VEHICLE QUEUE STORAGE GUIDELINES FOR ACCESSES TO PRIVATE DEVELOPMENTS IN CENTURION

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INTRODUCTION

In recent years, the control of vehicular access to private developments in Centurion has become increasingly popular. Access control is not only limited to commercial developments but is also common at residential and office land uses. Access control is provided primarily for the purpose of improved security. However, poor planning of these access control facilities often have a negative impact on the management of the urban road network. Vehicles queuing on the roadway whilst waiting to enter a development limit the capacity of such a road. More importantly, these vehicles are a traffic safety hazard, as the geometric layout of urban roads does not always ensure that sufficient sight distances can be maintained at the access points to these developments. It is therefore important that back-up of vehicles entering an access controlled development does not interfere with the movement of vehicles on the municipal road network. Provision should therefore be made to store vehicles waiting to enter private properties away from the municipal roadway (Stover & Koepke, 1988).

The Centurion Town Council (recently incorporated into the City of Tshwane Metropolitan Municipality) developed guidelines aimed at ensuring that developers provide sufficient queue storage space to accommodate anticipated vehicle queues at the accesses to developments. The expected vehicles queue length is a function of the number of access lanes to a development and the type of control, e.g. mechanical boom or sliding gates.

OBJECTIVES AND SCOPE

The objectives of this paper are to:

- present a summary of vehicle service rates, surveyed at security controlled accesses in the Centurion area;
- discuss the development of the guidelines for the required vehicle queue storage space; and to
- indicate how these guidelines should be used and applied in practise.

Various types of access control systems are available on the market. The most common systems are mechanical booms and sliding gates. The functioning of these systems is also affected by the method with which the boom/gate is activated, e.g. coded keys or cards, key ring remote controls, remote sensing devices etc.

The scope of this paper is limited to access control at the following land uses:

- Residential areas with mechanical booms and an exclusive visitors lane (up to 4 booms);
- Residential areas with mechanical booms and no visitors lane (one or two booms);
- Offices or residential developments with a single sliding gate;

- Office developments with mechanical booms and an exclusive visitors lane (up 4 booms);
- Office developments with mechanical booms and no visitors lane (one or two booms);
- Commercial developments (retail, light industrial, etc.) with up to 3 mechanical booms.

All of the access control systems included in the scope refer to the number of booms/gates at a single access point. Where a development has more than one access at different locations, combinations of the above mentioned access control systems may be used.

VEHICLE SERVICE RATES AT SECURITY CONTROLLED ACCESSES

One of the most critical aspects that influence the development of vehicle queues at access controlled gates is the service rate of the access control system to the development. The service rate of a specific gate or boom is the maximum number of vehicles that can pass through the gate during an hour and is normally expressed as the number of vehicles per hour. The lower the service rate of an access gate or boom the higher are the likelihood of vehicle queues forming at the access. A security gate with multiple access booms, but with a very low service rate may therefore result in longer vehicle queues forming than at a security gate with one access boom and a very high service rate.

Limited information is available on the service rates at access gates for South African land uses. Surveys were therefore conducted at developments in the Centurion area to determine the vehicle service rates at typical developments. The following types of development were included in the surveys:

- office developments (4 surveys);
- security villages (1 surveys)
- commercial development (1 surveys)

Surveys at other developments in the Centurion area were also attempted. However, these surveys were unsuccessful due to one of the following reasons:

- access control is not enforced during peak periods due to excessive vehicle queues; and/or
- the control booms or gates were out of order.

The vehicle service rates were surveyed during the applicable peak hour (e.g. PM peak for residential developments) at the accesses to the above mentioned developments. The service rate can only be observed when a sufficient queue of vehicles has formed at an access. For the queued vehicles the service time is the time from the moment that the first vehicle passed through the gate, until the moment that the second vehicle cleared the gate as well. The time intervals measured can be referred to as the service time. The service rate is the mathematical inverse of the service times. The service times and rates that were surveyed at a few developments in Centurion can be seen in Table 1.

Table 1: Surveyed service times and rates

Land Use	Control Type	Peak Hour Traffic Volume	Service Time (seconds per vehicle)				Service Rate (veh/hour)	
			Min.	Max.	Avg.	85th Percentile	Avg.	85th Percentile
Office	Mechanical Boom	37	6	18	9.0	10.9	400	330
		112	6	22	9.9	12.2	364	295
		153	5	33	9.1	12.2	395	295
		255	4	102	8.2	10.7	439	336
Group Housing	Sliding gate	25	4	24	7.2	14.3	500	252
Commercial	Mechanical Boom	103	4	35	11.2	13.0	321	276

It can be seen from Table 1 that average service rates for developments that were surveyed range from 321 to 500 vehicles per hour. It should be noted that the sample sizes of most of the surveys in Table 1 are probably too small to be used with confidence.

It can further be seen from the table that there is not a significant variation in the minimum service time recorded at the different developments. There is however, a significant variation in the maximum service time between 18 and 102 seconds. This variation can be ascribed to the influence of visitors that have to sign a register before being allowed into a development on the service time. Because of this variation it is important that provision should be made to accommodate visitors separately at any development where a significant number of visitors can be expected.

Using the above mentioned surveys as well as information on vehicle service rates provided in the City Council of Pretoria's ***Guidelines for Traffic Impact Studies*** (1998) an average design vehicle service rate of 325 vehicles/hour was determined for commercial developments. Similarly, design service rates of 385 vehicles/hour for office developments and 285 vehicles/hour for residential developments was determined. The average service rate for visitors to office and residential developments were taken as 50 vehicles/hour. It should be noted that the volumes are average values and provision is made in the simulations to introduce safety factors.

