USING VISUALIZATION FOR THE DESIGN PROCESS OF RURAL ROADS

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ABSTRACT

The three-dimensional image of a road, which gives drivers all the important information for driving, is only obtained when three design levels are superimposed. If design engineers do not follow current standards during this complex process, shortcomings may occur and effect road safety. That's why during the classical road design process he must check the three-dimensional alignment with the aid of perspective images.
In order to be able to avoid shortcomings it is necessary to develop a new methodology of road design by using special three-dimensional design elements. The three-dimensional design can consist of fixed dialogue and coupling elements. The three-dimensional course of the route is visually represented using a real time simulation and the three-dimensional image can be checked by stereoscopic techniques.

1 INTRODUCTION

Road design is still carried out at road planning authorities and planning offices in three separate phases using the horizontal and vertical alignment projections and the cross-section. This means that the three-dimensional image of the road is not obtained until these three design levels are superimposed on each other. As road users receive three-dimensional images when driving and derive their driving style primarily from their perception of the sequence of images in the driving area, it is essential to calculate virtual three-dimensional images at early stages in the design process from the driver's point of view and use these to provide an early check on the three-dimensional alignment of the road. In principle, there are two different design methods available[1] :

1. Classical road design (two-dimensional)

   Road design divided into the horizontal and vertical alignment projections and cross-section and checks on the three-dimensional alignment with the aid of perspective images (pseudo three-dimensional image).

2. New methodology of road design (three-dimensional)

   Road design based on three-dimensional design elements in a three-dimensional environment, where the three-dimensional alignment is checked by using stereoscopic images (three-dimensional).

2 CLASSICAL ROAD DESIGN

2.1 Perspective View

As drivers absorb images from a central perspective when driving along a road, it make sense to calculate virtual perspective views using suitable visualization modules and then use them to check the three-dimensional alignment.
Unified model assumptions that match the driver's vision must be set to ensure the comparability of the central perspective views. Following comprehensive research work, the following model assumptions for calculating perspective views are suggested as part of the design check (Tab. 1).

Table 1: Model assumptions for computing perspective views

	Height above road surface	**Position in the cross section**
Eye level	1.00 m	Centre of own lane
Aim	0.00 m	Centre of own lane
Forward orientation:	75 m	
Aspect ratio:	4:3 (width : height)	
Local distance:	50 mm / **angle of aperture:** hor. 40 °, vert. 27 °	

Virtual perspective views and sequences of perspective views can be drawn on to assess shortcomings in the three-dimensional alignment. Qualitative assessment criteria and quantitative checking factors should normally be used in conjunction with each other.

2.2 Shortcomings

Shortcomings in the three-dimensional alignment during the classical design process are normally the result of an inadequate harmonization of the horizontal and vertical alignments (axis and incline). They can lead to accidents on single carriageway rural roads and therefore impair road safety. If the superimposition process of the horizontal and vertical alignment leads to blind sections (Fig. 1), this creates what are known as safety-related shortcomings in the three-dimensional alignment like "dips" (Fig. 2) or "jumps" (Fig. 3). In both types of shortcomings, part of the road is not visible to the driver for a certain period. This means that during a potential overtaking maneuver, it is impossible to rule out an accident occurring with a vehicle in the oncoming flow of traffic situated in the blind section. "Dips" or "jumps" can normally be corrected by enlarging the summit and depression diameter within the incline or by altering the design elements in the horizontal alignment.

