Software Tools for Location of No-Passing Zones Using GPS Data

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Abstract

Locating no-passing zones on two-lane highways is a difficult task because of the amount of time necessary to locate the zones and the hazard involved in working on the highways in the presence of moving traffic. This paper presents the development of a software for the location of passing/no-passing zones based on GIS and GPS technology. First, X,Y, and Z coordinates are collected along the road using a GPS antenna mounted on top of a moving vehicle, then a road profile is established on both horizontal and vertical planes. This profile is used to calculate visibility for each GPS point on the road. Based on parameters like speed limit, minimum sight distance, target height, a passing/no-passing attribute is given to each GPS point and beginning and end of no-passing zones are located on the road. This application has been developed in Visual Basic using MapObjects® ActiveX controls.

Of all the maneuvers a motorist can have to execute, the overtaking of a vehicle is one of the most complex operations. This maneuver is a dynamic space-time relationship where two or more vehicles are involved. The driver has not only to estimate distances and speed of other vehicles, but also to accelerate, to take the left lane, to by-pass the slow vehicle, then to return in the right lane while keeping a safe distance from other cars. It is no surprise that road marking has been developed to help drivers in the decision taking process of overtaking or not a slow vehicle.

First works to estimate a minimum passing sight distance for safe overtaking are based on field observations carried out in the United States from 1938 to 1941 (Polus, Livneh and Fisher). Although many studies were conducted since 1940, a lot of work has to be done, especially when it comes to the location and marking of passing zones. The main objective of this paper is to describe a new method and software for the location of

passing zones based on GIS (Geographic Information System) and GPS (Global Positioning System). It starts with a review of the traditional methods used to locate passing/no passing zones and their limitations. Then we introduce our approach, using GPS and a software developed with MapObjects®, to establish horizontal and vertical road profile for minimum sight distance calculation. Data collection and processing, software development in Visual Basic and road profile analysis will be discussed. On site road testing and location of passing/no passing zones will be presented. Finally, we will conclude on the lessons learned from this experiment and its limitations.

PASSING SIGHT DISTANCE

The ability of a driver to overtake another vehicle is influenced by many human and physical factors. For example, traffic density, speed differential between vehicles, road geometry, sight distance, reaction time and driver's tolerance to risk can all have an impact on the decision to pass or not. According to literature, the available sight distance is a major criteria in the decision process of a car driver. This distance must be long enough to let the driver safely complete the overtaking maneuvers.

The Minimum Sight Distance

For a pass to be safely continued or aborted, it is necessary that both passing and the opposing car be able to see each other uninterruptedly during the maneuver. This minimum sight distance can be broken down in four parts (figure 1):

d_1 =   Distance covered during reaction time
d_2 =   Distance covered on left lane by passing vehicle
d_3 =   Safety distance between incoming and passing vehicle at the end
            of the maneuver
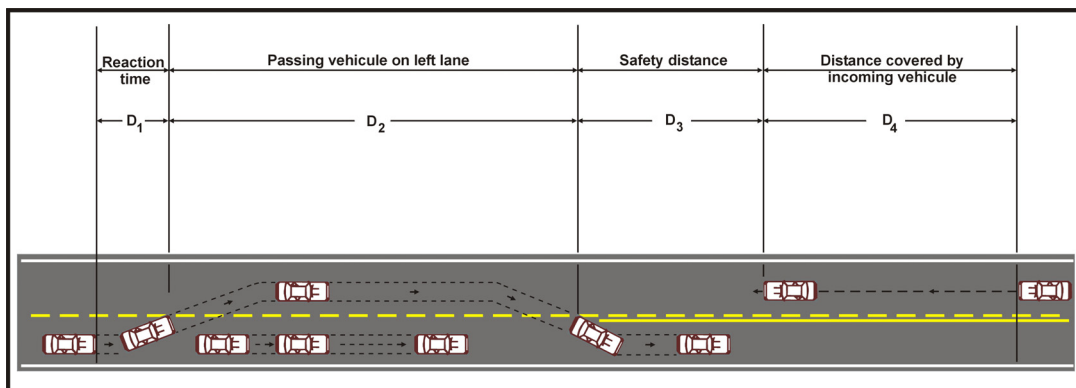d_4 =   Distance covered by incoming vehicle during the maneuver

