WHEN SHOULD PRIORITY T-JUNCTIONS INCLUDE GHOST ISLAND PROVISION, AND THE APPLICATION OF DMRB STANDARDS ON LOCAL ROADS

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1. INTRODUCTION

The 'Design Manual for Roads & Bridges' (DMRB) outlines the mandatory requirements for a ghost island right-turn lane at priority T-junctions on trunk roads, based on a threshold for minor road traffic flow of 500 vehicles per day at urban junctions (HA, 1995a). However, more recent guidance for local roads (CIHT, 2010) acknowledges that junctions without ghost island provision *"will often be able to cater for higher levels of turning traffic without resulting in significant congestion"*.

This research seeks to establish more applicable guidance for local roads, with the study specifically targeting urban junctions with a 30mph speed limit and built up environs in the United Kingdom (UK). Building upon a review of previous research projects, this study includes a detailed assessment of the two key design considerations relating to the provision of ghost islands: junction operation and road safety.

2. BACKGROUND

2.1 What is a Priority T-Junction?

Priority control is where movements at a junction that do not have assigned priority give way to other movements. Priority control is the most common form of junction control in the UK (O'Flaherty, 1996). This type of control is identifiable for road users by way of give-way road markings (see Figure 1) and associated signs.

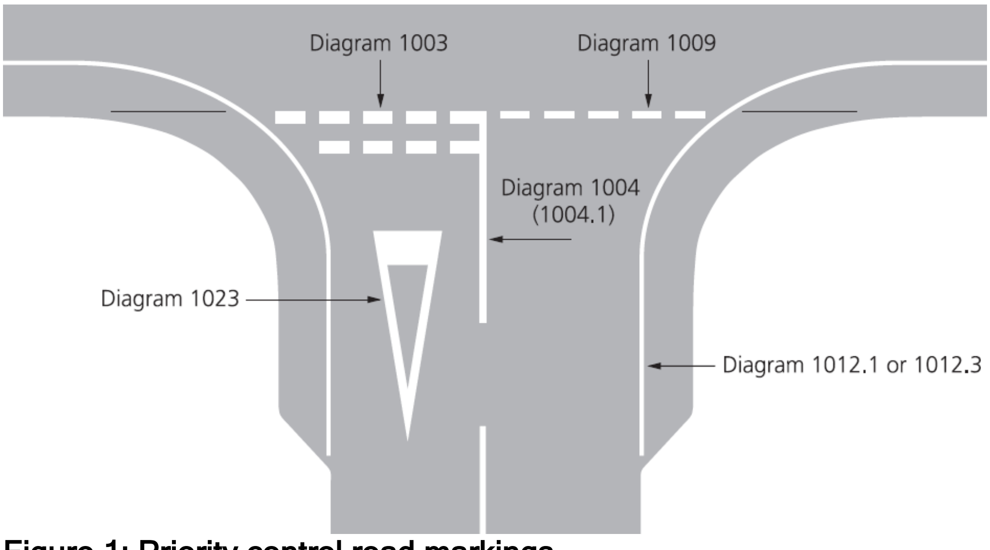

Figure 1: Priority control road markings
Source: DfT, 2003

There are different layouts for priority junctions, including 'Y' layouts, crossroads, staggered crossroads, and skewed approaches, however the simplest layout is the 3-arm 'T' junction, which is the focus of this research and is illustrated in Figure 2 (also showing the arm labelling convention):