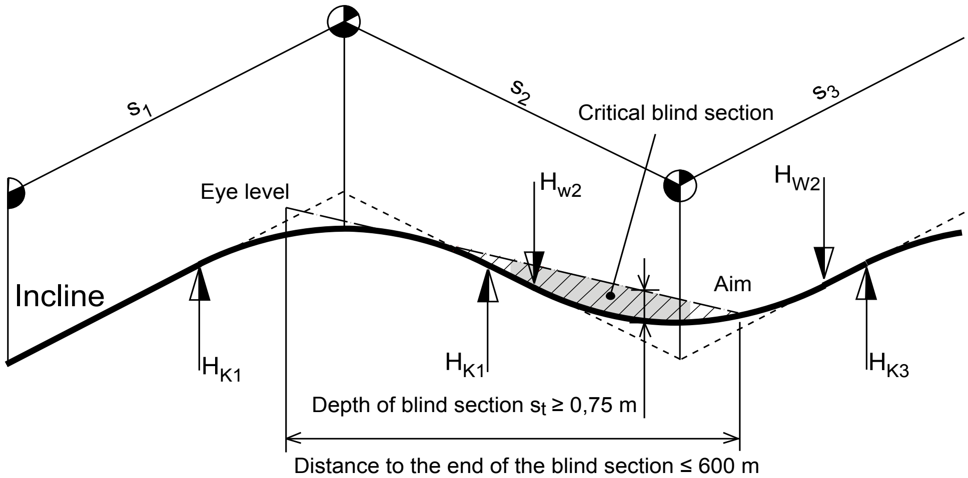

Figure 1: Model assumption of a critical blind section

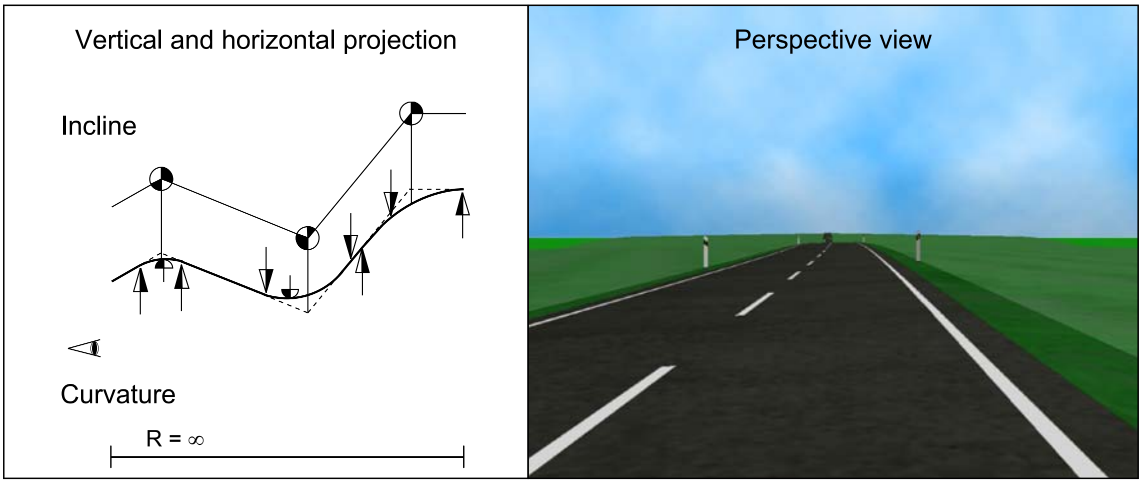

Figure 2: "Dip" shortcoming

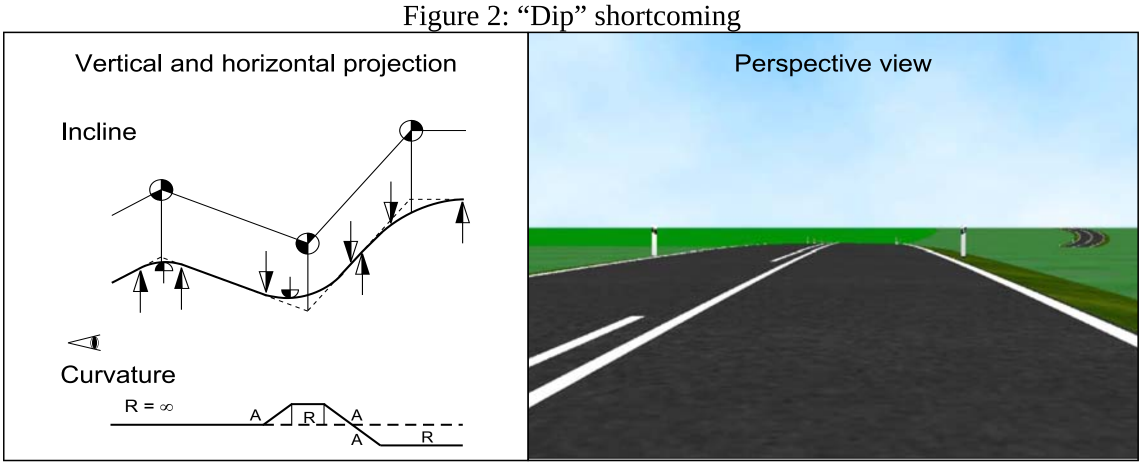

Figure 3: "Jump" shortcoming

2.3 Standard Three-dimensional Elements

So as to avoid the maximum number of shortcomings in the three-dimensional alignment during the design process, it makes sense to plan the route using standard three-dimensional elements. If this process is used, there is no need to coordinate the horizontal/vertical projections at a later stage. Standard three-dimensional elements and sequences of elements consist of standard superimposed horizontal and vertical projection elements. They occur if the beginning and end of a bend in the horizontal projection coincide with the beginning and end of crests or sags in the vertical projection. Slight fluctuations of up to 20% are possible. Figure 4 shows an example of a planned route with standard three-dimensional elements.

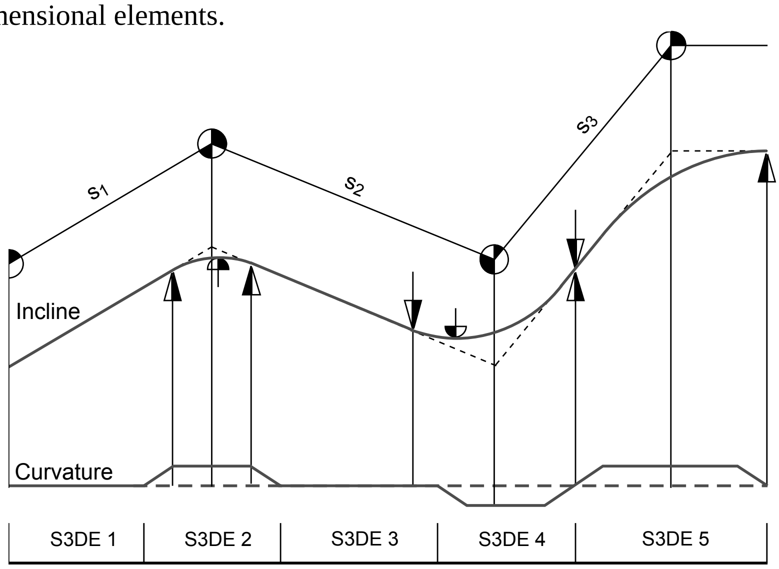

Figure 4: Alignment design with standard 3D elements

In principle, the following standard three-dimensional elements are possible:

- level straight (harmonizing a straight in the horizontal projection with a constant longitudinal slope in the vertical projection)
- straight sag (harmonizing a straight in the horizontal projection with a sag in the vertical projection)
- straight crest (harmonizing a crest in the horizontal projection with a constant longitudinal slope in the vertical projection)
- level bend (harmonizing a bend in the horizontal projection with a constant longitudinal slope in the vertical projection)
- bend in a sag (harmonizing a bend in the horizontal projection with a sag in the vertical projection)
- bend at a crest (harmonizing a bend in the horizontal projection with a crest in the vertical projection)

2.4 Checking Process

In order to avoid any shortcomings in the three-dimensional layout as early as the design stage, an assessment based on perspective images is required with the aid of qualitative assessment criteria and quantitative checking factors (Tab. 2).
If qualitative criteria are used, visual information can only be subjectively assessed from the perspective image, but if quantitative checking factors are used, the actual and desired values can be compared with each other numerically.

Fig. 5 illustrates the general configuration of a checking process. Once the road has been calculated using a suitable design program, the axis in the horizontal projection and the inclines in the vertical projection are determined. The design engineer must now check to see which sections of the route can be divided into standard three-dimensional elements and which ones reveal an arbitrary sequence of elements.