Figure 1: Minimum passing sight distance

One of the major factors affecting the minimum sight distance is the speed of the vehicles involved in the overtaking. There is a *linear* relationship between the required minimum passing sight distance and speed of vehicle (figure 2). However, different states or countries can have different standards leading to shorter or longer distances. For example, Canada has shorter distance than United-States for the 50 km/hr speed (150m. / 160m.) but longer distances at higher speed (figure 2).
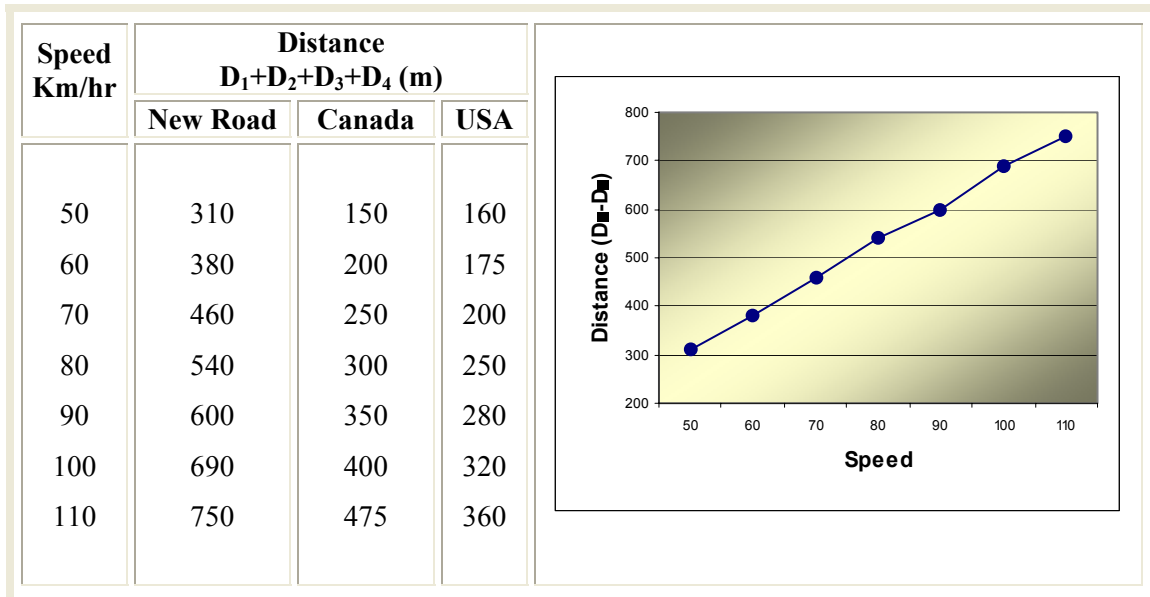
Speed Km/hr	Distance $D_1+D_2+D_3+D_4$ (m)		
	New Road	Canada	USA
50	310	150	160
60	380	200	175
70	460	250	200
80	540	300	250
90	600	350	280
100	690	400	320
110	750	475	360

Figure 2: Minimum passing sight distance (Canada & USA)

Road Geometry

Besides speed, road geometry also constitute a major element of passing sight distance. A sinuous road will reduce driver's line of sight, and thus limit the number and length of passing zones. It is common, for road marking specialists, to address the line of sight problem by reducing the road alignment to its two basic components: the vertical and horizontal plane.

Vertical plane corresponds to the succession of ups and downs of the road that create visual obstruction (figure 3). If there is an unobstructed line of sight between driver's eyes and the target, for a distance equal or greater than the minimum passing sight distance, road marking should be a dashed line (passing allowed). This condition must remain for at least 100 meters to be considered a safe zone for overtaking. On the opposite, if the line of sight is less than the minimum distance, road marking should prohibit overtaking with a solid line (figure 3).
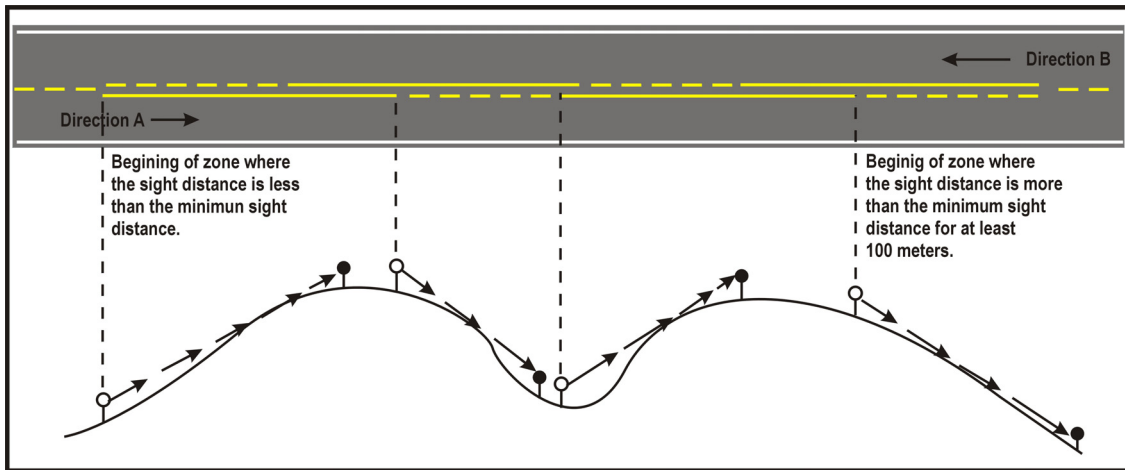
Figure 3: Line of sight, vertical plane

