THE DEVELOPMENT OF A SPATIAL PARAMETERS (SP) MODEL TOWARDS THE MACROSCOPIC PEDESTRIAN ASSESSMENT OF RAILWAY STATION DESIGNS

L F L Hermant

Goba (Pty) Ltd, P.O. Box 3275, Durbanville, Cape Town, 7551

ABSTRACT

Intersite Property Management Services, together with the SARCC, have recently embarked on a country wide programme to upgrade commuter rail stations in South Africa as part of a larger process towards improving the commuter rail service in the country.

The lack of infrastructure investment over many years has not only resulted in a declining service and loss in patronage but has led to a hiatus in station design philosophies. This paper presents a generic Spatial Parameters (SP) - model which has been specifically developed and applied to the design of the Athlone, Heideveld and Langa (AHL) railway stations in Cape Town, South Africa.

The model has since received further application in the preliminary spatial assessments of other station designs such as Khayelitsha and Nyanga stations (Arcus Gibb, 2008) and Windermere station (ITS, 2008). The SP-model is an Excel based spreadsheet that calculates station infrastructure sizing requirements in order to accommodate the station design peak flow rates at desired levels of service using macroscopic principles.

It is intended that the SP-model provide an indication of the initial station sizing requirements but should be supported with further microscopic pedestrian modelling. As there are dependant relationships between certain spatial parameters, the spreadsheet is proving to be a useful tool but is still to be considered a “work in progress” model. It is believed that there is a definitive role for the SP-model as a first-order model, which together with microscopic pedestrian modelling will improve the station design process in South Africa.

BACKGROUND

Intersite Property Management Services, together with the South African Rail Commuter Corporation (SARCC), now PRASA, who own and operate all passenger rail stations, have recently embarked on a country wide programme to upgrade commuter rail stations in South Africa as part of a larger process towards improving the commuter rail service in the country. The impending FIFA 2010 World Cup event has led to a revision of priorities and provides further impetus to improve the levels of service to public transport users both for current every day users as well as visitors to the country. The proposed station upgrades also supports the goals specified in the Service Charter (SARCC,2006).

The lack of infrastructure investment and rolling stock availability over many years has not only resulted in a declining service and loss in patronage (City of Cape Town, 2006)[1], but has led to a lapse in design philosophies (with particular reference to station design) in South Africa. The recent budgetary allocations to station re-design and construction, after many years of inactivity in this area, has resulted in adopting outdated design guidelines. It is from this background that the need for a Spatial Parameters (SP) - macroscopic[2] model was developed. The model allows design checks to be made with the added benefit that future design approvals processes and existing station capacities can be more speedily assessed.

[1] Patronage is now nationally back to 1986 levels
[2] A macroscopic model is one that bases it’s calculations on a group of pedestrians (aggregated over a set period of time, typically over a 1 minute peak period)

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The author has been fortunate to be directly involved in the transportation aspects of the Athlone, Heideveld and Langa railway station upgrades through an appointment with Intersite since February 2007, over which time the Spatial Parameters (SP) - model was developed (J&G, 2008).

The layout of this paper first describes the current issues associated with the South African station design process, then discusses the main component (ie. the development of the Spatial Parameters Model) forming the focus of the paper. The necessity for pedestrian modelling is discussed and future research requirements are presented before conclusions are made.

DESCRIPTION OF THE STATION DESIGN PROCESS PROBLEM

Introduction

The provision of efficient and integrated station infrastructure through an optimum design and standardised guideline process, providing appropriate Levels of Service as per the Service Charter, is considered of paramount importance for the future operational success of South African station designs.

Existing Station Design Process and Problems

Station design in South Africa is based on a twelve year old Norms, Guidelines and Standards (NGS) document[3] (SARCC, 1997). Since then, changes in legislation and software technology have changed the design principles recommended in this document. For example, new legislation requirements including the accommodation of Special Needs Passengers (SNP's) has significantly changed the design philosophy with regard to pedestrian accessibility. This aspect is important when one considers that an estimated 33% of the user population are SNP's (Stanbury et al & Jacobs, 2005).

The development of SNP user requirements and design standards is relatively new to South Africa and was first introduced in the Khayelitsha Station 4/4A and Lentegeur Station designs (Jacobs, 2005). The operational functionality of the designs however still needs to be assessed.
The introduction of microscopic simulation software in the recent decade has also made it possible to permit more accurate spatial assessments to be made.

