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Synthesis of Roundabout Design and Operations with Multi-Lane Flared Entries

Geometric Design Elements are Critical to Effective Lane Utilization - Achieving Reliable Capacity and Safety

Background

Introduction

Multi-lane flared entry roundabouts provide significant advantages to our roadway and transportation infrastructure, precluding expensive roadway and structure widening typical of our current traffic planning standards. However, there has been significant confusion among traffic researchers and practitioners when evaluating and designing flared entry roundabouts. This has led to erroneous conclusions and questions about the applicability of multi-lane flared entry roundabouts and their associated analytic methods to non-U.K. applications.

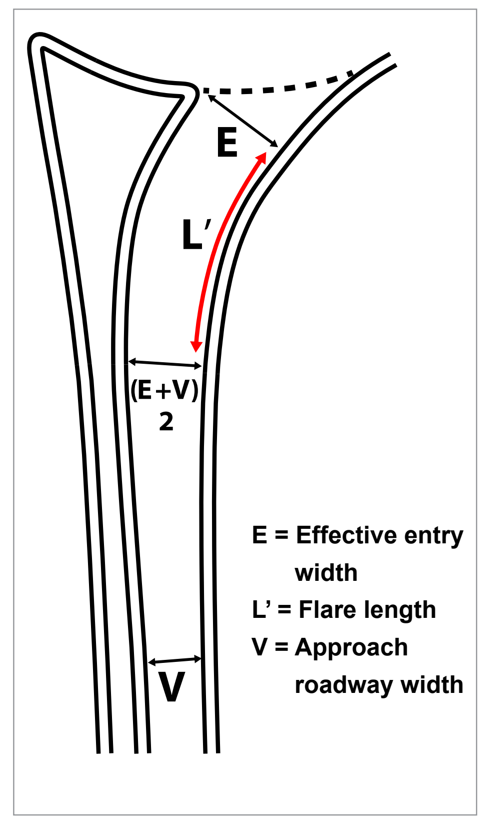
Multi-laned Flared Entry Design

The design and subsequent driver behavior and field-measured operations of multi-lane flared entry roundabouts are strongly interrelated. To achieve the predicted operations, the flared entry design requires correct geometrics and appropriate pavement markings and signage to facilitate effective lane utilization. Only then will predicted operations closely match field-measured operations.

The analysis of flared entry roundabouts is predicated on Professor Rod Kimber's empirical capacity equations. Kimber's equations provide operational prediction capabilities for flared entry roundabout design with three primary geometric parameters: Entry Width (E), Approach Roadway Width (V), and Flare Length (L'); with secondary geometric variables that include the Entry Radius, Entry Angle (Phi), and Diameter (D).

Flared entry roundabout at Main St. and Century Ave., Waunakee, WI.

Video of project implementation: www.mtjengineering.com/waunakee-wi-roundabout/



Flared entry design variables

Flared entry application

Necessary Design Elements and Traffic Conditions

A summary of the design elements and traffic conditions necessary for flared entries to work correctly include:

Geometrics

- Gradual smooth flaring from V to E
- Proper entry to circulating alignment
- Correct circulating to exit alignment with sufficient receiving distance and taper length

Pavement Markings

- Providing earlier indication to drivers to split/stagger into two streams.
- Provide a smooth transition from the single approach stream of traffic into the two entry lanes.

Signing

- Must relate to the overall design, account for lane assignment needs and corresponding pavement markings.
- The information must be clear, easily detected, and congruent.

Traffic Distribution

- The traffic distribution must be accounted for in the operational analysis and followed through to the design. If not, this may result in unbalanced lane use.

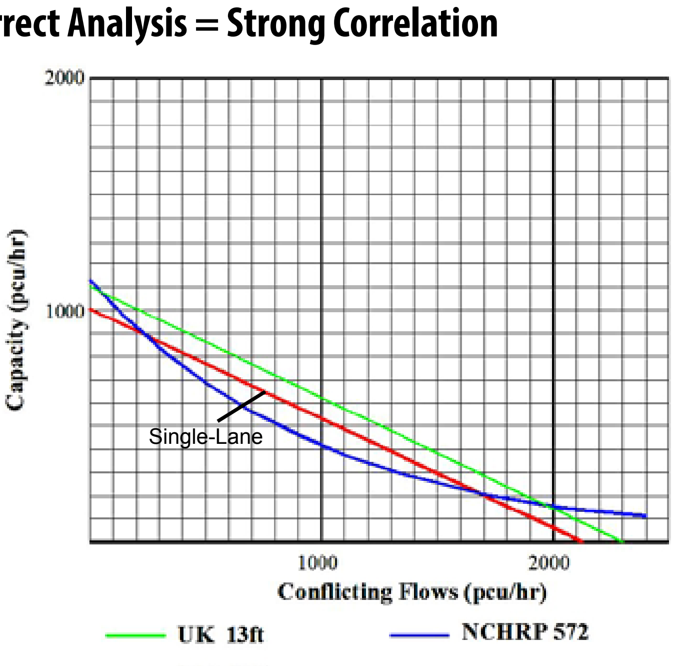
Design Analysis

Transferability to U.S.