EXPECTED VEHICLE QUEUE LENGTHS AT ACCESSES TO DEVELOPMENTS

The expected queue lengths at boom operated security gates can be determined for simple systems using queuing theory formulas. Normal queuing theory however, cannot be used to determine the expected queue length at systems with varying vehicle service rates such as at an access control gate that services employees/residents and visitors. Standard queuing theory formulas can also not be applied at sliding gate operated security gates. This is due to the fact that the service rate is influenced to a greater extent by the speed with which the gate opens or closes than the time that it takes a motorist to activate the gate. While the first vehicle in a queue might therefore have a very long service time, the second vehicle in the queue will have a very short service time due to the fact that the gate is already open. If the gate is only partially closed at the time of the arrival of a vehicle, the service time will also be significantly reduced.

Due to the expected variations in vehicle arrival rates, service times and human behaviour, it was decided that the expected queue length could in this case be addressed to a higher degree using computer simulation techniques, rather than queuing theory formulas. The simulations were done on a vehicle by vehicle basis, where every vehicle in the system is traced from the time of arrival at the gate until the time that it has passed through the system. For mechanical boom operated systems, the simulations were done using Excel spreadsheets, whilst the simulations for the sliding gates were done using a simulation program written in the Pascal programming language. The following assumptions and simplifications of actual vehicle behaviour at security gates with mechanical booms were made:

- provision was only made for the accommodation of visitors in exclusive visitor access lanes, or for systems where visitors are allowed to access the development through all access lanes. The situation where the visitors' access lane is used by residents/tenants as well, was therefore not considered;
- vehicle arrivals were assumed to be random;
- vehicle service rates were assumed to have a normal distribution;
- 5% of vehicles arriving at the access will be visitors;
- a design volume/capacity ratio of 0,85 was assumed;
- the assumed service rates makes provision for activation of the mechanical booms by swipe card or coded key card, conforming to the data collected in this study.

For sliding gate-controlled systems, the same assumptions were made except that:

- the assumed service rates makes provision for activation of the gate by remote control;
- the width of the sliding gate was assumed to be 3,0 metres with gate travel speed of 5,5 metres/second.
- only peak direction flows were simulated.

Due to the random arrivals of vehicles, as well as the normal distribution used for service times of departing vehicles, every simulation will result in different vehicle queue length as can be expected from day to day in real life. The queue storage diagrams that were developed were therefore based on multiple simulation runs to take account of the stochastic nature of the results.

QUEUE STORAGE GUIDELINES FOR CENTURION

The City Council of Centurion's ***Access Management Policy*** (1998) contains guidelines for the approval of accesses to developments. The approval is subject to amongst others, the location of the access relative to other accesses, the class of road on which the access is located, etc. The ***Access Management Policy*** classifies the roads in Centurion into 7 different classes, where class 0 is freeways with the highest access standard and class 6 is local access roads with the lowest access standard.

In terms of the ***Access Management Policy,*** no direct access to private developments is allowed off freeways. The queue storage guidelines that are discussed in this paper are therefore only applicable to road classes 1 to 6, i.e. major arterials to local access roads. The applicable design queue storage standard for the different classes of road in Centurion can be seen in Table 2.

Table 2: Queue Length Design Standard and Level of Access Classification

Functional Classification	Level of Access Classification	Applicable Design Standard
Freeways	0	Not Applicable
Major arterial street	1	95^{th} Percentile Queue Length
	2	
Minor arterial street	3	
Major collector street	4	
Minor collector street	5	85^{th} Percentile Queue Length
Local access street	6	

It can be seen from Table 2 that a 95^{th} percentile queue length should be used for streets with level of access classification 1 to 4. For street classes 5 and 6 a 85^{th} percentile queue length should be provided. A 95^{th} percentile queue length is the vehicle queue length that will only be exceeded 5 times out of 100. Similarly, when a specific vehicle queue length will only be exceeded 15 times out of a 100, it can be described as a 85^{th} percentile queue length. A 95^{th} percentile queue length will therefore be longer that a 85^{th} percentile queue length.

More vehicle storage length should therefore be provided to accommodate a 95^{th} percentile queue length. On minor collector and local access streets, the possible negative impact of queue back-up into the roadway is not as critical due to the low traffic volumes and lower free flow speeds. For this reason sufficient queue storage should therefore be provided on minor collector and local access streets to accommodate 85^{th} percentile queue lengths.

Queue storage diagrams were developed and are included in Appendix A. The diagrams were developed for different combinations of land use and access control systems. Table 3 provides guidelines for the identification of the correct queue storage diagram for a specific development. The identification table makes provision for office, residential and commercial developments, with either sliding gates or mechanical booms. In the case of mechanical booms, provision is made for an access configuration with exclusive visitors' lanes or for a system where visitors can use all access lanes at the security gate.

Table 3: Access Guideline Identification Table

Type of Development	Control System		
	Sliding Gate	Mechanical Boom	
	Only One Access Lane Permitted	No Exclusive Visitors Access Lane Provided	Exclusive Visitors Access Lane Provided
Office	Figure A – 1	Figure A – 3	Figure A – 4
Residential	Figure A – 2	Figure A – 5	Figure A – 6
Commercial	N/A	Figure A – 7	N/A

It can be seen from Table 3 that provision was not made for sliding gates at commercial developments. Due to the nature of these developments and the possible high trip generation, the use of sliding gates at these types of developments is not recommended. Further, no provision is made for the exclusive accommodation of visitors at commercial developments, as all the patrons of these type of developments can be regarded as "visitors".

A typical queue storage diagram can be seen in Figure 1. The different components of the diagram, labelled ("A" to "G") should be interpreted as follows:

A: Type of control at the security access, either mechanical booms or a sliding gate.
B: Title, indicating to which type of land use the diagram may be applied. It also indicates whether the diagram contains 85th or 95th percentile queue storage graphs and if exclusive provision should be made for visitors. No queue storage graphs for visitor-only access-lanes are provided.
C: Queues of 10 vehicles (± 60 metres) were taken as the practical maximum queue that should be provided for at a development. Large developments such as regional shopping centres are therefore excluded from these guidelines, as these types of developments would warrant a traffic study, in which the accesses are investigated as well.
D: The maximum queue length that can be expected. It is important to note that the 85th and 95th percentile queue lengths may be significantly shorter than the expected maximum queue length. This implies that the design queue might therefore still cause road capacity and safety problems from time to time.
E: The queue storage space that should be provided in metres allows for 6 metres storage space per vehicle.
F: 85th or 95th percentile queue storage graph, as discussed in previous sections of this paper.
G: Size of the development, specified in gross leasable area (GLA-m^2) for office developments, the number of units for residential developments and the number of peak direction trips generated in the peak hour for commercial developments.
H: The queue storage space that should be provided in number of vehicles.