The description of the SARCC Feasibility / Concept design stage, as outlined in the NGS document, is shown in Figure 1. The "*First Order Concept Design*" stage entails producing a proposed station block diagram, that according to the design process, needs to be optimised before the station concept is approved.

[3] Note that portions of the NGS Guideline documentation are currently under revision.

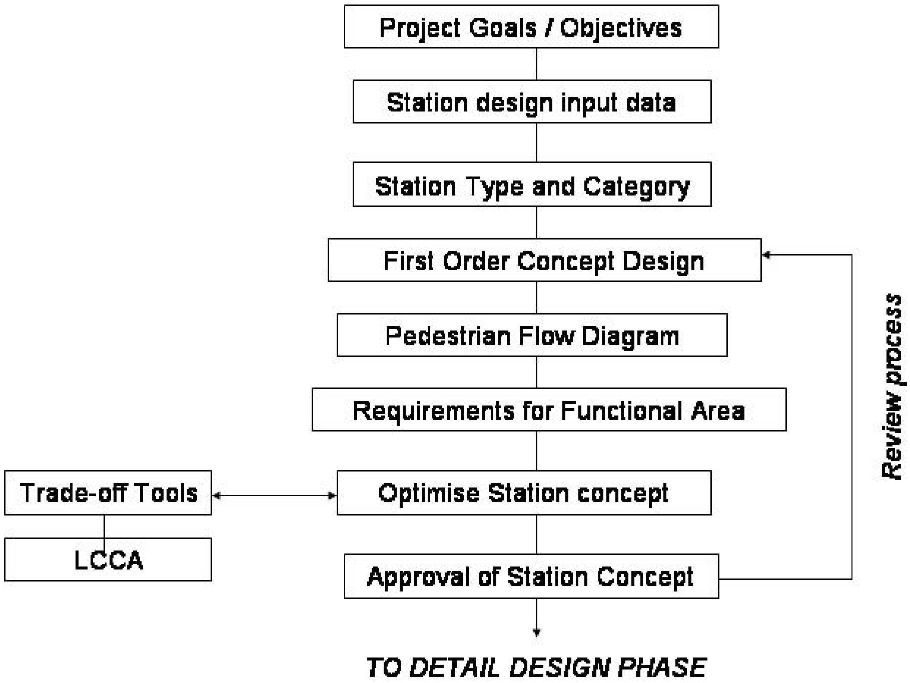

Figure 1 : SARCC Feasibility / Concept Station Design Phase (SARCC, 1997)

The NGS document further mentions that "*all design characteristics shall be identified and the determination of the specific parameter per station shall be according to the* <u>*prescribed method*</u> *or* <u>*any acceptable transport engineering method*</u>*. Some of the methods (models/procedures) are however currently in the process of normalisation and finalisation*" (SARCC, 1997).

There are two problems with this general guideline. Firstly, there are no set "*prescribed methods or models/procedures*" proposed in the document. Secondly, the general guideline, "*any acceptable transport engineering method*" in the determination of station functional areas *is unclear* and therefore open to varied ambiguous assessment techniques making the (client) review process and signoff complicated and lengthy.

In the design process of the Khayelitsha Stations 4 and 4A, the respective design report indicated that the "*NGS document is vague*" and "*there is no guidance on the spatial provisions of the concourse in the NGS and similarly, the spatial requirements for queuing at the ticket office*." (A3 Transportation Engineers et al, 2004). Furthermore, whilst evacuation procedures are addressed separately via operating procedures from a risk management perspective, these are not discussed in the guideline document.

During the course of the AHL design process, it became clear to the author and the client body (SARCC/Intersite), that the station design process is incomplete, offers varying outputs, is not rigid and is in the process of "evolving".

The "Evolving" Station Design Process

With the recent intention (in 2007) by the client body to upgrade the AHL Stations, the design process has incorporated pedestrian modelling. The outcome of the pedestrian modelling, applied to the evaluation of the station design, was essentially conducted to confirm the results of the SP modelling and address other microscopic[4] behavioural issues, such as the impact of bi-directional flows on concourse and passageway capacity and concourse levels of service, which is difficult to calculate numerically.

The author believes there is a definitive role for a SP-model which will provide the initial spatial parameters to a station design, which is a necessary step before progressing to the microscopic modelling phase. The inputs from the model help reduce the number of iterations between architectural design and microscopic modelling and is therefore considered an efficient design tool. As the model is still considered a “work in progress” model, it is intended to improve the model by incorporating station evacuation requirements and TCQSM (Transit Capacity and Quality Service Manual) rather than HCM (Highway Capacity Manual) levels of service.