Table 2: Assessment criteria and checking factors

Qualitative Assessment Criteria	Quantitative Checking Factors
Design and consistency of the determining lane lines	**Checking factor 1**
Checks on sharp bends and relationships within the sequence of elements	Critical blind section
Balance and homogeneity of the three-dimensional alignment	**Checking factor 2**
Checking the sequence of elements for alignment shortcomings (dips, jumps, switchbacks)	Concealed beginnings of bends
Perception and comprehensibility of the driving area	**Checking factor 3**
Checking the individual elements in the driving area (guiding equipment, slope design, ground cover)	Visible lane surface

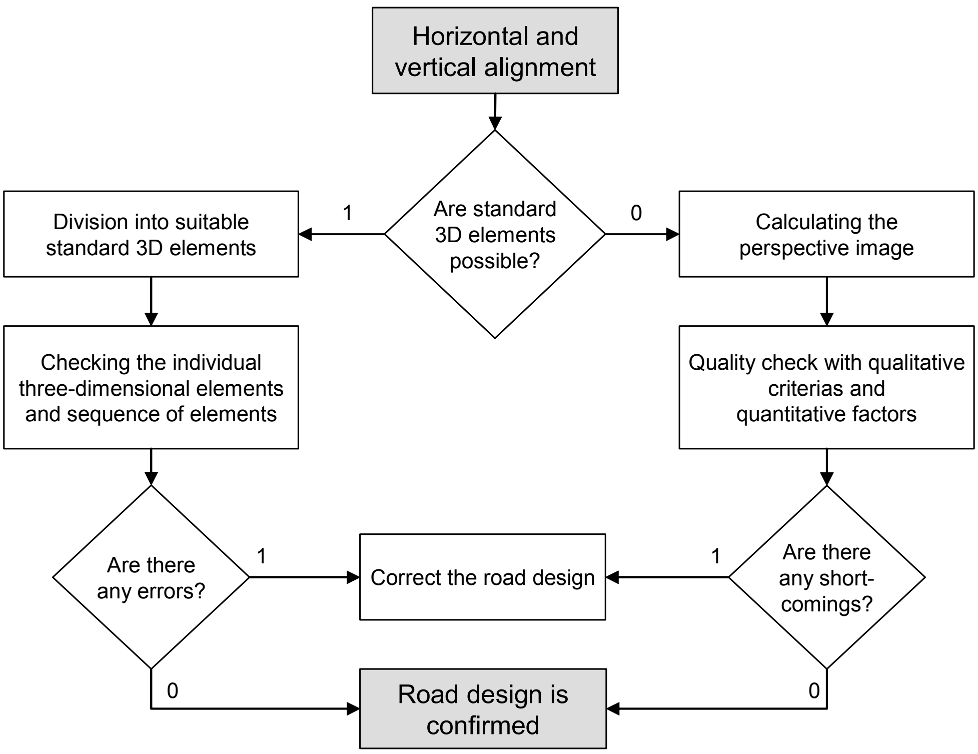

Figure 5: Checking process

3 NEW KIND OF ROAD DESIGN

3.1 Introducing the Model

In order to be able to avoid shortcomings in the three-dimensional alignment because individual design levels are processed separately and then superimposed on each other, it is necessary to develop a three-dimensional design methodology using a suitable mathematical model. The fundamental idea is that the design engineer should design and calculate a three-dimensional road as part of an iteration process by using three-dimensional design elements. The three-dimensional course of the route is visually represented on the basis of a real time simulation and the three-dimensional depiction can be checked by using stereoscopic techniques. The basic precondition for a methodology of this kind is a suitable mathematical model. The various sections of the three-dimensional route are composed of new kinds of three-dimensional design elements, which may have a different design from a mathematical point of view. Analyses have shown that in various sections, functions (splines) have special design technological features like making routes as direct as possible, minimizing bends at pre-set interpolation points, providing consistent changes in curves and repeating symmetries, they are three-dimensionally defined and are highly suitable for numerical calculations. A three-dimensional road can consist of the following design elements in various sections (Fig. 6):

- fixed elements
- dialogue elements
- coupling elements.

While the course of the route is determined by the constellation of interpolation points at the fixed elements, this can be varied in the dialogue element area by altering various parameters; this means that it can be adjusted to match the existing constraints. The coupling elements serve to link fixed and dialogue elements or regulate the boundary conditions at the beginning and end of the bend.