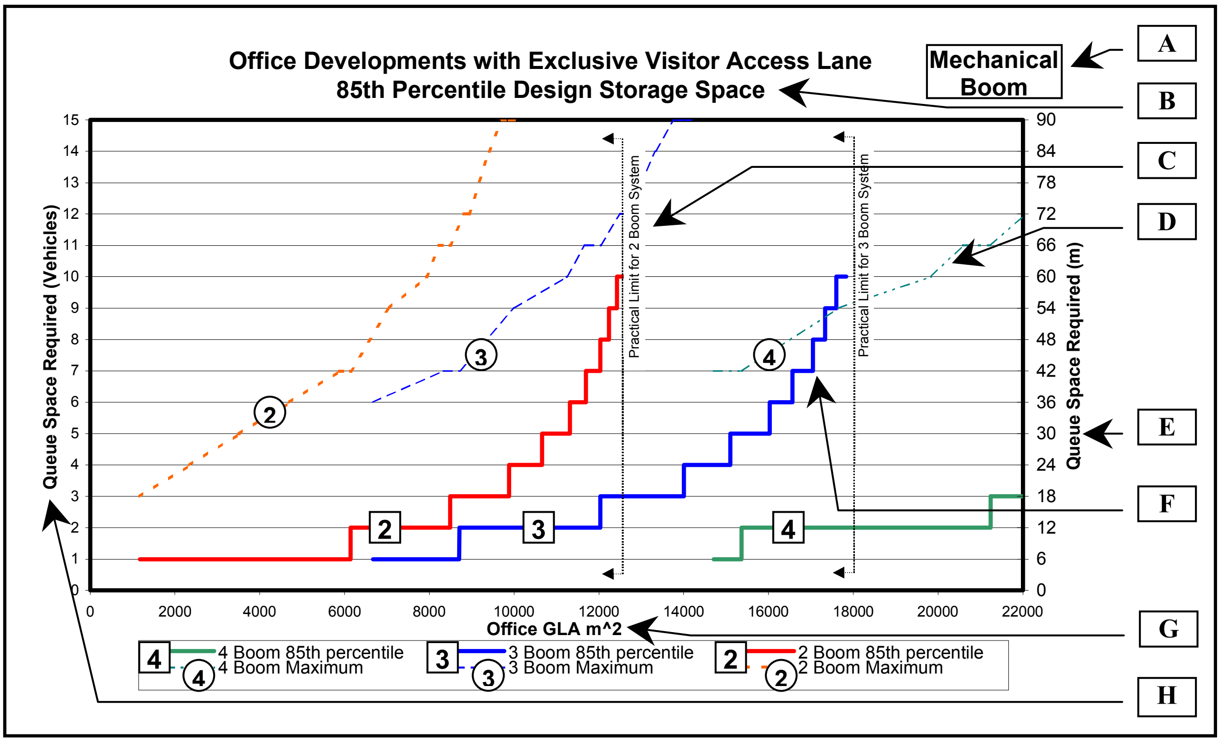


Figure 1: Typical Queue Storage Diagram

WORKED EXAMPLE

The application of the graphs are illustrated in this section with the use of a worked example.

Problem: A developer wishes to develop 15 000 m^2 of office area with mechanical boom access control, with exclusive visitors access lanes. The development will be situated next to a major arterial road.

Solution: Being situated next to an arterial route, 95th percentile queue storage graphs should be used (refer to Table 2). From Table 3 it can be seen that the relevant queue storage graphs is provided in Figure A-4.

From Figure A-4 it can be seen that the developer can either construct a three boom access gate, with sufficient queue storage space for 7 vehicles (42 metres) at all three access lanes, or a four boom access gate with provision for 2 vehicles storage.

RECOMMENDATIONS

Based on the findings of this paper it is recommended that:

- the recommended vehicle queue storage in Figures A-1 to A-7 should be provided on private property. The road reserve should therefore not be incorporated into the required queue storage, especially where future road upgrading is expected;
- the required queue storage for any development that does not fall into the categories for which these guidelines were developed, or any deviation from these guidelines should be motivated by a professional traffic engineer.
- all local authorities should consider the implementation of guidelines such as these, to ensure that the possible negative impact on road capacity and safety of poorly designed security controlled accesses is prevented. These standards should be communicated as early as possible during the development process to developers and their professional team.

REFERENCES

Centurion Town Council, 1998. ***Centurion Access Management Policy***. Gibb Africa: Pretoria

City Council of Pretoria, 1998. ***Guidelines for Traffic Impact Studies***. BKS: Pretoria

Stover, V.G. & Koepke, F.J. 1988. ***Transportation and Land Development.*** Institute of Transportation Engineers, Prentice Hall: New Jersey

APPENDIX A:

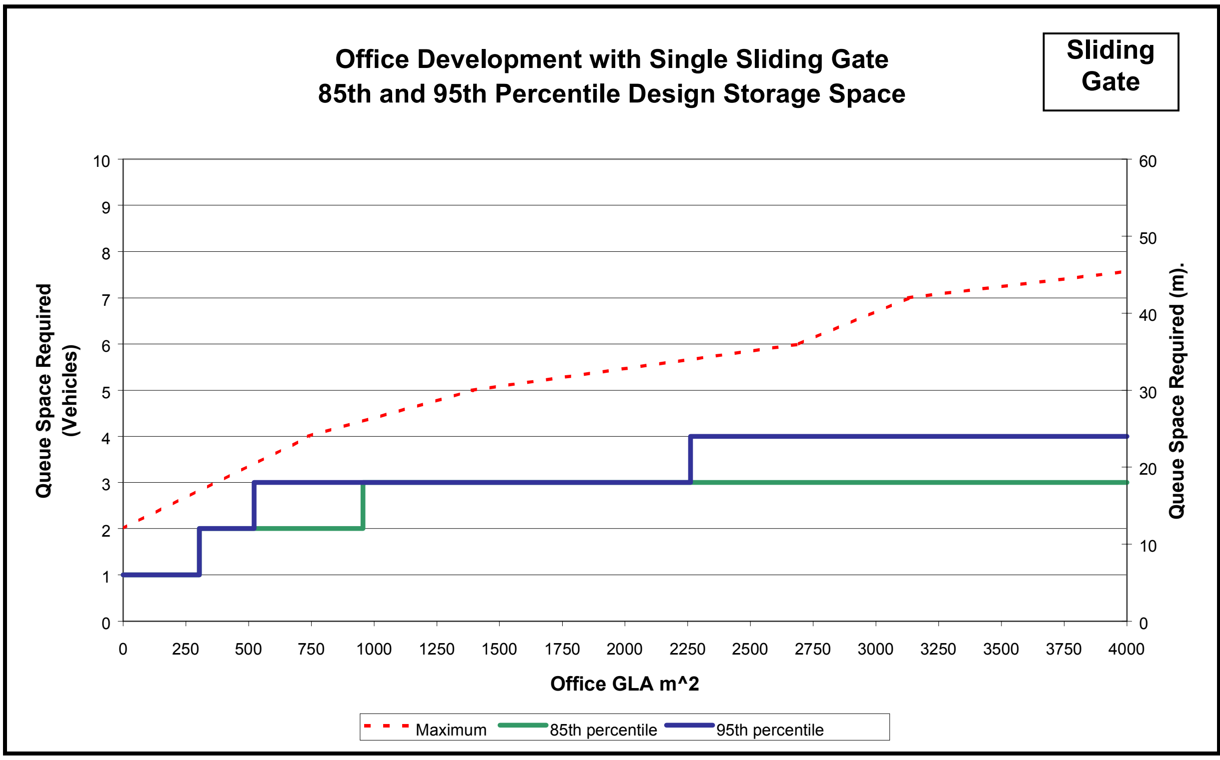


Figure A - 1: Queue Storage Graphs – Office Developments with access control by sliding gate

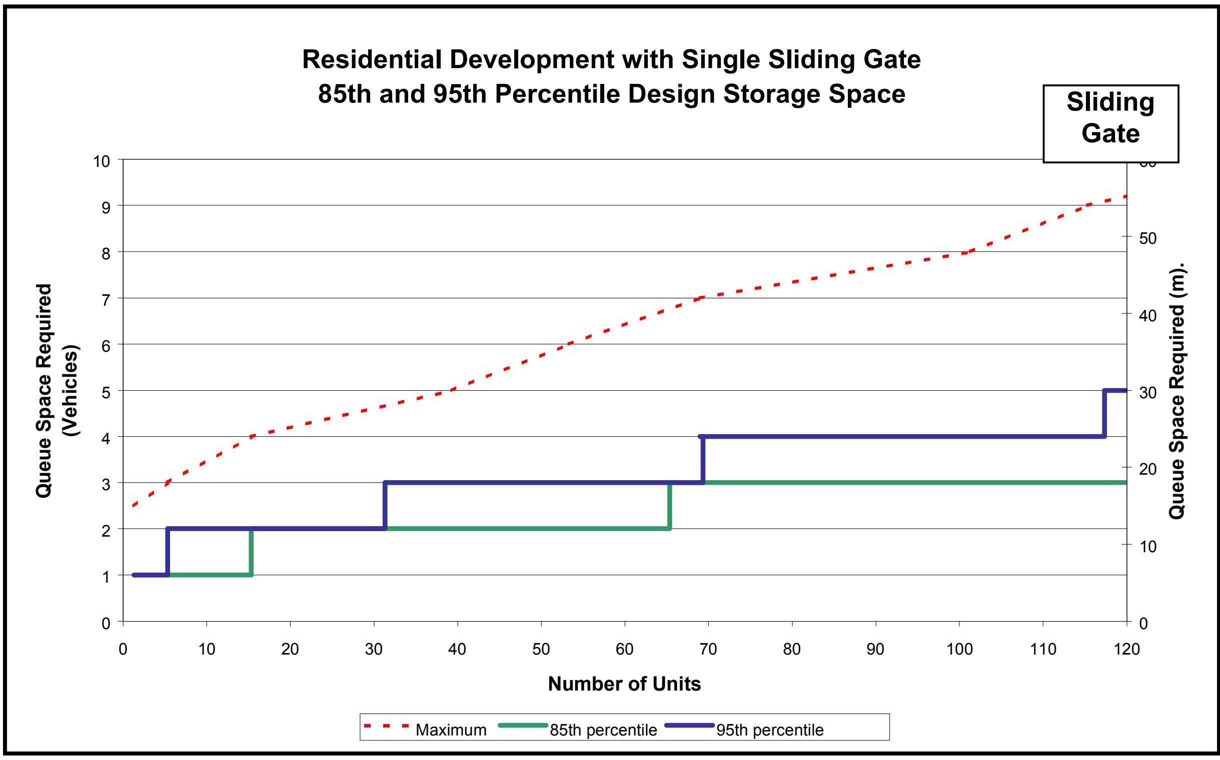


Figure A - 2: Queue Storage Graphs – Residential Developments with access control by sliding gate

