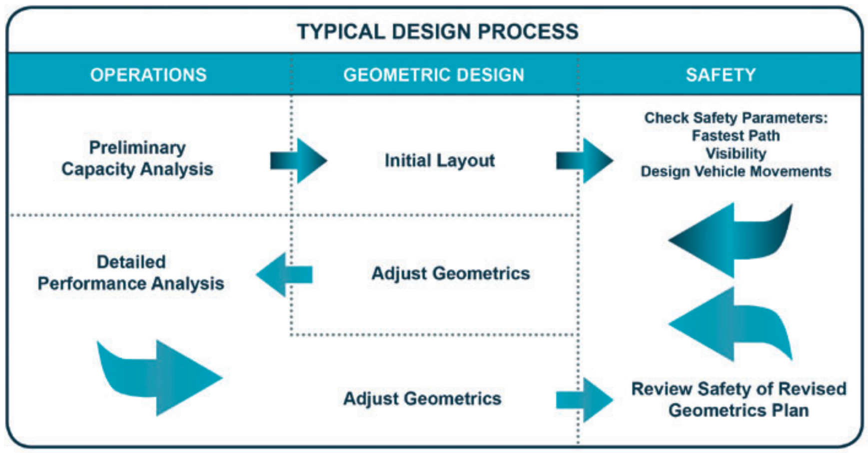
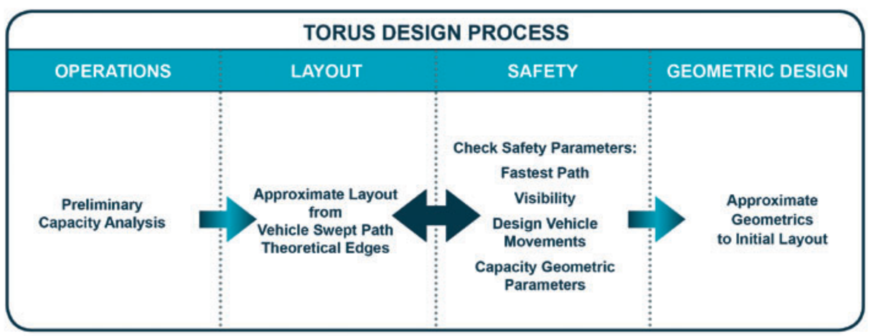
Dynamic roundabout design: Research and development

Software has been developed to speed up the often long winded, iterative method of roundabout design. Daniel Shihundu describes the research and development behind development of TORUS.

Introduction

Few motorists will appreciate the process that underpins the operational and safety benefits inherent in good roundabout design. High quality design promotes safer driving with improved traffic flow. It is a delicate balance between traffic capacity and physical geometry. This paper summarises the typical roundabout design process with regard to the inter-relationship between layout and traffic speed. Field research conducted in the development of a new dynamic and integrated approach is described with the work flow for one practical modern solution.





Traditional methods

Roundabout design is generally iterative, requiring many interrelated parameters to be checked simultaneously. Traditionally, this design process involves laying out a roundabout based on typical values specified in the established highways standards, ie, in the UK: TD16/07 of the Design Manual for Roads & Bridges.

Design vehicle paths and speeds are then checked against this preliminary layout. If the vehicle paths and speeds do not meet the design requirements, the roundabout geometry is revised and the checks repeated until the design criteria are satisfied. This can be a monotonous, costly and time consuming process.

Integrating vehicle paths and speeds at the earliest possible stage of roundabout design enhances the design process and reduces labour intensive iteration.

Development of TORUS – field study

Design tools are available with work flow processes that incorporate these features, such as Transoft Solutions' TORUS software. This is a CAD based roundabout design package featuring design vehicle characteristics and leveraging on the widely used AutoTURN vehicle swept path algorithm.

TORUS instantly updates the entire roundabout when changes to parameters are made. It was developed over a period of two years, through a process including GPS field studies on vehicle paths and speed profiles (patterns) to refine the software algorithm.

The GPS field study for vehicle driving paths and speeds was conducted in collaboration with the German University of Bundeswehr München. The objective was to examine the driving speeds and natural path patterns, related to acceleration, deceleration and vehicle positioning for approximately 300 runs through different roundabout configurations.