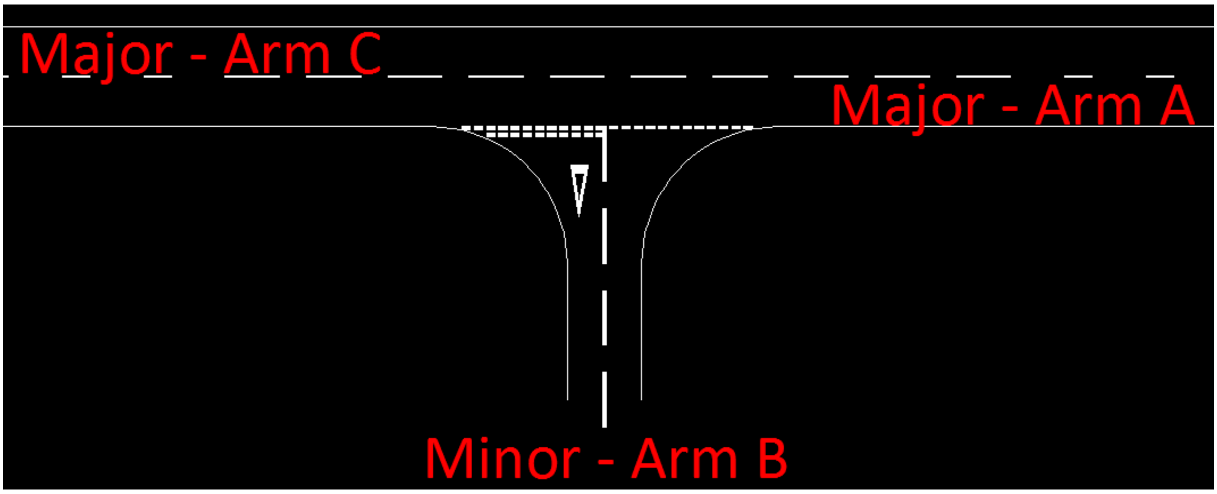

Figure 2: Simple priority T-junction layout (with arm labelling convention)

2.2 What is a Ghost Island?

'Ghost islands' take the form of a dedicated traffic lane for vehicles turning right from the major road, at junctions under priority control, with non-physical separation provided by road markings to allocate road space. An illustration of a priority T-junction with a ghost island is provided in Figure 3:

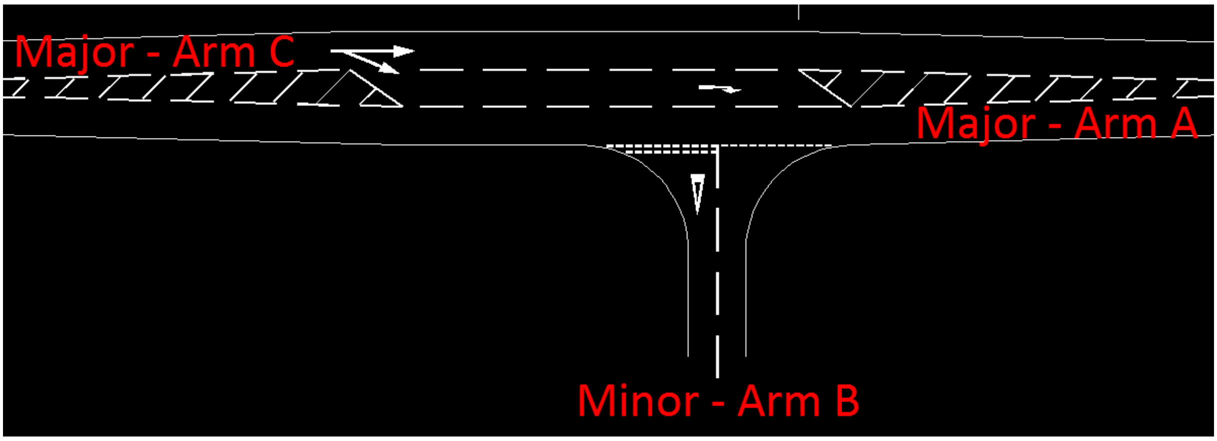

Figure 3: Ghost island T-junction layout (with arm labelling convention)

Highway design guidance defines a ghost island as *"an at-grade junction, usually a T- or staggered junction, within which an area is marked on the carriageway, shaped and located so as to direct traffic movement"* (HA, 1995a). Conversely, 'simple' junctions do not have any ghost or physical islands in the major road.

The purpose of a ghost island is stated as *"to provide right turning vehicles with a degree of shelter from the through flow"* (HA, 1995a).

3. DESIGN GUIDANCE

3.1 Design Manual for Roads & Bridges (DMRB)

3.1.1 Application of DMRB

The highway design guidance in the UK with the most detailed information on the siting and design of ghost island facilities is provided within DMRB.

DMRB details mandatory standards for application to all schemes involving trunk road schemes, which includes all motorways and major strategic routes that form part of the 'A' road network. All other roads in the UK are non-trunk roads, either managed/maintained privately, or in most cases, by the relevant Local Highway Authority (LHA).

As acknowledged within DMRB, and companion documents such as 'Design & Maintenance Guidance for Local Authority Roads' (UKRLG, 2011), *"the decisions on the choice of (DMRB) standards and their incorporation into designs remain in the hands of local highway authorities".* It is suggested that the non-mandatory standards also represent a standard of good practice that *"may be applicable in part to other roads with similar characteristics"* to trunk roads; although it also warns that the application of DMRB standards on local road schemes should not compromise key objectives such as health, safety, value for money or the impact on the environment (HA, 2008).