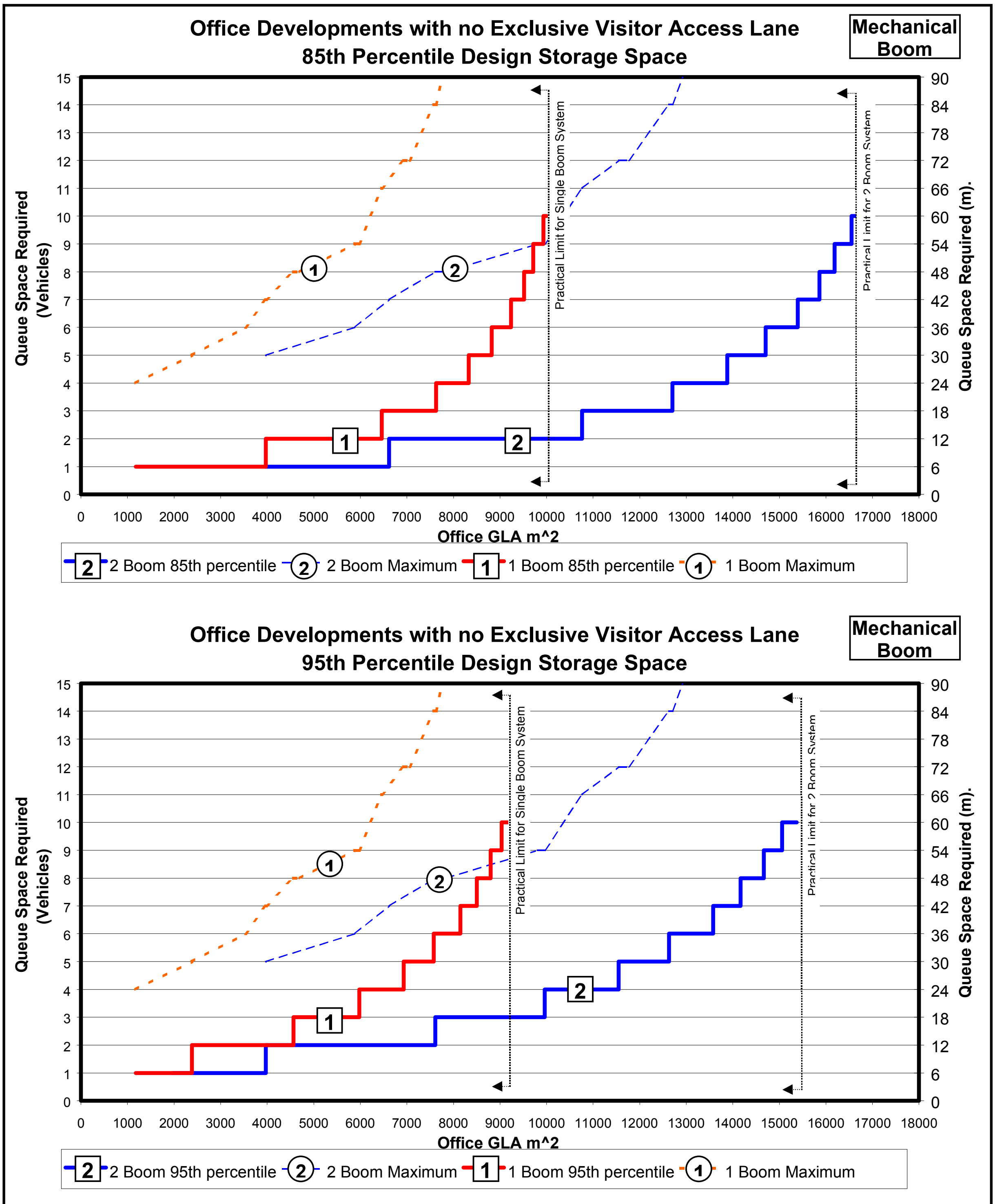
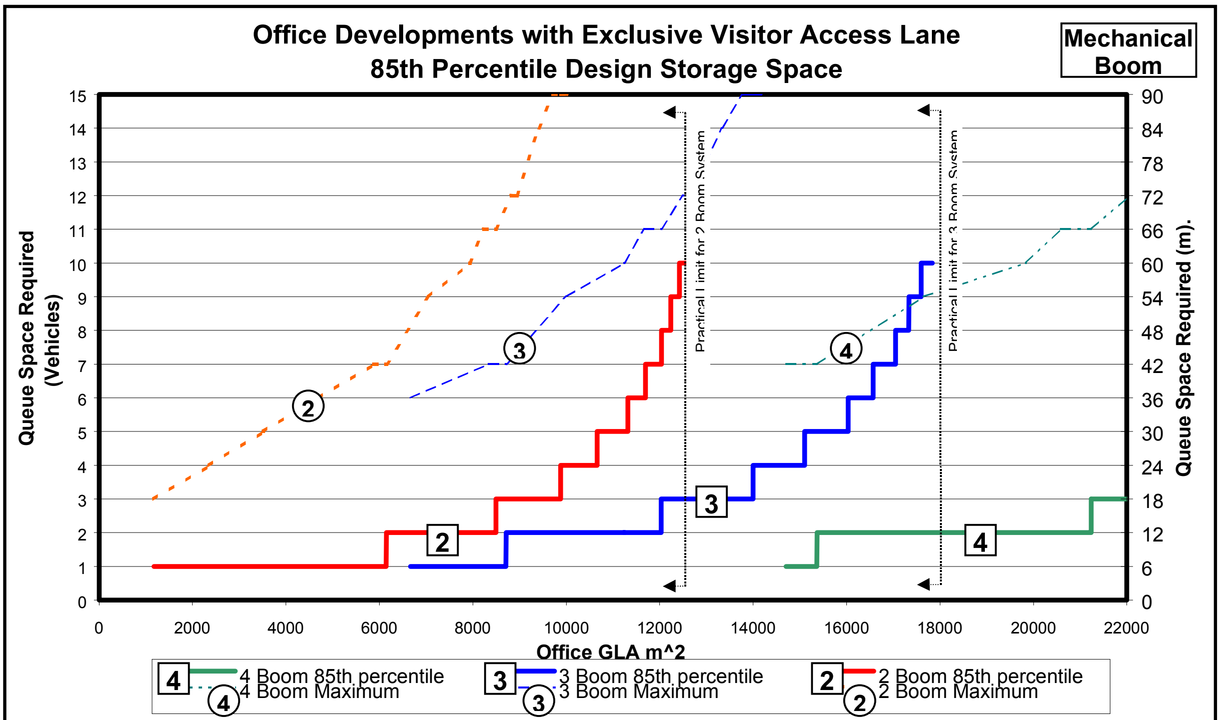


