Microsimulation of mass transit operations in Africa

Robin Kaenzig

With extraordinary levels of demand for public transport in its cities, Africa is an exciting place to develop new transit systems. Catering for such demand brings its own challenges, particularly at an operational level in providing the necessary capacity to satisfy travel movements. Bus-based systems can meet the levels of demand through the provision of high bus frequency and dedicated infrastructure. However, as the frequency of operations increases, greater stress is placed on the operating infrastructure and system management. With lower tolerance to disruption, careful design and planning is required to ensure that the system operates efficiently not only in perfect conditions where all elements run as planned, but can cope when things don't run as smoothly.

The transit system design process must ensure that the infrastructure, service plan and operational management work together to ensure efficient operations in the conditions within which the system must operate. This paper looks at how microsimulation can serve as a valuable tool by testing the system design under the inherent day-to-day variability affecting operations.

The Bus Rapid Transit (BRT) concept is generally considered to have been born in Latin America, but has now been adopted and adapted in many cities around the world, delivering high quality public transport with the flexibility to fit into very different environments. BRT follows a system-based approach which considers all elements of a journey, offering bus priority measures to ensure improved journey times and reliability, enhanced waiting environments, efficient ticketing and information systems, and a service plan focused on meeting user needs.

BRT has proved particularly appropriate to the needs of developing countries where mass transit can be delivered affordably and has demonstrated the commercial viability to attract the private sector involvement and to be self sustaining.

In the capital city of Ghana, and with a population of around two million people, Accra experiences its fair share of congestion. Far from alleviating the problem, the city's public transport services, comprising mainly of small old minibus vehicles known as trotro, are a significant factor behind the poor traffic conditions. Erratic driving behaviour and undisciplined stopping for boarding and alighting often lead to one or more lanes of the major arterial routes being blocked around the main stopping points.

To tackle the transport problems, the Department of Urban Roads (DUR) in Ghana has overseen a study into the feasibility and detailed design of a 'pilot' BRT corridor, to run along an arterial highway into the heart of the city. With the planning phase nearing completion and the contracts for construction let, Ghana is now looking forward to its first experience of BRT.

ACCRA BRT

The BRT system will operate within segregated infrastructure for the majority of the 12km pilot route, running in the median between two lanes of highway traffic in each direction. Enhanced stations at 10 locations along the core BRT corridor (see Figure 1) will be provided in bilateral configuration (to either side of the BRT runningway) accessed by pedestrian overbridges and further terminals at the origin of different routes.

The levels of travel demand observed along the pilot corridor are high. Given the limited modal choice and inadequacy of the existing public transport offer, BRT will enjoy high levels of abstraction, with forecast passenger flows in excess of 10,000 passengers by direction in the peak hour, totalling over 100,000 trips per day. Accommodating this level of demand on a fleet of 12m buses (determined to be most appropriate to coping with the conditions of the local environment) will require very high frequency operations, with headways along the BRT corridor falling to under 30 seconds in the peak hour.

A service plan has been developed to best meet the needs of travellers, providing direct services where possible, but ensuring that access is provided from any given BRT station to any other with a maximum of just one interchange. The resulting service plan consists of tributary routes (joining the BRT corridor from outlying origins) and feeder routes (bringing travellers to interchange points with the BRT corridor). Within the segregated BRT infrastructure there are stopping services and semi-express services only serving a limited number of BRT stations.

Figure 1: BRT station

AUTHOR'S DETAILS
Robin Kaenzig is a Principal Transport Planner with Integrated Transport Planning Ltd. Robin carried out the demand forecasting and operational planning for Accra BRT Feasibility and Detailed Design Study led by Mott McDonald. Robin is also working on BRT projects in Nigeria, Kampala and the Philippines. He can be contacted by email at Kaenzig@itpworld.net

The resulting service plan consists of:

- 12 individual services of which 5 are tributary routes
- 3 inbound destinations
- Service headways ranging from 1 bus per minute to 1 bus every 20 minutes
- Express services, semi-fast services and stopping services

Whilst this choice of services provides great amenity to the traveller, there are operational challenges. A multitude of services running at different headways and with different stopping patterns makes management of headways more difficult. In addition, the tributary services coming from off the corridor operate outside the segregated infrastructure for a proportion of their route and as such have inherent variability in arrival onto the corridor.

The BRT infrastructure must be able to cope not only with the frequency of buses, but also the with the interaction of the different services as they progress through the BRT infrastructure. This necessitates passing bays at stations to ensure express services are not impeded by the stopping services. Junction operation is also critical to assisting the progress of the BRT buses and keeping the system flowing, whilst not causing unacceptable delays to other highway traffic. Finally, but not to be overlooked, is the functioning of the BRT stations, which in certain locations must allow the throughput of up to 6,000 passengers in the peak hour. These must function efficiently from the passenger perspective and also for the bus vehicles which must dock smoothly and rapidly, ensuring minimum boarding and alighting times to free up the stop for the subsequent bus.

