Investigation of Unexpected Crossing-Lane Activity on Curving Road Using Digital Human Modelling Analysis

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Abstract
This study investigates the truck driving posture, vision safety, and perception time safety for truck drivers adjusting their velocity at the curving road due to crossing lane activity. The investigation method starts defining the road contour of the target using Geospatial Information System software (QBase). After the road elevation projection was made, the line was drawn to the surface in CAD software. After that, Digital Human Modelling (DHM) was created on the Japanese population with Indonesian anthropometry properties of 50%ile. The environment scenario was assembled based on the 3D model road surface and 3D vehicle models, and DHM in series. The objective scenario used vision analysis and driver perception response analysis. The result shows that even if the truck and SUV blockage has not appeared, the truck driver will not see the motorcycle on the corner. After that, pillar-A also contributes to blocking the truck driver’s vision. Since it contributes to construction safety, the trade-off cannot be negotiated. A speed trap shall be applied before the curving zone to increase safety. The speed trap could instantly reduce the truck and other vehicles’ speed in both lanes.

Keywords: curving road accident, truck driving posture, truck driver visual impairment

INTRODUCTION
Several accidents and fatalities in road safety are the main issues to be solved in most countries. NTSA in the USA revealed the crash factor on scene perspective occurred at about 36% at intersections, with around 11% of vehicles across the lane line, while overspeed and loss control shows 5%. A critical reason the accident happened was recognition error and decision errors 55.7% and 29.3%, respectively. The contributing factors that led to an accident recognition, mostly human fatigue, and inadequate surveillance, caused visual impairment (Choi, 2010). In comparison, Indonesia Police Traffic Management Centre (KORLANTAS POLRI) shows that in 2021 about 5.82% of 103,645 accidents occurred by geometric type in Indonesia (Indonesian National Police: Law Enforcement Directorate, 2021). It has always been contributing to the fatality record if there is no intervention from the local authorities. Several issues in the Megacity sort of Jakarta found the potential problem related to lane crossing, one of the contributions to the accident from road geometric and visual impairing. The geometric road problem occurred when traffic at the crossing lane was a curving road. Along curving, road visibility is deteriorating due to curve sight or a barrier. The driver needs the proper reaction time to avoid hard deceleration and crashes during travel at the corner. Subsequently, human fatigue is dynamic and inconsistent to be measured, and humans
rely their navigation on visual ability. ISO 24509 revealed that human vision is affected by several variables: distance, age, and lighting (ISO, 2019). Regarding driving activity, road geometry and its environments also contribute to visual impairment. Experimenting with visual impairment is costly, time-consuming, and risky.

To sum up, since few studies discussed on vision safety of truck driver driving posture, then, this study proposes an investigation on truck driving posture and vision safety and perception time safety for truck drivers adjusting their velocity for the cross lane at curving geometric road using Digital Human Modeling (DHM).

LITERATURE REVIEW
Several studies were conducted about Digital Human Modelling (DHM) in vehicles or other transportation. Bong-Choi et al. (2009) compare a visibility technique using DHM as a design factor when the driver does maneuver on the forklift (Choi et al., 2009). Summerskill and Marshall (2015) started their study regarding a large truck against cyclist accidents in London. This case revealed that using DHM, the significant truck driver has a direct visual impairment (blind spot) to cyclists due to the truck's geometric design (Summerskill & Marshall, 2015).

Another visual impairment analysis study was presented, Summerskill et al. (2016) studied volumetric projection by the large truck primary mirror and additional mirror as a path to reduce the truck’s blind spot according to UNECE Regulation 46 (2009) (Marshall et al., 2020). The result indicates that the existing truck with a limited mirror has the potential to be a causal factor in an accident. Figure 1 describes a satellite image of a crossing lane on a curving geometric road. Two crossing lane sites are scattered at BRIN Serpong- South Tangerang Area: (a) Puspiptek and (b) Gunung Sindur. All geometric roads have a width of around 10-12 meters, respectively, and their length is cut to 200 meters. Olson (1989), through the SAE article, revealed that a roadway system needs to understand how a driver responds to an unexpected situation. The information from the eye sensor through data processing in the brain resulting a time response to perceive. Therefore, the delayed perception versus driver velocity and distance of the vehicle were reviewed as the subject (Olson, 1989).

