DESIGN OF MEDIAN ENDS AT AT-GRADE INTERSECTION LAYOUT PLANS

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Abstract

Median represents a portion of an urban road separating opposing directions of the traveled way. Due to their function to provide enough space for separate traffic lane and storage of left-turning vehicles, the medians are highly desirable on city arteries carrying two or more lanes per travel direction. Type and dimensions of turning vehicles significantly affect the design of a median openings and median ends. The design solution and the geometry of median ends should be based on the composition of all left-turning movements occurring simultaneously at at-grade intersection. After selection of design vehicles for swept path analysis of the characteristic turning maneuvers in intersection, larger vehicles should be further checked for their ability to turn without undue encroachment on adjacent traffic lanes. The critical design parameter is the median width, especially at the ends of the median openings. Dragging paths of left-turning vehicles shape the median ends geometry. In traditional design practice established in Europe, three-centered compound curves with radii rations R1 : R2 : R3 = 2 : 1 : 3 and R1 : R2 : R3 = 2.5 : 1 : 5.5 are used to approximate dragging pahs of turning vehicles. In this paper, considering the median width, the deficiencies of the traditional design approach are revealed and new findings regarding the design of the median ends at at-grade intersections are presented.

Keywords: At-grade intersection, layout plan, median end, three-centered compound curve

1 Introduction

Left-turn lanes design elements of channelized four-leg intersections with medians and raised islands used for the separation of intended vehicle paths are analyzed in this paper. Traditional design procedure for the four-leg at-grade intersection usually includes several stages in which different geometric elements of layout plan are designed first and then integrated into unique civil engineering design. The selection of adequate design vehicle and swept path analysis represent one of the key stages in the intersection design process, especially at the end of the process when adopted design elements should be checked and poorly shaped roadway and traffic islands edges finally corrected. Although existing Serbian design guidelines [1] comply with relevant German [2] and Swiss [3] design standards, intersection design procedures and methodology defined in these standards are based on the traditional design approach. In recent years, only small number of papers [4, 5] have been published in which new design procedures for four-leg channelized intersections were presented. In addition, even rarer was the research [6, 7] focused on the composition of geometric elements in three-centered compound curves used for the formation of the pavement edges geometry in right and left-turn channelization.

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Traditional design methodology implies that geometric elements of intersection layout plan are separatelly designed and later integrated following the “INSIDE-OUT“ principle. In essence, this means that at the beggining vehicle movement trajectories for simultanious left-turning maneuvers in the center of intersection conflict area are defined (Figure 1), based on which roadway edges of left-turn auxulury lanes and the locations of median ends are determined. In relation to the previously positioned median ends, crosswalks at the major and minor street are than set. Crosswalks endings in the direction of original roadway edges dictate the position of triangular islands for right-turns channelization. At the end of the procedure, swept path analysis for right-turning vehicles are performed and the final geometry of outer roadway edges in relation to the modified triangular channelizing islands is set.

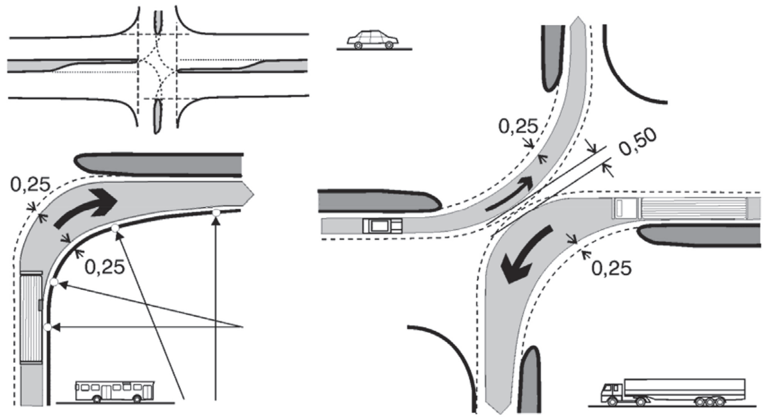

Figure 1 Minimal protective lateral widths along dragging paths of turning vehicles performing right and simultaneous left-turn maneuvers [8]

The above described procedure imposes as a major issue: How the shaping of median ends impacts on the size of intersection conflict zone and consequently on the scale of the whole intersection layout plan? Naimly, this issue was the key motivation for the research presented in this paper.