Other national highway guidance in the UK cautions that the *"strict application of DMRB to non-trunk routes is rarely appropriate in built up areas, regardless of traffic volume"* (CIHT, 2010).

3.1.2 Ghost Island Standards

DMRB details trunk road standards for the siting and design of ghost island facilities within 'TD 42/95: Geometric Design of Major/Minor Junctions' (HA, 1995a), stating that the decision on whether to provide a simple or ghost island priority junction *"should be based on a wide range of factors, taking into account design year traffic flow, the nature and proportions of large goods and passenger carrying vehicles, geometric and traffic delays, an initial estimate of entry and turning stream capacities, and accident costs".* Additional suggested considerations include site constraints, topography, and other roads users (pedestrians, cyclists, buses), although the guidance appears to pick out the impact of the junction on road safety and the ability to accommodate the expected traffic mix/levels as key considerations.

DMRB provides guidance on the research question for three situations; existing and new rural junctions (50mph or 60mph), and urban junctions (30mph or 40mph). All criterion for the different road environments (rural/urban) and construction type (new/exiting) relate to either traffic flow or road safety.

3.1.3 Existing Rural or Urban Ghost Islands

At existing rural junctions, or at urban junctions (existing or new), there are 3 stated situations for which a right turn facility (not specifically a ghost island) *"should always be considered"*:

1) where *"the minor road flow exceeds **500 vehicles 2-way AADT**"*. AADT is Annual Average Daily Traffic (a measure of daily traffic, averaged to account for daily and seasonal differences);

2) where *"a right turning accident problem is evident"*; or

3) where *"vehicles waiting on the major road to turn right inhibit the through flow and create a hazard"* (HA, 1995a).

The above forms part of a mandatory standard for trunk roads, although the subjective and undefined nature of criterion #2 and #3 appear to leave scope for differences in interpretation. The advice also suggests that it may be possible to utilise simple junctions for higher levels of traffic flow than stated in criterion #1, if the results of capacity assessments suggest that the Ratio of Flow to Capacity (RFC) values for the design flow will be suitably low.

DMRB states that the recommended minor road traffic flow is based on consideration of traffic delays and collision costs, although no reference is provided to the source of any underlying research. The Highways Agency (HA – now Highways England) and the Department for Transport (DfT) have been contacted to establish the foundation for the flow thresholds and inform this study, although no response has been received. Having extensively reviewed the relevant research published by these government departments and associated subsidiaries, it is expected that the thresholds were defined based on the experience of engineers.

3.1.4 Ghost Island Road Safety

DMRB suggests that ghost islands are *"highly effective in improving safety"*, although there is no reference to research that validates this particular claim. There is some selective presentation of research results within DMRB, including the research from Pickering et al. (1986) which indicates that rural ghost islands have been shown to reduce the frequency of collisions involving right turn movements from the major road by 70%. However, this only represents one type of collision, and actually the overall conclusion from the Pickering et al. research indicates that rural ghost islands do not provide a statistically significant road safety benefit versus simple junctions.

3.2 National Guidance

Currently, there are no directly applicable standards or guidance regarding the provision of ghost islands in non-trunk road environments (i.e. local roads).

‘Manual for Streets 2’ (CIHT, 2010) extends the philosophies set out in ‘Manual for Streets’ (DfT, 2007) and it outlines the following advice in relation to ghost islands:

“TD 42/95 recommends that consideration should be given to providing a right turning lane at priority junctions where the side road flow exceeds 500 vehicles per day, but this advice relates to trunk roads, where there is an emphasis on providing an unimpeded route for through traffic. It is a relatively low flow, and ***<u>junctions without right turn lanes will often be able to cater for higher levels of turning traffic</u>*** *without resulting in significant congestion”*.

This research looks to explore this suggestion further, attempting to establish whether a higher traffic flow threshold can be defined for ghost islands at urban junctions.

4. EXISTING RESEARCH

4.1 Junction Operation Implications

It is understood that much of the guidance within the DMRB suite of documents was based on research by former government organisation Transport and Road Research Laboratory (TRRL), which latterly became the Transport Research Laboratory (TRL), with ownership transferred to a private organisation (TRL Limited) in 1996.

Various chapters within DMRB recommend modelling the operation of priority junctions utilising the PICADY software programme (Priority Intersection CApacity and DelaY), which is produced by TRL and provides an industry-standard method for assessing junction capacity, queuing and delay. This tool has been developed over the years since creation, however the underlying empirical formulae that it utilises have not changed since the models were first developed on behalf of TRRL in the late 1970s and early 1980s.

