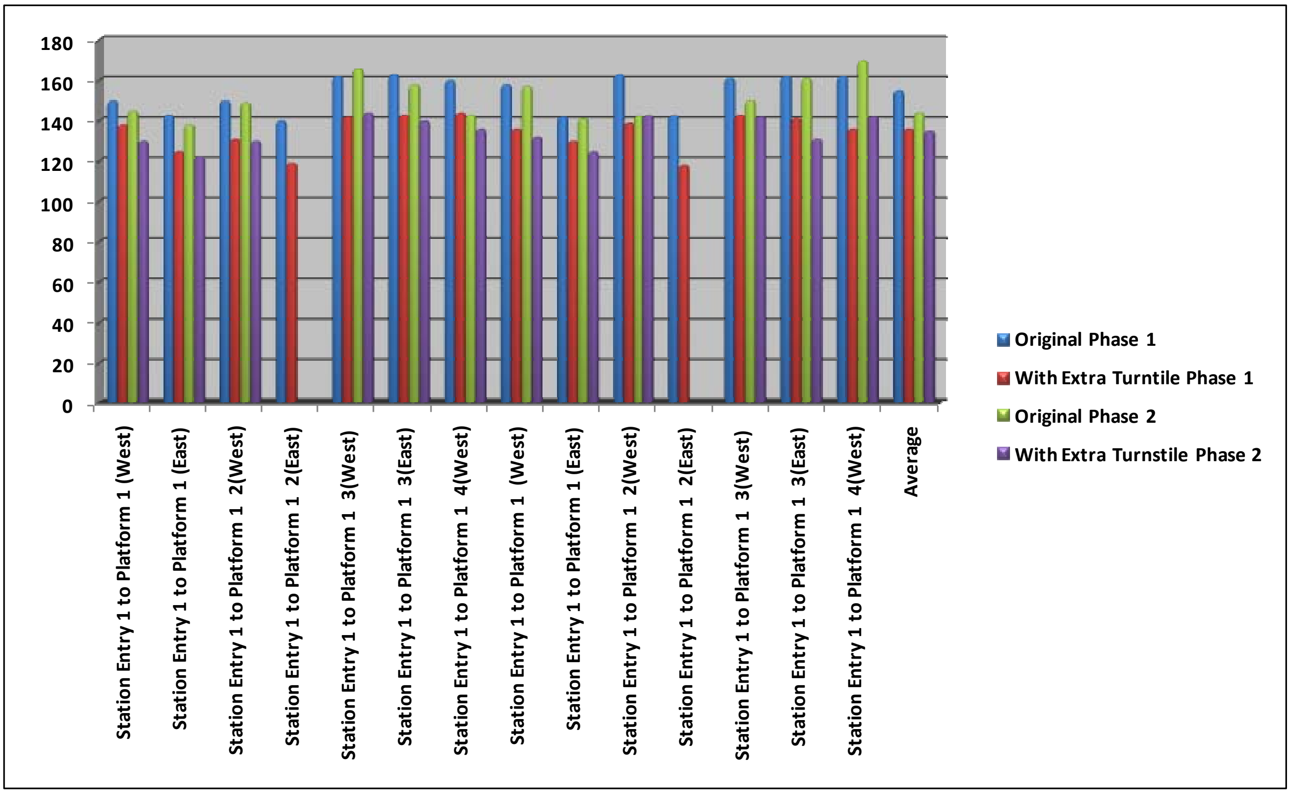


Figure 0-2: Average Travel Times for Various Routes (Source: Refer reference 2)

iii. Turnstiles are generally considered the point at which congestion occurs in a station due to their limited throughput capacity. The queue length analysis output (at turnstiles) can indicate whether or not the queue lengths are within acceptable standards or if they conflict with any through movements. During the initial evaluations, queue lengths at some turnstiles were conflicting with the general concourse pedestrian movement, which contributed to congestion and lead to an increase in travel times and worsened the operating conditions. The analysis therefore recommended the inclusion of an additional turnstile which improved the operating conditions to within acceptable levels. This analysis showed that the additional turnstiles added to both phase 1 and phase 2 improved the queuing lengths considerably hence improving the levels of service at the turnstiles. Figure 5-3 below summarises the results of the above analysis.