It is proposed through this paper that the new “evolving” process of railway station design incorporates the use of a standardised SP-model for the “*Requirements for Functional Area*” and “*Review Process*” as shown earlier in Figure 1. It is believed that the benefits of including SP-(macroscopic) modelling to the current design process will improve station design in South Africa.

DEVELOPMENT OF A spatial PARAMETERS (SP) MODEL

Background to the formulation of the SP-Model

The SP-model was developed to calculate station infrastructure sizing requirements in order to accommodate the station design peak one-minute flow rates at acceptable levels of service. As there are dependant relationships between certain spatial parameters, the spreadsheet proved to be a useful tool. The SP-model spreadsheet incorporates traffic engineering, pedestrian flow theory, queuing theory and Level of Service assessment criteria (HCM, 2000).

After several trial versions, the SP-model (version 05) became the benchmark model for the design of the AHL stations although it is acknowledged that the model is still evolving and its outputs are not to be considered as rigid spatial requirements.

Revisions to the SP-Model since AHL Project Inception

The SP-model has undergone several revisions since February 2007, culminating in a version 05 status, dated 8 October 2007. This model was finally approved by the SARCC after a formal presentation by the author to SARCC/Intersite stakeholders on 23 January 2008.

The successive revision of the SP-model outputs (together with cost estimation revisions dependant on these outcomes) became the major driver of the “*Review Process*” as indicated in Figure 1. Throughout the design process, model improvements were made to address specific requests by the Architects (J&G, 2007a & b).

A version 06 model was produced in April 2008 which models the relationship between number of ticket verification points (TVP’s) and queuing space and also provides a queuing area requirement rather than a queue length output. This is essential as queuing behaviour observed at turnstiles in Cape Town follows an aggressive/competitive behaviour, rather than an orderly linear queuing process (J&G, 2008c).

Features of the SP-Model

The model is built on a MS-Excel platform and is easy to use. There are no complex macros to run and the entire spreadsheet can be plotted out on an A3 landscape paper format.

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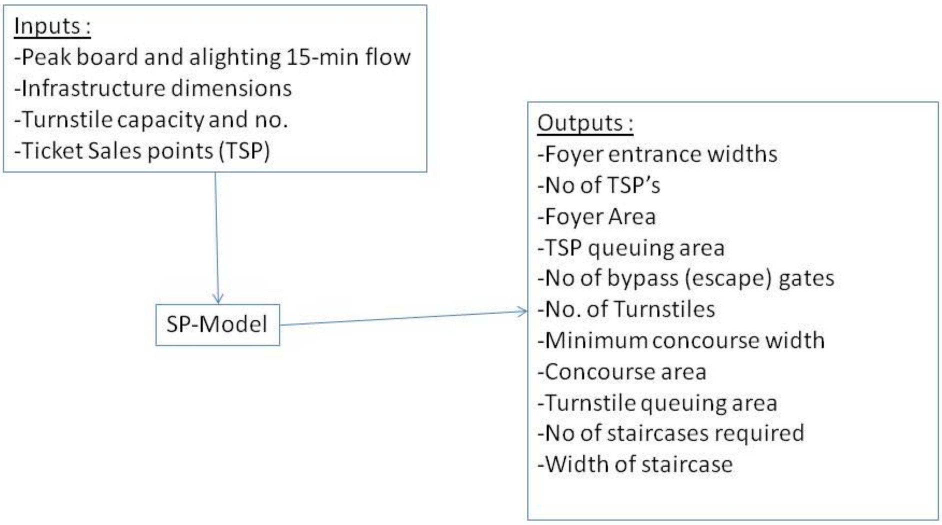
[4] *A microscopic model is one which bases its calculations on the movement or behavior of individual agents (or pedestrians).*

The pedestrian one minute peak hour alighting and boarding volumes forms the main input into the entire model. Inputs and outputs of the model are shown below :



The model is split into a Foyer area (the concourse area located upstream of the turnstiles) and a concourse area (located downstream of the turnstiles). Figure 2 graphically depicts the station parameters defined in the model. From the figure, it is evident that the current model is restricted to typical concourse line stations only and cannot be applied to larger terminal stations like Cape Town station itself.

The model also includes the assessment of overhead walkway and staircase widths due to street-to-street pedestrian volumes using the same overhead walkway as rail passengers.