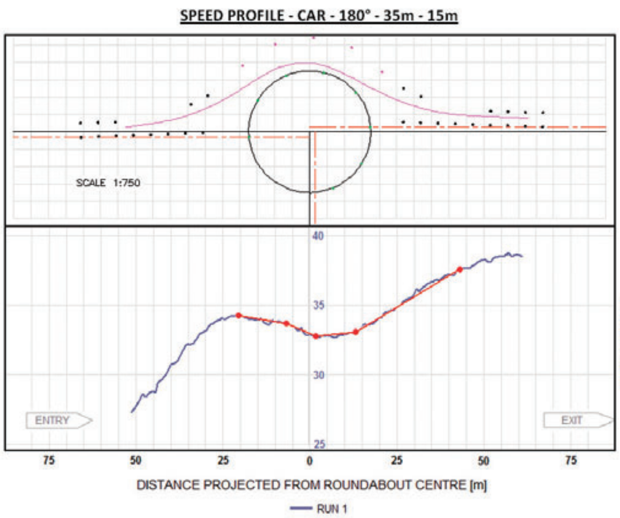
A typical passenger car, bus and articulated lorry were used in these tests. Data was reproduced in CAD and the graphical summaries produced and studied for the various runs. These findings provided insights into the innovative concept of designing roundabouts based on idealised paths. The speed profiles indicating the acceleration and deceleration zones provided feedback into the comfortable driving speeds for the different roundabout sizes.

Design process and work flow

The TORUS design process can be simplified into two main steps. Step 1 lays out the roundabout for single or dual carriageway while considering the design vehicle movements, fastest path and required visibility.

The vehicles are configured initially in the relevant design guideline and are assumed to travel on idealised paths composed of a series of curves. These

A bus with GPS units manoeuvres within a roundabout configuration with a central island diameter of 35m. A car and an articulated lorry were also tested on this configuration



Sample Drive Path (top) and Speed Profile (bottom) of a test run from the GPS Field Test. The plan view of the path shows only 1 of 10 runs

pre-determined paths make generation of vehicle movements straightforward by simply identifying the entry and exit carriageway.

In addition, offsets from the swept paths provide an initial approximation of the roundabout layout. Using this initial design, fastest paths and visibility related issues (landscaping or right of way encroachments) are evaluated accordingly.

The fastest paths are dynamically calculated with the entry path (the radius of path at the vehicle's centre) approximated. This occurs as the roundabout parameters are modified. For example, the roundabout centre is moved, deflection in the arms is varied and the inscribed circle diameter increased. Speed consistency checks for entering, circulating, exiting and turning paths are carried out and updated at the same time.

Sight line analysis is important for determining safety constraints. TORUS calculates and checks minimum stopping sight distances and through graphical representation, helps identify hazard zones and effects of obscuring features.

Visibility checks are also calculated dynamically and include minimum stopping sight distance on approach, forward visibility at entry, visibility to the right, circulatory visibility and pedestrian crossing visibility. Also in Step 1, other important aspects of the roundabout are generated: extent of the over run area, effective dimensions of entry and exit width, entry angle, approach half width, circulatory width, all based on the design vehicle swept paths.

Step 2 approximates the geometric elements typically representing curbs or painted lines. TORUS features tools that assist in approximating the entry and exit curb radius for the initial design. The fastest path can also be verified on the final geometric elements.

Design standards provide guidance for a wide range of key parameters based on a given roundabout size or type. Step 2 allows the engineer to determine the value within the range that would best fit the design situation. Though similar to traditional design methods, the crucial difference is that the initial geometry is laid out from valid, accurate design vehicle paths and at inception meets fastest path, vehicle movements and visibility criteria.

The TORUS work flow differs from that traditionally employed by some design engineers, but is easily integrated within the manual process; enhancing design quality and productivity.

The opportunity for improved junction design with further use of roundabouts is well documented. The pressure is mounting for increased quality and productivity in the roundabout design process. New methods and processes often meet with some resistance. However, history has proven many times that it is only through the development of innovative solutions that design processes become simplified and improved.

Daniel Shihundu (MIHT) is a senior civil engineer at Transoft Solutions in Canada. He was instrumental in the research and development of key algorithms for Transoft's TORUS roundabout software; research that has provided insights into the driver behaviour pertaining to vehicle acceleration, deceleration, speed and fastest paths. Daniel has recently provided technical advice to the North American AASHTO committee on geometric design based on vehicle kinematics and turning templates.

Daniel is a graduate of the University of Nairobi, Kenya and holds an MBA degree from the School of Management at the University of the Free State in South Africa. He is a registered professional engineer both in the province of British Columbia, Canada and South Africa. Daniel is a member of the South African Institution of Civil Engineering as well as IHT. His main interest lies in the development of software solutions for solving complex engineering problems.

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