![Figure 1](image-url)  
Figure 1. Two site locations of crossing lane (a) PUSPIPETEK rear gate and (b) Gunung Sindur curving road
RESEARCH METHOD

A. Crossing Lane Scenario

Figure 2 illustrates potential conflicts scenario on a curving road. The two trucks were in a dual lane on a curving road; at the same time, it was a sports utility vehicle (SUV) in front of the main truck, while on the opposing side, there was already a motorcycle cross-lane at the rear truck. The main lorry to motorcycle assumed about 8 meters. Two Scenarios were the same setting on two different road geometry.

![Figure 2. Crossing lane scenario conflict on two curving road sites](image)

B. Vehicle Geometry

The scenario was challenged; the vehicle was downloaded from the GrabCAD community library (GrabCAD, 2022). The truck was selected due to causing the most fatality in the accident (Indonesian National Police: Law Enforcement Directorate, 2021), whereas the blocker truck was randomly selected. The SUV was selected because it is boxy and represents the favorable Indonesian car type and its geometry roles as a blocker. Then, a naked motorcycle was selected over a scooter since the scooter model equally represents the geometric length and width. The following table summarizes the vehicle geometry data as a part of the crossing lane scenario.

| Role of Plays | Illustration | Dimension (mm) |
|---------------|--------------|----------------|
| Main Lorry    | ![Main Lorry Illustration](image) | Out. Length 7520 |
|               |              | Out Width 2450  |
|               |              | Driver Height Position 2400 |
|               |              | Out. Length 2031  |
**C. Manikin Digital Human Modelling and Truck Posture Setting**

Digital human modeling was built on Computer Aided Software (CAD). The gender of manikin was defined as man, and the population set was Japanese. Using the posture editor, the detail sets were adjusted following Indonesian anthropometry provided by the Indonesian Anthropometry website (Antropometri Indonesia, 2013). Potter and Gyi (1998) found ergonomic driving posture packages for ranges of percentile and genders on sedan driving rigs. The results were determined on several criteria, for example, seating position, control position, and pedals (Potter & Gyi, 1998). Overall, the whole method was derived and adopted for truck posture based on Potter and Gyi (1998) and SAE Class B regulation of seat position and the truck's cabin geometry. Figure 3 describes the package criteria to construct truck driving posture regulated by SAE J1517_201110 (Truck and Committee, 2011; Philippart et al., 1986).

**D. Road Surface Contour Extraction and 3D modeling**

Before extracting the road contour, the targeted area was scattered at BRIN Serpong Technopark. There were two sites to be projected as contour: (a) Rear gate Puspiptek and (b) Gunung Sindur. The corridor road length was determined to be about 300 meters due to memory saving of a larger scale road model, and the unit meter was chosen. Throughout the study (shown in Figure 1), the offline map and digital elevation model data (DEM) of the target area were downloaded using mapping software (QBase 3D 2.30.48, Germany). Once the map and DEM were combined, the road contour can determine using the corridor element setting with parameter explained as follow: corridor width 10 meters and altitude 60 meters. The road surface contour result will be shown on the contour plot feature.
Investigation of Unexpected Crossing-Lane Activity on Curving Road Using Digital Human Modelling Analysis

Apid Rustandi, Sinung Nugroho

E. Models Assembly and Vision Analysis Setting

Subsequently, Summerskill et al. (2016) used digital human modeling (DHM) as an application for measuring driver direct vision through cabin glass. The road 3D model, vehicle, and DHM manikin components were imported and assembled into one assy according to the defined scenario (see Figure 2). Before the visual simulation, the manikin vision was set up as a binocular type with a field of view limit around horizontal monocular and binocular, vertical top, and bottom as default. The distance was divided into three variables: punctum proximum, remotum, and focus distance. The manikin would display as a line of sight and visual cone bounding.

F. Perception Driver time

Stopping sight distance was calculated to regulate the minimum distance required when a driver spotted a stationary object (e.g., a navigation sign) at the designed velocity (Olson, 1989). To prescribe the calculation, the first part of the general equation governs the reaction time first, as follows:

\[ d = d_{pr} + d_{brake} \]  

where \( d \) is the "distance for vehicle stopping" \( d_{pr} \) is the "distance when the driver perceives and reacts to an object", and \( d_{brake} \) is the brake distance. However, one component can be assumed according to the design or reaction scenario to get the reaction time or distance. Subsequently, the Equation 1 result will answer the stop-sight distance shown in Equation 2:

\[ SSD = V_0 \cdot T_{pr} + \frac{V_0^2 - V_f^2}{2g \left( \frac{a}{g} + G \right)} \]  

Where stop sight distance is set as "SSD" the initial velocity is set as "\( V_0 \)" while the acceleration or deceleration is set as "\( a \)" and "\( T_{pr} \)" sets as reaction time. Gravity is set as "\( g \)" then the level of roadway (e.g., Inclination level) set as "\( G \)" refers to Australia Road Design...
Guide: Geometric (Hubner et al., 2010). The velocity and distance will be assumed regarding average speed on allowable city speed by regulation.