PICADY utilises research undertaken by Kimber (1976), Kimber & Hollis (1979), and Kimber & Coombe (1980) to establish predictive models for capacity, queuing and delay at priority junctions. Prior to this research, the operation of priority junctions was based on gap acceptance theory, although Kimber (1976) suggested that such models were inaccurate due to the varying time gaps, impractical to measure, unrepresentative of congested conditions, and overly sensitive to the chosen gap acceptance values. Kimber & Coombe (1980) found that the capacity of non-priority streams was linearly dependent on the *“relevant priority streams on the major road”*, in contrast to the non-linear relationship utilised in the previous gap acceptance theory, with the capacity relationships also dependent on geometric parameters such as lane width and visibility.

Kimber & Coombe (1980) utilised linear multivariate regression analysis of empirical data to establish the capacity models that are incorporated within PICADY. It is noted that, although the abstract and capacity formulae (reproduced elsewhere) from Kimber & Coombe's grey literature research paper (1980) have been obtained, a full copy of the report has not been sourced, despite queries with all relevant libraries (including TRL Limited's database of reports published by TRRL/TRL). This raises some question marks over the robustness of the research, as the original study paper does not currently appear to be available for further scrutiny (unlike other TRRL reports from the same era). Unpublished commentary on the research indicates that the study was based on empirical data from approximately 50 junctions, although it is not known how many of these junctions included a ghost island.

The prediction of queue lengths and vehicle delay within PICADY is based on the time-dependent queuing theory developed by Kimber & Hollis (1979), which looked to determine a model that could adequately represent the operation of junctions when the demand and capacity are approximately equally, something that Kimber & Hollis indicate was not achieved by the previous steady-state or deterministic approaches. Kimber & Hollis' model (1979) utilises random arrival theory and a probability distribution queuing technique to estimate queuing time, with vehicle delays calculated directly from the queuing results. Unlike the capacity prediction model included within PICADY, this queuing and delay research was not empirically based, although it is understood to have subsequently been tested on public roads.

Interestingly, Kimber & Hollis (1979) outline that junction design standards could be updated to reflect the ability to more accurately model vehicle delays, although this has not since been included within DMRB, with a continued reliance on AADT traffic flow thresholds for the mandatory standards.

4.2 Safety Implications

4.2.1 Introduction to TRRL/TRL Studies

The collision impacts of various physical features were studied by TRRL/TRL in the 1980s and 1990s as part of a series of research reports, with the two key reports pertaining to this study investigating 'Accidents at Rural T-Junctions' (Pickering et al., 1986) and 'Accidents at Three-Arm Priority Junctions on Urban Single-Carriageway Roads' (Summersgill et al., 1996). Both of these studies detailed an investigation into causal relationships between traffic flow and collisions, as well as geometry and collisions. Through appraisal of collision records at a large number of study sites, collision frequencies relative to traffic and geometric factors were tabulated.

As well as informing advice and standards issued by the HA and the DfT in the form of DMRB, the results from these studies also provide the empirical formulae the collision analysis models in PICADY, as utilised in Section 6.

4.2.2 Urban Priority T-Junctions

The study undertaken by Summersgill et al. on behalf of TRL (1996) investigated collision records at urban priority T-junctions, with a posted speed limit of either 30mph (790 junctions) or 40mph (190). A total of 980 urban T-junctions were assessed, and as with the Pickering et al. study (1986), the locations were stratified based on traffic flow levels (AADT), but also on the number of pedestrian crossing movements. 115 of the studied intersections had a ghost island present (11.7%), with the remaining 865 majority representing simple junctions (88.3%).

A large proportion of the methodology adopted by Summersgill et al. (1996) was consistent with the Pickering et al. approach (1986), with some expected variations. The study period covered a full 5 year period from April 1983 to March 1988, which was somewhat historic by the time the study was published in 1996). In total, the research interrogated 2,699 Personal Injury Collisions (PICs), and similarly to the rural junction study (Pickering et al., 1986), collisions were disaggregated into 23 categories (16 vehicle-only and 7 pedestrian collisions) and 146 sub-categories (98 vehicle-only and 48 pedestrian collisions) based on the movements involved in the collisions.

The key differences in the adopted urban and rural junction study methodologies was the inclusion of pedestrian flows within the urban assessment, and a focus on collisions occurring within 20m of the junctions only, both of which appear justified.