Figure A - 3: Queue Storage Graphs – Office Developments without exclusive provision for visitors



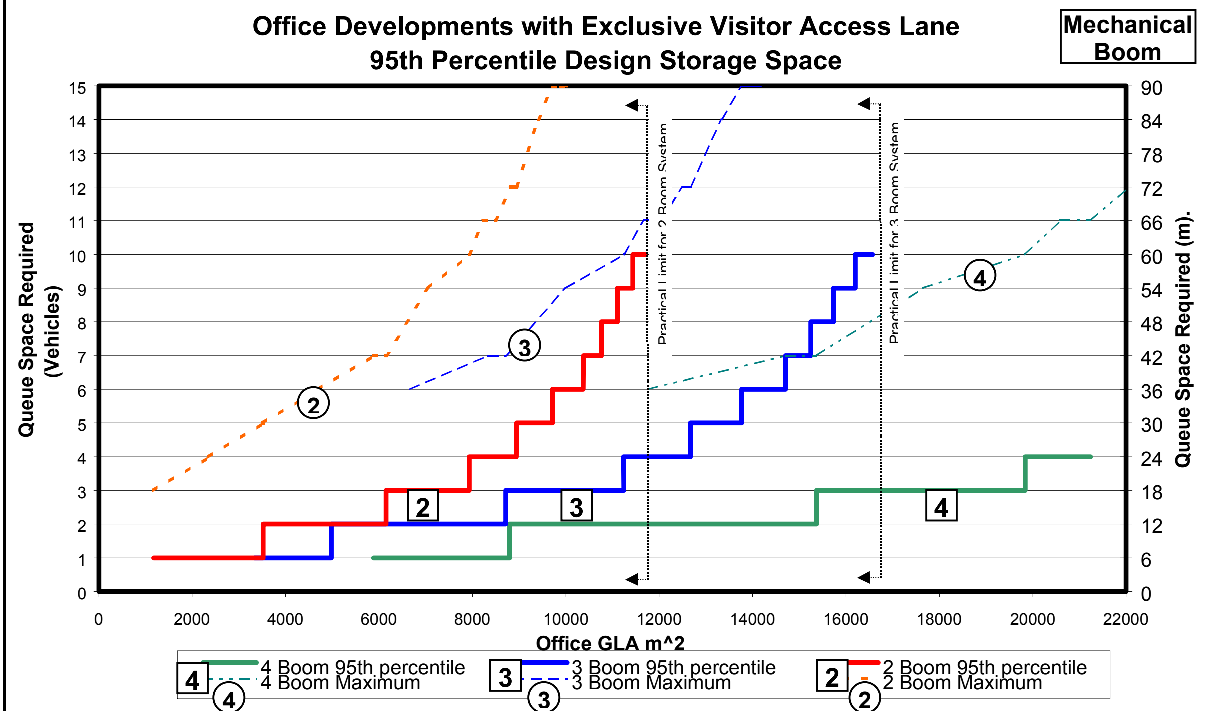


Figure A - 4: Queue Storage Graphs – Office Developments with exclusive provision for visitors