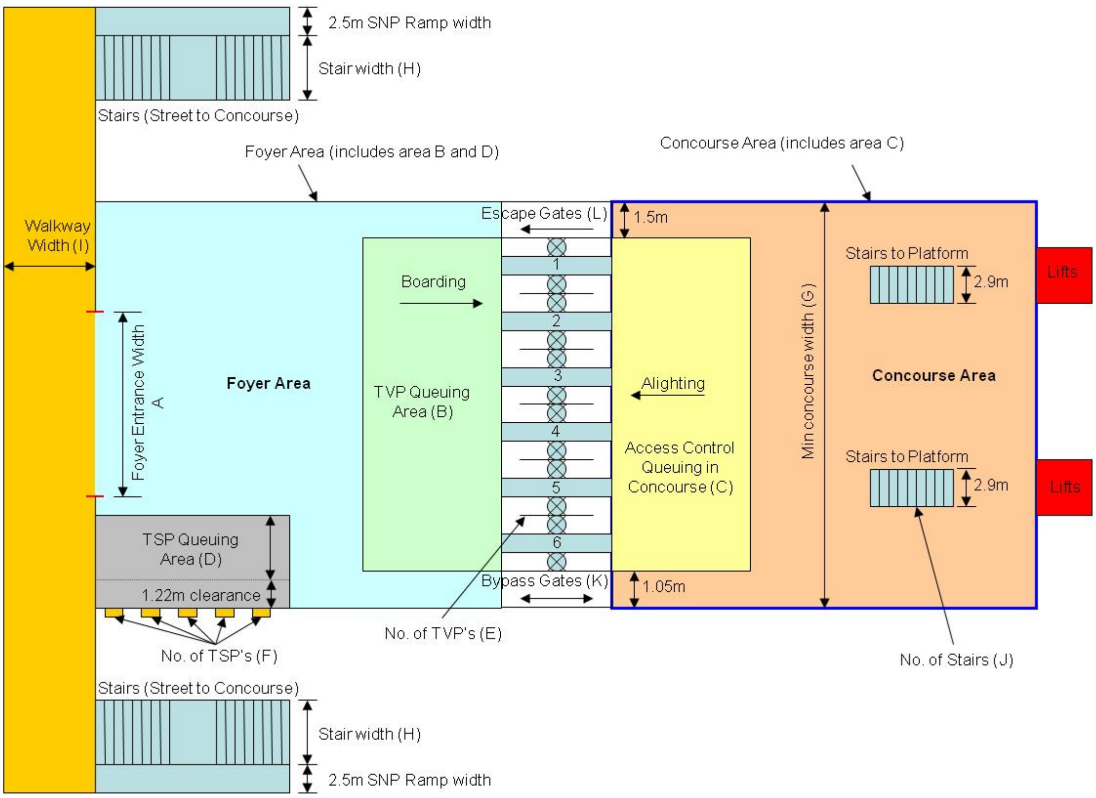


Figure 2 : SP-model Spatial definitions

The number of turnstiles required is a choice between available queuing area and number of turnstiles and the user has the option to test certain options. Figure 3 shows a typical graphic output for a passenger boarding profile for six 10 sec periods over the peak one minute period, based on a turnstile capacity of 30 pedestrians per minute [5]and four turnstiles servicing the boarding passenger demand.