2 Definition of the problem

After setting of vehicle movement trajectories for the left-turning vehicles in intersection conflict area, the precise position of median ends (noses) could be defined. The essential dimension which impacts on the placement of crosswalks and further on the geometry of outer roadway edges is the distance between median end and the center of intersection (L_{ostrva}) where the axes of the crossing streets intersect (Figure 2).

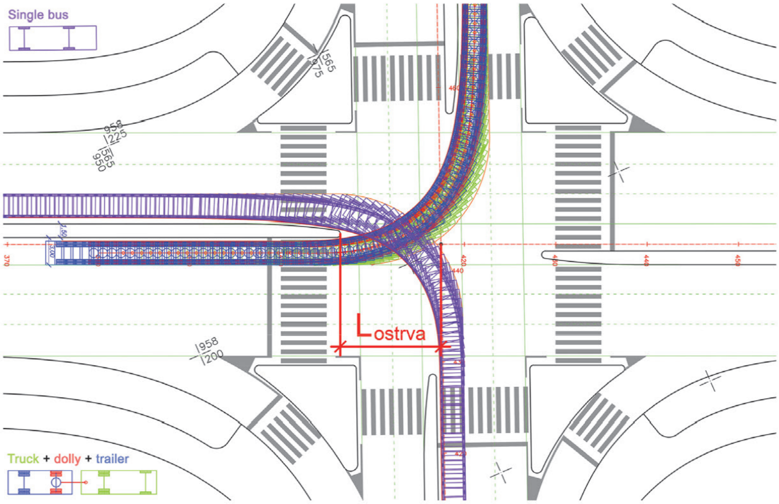

Figure 2 Determining the position of the median end in relation to the left-turning vehicles dragging paths

In traditional design approach, dragging paths of left-turning vehicles are usually aproximated by three-centered compound curves with well known radii rations R1 : R2 : R3 = 2.5 : 1 : 5.5 and R1 : R2 : R3 = 2 : 1 : 3. Starting and ending segments of this curves (circular arcs of radius R1 or R3) physically represent edges of raised curbs at median ends (Figure 3). Adopted geometric elements of three-centered compound curves for shaping of median ends imply that minimal protective lateral widths along dragging paths of left-turning vehicles are secured.

When placing crosswalks in relation to median ends, pedestrian safety should be carefully considered, especially for intersections located in urban areas. Bearing this in mind and according to Serbian guidelines for urban intersection design [8], minimum width of 1.5 m between opposite edges along adjacent crosswalk marks at median ends should be provided. This width guaranties enough space for temporary stopping of disabled persons in wheelchair and women with baby strollers when crossing the street.

However, when intersecting angles deviate from 90°, especially from the recommended range 60° - 120°, shaping of median ends and correct placement of crosswalk marks becomes even more complex (Figure 4). By further movement of crosswalks away from the median ends, triangular islands for right-turning vehicles channeling get bigger and bigger, and the whole area covered by the intersection layout plan increases too (Figure 5). So, as the key question arises: What is the optimum ration for the circular arcs and their corresponding central angles in three-centered compound curves which can provide precise shaping of median nose and consequently rational dimensions of triangular islands and intersection conflict area? It is already known from the literature [9, 10] that as the intersection conflict area gets larger in the signalized at-grade intersections, the duration of the red light signal for all vehicles consequently extends, thus the intersection capacity decreases. Hence, one of the main goals of road designers is to reduce as much as possible the intersection conflict area.