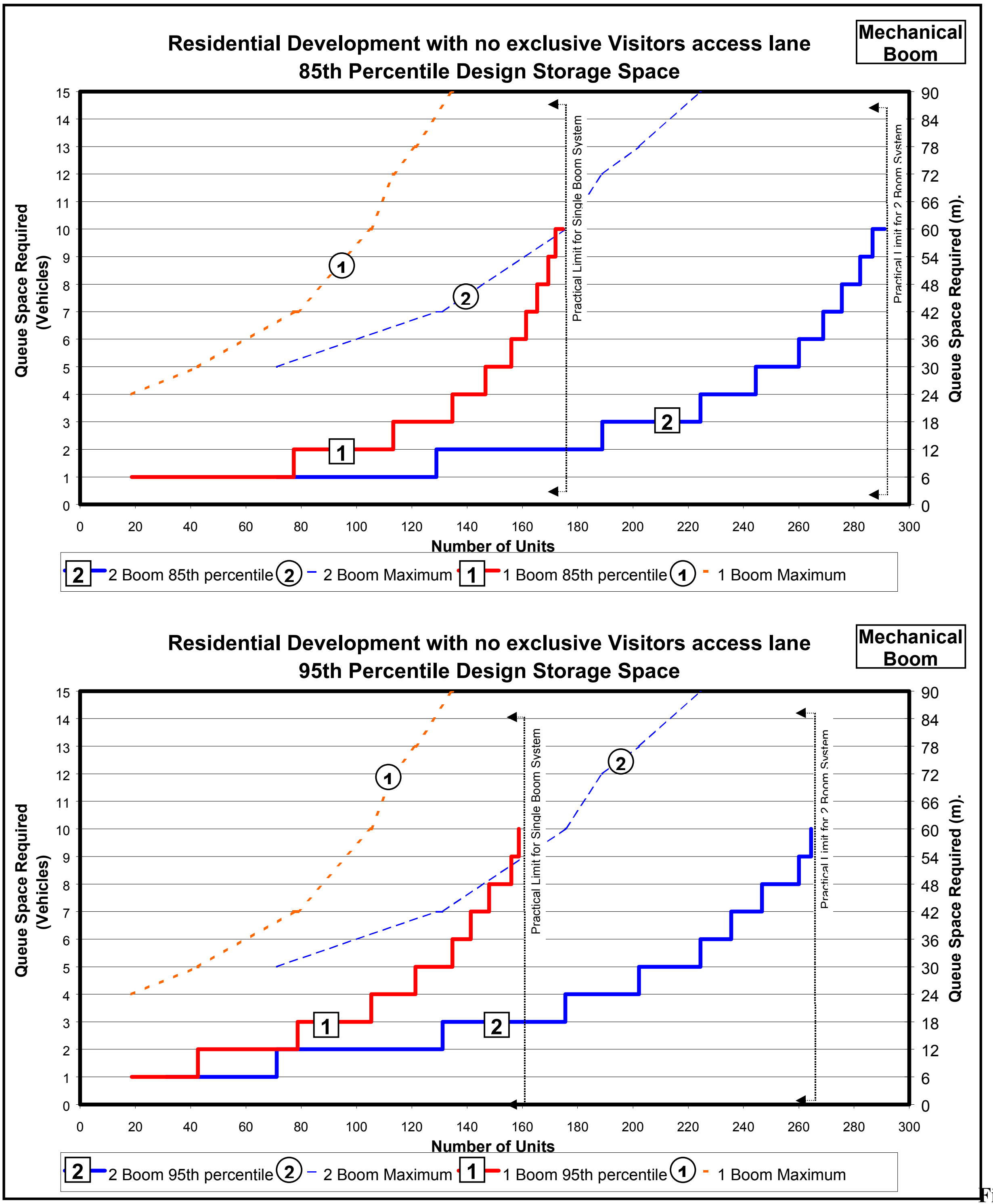


Figure A - 5: Queue Storage Graphs – Residential Developments without exclusive provision for visitors

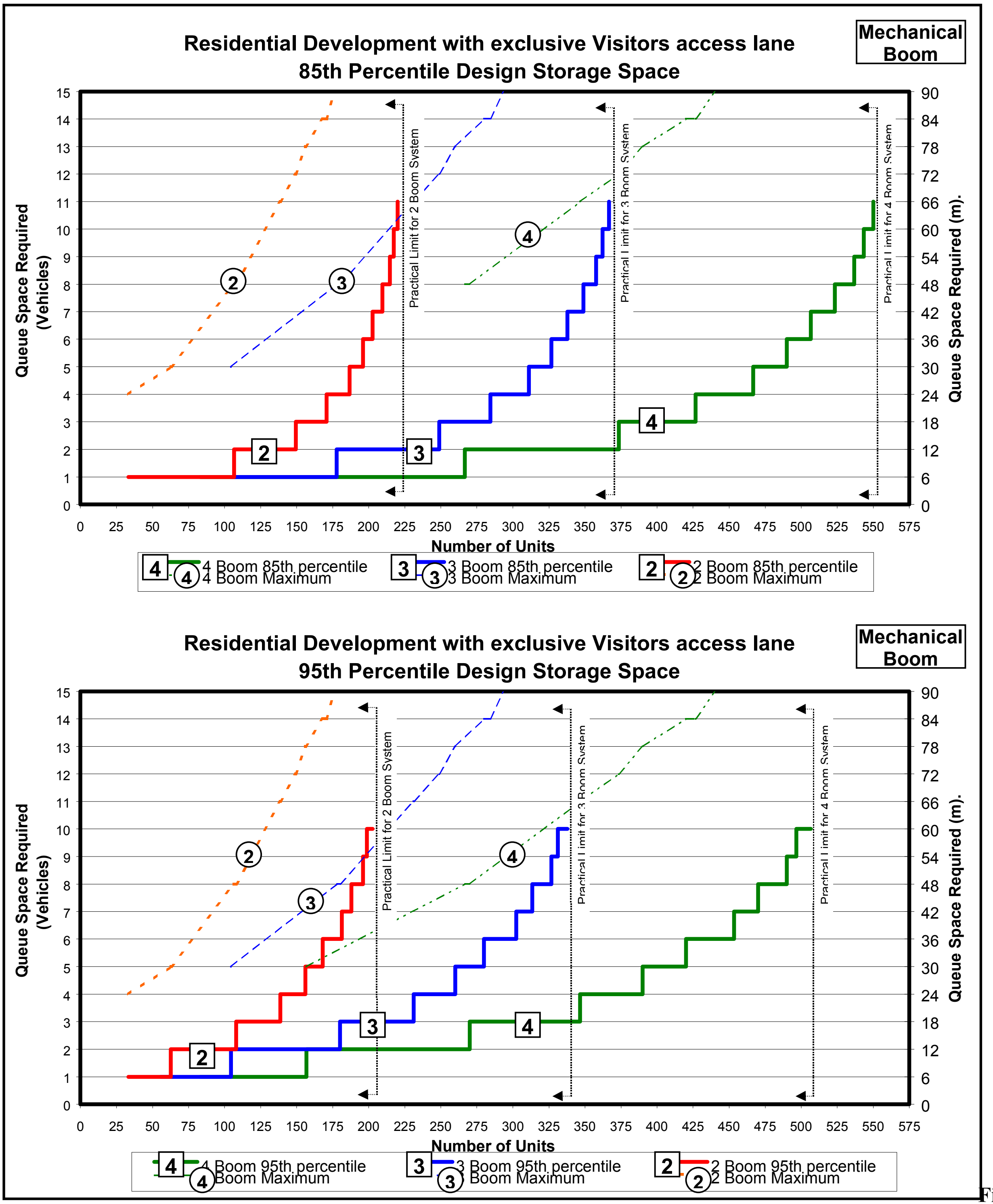
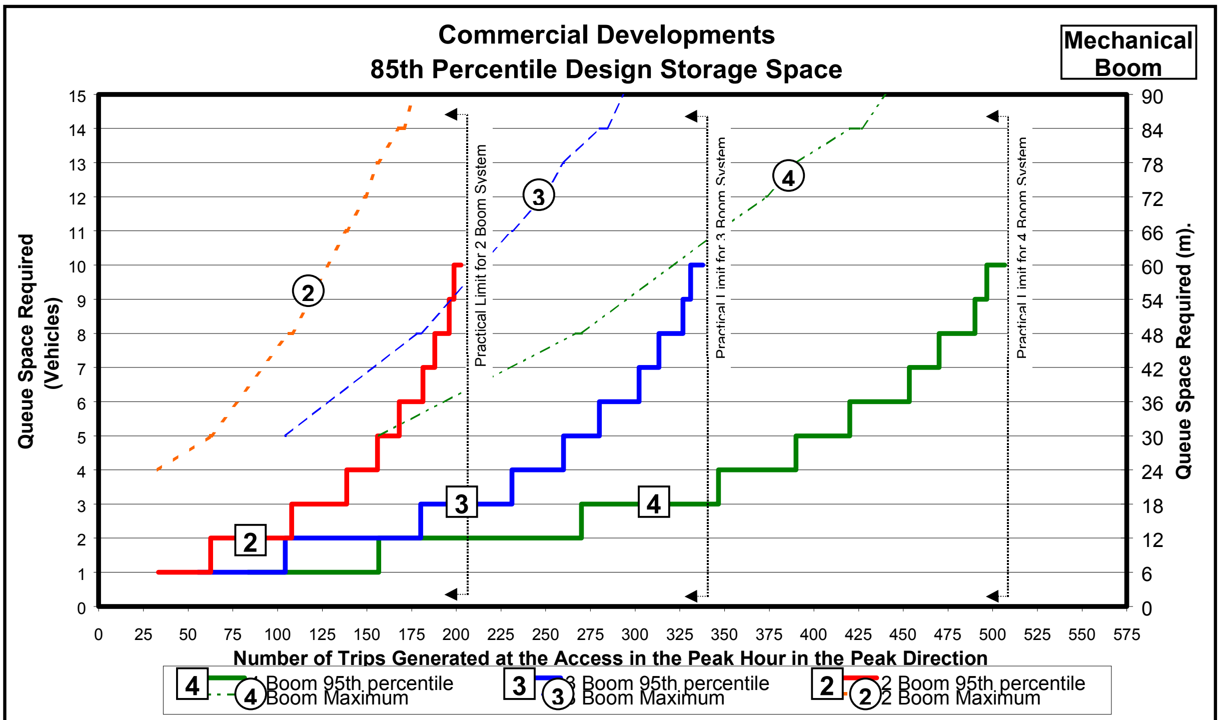