The horizontal plane refer to horizontal road curves which limit drivers visibility on long distances. Typical rural roads with more or less sharp curves will keep line of sight below the minimum passing sight distance for a safe overtaking (figure 4).
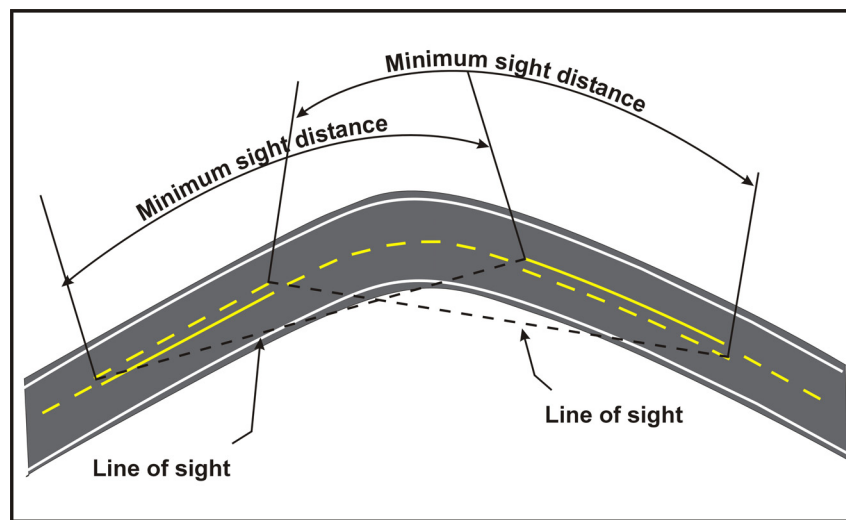

Figure 4: Line of sight, horizontal plane

In the case of a curve to the right, sight distance is measured according to a straight line, tangential to the edge of the pavement, drawn from driver's eyes on the right-hand side of the road. For a curve to the left, line of sight is measured the same way, but the straight line is *tangential to the left road shoulder* (figure 4). In real road situation, horizontal and vertical planes merge to create a compound curve. Both planes must then be simultaneously considered for the final line of sight calculation. Also, roadside obstacles can play a major role when locating passing zones. Accumulation of snow or vegetation can significantly reduce driver's visibility. To keep a safety margin, one should not

consider area outside road shoulders when performing a line of sight calculation on the horizontal plane.

Location of no-passing zones

Transportation agencies establish no-passing zones when the measured passing sight distance falls below the required passing sight distance. This operation is usually done when a road is resurfaced, when highway's speed limit or operating speed changes or for any other reasons. A survey showed that in United States, eight different methods are used by departments of transportation (Brown & Hummer). The most two popular ones are the walking method and the two-vehicle method.

The walking method involves two employees walking through a site separated by a rope equal in length to the required passing sight distance. Each employee holds a pole at one end of the rope. Pole's height is set at the standard driver's eyes height (1.05m). A no-passing zone begins where the rear employee can no longer see the lead range pole. When the lead pole become visible again, the end of the no-passing zone is marked on the pavement. At the end of the site, the crew reverse roles and walk in the opposite direction to mark both sides of the road. The walking method is the most accurate method but also the most time-consuming and sometime risky for employees.

The two-vehicle method uses two trucks equipped with two-way communication system, distance measuring instruments and a paint sprayer. Upon starting, the first vehicle moves away, the required passing sight distance ahead of the other. Both vehicles begin to drive slowly through the road, using the two-way communication system and the distance measuring instrument, to maintain the required separation. When the rear driver loses sight of a point at standard height on the lead vehicle, he marks the beginning of a no-passing zone. When the lead truck comes back into view, the end of the no-passing zone and the beginning of the passing zone is marked.

Whatever methods used, transportation agencies are facing same problems. Location of no-passing zones is a cumbersome task involving two or more employees, instruments, vehicles and a lot of time. It is clear that such job could benefit from the application of geographic information systems (GIS) and global positioning systems (GPS).