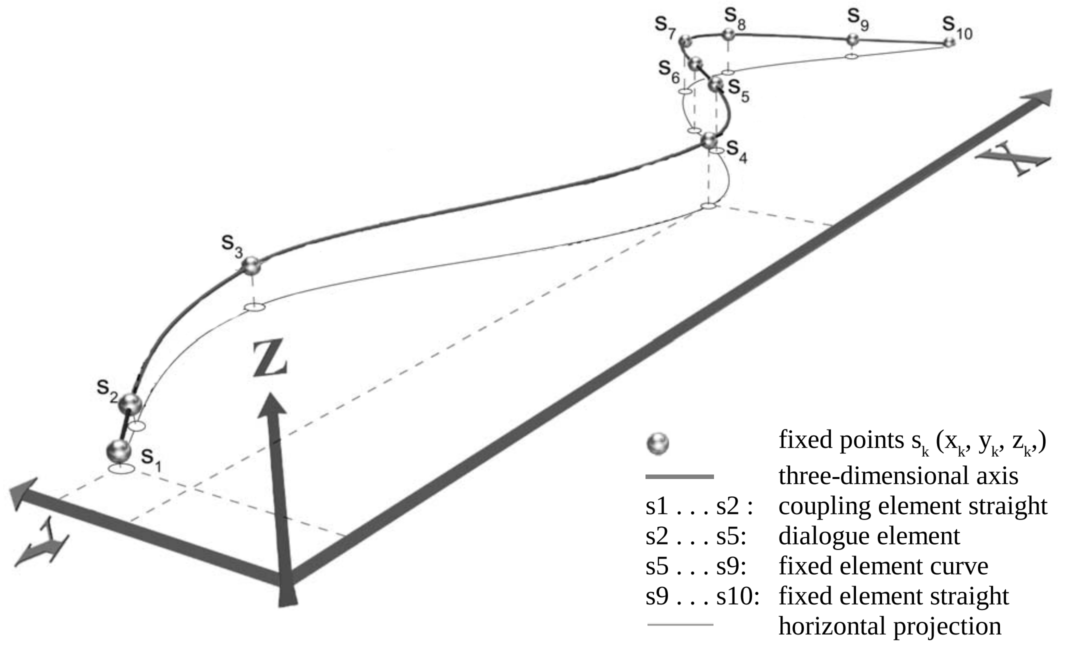

Figure 6: Three-dimensional model

3.2 Workplace

3.2.1 Basic Principles

The development of a three-dimensional design method not only requires new types of models, but also a workplace for the design engineer, which is equipped differently in terms of hardware and software. Powerful software systems are required, which allow interactive processing in real time mode, and also immersive projection systems so that the design engineer can visually perceive and assess the design elements in a three-dimensional realm.
In contrast to 2D screens, immersive projection systems allow three-dimensional images to be seen in virtual surroundings. This involves an image of the object being provided for each eye from the relevant perspective (stereoscopy). The actual three-dimensional impression does not emerge until the information on the depth of the images (not normally available with normal perspective images) can be perceived. Various processes are available for the necessary separation of channels. Active image technologies work according to the time multiplex procedure, i.e. the images earmarked for the right and left eyes are generated after each other in terms of time. This is why these systems can work with just one screen or projector. Passive image technologies, on the other hand, provide both images at the same time and therefore normally require two projectors; the images are then superimposed.

3.2.2 Configurations

Various configurations can be used to arrange the workplace (Tab. 3). While the design workplace is ideal to serve as an individual work area for three-dimensional design processing in real time mode, the various projection systems are designed for configuring what is known as a “virtual reality room”, where presentations can be given for a wider audience.

Table 3: Workplace configurations

Design Workplace	**Presentation Workplace**
3D-screen (auto-stereoscopic display)	Shutter-technique with 3-chip-DLP-projector
Shutter-technique with Tube monitor	Polarization filter technique with 2 projectors
Head mounted display	Interference filter technique with 2 projectors

- 3D screens (auto-stereoscopic displays)

  These screens do not require any other resources for three-dimensional observations. The images separated for both eyes are generated through subpixels, which are made visible for each eye by means of lenticular technology.