MICROSIMULATION AS A MEANS OF TESTING THE SERVICE PLAN

Conventional service planning calculations can be used to determine the capacity requirements of the system, to establish the combined headways along any particular section of the system and the average arrival frequencies at the BRT stations. However, often these calculations only represent a scenario in which every service adheres precisely to its scheduled movements. There is a danger that infrastructure built to these modelled requirements will not cope with the realities of day-to-day operation with the variability of conditions and unforeseen incidents which will occur as a matter of course.

Microsimulation, however, provides a means of evaluating the system design in conditions which reflect the variability of bus operations. BRT runningways, stations and the interaction between the bus services could be modelled with the inclusion of run time uncertainty, variable dwell times and the complexities of individual vehicle interaction which would occur as the different service pass through the infrastructure and stop at the stations.

The S-Paramics microsimulation software was used to code the BRT route, representing the runningways, stations and the junctions along the route. The movements of other highway vehicles were modelled within the network where they had a direct impact on BRT movements, for example in areas of mixed running and where other highway movements cross the BRT route.

The progress of buses through the BRT infrastructure could now reflect the headway compression effects of delay at the signalised junctions and variable arrival of tributary services.

Further realism was possible in modelling the bus service patterns. The public transport modelling module within S-Paramics allows the user to specify bus routes, list the stops a particular service will call at, and also choose from various options in terms of type of bus stop. The most straightforward of these is a simple stop in a designated location which accommodates one vehicle, other buses queuing until the stop becomes free. A second option allows a number of boarding points at given intervals, all for the same stop, whilst a third 'dynamic' option allows buses to pull up anywhere within a specified length of route to board or alight passengers.

To accommodate the high bus frequencies, different destination options at a single stop and the potential for simultaneous arrivals, extended bus stations were designed with multiple boarding and alighting points. As such, the major stations have up to four boarding points, each serving a different destination set, and at each of these points, there is holding provision for two buses, the first for boarding and alighting and the second permitting alighting whilst waiting to advance to the boarding point. (See Figure 3)

The S-Paramics model also offers the user flexibility in modelling dwell time behaviour of buses. Either a fixed dwell time can be applied (in seconds) to each stop or a passenger arrival rate can be specified, with a given boarding time per person. The latter is effectively constrained by the capacity of the passing vehicles, so passengers can only board if there is space to accommodate them on the bus.

This ability to model passenger boarding behaviour provides a valuable means of adding variability to bus movements, allowing the modelling to better reflect real conditions where bus dwell times will not be for fixed periods. Stop-by-stop passenger demand forecasts were used to profile the relative arrival patterns at each stop and for each of the different services. Consequently, the services experiencing higher demand would generally exhibit longer dwell times within the model. The only drawback to the passenger modelling functionality was a limitation of a maximum specified 360 passenger arrivals per hour, compared to a forecast arrival rate of over 5000 in the peak hour at certain stations in Accra! (This was easily overcome by using an increased boarding time to factor boarding times.)