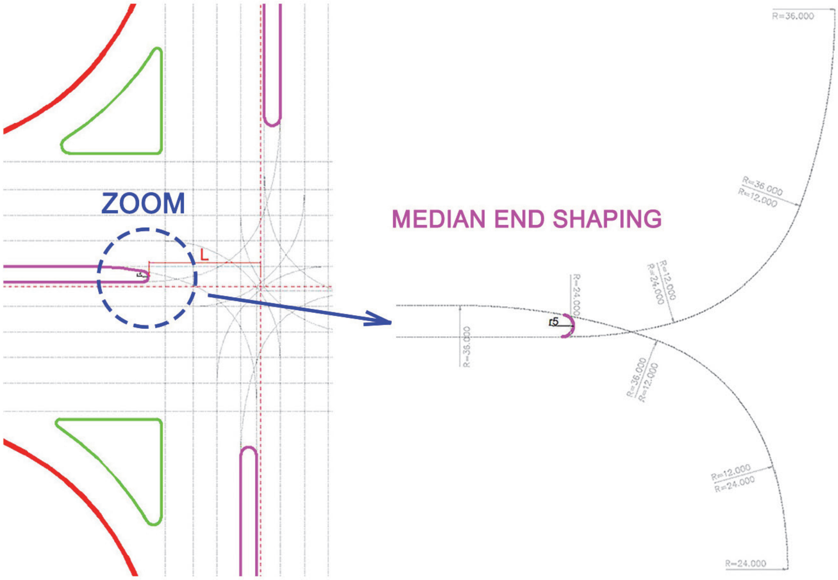

Figure 3 Shaping the median nose by three-centered compound curves used for the aproximation of left-turning vehicles dragging paths

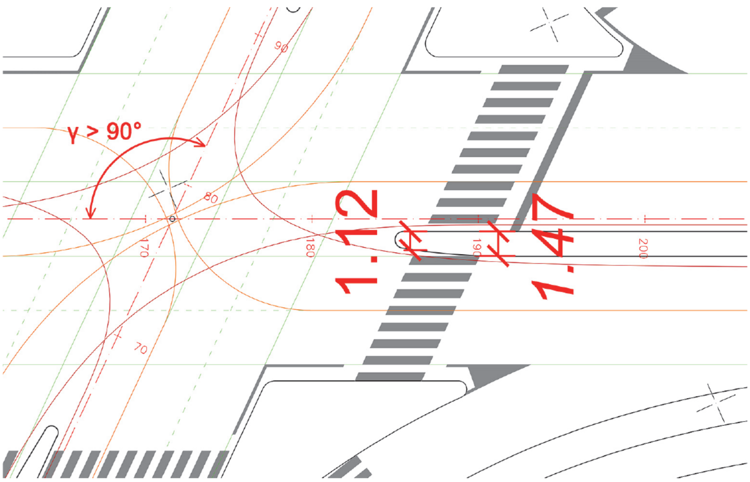

Figure 4 Median nose shaping when the intersection angle deviates from 90°

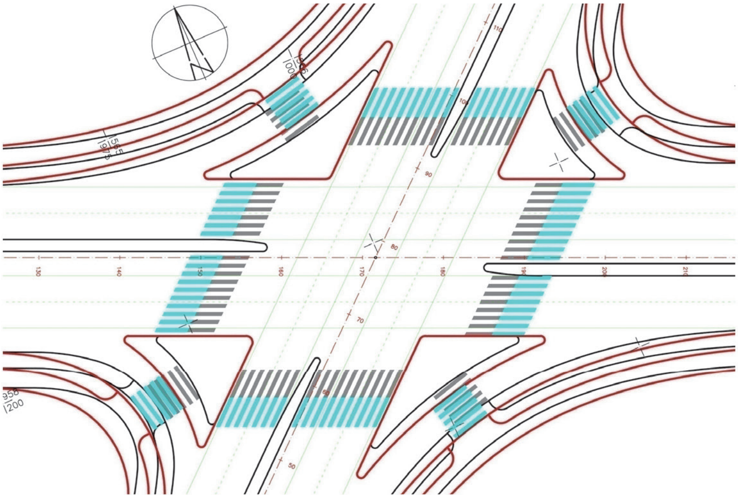

Figure 5 Displacement of crosswalk marks due to insufficient width of median ends (< 1.5 m) and consequently increase of the intersection area