- Shutter technique (screen or projection)

  The shutter technique is one of the active processes because of the changing images for the left and right eyes. The sluggishness of the human eye is used, as it cannot differentiate the image formation at high image frequencies. Because of the changing type of image, only one screen or projector or set of shutter glasses is required. This masks either the right or left eye in step with the relevant image on the screen by means of a liquid crystal field in front of both eyes.

- Head Mounted Display (HMD)

  The HMD is a helmet on the viewer’s head and it generates very good immersive images, particularly if a tracking system is attached, by using two controlled screens, which operate independently of each other.

- Virtual Reality Room (VRR)

  The VRR is normally used for immersive presentations where a larger circle of people take part. The various images for the left and right eyes are generated using 2 projectors and are superimposed on the screen. Various filters in front of the projectors and the glasses separate the channels. The fundamental configuration of the design workplace with shutter glasses and the VRR with projection techniques can be found in Figs. 7 and 8.

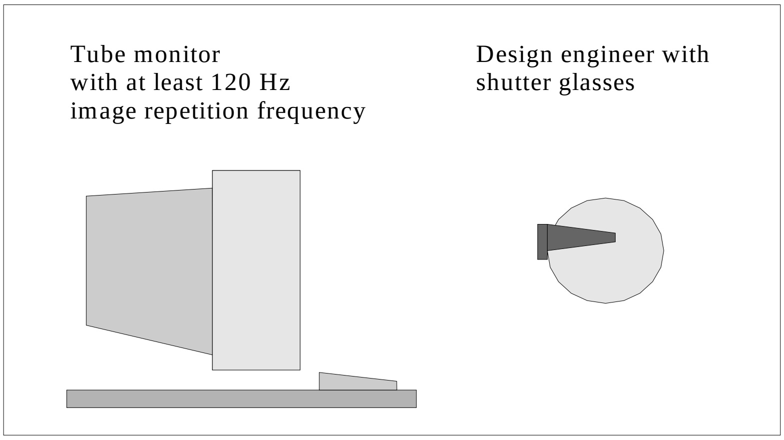

Figure 7: Design workplace with shutter glasses

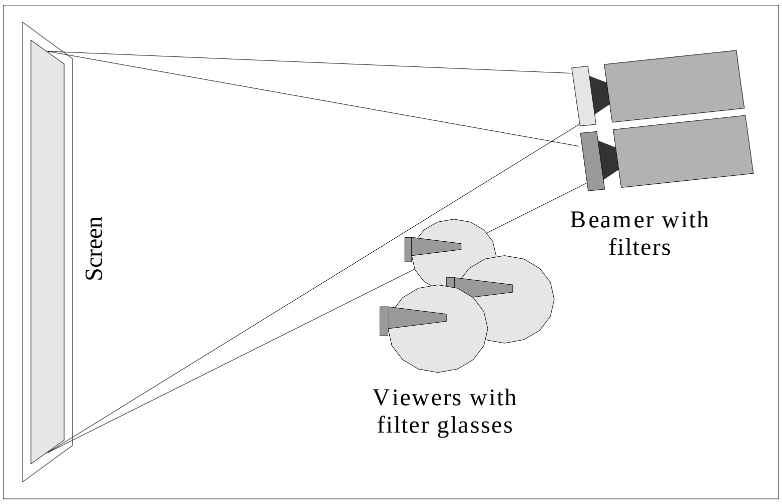

Figure 8: Presentation workplace (VRR)

4 METHODOLOGY

The technological process for a three-dimensional design methodology is shown in Fig. 9. After determining the three-dimensional interpolation points, a digital design line is calculated and drawn along all the points. Depending on the existing constraints, the fixed, dialogue and coupling elements are determined in each section. After calculating the defining points for the fixed and coupling