Figure A - 6: Queue Storage Graphs – Residential Developments with exclusive provision for visitors



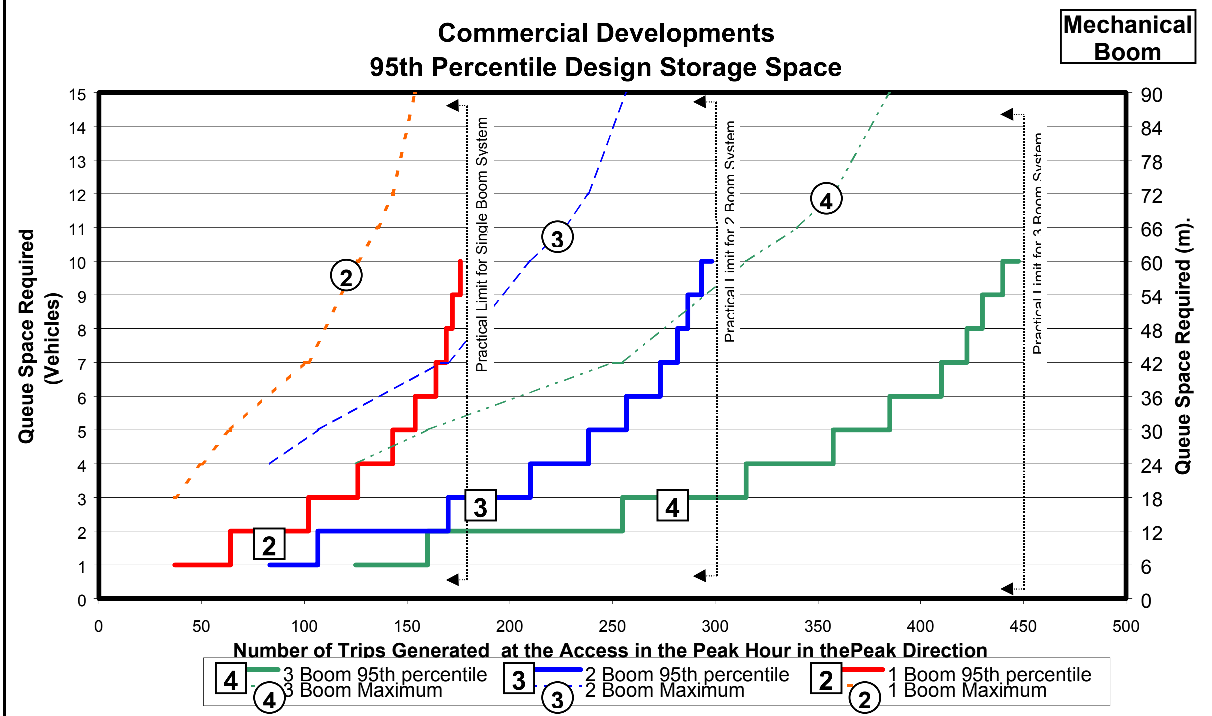


Figure A - 7: Queue Storage Graphs – Commercial Developments

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Jaco de Vries graduated from the University of Pretoria with a Bachelors Degree in Civil Engineering in 1995. He joined Portnet during 1996 at the Port of Durban, gaining valuable experience in harbour and railway engineering. In 1998 he moved to Pretoria and started working at V3 Consulting Engineers. He specialised in the field of traffic engineering working on a wide range of projects, ranging from traffic impact and safety studies to both macroscopic and microscopic traffic modeling using software packages such as *SATURN* and more recently *Paramics.* He is currently employed in Pretoria by the specialist traffic engineering company, ITS - Innovative Traffic Solutions.

Mr De Vries was awarded a Post Graduate Diploma in Civil Engineering by the University of Natal in 1998. He is currently working towards a Masters Degree in Transportation Engineering at the University of Pretoria.

At the time when the research was completed, both Messrs. De Vries and Pretorius were employed by V3 Consulting Engineers in Pretoria.