3 Application of traditional geometric forms of three-centered compound curves for vehicle dragging paths approximation

Special "simulation" experiment in AutoCAD was performed in order to estimate the "geometric" eligibility of three-centered compound curve to approximate dragging paths of selected design vehicles. Tractor-semitrailer truck and single bus were selected as design vehicles for vehicle turning simulation run under GCM++ software [11] in AutoCAD environment. Steering path alignment was configured as a set of simple road curves with turning angles ranging from 60° to 120°. When setting the steering path alignment, minimum turning radius of selected design vehicles were drawn first. Then these minimum radii were offset towards their corresponding curve centers for the half of design vehicle width including mirrors and used later, together with the accompanying entrance and exit tangents, for the steering path alignment shaping. Both test vehicles follow previously set steering path alignment by the vehicles' front bumper midpoint. As an example, one of the simulated turning maneuvers for single bus following steering path shaped as 90° circular curve is presented in Figure 6. In the same figure, the position of three-centered compound curve, drawn with the recommended value of central radius R2, in relation to the single bus dragging path is shown.
Three centered compound curves, used for the approximation of vehicle dragging paths, were constructed with the conventional radii ratios (R1 : R2 : R3 = 2 : 1 : 3 and R1 : R2 : R3 = 2.5 : 1 : 5.5), using diagram displayed in Figure 7 for determing the value of central radius R2 as a function of vehicle minimum turning radius R_s and intersection angle γ. This diagram, described in Serbian guidelines, is based on the similar diagram originally presented by Krenz and Osterloh [12].

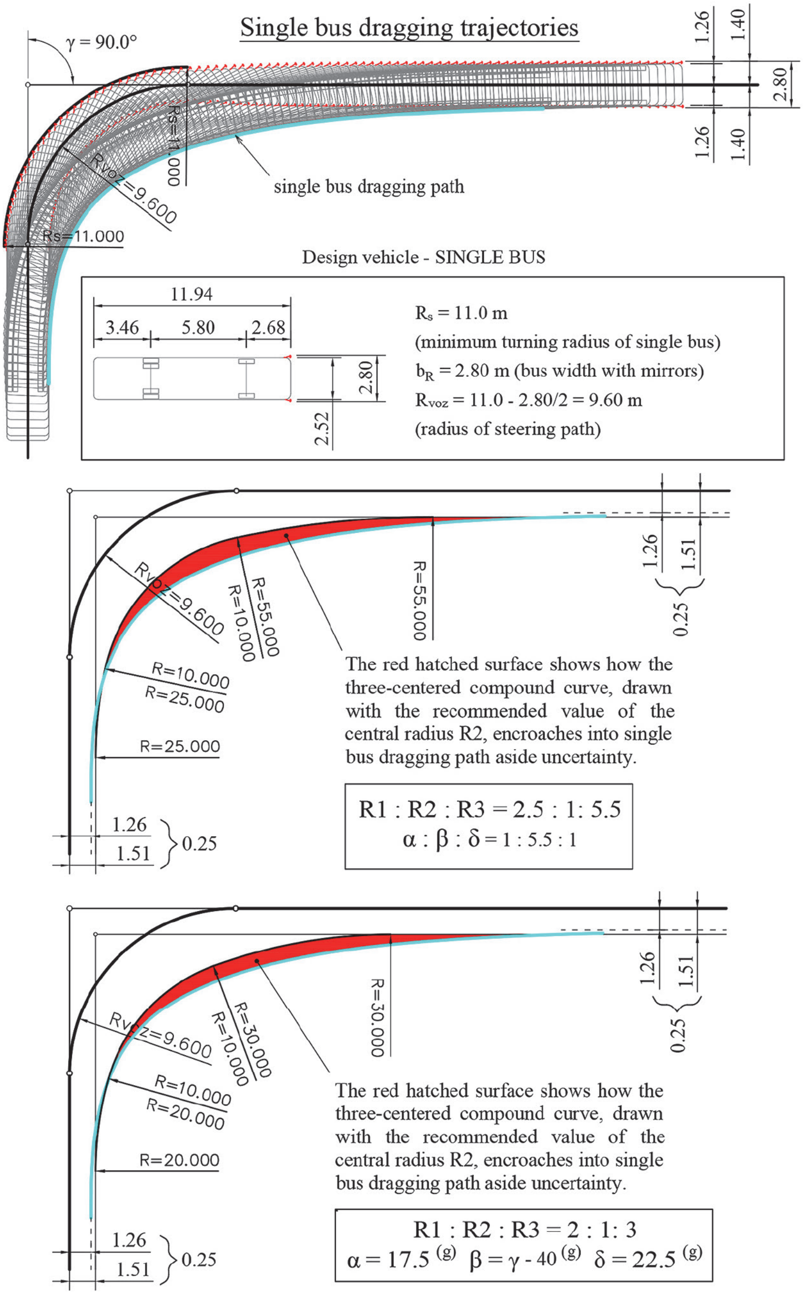

Figure 6 The position of three-centered compound curve drawn with the recommended value of radius R2 in relation to vehicle dragging path