Basic appraisal of overall collision frequencies found a mean of 0.83 PIC per year at junctions with a ghost island, and 0.51 at simple junctions; so a 62.7% higher collision frequency at ghost island junctions. This collision frequency at ghost island junctions is very similar to the 0.86 PIC per year for rural junctions (Pickering et al., 1986). These results still indicate that collision frequencies and collisions rates are higher at junctions with ghost islands, than those without, even when the impact of other layout features (e.g. pedestrian crossings) is segregated from this analysis.

The difference between the two junction types is less pronounced when the level of traffic flow is considered, with a mean of 12.5 PIC per 100 million yearly vehicle movements at junctions with a ghost island, and 11.2 at simple junctions; so an 11.6% higher collision rate. Summersgill et al. point out that, although this collision rate relates the collision frequency to the level of traffic flow at the junction, it only relates it to the total volume of movements at the junction, with no consideration of the turning proportions involved. Further analysis using the results reported by Summersgill et al. (1996) highlights that these differences are statistically significant at a 95% confidence level.

Unlike the Pickering et al. research (1986), Summersgill et al. (1996) did not explicitly consider the presence of a ghost island in the development of the collision prediction models. Instead, an array of geometric parameters was utilised to define the collision patterns, with a ghost island linked to multiple adopted parameters, including the number of traffic lanes, entry width on the major road, and central hatching width. Through review of the published results in the study, it is not possible to form specific conclusions regarding the impact of a ghost island. Therefore, this research has utilised the predictive models developed by Summersgill et al. (1996), made available within PICADY, to test different ghost island and simple junction layouts, specifying values for these ghost island related parameters based on typical values.

4.2.3 Use of TRRL/TRL Studies

It is clear that the scale of these research projects (and the available resources) was significantly greater than the scope of this research, because in addition to consultation with several LHAs in order to obtain collision data and identify suitable study sites, the study also included reconnaissance over a large geographic area, at least 4 hours of traffic flow surveys (pedestrian crossing surveys at the urban sites), measurement of vehicle speeds, and extensive site work and measurements at all junctions. With such substantial sample sizes, comprehensive data collection, and transparent methodologies, it is considered that the results of the two research reports to be robust, therefore the findings of the research have been utilised, as well as the developed urban collision prediction model, to inform this study,

However, they are detailed technical reports, not focusing on the application of the results, but with the stated purpose of helping to *"identify potential design improvements and to provide accident estimates for the economic appraisal of road schemes"* (Summersgill et al., 1996). For this reason, the overriding results of the research are not clearly highlighted, in particular the conclusion that a statistically significant difference in the safety records of ghost island and simple junctions was not found for rural junctions (Pickering et al., 1986), which is a notable omission from DMRB (HA, 1995a).

Furthermore, both projects were based on appraisal of collisions occurring during the mid-1980s, now close to 30 years out of date.

No other pertinent papers relating to the research question were identified during the review of literature.

5. JUNCTION OPERATION

The operation of the two junction types has been assessed utilising the empirical traffic capacity model developed by Kimber & Coombe (1980), as well as the vehicle delay model developed by Kimber & Hollis (1979). These models are incorporated into the PICADY software programme, which has been utilised to undertake detailed junction operation assessments.

Two simple priority T-junction layouts (Simple A and Simple B), reflecting some variation in major road width, and two ghost island priority T-junction layouts (Ghost C and Ghost D), reflecting some variation in the length of the ghost island lane, have been assessed as part of this research. The adopted geometric parameters for these junction layouts have been defined to represent typical values for urban priority T-junctions, as shown in Table 1:

Table 1: Modelled Geometric Parameters

Type	Parameter		Simple A	Simple B	Ghost C	Ghost D
Variable	Major Road Width (excluding right-turn provision)	W	6.0m	7.3m	6.0m	6.0m
	Major Road Right-Turn Width	W_{C-B}	0m	0m	2.5m	2.5m
	Total Major Road Width		6.0m	7.3m	8.5m	8.5m
	Stream C-B Blocks Stream C-A? (queuing vehicles before blocking)		YES (0)	YES (0)	YES (5)	YES (2)
Fixed	Central Reserve Width	W_{CR}	0m	0m	0m	0m
	Stream C-B Forward Visibility	V_{C-B}	100m	100m	100m	100m
	Minor Road Visibility to the Left	V_{B-C}	25m	25m	25m	25m
	Minor Road Visibility to the Right	V_{B-A}	25m	25m	25m	25m
	Minor Road Lane Width	W_{B-C}	3.0m	3.0m	3.0m	3.0m

The four junction layout models have been tested against 25 traffic flow scenarios, with a mix of major road traffic flows, minor road traffic flows (see Table 2), and turning proportions. A specific traffic scenario that looks to represent the threshold defined by DMRB for a ghost island (HA, 1995a) has also been specifically tested.