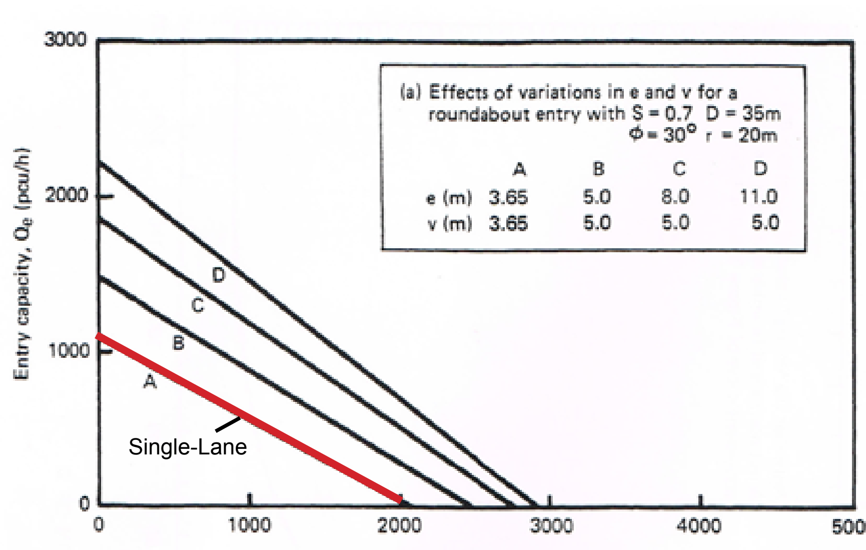
Early U.S. research erroneously concluded that the U.K. model overpredicted U.S. roundabout capacities. These spurious high capacities were arrived at based on incorrect application of Kimber's equations. This raised questions about the validity and transferability of Kimber's equations to U.S. conditions.

However, correct application of Kimber's equations shows unequivocally a strong correlation to U.S. capacity data, which supports the validity and transferability of these equations to the U.S.

Correct Analysis = Strong Correlation



Source: Rodel Roundabout Analysis Software



Line A is for Single-Lane (V= 3.65 m, E= 3.65 m) from Kimber LR 942, 1980. This capacity line closely matches original NCHRP data.

Source: TRRL Laboratory Report 942, The Traffic Capacity of Roundabouts, R. M. Kimber, 1980

Application Implementation Issues

Modeling vs. Field Measurements

Correct visual information provided with the design is necessary to address the human factors that enable appropriate utilization of flared entry roundabouts. The geometrics, signing, and pavement marking must all provide a congruent and consistent message to drivers in order to facilitate achievement of anticipated capacity as predicted by Kimber's equations.

Examples A and B are missing one or more of the essential design elements, resulting in field-measured capacity not matching Kimber's predicted capacity. These situations can lead to the conclusion that "flared" entries do not work – and that Kimber's equations are therefore not applicable to drivers outside of the U.K.

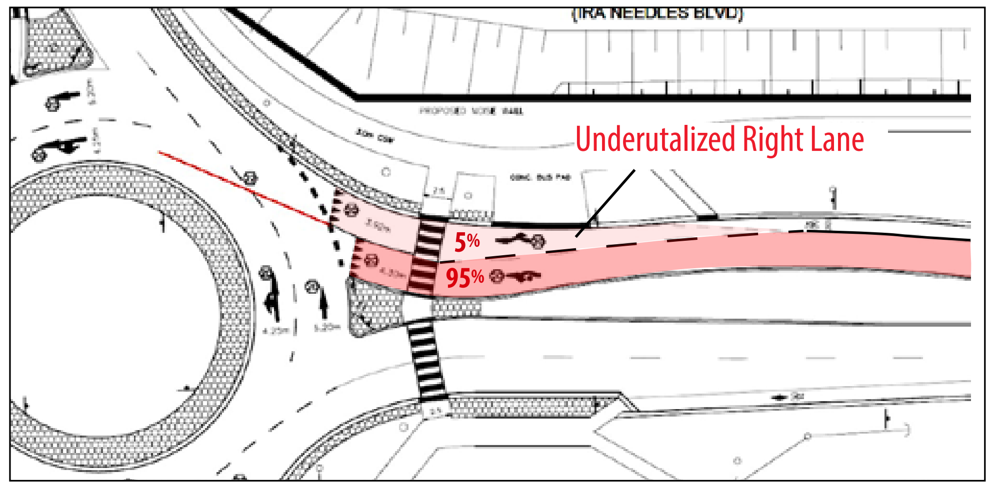
When in fact, examples A and B below illustrate that the actual cause of the measured data not matching predicted data is due to either missing or incongruent visual information leading to inefficient and incorrect operations, or as illustrated in example C, misunderstanding of the differences between a wide single-lane entry for large trucks versus a true two-lane entry.