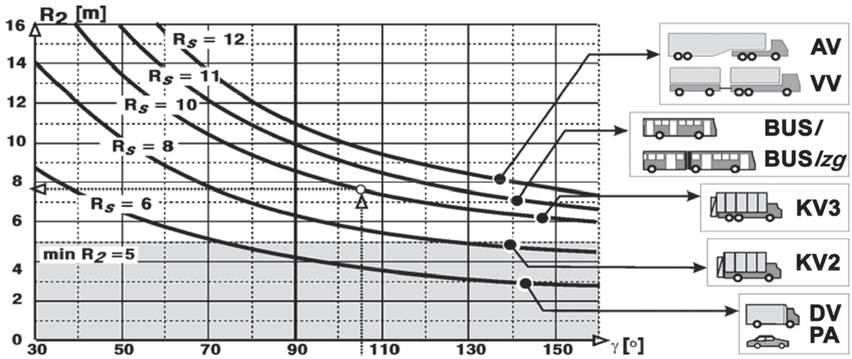

Figure 7 Central radius R2 of 3R compound curve expressed as a function of design vehicle minimum turning radius R_s and intersection angle γ [8]

Tangents for the construction of three-centered compound curves were drawn parallel to the original tangents of circular steering paths at the distance of the half of the vehicle width increased for the protective lateral width of 0.25 m. The Figure 6 clearly shows for both conventional radii ratios (R1 : R2 : R3 = 2 : 1 : 3 and R1 : R2 : R3 = 2.5 : 1 : 5.5) that three-centred compound curves, drawn with the central radius R2 adopted from the diagram in Figure 7, encroache into single bus dragging paths aside uncertainity. For the second longer test vehicle tractor-semitrailer truck, this encroachment is even wider. In practical terms, this phenomenon will be manifested as shortage of auxiliary traffic lane surface for left-turning vehicles. Due to this traffic lane surface shortage, the wheels of longer and wider vehicles will run into raised median ends and curbs along median nose edges will be phisically damaged.

4 Conclusions and future research

The shaping of median ends represents crucial stage of four leg at-grade intersections layout plan design. Critical dimension for placing of crosswalk marks and consequently repositioning of triangular channeling islands is the width of median nose. Therefore, besides providing sufficient clearance for unobstructed left-turning maneuvers, optimal geometrical formation of median nose edges is essential in order to get compact intersection conflict area with rationally programmed traffic signal timing.
Results of the simulation study obtained in this paper clearly indicate that widely used geometrical form of three-centered compound curve with the conventional radii ratios R1 : R2 : R3 = 2 : 1 : 3 and R1 : R2 : R3 = 2.5 : 1 : 5.5 could not be applied for the precise approximation of design vehicles dragging paths around median ends. Also, existing diagram in national intersection design guidelines, used for the selection of central radii R2 values in three-centered compound curves should be revised and corrected for various types of design vehicles. In addition, new ratios of circular arcs R1 : R2 : R3 and their corresponding central angles α : β : δ should be established and verified through comprehensive simulation tests for different turning maneuvers.
Revised geometrical form of three-centered compound curves will provide optimal shaping of median ends, decrease of the intersection conflict area, as well as rationalization of expropriated surface occupied by the whole intersection area. The final goal is to get reliable diagrams for the selection of three-centered compound curve design elements in order to eliminate iterative process of swept path controls and consequent road edges geometry adjustments after simulation of vehicle turning maneuvers in the final stage of intersection layout design.

However, besides optimal composition of geometric elements in three-centered compound curves, other specific curve forms (two-centered compound curves, curves shaped as fillet designs at airport runways and taxiways, etc.) potentially applicable as retraction curves, should be tested too. Bearing in mind a significant shortage of free space for the construction of new transportation infrastructure in urban areas, design of compact intersections and efficient space utilization are absolute imperative for all urban road planners and designers.

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