PROJECT OBJECTIVE AND METHODOLOGY

The main objective of this project was to improve no-passing zones location methods on two-lane highways. It aims to suggest a methodology to standardize the process of no-

passing zones location, according to posted speed, road geometry and current passing sight standards in Canada.

A second objective was to develop a software, based on GIS technology and GPS data, easy to use by non specialists, to establish road profile and make line of sight calculations. The chosen development environment is ESRI MapObjects® for its flexibility, the richness of mapping functions it offers and its use of standard programming languages like Visual Basic for coding.

Two sites were selected to test the method. Both sites, located south of Montreal, are sections of rural highways. Site 1, on road 104, is 6.343 kilometers long with many horizontal curves while site 2, on road 205, has many vertical curves with a total length of 5.855 kilometers (figure 5). Before each GPS survey, a base station was established on a nearby geodetic benchmark for data post-processing. Two GPS, located on top of a minivan, gathered X,Y and Z data at the rate of 1 position each second, with an average vehicle speed of 40 km/hour. The first system, a CMT-Z33 from Corvalis Microtechnology, is a high precision dual-frequency GPS. The second GPS, a Garmin G17N with WAAS, was used to compare results with a low cost system. However, only the data captured with the Corvalis GPS have been post-processed because of the unavailability of RINEX output from Garmin systems at that time.

Figure 5: Curves examples, road 205 and road 104

Following on site data collection, post-processing took place with the closest base station. Data collected with the mobile GPS were corrected with the ones from base station located on a geodetic benchmark. Afterwards, both data sets (Corvalis and Garmin) were imported into ArcGis® for a first visual check. After displaying GPS points in ArcGis® we noticed many gaps along the trace coming from Corvalis system. On road 104, these gaps were up to 200 meters long, but did not exceed 70 meters on road 205.

This situation comes from poor satellite signal reception from Corvalis GPS resulting in more or less extended holes in the trace. A corridor effect, created by high trees on each side of the road, reduced considerably the number of available satellites with a direct impact on data post-processing. On the other hand, Garmin G17N was less prone to signal loss and showed a very regular trace with almost no gaps.

We also established, for both road sections, a vertical profile to check altitude or «Z» data. Again, poor signal reception from Corvalis GPS resulted in erroneous values not suitable for line of sight calculation (figure 6).

Figure 6: Vertical road profile

These points present height values sharply different from neighboring points, sometime more than 50 centimeters in altitude. They create false peaks and lows that can result in bad line of sight calculation.

After some unsuccessful attempts to correct the situation with Corvalis GPS, we decided to use Garmin trace to test our approach. Even though Garmin G17N is not a professional GPS with sub-meter accuracy, it gave very stable and smooth traces for both road sections. It was less prone to signal loss than Corvalis, especially on road 205 with dense vegetation. The next step, after data collection, was to create two traces (one for each road direction) and for both test sites. These traces are 3D linear objects for which every vertex has X,Y and Z coordinates (3D shapefile).

SOFTWARE DEVELOPMENT

MapObjects® activeX control is the foundation of **Argos-Vision**, the no-passing zones location software developed in this project. We programmed all the tools in Microsoft Visual Basic 6.0®, using MoView2® sample code from ESRI as the basic interface for map display and manipulation. Besides functionalities like GPS data conversion into shapefile, map display and manipulation, the main function of Argos-Vision is the «Passing Zones Location» menu (figure 7).

Figure 7: Argos-Vision passing zones location menu

Zone location options can be divided in three groups (figure 7). Group one is a standard input-output file option that users specify at the beginning. Input shapefile must be a 3D shapefile to proceed to analysis. Group two refers to passing sight distance parameters. Posted speed limit and minimum sight distance are directly related, the later being fundamental for the analysis. Users can set a minimum length for passing zone. For example, if a passing zone is less than 100 meters long, it will not be marked as a safe place to overtake because of the too short distance available to complete the passing maneuver. Height of driver's eyes and target height can both be set by user for simulation purpose.

The last group of parameters is specific to road geometry and vehicle position for line of sight calculation. Lane and roadside width are needed for buffer creation. On the

horizontal plane, a buffer is drawn from road centerline to roadside. It is within this buffer that line of sight is calculated for each road section. Driver offset is the offset of overtaking driver from road centerline. The effect of this offset will be maximum for short lines of sight and insignificant for long ones. Finally, vertical error margin is the error margin for vertical line of sight calculation. If the distance between line of sight and road pavement is less than the error margin, target will be marked as not visible. Such a margin is needed to avoid situation where line of sight would be too close to road surface and unsafe for overtaking. When Argos-Vision is run, a line of sight calculation is performed for each GPS point and on both planes. Output shapefile store the results for each point and both planes in two fields that are automatically added to table structure.