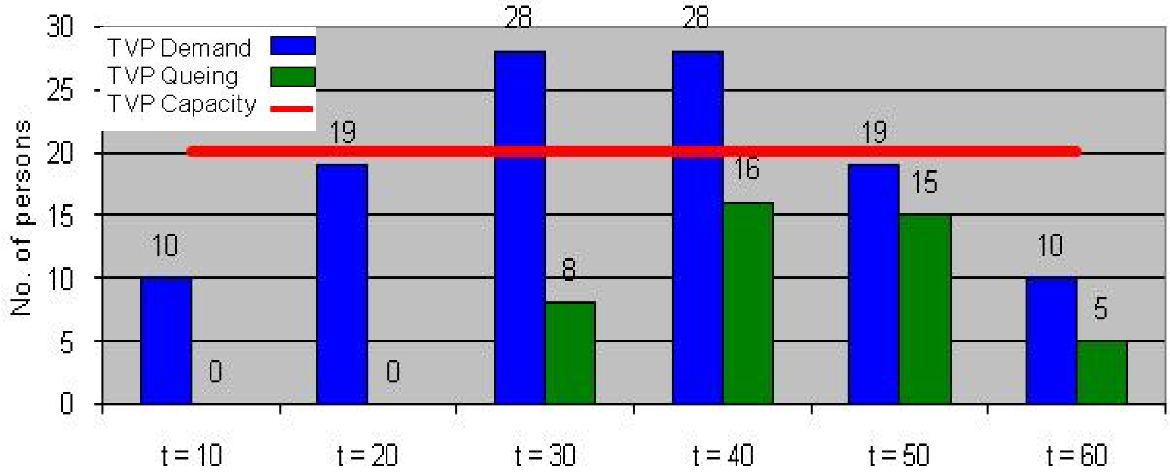


Figure 3 : SP-model output of turnstile queuing for boarding passengers

The results indicate that, for a boarding rate of 110 persons per minute, a maximum queue of 16 persons for the four turnstiles, (or four persons per turnstile) will develop over the peak one min period, requiring a 4m^2 queuing area to fulfil a LOS C requirement. Reducing the number of turnstiles to three, reveals a maximum queue length of 12 persons per turnstile, requiring a significantly greater queuing area of 12m^2 to fulfil a LOS C requirement. The guidelines unfortunately do not stipulate minimum queuing times.

Benefits of applying the SP-Model

Updating earlier versions of the SP-model (J&G, 2007a) and the subsequent review of the model to a version 05 (J&G, 2007b) resulted in a significant reduction in all AHL concourse sizing requirements resulting in considerable cost savings to the client. The main space saving resulted from the provision of a LOS C standard instead of a LOS A originally used and recommended in the NGS guidelines. Street-to-skywalk staircase widths were also reduced as a result of a drop in LOS from C to D together with the introduction of standard compulsory ramps for SNP access (SARCC, 2001).

Resulting from the recent significant savings effected by way of SP-model outputs, the client body commissioned, in April 2008, a pedestrian modelling exercise with two primary objectives in mind as follows:

- To confirm the spatial requirements determined by the SP-model.
- To amend or “fine tune” the final design as required eg. pinch points, integration of functions etc which is difficult to calculate numerically.

PEDESTRIAN MICROSCOPIC SIMULATION MODELLING

Until very recently, pedestrian microscopic modelling has not been incorporated into the design of railway stations in South Africa. The recent developments in station design described in the

[5] Based on current turnstile technology, to be replaced by higher capacity access control devices.

previous sections have led to the incorporation of such modelling to assist/augment and confirm the spatial designs. There is no doubt that microscopic modelling provides significant beneficial value, particularly with regard to modelling interactions between conflicting pedestrian flows (Hoogendoorn et al, 2004), but it is apparent that such benefits have not been fully exploited in South African and should be encouraged. The sensitivity and alignment of pedestrian modelling outputs to the SP-model outputs is of key interest to the author and will form a major informant towards updating future versions of the SP-model.

FURTHER RESEARCH AND IMPROVEMENTS

The current status of the limited SP-model is that it cannot account for pedestrian volume variation within the peak 15 minute design period as it uses a uniform flow distribution over this time period. There is a therefore a risk to stakeholders that the station is either under designed (to the discomfort of users) or over designed (at unnecessary expense to the client). It is also believed that merely applying International design standards may not be the most appropriate for designing Public Transport facilities for the multi-cultural pedestrian population prevalent in South Africa. The extent to which an unacceptable LOS can be tolerated in station design is also to be addressed.

It is the intention that further research be conducted in South Africa which will further refine and develop the model to be sensitive to input variations and environments. It is intended that station evacuation requirements be built into the SP-model. This will ultimately allow for a more confident use of the SP-model and reduce the optimising and review process time and better inform station infrastructure dimensioning requirements. It is envisaged that the SP-model provides a toolkit to stakeholders and clients enabling checking capacities of existing and proposed new station designs.

CONCLUSION

The AHL station design process has revitalised a new station design philosophy out of which has emerged a "work in progress" SP-model for testing spatial and other operational parameters. Recent microscopic modelling results indicate that the model results are not inaccurate and therefore can be applied as a means to determine initial architectural sizing requirements for conceptual and "first-order" design purposes. The essence of the model is in its simplicity. Built on an MS-Excel platform, the model is simple to operate and the user does not need to be an advanced computer user.

Within the context of the AHL project, the SP-model provided output parameters which significantly reduced initially proposed sizing estimates that resulted in significant capex cost savings.

Once the initial concept design are drawn, it is nevertheless recommended to test the station design using commercial microscopic modelling applications to confirm spatial arrangements which takes the proposed train schedule and associated pedestrian peaking load within the 15-minute period into account.

It is intended that future versions of the model will provide a tool for confidently providing the "first order" spatial requirements for concourse station facilities, significantly reducing the design time and cost required for approving railway station designs.

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