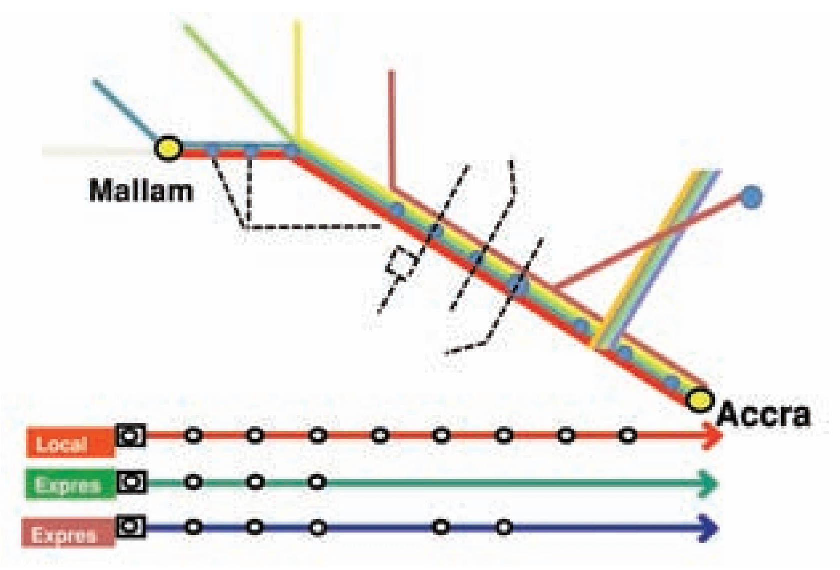

Figure 2: Accra Network, Service Plan Schematic

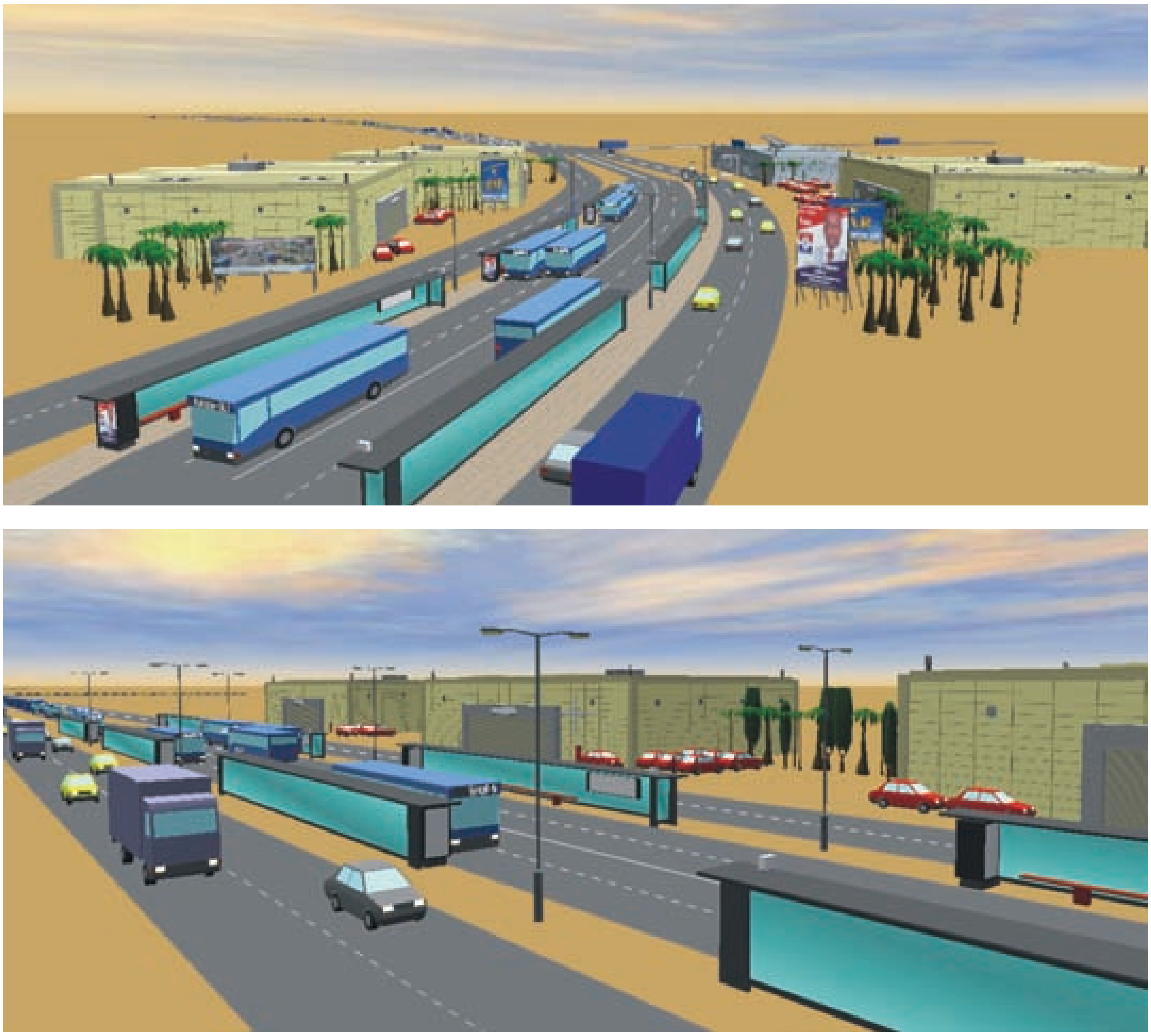

Figure 3:
Bus stop layout

ANSWERING THE IMPORTANT QUESTIONS

S-Paramics can output a wealth of summary statistics ranging from average journey times by route, to queuing statistics at junctions and bus delay. Whilst these were of use in reporting and analysing the modelling, in many cases the most useful aspect of the micro-simulation exercise was simply to take time watching the progress of the various bus services down the corridor in 'real' time, seeing behaviour of the buses at the stops, the interaction of the various trunk and feeder services, and watching the build up of buses at the major junctions along the route. This simple analysis allowed greater insight into what problems might be thrown up in live operation, and aid the imagination in questioning 'What if . . .' scenarios.

For instance . . . what if three buses arrive at a stop all at once, what if there is a vehicle break down in the segregated section of corridor, what if one stop has a much greater than expected level of demand – say for a public event etc.

The modelling highlighted headway compression occurring at junctions, particularly at points where trunk and feeder services converged, which led to re-adjustment of the planned signal phasings. The frequency of multiple arrivals at stops was also analysed and found to generally fall within operational limits, with contingencies put in place for the rare occurrences of excess vehicle arrivals.

CONCLUSIONS

Applying micro-simulation to the development and planning of bus operations gives the practitioner valuable insight into the practical issues, both physical and operational, which will determine the ultimate performance of the transit system. The ability to add the realism of variability in dwell times, run time 'un-reliability' of mixed-flow running, and the headway compression effects of travelling through even the segregated BRT infrastructure means that the service plan can be tested, not just under 'perfect' operating conditions but far more importantly under 'imperfect' operating conditions.