Table 2: Modelled Peak Hour Traffic Flow Levels for each Arm

		Minor Road		
		Low	Medium	High
Major Road	Low	A = 200 B = 50 C = 200	A = 200 B = 150 C = 200	Not assessed
	Medium	A = 500 B = 50 C = 500	A = 500 B = 150 C = 500	A = 500 B = 250 C = 500
	High	A = 800 B = 50 C = 800	A = 800 B = 150 C = 800	A = 800 B = 250 C = 800
DMRB Scenario: A = 160 / B = 10 / C = 160				

Three combinations of major road turning proportions have been adopted in order to broadly represent the range of patterns occurring at typical urban junctions, as outlined below:

- Set A: Typical ratios

    - 75% straight ahead
    - 25% turning

- Set B: Heavy turning flow

    - 50% straight ahead
    - 50% turning

- Set B: Low turning flow

    - 90% straight ahead
    - 10% turning

An equal turning ratio of 50/50 has been adopted for minor road traffic in all scenarios.

The results, which are available in full upon request, indicate that the capacity levels for the minor road traffic streams are generally consistent across the low and medium major road flow scenarios for the assessed junction layouts. However, there are pronounced differences when the major road traffic flow levels are high, with the wider simple junction (Simple B, 7.3m wide major road) expected to provide greater capacity than both of the ghost island layouts for most traffic scenarios (with the exception of when heavy turning proportions are expected).

The vehicle delay results are consistent with the patterns highlighted by the capacity modelling, with lower traffic capacities corresponding to commensurately longer queues and delays.

The likely suitability of the assessed junction layouts in terms of capacity and delay has been established based on the junction operation assessments, with consideration of the 25 different traffic scenarios, as shown in Table 3:

Table 3: Likely Suitability of Junction Type in terms of Capacity and Delay

Major Road Flow Level	Minor Road Flow Level	Turning Set A				Turning Set B				Turning Set C			
		Simple A	Simple B	Ghost C	Ghost D	Simple A	Simple B	Ghost C	Ghost D	Simple A	Simple B	Ghost C	Ghost D
High	High	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
High	Medium	NO	?	?	?	NO	NO	NO	NO	?	YES	?	?
High	Low	NO	?	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES
Medium	High	?	YES	?	?	?	YES	?	?	?	YES	?	?
Medium	Medium	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Medium	Low	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Low	Medium	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Low	Low	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DMRB	DMRB	YES	YES	YES	YES	DMRB Turning Set							

There are not expected to be any capacity, delay or congestion issues at simple junctions for the estimated level of peak hour traffic flows that correspond with the DMRB threshold for a ghost island (500 two-way minor road AADT), with a maximum RFC of 4%, which is comfortably below the 85% level that is widely adopted as an indicator of satisfactory junction operation. This level of traffic flows would also be expected to maintain negligible vehicle delays, with average delays of approximately 8 seconds for minor road traffic, and up to an average of 1 second for major road traffic (Arm C).

This appears to confirm the view expressed in 'Manual for Streets 2' (CIHT, 2010), which suggests that priority T-junctions without a ghost island *"will often be able to cater for higher levels of turning traffic without resulting in significant congestion".*

The level of turning traffic that can be satisfactorily accommodated at a simple junction depends on the major road traffic flows and turning proportions, as well as the minor road traffic. That said, the modelling results suggest that a simple junction would generally be expected to operate without significant congestion for peak hour major road flows of up to 1,000 two-way, irrespective of turning flows/proportions; which is estimated to represent an AADT of approximately 11,750.

6. SAFETY

The road safety performance of the two junction types has been analysed through use of the collision prediction model developed by Summersgill et al. (1996).

The four junction layouts (two simple and two ghost island junctions) and 25 traffic scenarios assessed as part of the junction operation assessment have been tested utilising the urban collision prediction model of Summersgill et al. (1996), which is incorporated into PICADY.

This collision model doesn't specifically assess whether there is a ghost island or not, but rather it utilises geometric parameters such as carriageway width and hatching width that can indirectly represent a ghost island. Therefore, suitable values for the input parameters have been defined to represent the typical urban situation, taken from relevant sources of information.

It is acknowledged that the collision frequencies derived by Summersgill et al. (1996) are based on collisions records in the 1980s, and as such are unlikely to be representative of current and future collision frequencies. Therefore, changes in road safety records have been assessed, with all results presented in this report based on the expected collision values in the most recent 5 year period of 2009/13, calculated using an appropriate scaling factor.