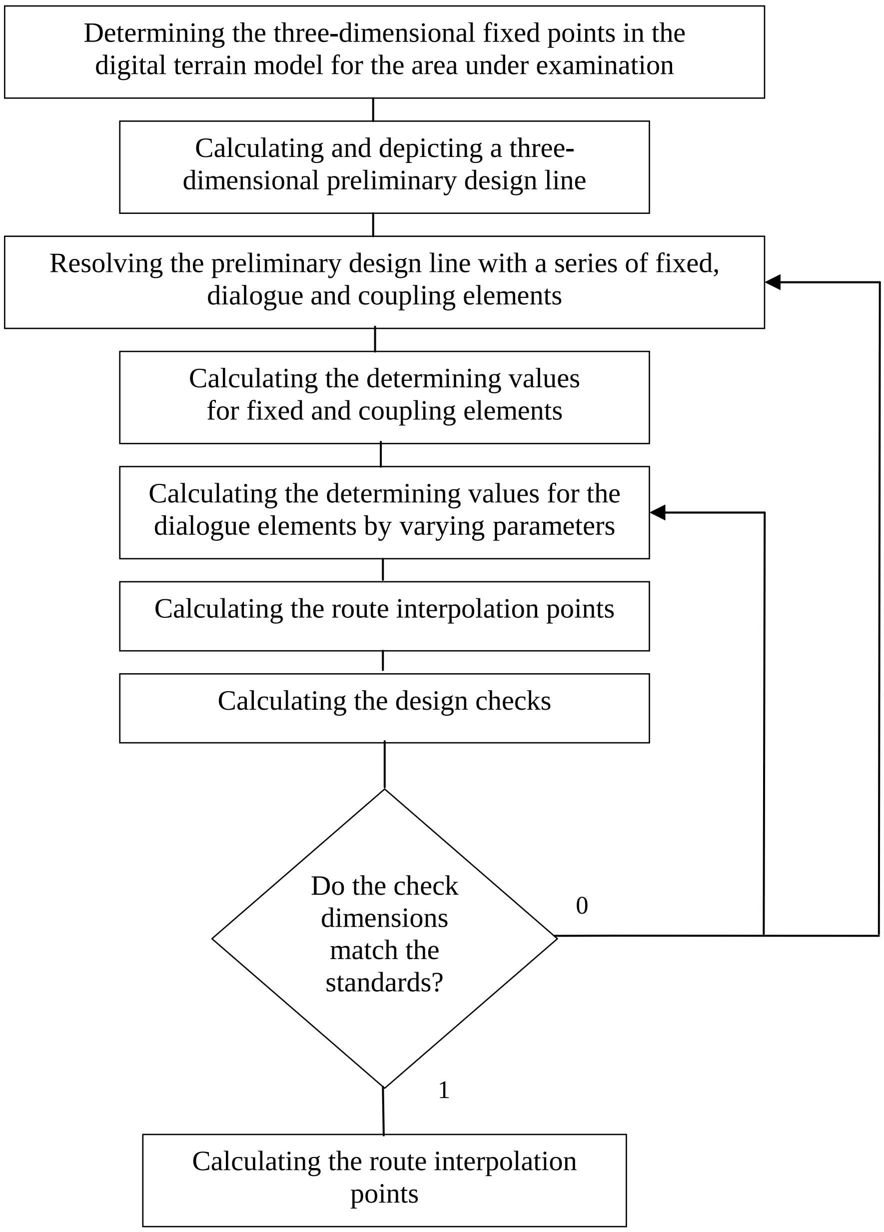

Figure 9: Technical sequence for processing three-dimensional design methodology

elements, the defining points for the dialogue elements are calculated on an interactive basis by varying the parameters.

If the defining points are available for all the design elements, the interpolation points can be calculated. It is necessary to provide a three-dimensional bend visualization to check the quality of the three-dimensional route (Fig. 10), i.e. the design result is constantly presented to the design engineer in visual form as part of the real time simulation process.