LOCATION OF NO-PASSING ZONES ON TEST SITES
We tested the software on both sites with Garmin traces, a minimum sight distance of 350 meters and target and driver height of 1.05 meter. Buffer width (lane + roadside width) was 10 meters for road 104 and 7 meters for road 205.
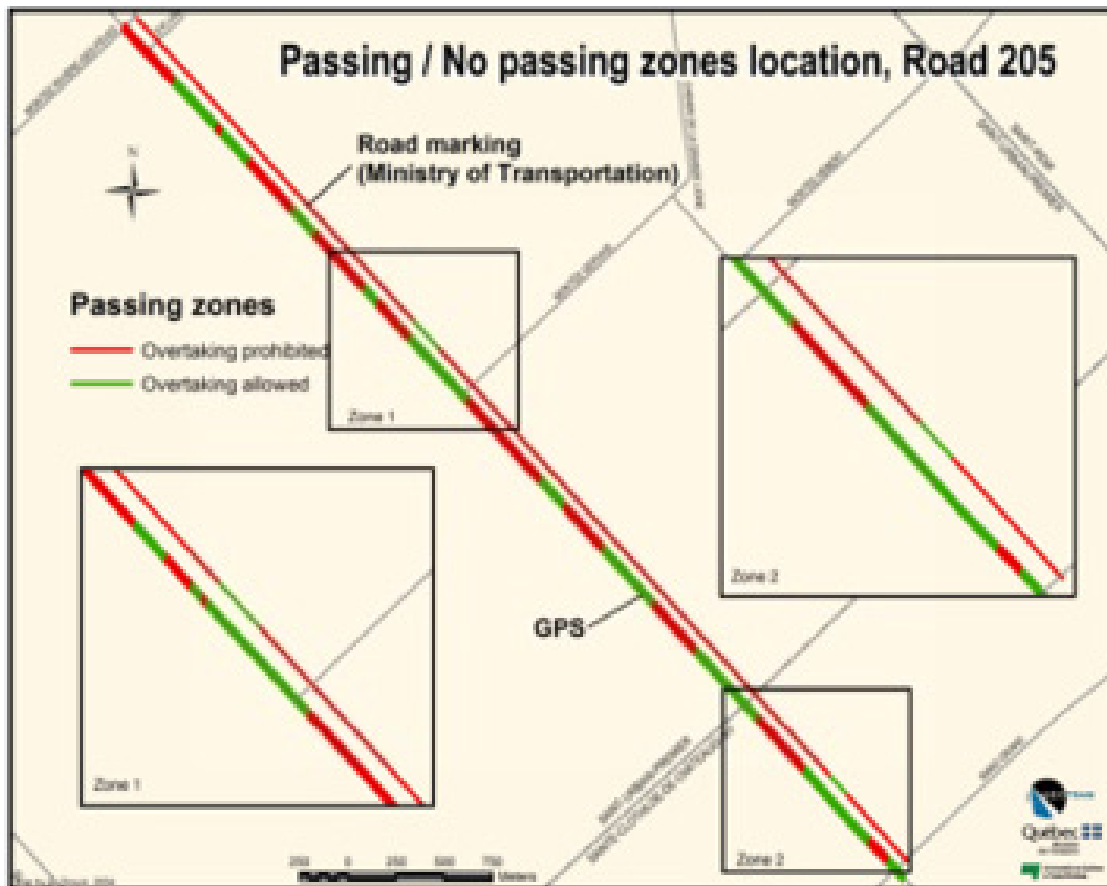

Figure 8: Passing/no-passing zones location with Argos-Vision

Figure 8 shows an example of passing/no-passing zones location for a section of road 205. It appears that actual passing zones could be extended and two new zones added while keeping minimum sight distance of 350 meters. Similar results were obtained with road 104 where overtaking was totally prohibited for the whole section.

CONCLUSION

Our results show that GPS and GIS can be used for locating potential passing/no-passing zones on two-lane highways. It is a cheap and fast method compared to walking method and doesn't need sophisticated equipment.

However, data collection with high precision GPS need to be improved to overcome gaps in traces and erroneous altitude values. Stability and regularity in a GPS trace are as important as data precision and accuracy. MapObjects$^®$ is a perfect environment for the development of tools like Argos-Vision. It offers flexibility and many map display and manipulation functions that can be easily embedded in a Visual Basic application. The software and method developed in this project are a first step toward the use of GPS data to locate passing/no-passing zones on two-lane highways and we plan to improve this approach in a near future.

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