The results, which are summarised in Table 4 and are available in full upon request, highlight that the ghost island layout is expected to result in higher collision frequencies than both of the simple junction layouts for all combinations of major/minor road traffic flow and turning proportions:

Table 4: Collision Prediction Modelling Results – PICs per annum (adjusted to 2009/13)

Major Road Flow Level	Minor Road Flow Level	Total Vehicle Movements	Turning Set A			Turning Set B			Turning Set C		
			Simple A	Simple B	Ghost C/D	Simple A	Simple B	Ghost C/D	Simple A	Simple B	Ghost C/D
High	High	1850	0.54	0.54	0.63	0.53	0.53	0.61	0.53	0.53	0.62
High	Medium	1750	0.49	0.48	0.57	0.47	0.47	0.54	0.47	0.46	0.55
High	Low	1650	0.41	0.40	0.48	0.40	0.39	0.46	0.39	0.38	0.45
Medium	High	1250	0.39	0.39	0.45	0.38	0.38	0.44	0.39	0.38	0.45
Medium	Medium	1150	0.35	0.34	0.40	0.34	0.33	0.39	0.34	0.33	0.39
Medium	Low	1050	0.28	0.28	0.33	0.28	0.27	0.32	0.27	0.27	0.32
Low	Medium	550	0.19	0.19	0.22	0.18	0.18	0.21	0.19	0.19	0.22
Low	Low	450	0.15	0.15	0.18	0.14	0.14	0.17	0.15	0.15	0.17
DMRB	DMRB	330	0.11	0.10	0.13	DMRB Turning Set					

Against the Simple A junction layout, the ghost island layout would be expected to increase the number of PICs per annum by between 0.02 and 0.09, with a mean proportionate increase of 15.9% across the 25 assessed traffic scenarios.

The road safety performance of layout Simple B is marginally better than Simple A for all scenarios. Therefore, the relative differences between the ghost island layout and Simple B are slightly greater than those recorded between the ghost island layout and Simple A, with a mean proportionate increase of 16.8% for the ghost island layout.

The collision prediction model provides a detailed breakdown of the collision types, analysis of which highlights that there is not predicted to be a difference in road safety performance between simple and ghost island junctions for the majority of collision types (12 of the 16 categories).

Ghost islands are not expected to reduce the collision frequency relative to simple junctions of any of the 16 collision types, for any of the 25 tested scenarios, with at best a nil detriment outcome.

Ghost islands are expected to increase the prevalence of the following four collision types:

- V3: Rear shunt/lane changing from major left (Arm C);
- V8: Right-turn from minor (Stream B-A) with major right-to-left (Stream A-C);
- P1: Pedestrian with vehicle entering on major left (Arm C); and
- P4: Pedestrian with vehicle exiting on major right (Streams B-A and C-A).

7. CONCLUSIONS

7.1 Key Findings & Recommendations

The results of this research appear to indicate that ghost islands can provide capacity and delay benefits with respect to non-priority ***major road*** traffic, relative to a simple junction. However, the overall operation of a junction can be primarily influenced by the level of capacity and delay for the non-priority ***minor road*** traffic, and the results show that ghost islands can increase delays for this stream during the majority of the assessed scenarios. So ghost islands would be preferred to simple junctions for some traffic patterns, with the converse true for others, in terms of capacity and delay implications.

Recommendations on the type of priority T-junction for the different assessed level of traffic flow and turning proportions have been derived from the junction operation results, as illustrated in Table 5:

Table 5: Recommended Priority T-Junction Form (Based on Junction Operation)

Major Road Peak Hour Entry Flow	Minor Road Peak Hour Entry Flow	Typical Turning Proportions (75/25)		Heavy Turning Proportions (50/50)		Low Turning Proportions (90/10)	
		6.0m Major	7.3m Major	6.0m Major	7.3m Major	6.0m Major	7.3m Major
800	250	Other	Other	Other	Other	Other	Other
800	150	Ghost	Ghost	Other	Other	Ghost	Simple
800	50	Ghost	Ghost	Other	Other	Simple	Simple
500	250	Ghost	Simple	Ghost	Simple	Ghost	Simple
500	150	Simple	Simple	Simple	Simple	Simple	Simple
500	50	Simple	Simple	Simple	Simple	Simple	Simple
200	150	Simple	Simple	Simple	Simple	Simple	Simple
200	50	Simple	Simple	Simple	Simple	Simple	Simple
160	10	Simple	Simple	Simple	Simple	Simple	Simple

In terms of road safety, this research indicates that ghost islands are likely to increase the number of collisions at a priority T-junction. This is not fully consistent with the study undertaken by Pickering et al. (1986), which indicated that ghost islands would not have a statistically significant impact on collision frequencies; although this research was specific to rural junctions with a 50mph or 60mph speed limit. That said, neither the Pickering et al. study (1986) nor this new research indicate that there are road safety benefits to ghost islands at urban junctions.