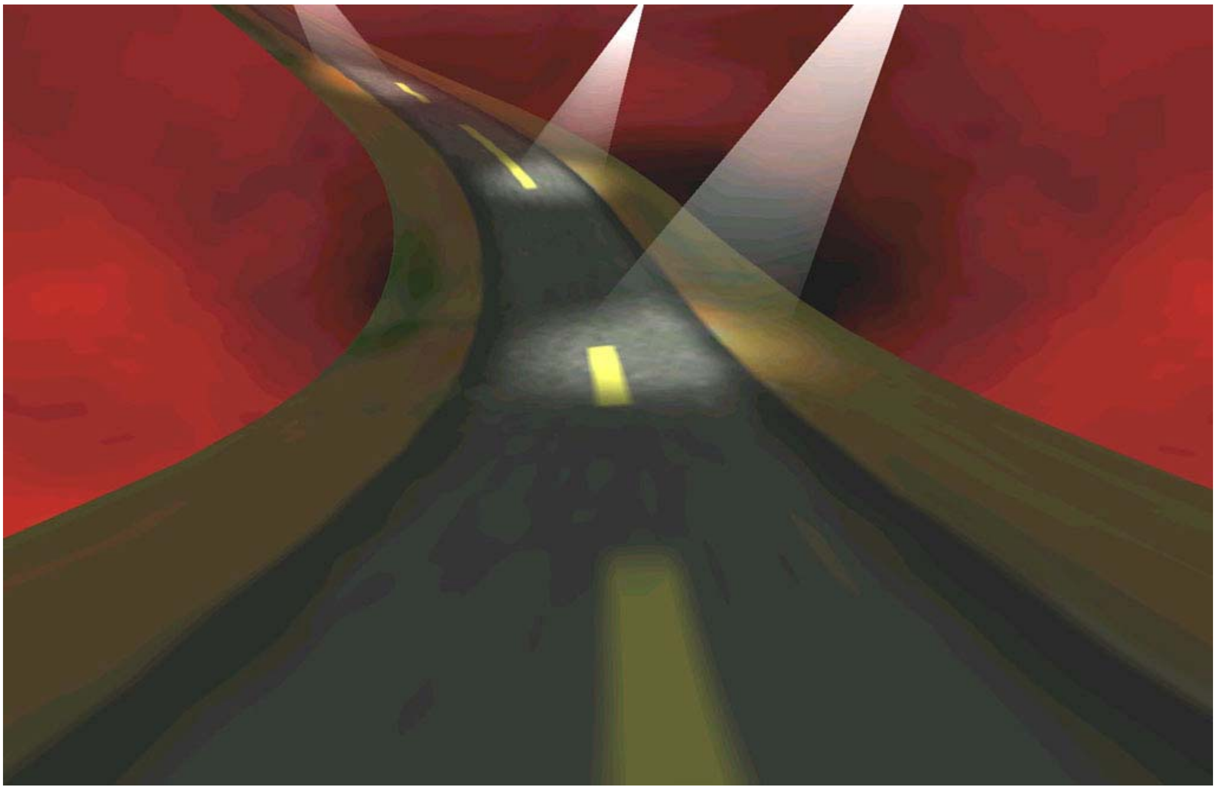

Figure 10: Visualization of a three-dimensional bend

5 SUMMARY

Suitable computer simulation and visualization procedures must increasingly be integrated in the design process (search for various options, axis calculation, design checks etc), in order to automate the design process still further and improve the quality of designs overall. A suitable checking procedure based on perspective images with the help of qualitative criteria and quantitative parameters must be prepared and introduced into daily practice for classical axis calculations, in order to avoid shortcomings in the three-dimensional route when superimposing horizontal and vertical projections.
New hardware and software conditions and new kinds of models are required in order to develop a three-dimensional design methodology, i.e. the workplace of the design engineer must change fundamentally. With the aid of stereoscopic procedures, the design engineer can visually observe a three-dimensionally designed route using special design elements (fixed, dialogue and coupling elements) and can constantly check these as part of a real time simulation. The checks on the design from the driver's point of view can take place using three-dimensional bend visualization.
In conclusion, it can be said that by using new kinds of visualization technologies, the dream of any design engineer of having three-dimensional axis design could become a reality in the near future.

REFERENCES

[1]Kühn, W. (2003) *Untersuchungen zu neuartigen Modellvorstellungen und Verfahren – Ein Beitrag zur Weiterentwicklung der Entwurfsmethodik für Straßen,* Post-doctoral lecture qualification,. Technische Universität Dresden, Fakultät Verkehrswissenschaften