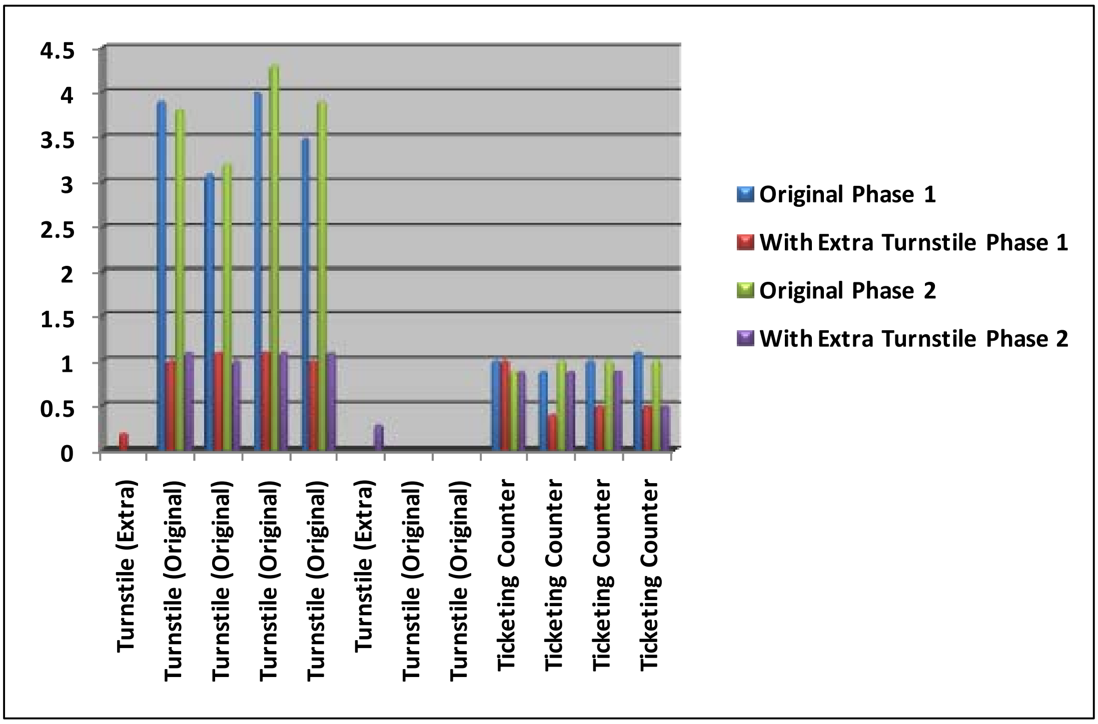


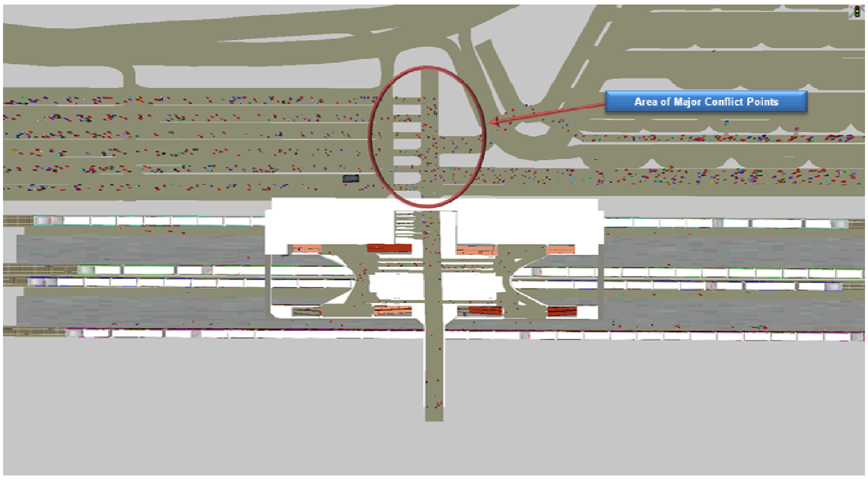
Figure 0-3: Average Queue Length Comparison for the Various Scenarios (Source: Refer reference 2)

SUMMARY OF FINDINGS

The development of a pedestrian model had a profound impact on the final design of the intermodal interchange. The resultant change in the operational areas was:

- Additional turnstiles were required in the rail concourse area due to the excessive queues conflicting with the concourse area. The primary reason for this change was operational.

- The bus and taxi rank needed to be reconfigured from being adjacent to one another to be being placed above and below one another on separate levels. This was due to the conflict between pedestrians and vehicles entering the taxi rank as well as the conflict between pedestrians entering the rail concourse area and



pedestrians changing between the taxis and busses. (Refer to Figure 6-1 below).

Figure 0-1: Pedestrian Density Diagram Indicating Area of Major Conflict

QUESTIONS & ANSWERS

Subsequent to the submission of the paper a number of questions/queries were raised by the referee of this paper. These have been dealt with in this paper under questions and answers.

Question 1:

AIMSUN has also been used in South Africa and has a Pedestrian package as well.

Answer 1:

The AIMSUM pedestrian module was launched in November last year. The pedestrian module is an input from the developers of Legion into AIMSUN. This product is fairly new as a combination hence we have not researched it in detail by us. However this combination is similar to the VISSIM package which can model multi modal problems. Like all international packages it is expensive as well.

Question 2:

As a new station, it was not possible to do surveys and calibrate the model. How was this overcome and what input data is needed. For an existing facility, what surveys would be needed and what would survey cost be. What accuracy can be expected from such model?

Answer 2:

Pedestrian analysis using micro simulation is a fairly new field in terms of micro simulation. One of the difficulties that has been indentified during the development of this model and other models was that the consistency of input and output data needs to be defined more clearly. The problem of the input data was overcome with the assistance of colleagues from the Imperial College of London who have done extensive research into pedestrian behavior. These parameters were used in the development of the model.

Regarding the surveys there are two main types of the surveys that can be conducted.

a) Pedestrian and environment characteristics
   - Car following, Gap acceptance, Lane Changing, Aggressiveness, Acceleration, Braking, Link characteristics

b) Statistical Data
   - PT and Traffic Signals information
   - Pedestrian Counts and Survey: “Tracking” technique, Questionnaire

Item a is a research topic which is currently being considered by PRASA and would form a standard for pedestrian model development. Item b would be a requirement specific to the each model developed. This cost will vary from project to project.

Question 3:

Have you considered the vehicle pedestrian interaction in order to get best lay-outs for pedestrians and vehicles?

Answer 3:

In this particular model we focused on the station layout. However, we have developed a subsequent model which undertakes the road side analysis as well. This is currently being further refined.

Question 4:

What are the conclusions regarding accuracy and usefulness of the model?

Answer 4:

Our conclusions regarding the accuracy was that the model was a good representation of the worst case scenario for daily operations that may occur based on our assumptions.

This model proved to be useful for a number of reasons:

a) Proved that the course and platform areas were adequate

b) Proved that additional turnstiles were required.

c) Proved that the staircases and escalators were sufficient

d) Highlighted that the external bus and taxi rank need to be addressed in greater detail to deal with conflicts between pedestrians and road based public transport vehicles. (This resulted in a vertical separated bus and taxi rank versus a horizontal separated bus and taxi rank.)

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