There is, therefore, a strong case that ghost islands should not be provided at urban priority T-junctions on road safety grounds. On a site-by-site basis, a detailed economic appraisal would help balance the possible benefits in terms of reduced delay, against the expected disbenefits in terms of collision costs. However, this analysis would need to carefully consider whether the junction is new or existing, and also whether a public or private organisation would be funding the works, as the implications of a cost-benefit analysis is likely to vary for these different contexts.

Overall, it is considered that the recommendations outlined in Table 5 relating to junction operation are a suitable starting point when considering whether to provide a ghost island at an urban priority T-junction on a non-trunk road.

7.2 Main Limitations

This research into junction operation relies heavily upon the traffic capacity model developed by Kimber & Coombe (1980), as well as the queuing and delay model developed by Kimber & Hollis (1979). The capacity model is based on empirical data, with several associated limitations that constrain the robustness of the model, and therefore this research, such as:

- The age of the data, which is based on 1970s/80s studies, and would therefore be expected to be unrepresentative of modern roads due to changes in the vehicle fleet (e.g. greater acceleration) and driver behaviour (e.g. smaller gap acceptance).

- The limited number of junctions considered (understood to be approximately 50).

- The limited range of junction geometries considered (e.g. major roads of 6.0m width or more only).

As this empirical data is incorporated within PICADY, which is an industry-standard tool for the assessment of junctions, it would seem to be prudent to undertake new research to recalibrate the model developed by Kimber & Coombe (1980), or alternatively to develop a new model that can be calibrated and validated against real-world junctions to specifically assess the differences between the two junction types; it is recognised that the scope of these studies would be extensive, particularly in terms of data collection.

Similarly, this research into road safety implications relies heavily upon the collision prediction model developed by Summersgill et al. (1996). Again, this is also based on empirical data that is now potentially unrepresentative of the current situation, particularly with regard to the number of collisions at junctions, but also possibly the nature of the collisions. It would therefore appear to be prudent to undertake new research to recalibrate the urban collision prediction model developed by Summersgill et al. (1996).

An additional limitation on this road safety research, as well as the Summersgill et al. research (1996), is the reliability and coverage of the STATS19 data, which provides the underlying collision data. The DfT (2013a) acknowledge that damage-only collisions are not included within the STATS19 system, but also not all personal injury collisions are reported. Therefore, analysis of STATS19 data should be considered in the context of this under-reporting.

It is worth noting that the road environment, which has been investigated as part of this research in the form of junction layouts, is only one factor in road collisions, with a potentially stronger causal relationship between collisions and factors relating to the driver and the vehicles.

7.3 Wider Application of DMRB Standards

The stated traffic management aims for the trunk road network differ from those typically adopted by LHAs, as *"the primary purpose of the trunk road network is to provide for the safe and expeditious [sic] movement of long distance through traffic"* (HA, 1995b). Traffic management on the local road network varies for each LHA, however it is typical for urban areas to cater for a mix of road users (e.g. vehicles, cyclists, pedestrians, and buses) and journey purposes (e.g. traffic passing through a settlement, commuting traffic, and short education escort trips), with traffic management aims suitably reflecting this variation in users. That said, it is recognised that the 'Traffic Management Act 2004' places a duty on LHAs to *"secure the expeditious movement of traffic on the authority's road network"*.

It is considered that the standards outlined within DMRB, and specifically the traffic flow threshold for urban ghost islands discussed in this paper, are underpinned by the traffic management aim of accommodating long-distance traffic, which infers that delays to major road traffic should be minimised. It is considered that the ghost island threshold is low as a result of this prioritisation, and that the different aims associated with the management of local urban roads provide greater scope for guidance that is more balanced between major and minor road traffic, as well as the movements of non-vehicular users.

It is also acknowledged that there are various other highway design standards within DMRB that are unlikely to be relevant to local roads, particularly at junctions and relatively low-speed urban environments. It is therefore considered that there may be merit in the provision of new design guidance for u on non-trunk schemes.

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