FINDINGS AND DISCUSSION

A. Road Contour and Scenario Assembly
In order to identify accidents of interest to critical reasons for curvature crossing lane accidents, some relevant variables such as road contour level and distance are explored, explained in Figure 4. The software Q-Base estimated the 2D side contour of the elevation model for distance and elevation (altitude). (a) PUSPIPETEK rear entry gate and (b) Gunung Sindur Corner. It can be shown that the road contour (a) is climbing about 15% (length /height) while (b) the contour is relatively flat.

![Figure 4](image_url)

**Figure 4.** Puspiptek and Gunung Sindur road elevation contour in two-dimensional projection (2D)

The contour drawn in QBase software accurately represents the actual elevation and distance. The Puspiptek rear gate inclines, while at the Gunung Sindur, the contour is projected flat. It indicates that the Puspiptek rear gate is riskier to overcome due to the inclination contour. The unit distance using (km) and altitude in the meter of MSL (mean sea level). A 3D CAD model generates the scenarios based on the 2D elevation contour method.
Figure 5 shows two comparisons of the PUSPIPETEK rear gate site curving road versus the 3D scenario model. The green lorry (green color) identifies the motorcycle on the opposite lane. In contrast, the motorcycle must cross the lane on a curving road as they need to do so. Another vehicle and side perimeter object rolling as vision blocker, e.g., a white lorry, SUV, and business loft building. None of the convex mirror was found.

![Image of Figure 5](image_url)

**Figure 5.** Puspiptek real site situation via google map versus and 3D modeling comparison

Figure 6 shows the Gunung Sindur curving road geometric situation compared to the 3D model scenario. Similar to the Puspiptek scenario. Through windshield glass, the green truck and DHM generate vision line sight to the crossing point. Similarly, none of the convex mirror was found. Since the scenarios are framed statically, the critical moment of the problem cannot be captured accurately. There are considerable factors counted, for example, time and velocity. It means the critical scenarios simulated possibly do not represent the actual situation.

B. Digital Human Modelling and Posture Setting

From the Indonesia anthropometry data that has been arranged, it was revealed using DHM that Figure 7 (a) shows the percentile of stature comparison in series. The statures are 5%ile = 1170 mm; 50%ile= 1688 and 95%ile= 1870 mm. Regarding DHM’s standing posture result, the 50%ile selected to represent the mean population. While the following picture illustrates the driving truck posture constructed from Philipart et al. (2018) and
SAE driving posture setting to truck cabin position. The posture represents the steering wheel section dimension, the full-back spine derived from the seat section, and the lower limb consequential from the pedal and seat section, as shown in Figure 7 (b).

Figure 6. Gunung Sindur capture site via google map compared to 3D model scenario

Figure 7. Package definition of driving posture platform for truck driving posture set
To better understand the objective parameter of truck posture, Table 2 explains the output parameter value for truck driving posture generated from DHM 50%ile. The value L31-1=1060 describes how a neutral point (SgRP) correlates stature through pedal position and seat angle to the X direction. At the same time, H30-1= 332 mm represents the neutral point in the Y direction. Other results show in the steering dimension section, whereas the L11 determined around 320 mm, from the pedals to the steering wheel or hand reaching. The H17=607 mm defined height distance from the pedal to the center of the steering wheel. A-18 adjusted to 70° as a consequence of the truck design cabin.

| Table 2. Truck driving posture output value parameter |
|-----------------------------------------------|
| **Driver Cabin** | **Item** | **Code** | **mm** | **deg** |
| **Seat Section** | (SgRP) | L31-1 | 1060 | |
| | | W20-1 | -295 | |
| | | H30-1 | 332 | |
| **Travel path** | A-19 | 0 | |
| | TL2 | 50 | |
| | TL-18 | 265 | |
| **Cushion** | A271 | 20 | |
| | A40-1 | -10 | |
| **Steering Wheel** | Frame SW | L11 | 320 | |
| | | W7 | -380 | |
| | | H17 | 607 | |
| | | W9 | 400 | |
| | A18 | 70 | |
| **Pedal Section** | Grip | Diameter | 30 | |
| | Rotation Axis and Position | L8 | 380 | |
| | | W8 | -235 | |
| | | H8 | 180 | |