Example A - Incorrect entry alignment

Ineffective entry width; West Vail, CO

This image shows, via the tire patterns, that drivers are not utilizing the inside approach lane. This is caused by incorrect alignment of entry to circulating roadway, making it physically difficult, or in this case nearly impossible, to utilize the entry available with the two-lane entry width. The resulting driver behavior and operations (queue and delay) will match a single-lane entry.

Example B - Incorrect alignment and pavement markings



Underutilized right lane in two-lane flared entry roundabout.
Ira Needles Blvd. & Erb St., Kitchener, ON. Source: Region of Waterloo, ON

The figure above shows the effects of a combination of geometrics and pavement markings that result in severely unbalanced lane use of this two-lane flared entry roundabout (95% left lane, 5% right lane). Traffic distribution was not the cause, as major flow is in the through movement.

1) The approach marking is developed in a manner that does not provide indication of two through lanes, but rather the markings are more indicative of a designated exclusive right-turn lane.

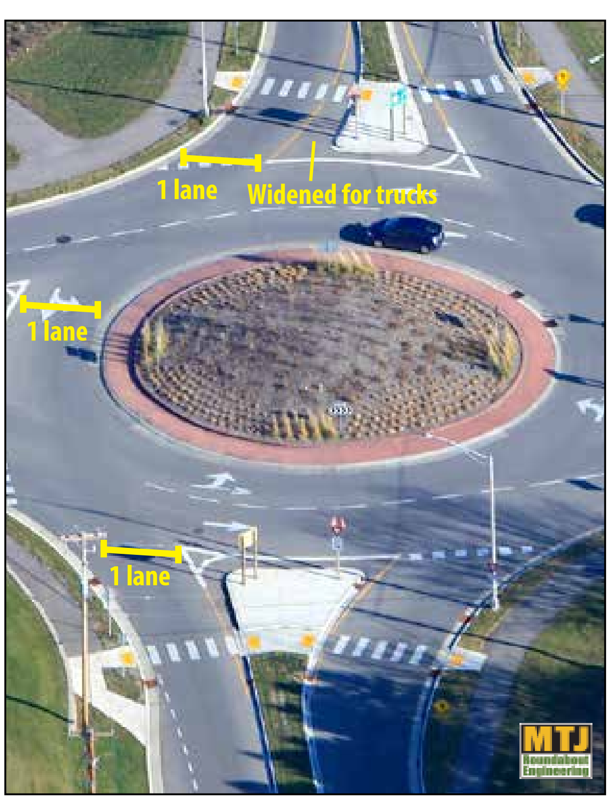
2) The alignment at entry to the circulating lanes is poorly aligned. This misalignment further reduces the visual cues to help drivers utilize both lanes.

This illustrates the importance of congruent visual messages to drivers, via pavement markings and geometrics, to achieve effective lane utilization.

Zippering and Doubling Up

The roundabout in example C is a single-lane entry design (widened for trucks) with single circulating and exit lanes, and in these cases drivers also will not zipper or double up at entry. Whereas, the roundabout on the right is designed as a "flared" two-lane entry with correct and effective geometrics and corresponding pavement markings. This flared entry design which contains the essential design elements will elicit the driver behavior of zippering and doubling up, achieving effective lane utilization which enables Kimber's predicted capacity and field-measured capacity to match.

Example C - Single lane



Brookfield and North Ave, Waukesha, WI

Single-lane widened for trucks

- Single-lane entry
- Single-lane circulating width
- Results in single-lane entry utilization

Dual-lane flared entry

Main St. and Century Ave., Waunakee, WI

Dual-lane flared entry

Effective lane utilization at flared entry:

- Flared two lane entry
- Dual-lane circulating width
- Results in dual-lane entry utilization

Effective multi-lane flared entry utilization

Main St. and Century Ave., Waunakee, WI

Videos of the Waunakee roundabout (links below) show how vehicles approach in the single approach lane and smoothly zipper or stagger. They then divide into the available width, creating effective lane use at the entry. The videos show that driver behavior on a multi-lane flared entry roundabout in a small community in Wisconsin matches U.K. driver behavior.

www.mtjengineering.com/flared-entry-1
www.mtjengineering.com/flared-entry-2
www.mtjengineering.com/flared-entry-3

Summary

Multi-lane flared entry roundabouts provide significant advantages to our roadway and transportation infrastructure, with the potential to provide solutions to congestion that avoid or minimize expensive roadway widening and the impacts and costs associated with current traffic planning with signals.

However, multi-lane flared entry roundabout analysis and design represent a significant change from conventional U.S. traffic planning analysis methodologies that are based on signalization and stop-control procedures. Existing procedures rely on adding lanes at the intersection and widening the associated roadway links to add system capacity.

When analyzed, designed, constructed, and maintained properly with inclusion of essential design elements for the specific traffic distribution, multi-lane flared entry roundabouts are shown to operate as discussed in U.K. research literature that forms the basis for Kimber's equations. This is thought to occur because the inherent and natural driver behavior is elicited with these design elements applied, irrespective of country of origin.

See the full paper at **www.mtjengineering.com/paper.pdf**