Truck driver perception time on the curving road on several velocity scenarios majority of sitting reference points (SgRP) is designed for 95%ile driver stature. However, this simulation uses a neutral point reference based on 50%ile, which means the highest percentiles (95%) can be riskier caused by the pillar-A and head roof blockage of the driver vision. Vice versa, the lower percentiles (5%) have a wide-angle vision. The simulation output parameter also generates value for setting reference of driving posture for truck class B.

C. Vision Analysis

Regarding vision using the binocular setting display in both scenarios, the vision performance of Truck DHM shows a focus point and blockage pillar on the binocular area. In contrast, the surrounding truck object identified with blurry vision e.g., mirror glass (RH), opposite truck (RH), and SUV car. Figure 8 indicates that none of the motorcycle’s silhouettes are seen in the scenario. Curving road, opposite truck, and pillar are blocking the line sight of the driver. Another figure illustrates the cone bounding focus distance of driver sight through windshield glass (e.g., 8000 mm) in the scenario. At this level, the driver focuses on the peak curving section area. The figures also explain the coverage of the cone bounding vision linearly to focus distance.
Investigation of Unexpected Crossing-Lane Activity on Curving Road Using Digital Human Modelling Analysis
Apid Rustandi, Sinung Nugroho

D. Perception Time
According to driver response perception, the parameter inputs were distributed to the formula described (see Equations 1 and 2). Table 3 shows the result of how velocity and time response generate a consequence of deceleration. The setting was grouped into two sections: distance to the final velocity, the initial velocity around 70 km (19.6 m/s), and about 8 to 5 m before entering the peak of the curving road when the motorcycle crosses the lane. The final velocity of the truck when it arrived on the peak curving road was around 30 Km/h (8.4 m/s). The result shows that at about 6.9 seconds, the driver’s minimum reaction time should decelerate at 8 meters to avoid the crash. In comparison, using the distance scenario about 5 meters with a similar setting, the reaction time obtained about 3.93 seconds to the truck driver reduces the velocity when seeing the motorcycle prepare to cross the lane. From the Australian standard road design, the allowable reaction time for the driver crossing in typical road conditions starts from 1.5 through 2.5 seconds (Hubner et al., 2010), while the truck simulation shows the minimum result of 6.93 and 3.93 seconds.

Table 3. Truck driver perception time on the curving road on several velocity scenarios.

| Velocity | Distance-1 | Distance-2 | Rt-1 | Rt-2 | SSD-1 | SSD-2 |
|---------|------------|------------|------|------|-------|-------|
| Km/h    | m/s        | (m)        | (m)  | (sec)| (m)   | (m)   |
|70       | 19.6       | 8          | 5    | 6.93 | 165.17| 114.77|
|60       | 16.8       | 8          | 5    | 8.00 | 183.21| 132.81|
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Apid Rustandi, Sinung Nugroho

### CONCLUSION AND FURTHER RESEARCH

The study indicates that the activity of crossing lanes on the curving road is dangerous and potentially to lead an accident. It can be drawn from eyes physiology that the more eyes expose detailed objects then, the surround will be seen as blurry. Even if the truck and SUV blockage has not appeared, the truck driver will not see the motorcycle on the corner. After that, pillar-A also contributes to blocking the truck driver’s vision. Since it contributes to construction safety, the trade-off cannot be negotiated.

The perception time of the truck driver from distance and velocity scenario indicates that the truck cannot decelerate hard. Based on geometric design standards, it needs more time and distance to decelerate smoothly. A speed trap shall be applied before the curving zone to increase safety by reducing the truck’s velocity and another vehicle on both lanes. After the speed is reduced, the convex mirror with > 1-meter diameter can work effectively. Furthermore, adding and assessing how the convex mirror at the corner effectively projected and helped the driver see beyond the corner at the range of speed is a challenge for further research.

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Investigation of Unexpected Crossing-Lane Activity on Curving Road Using Digital Human Modelling Analysis

Apid Rustandi, Sinung Nugroho

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