Performance Accuracy of Real-Time GPS Asset Tracking Systems for Timber Haulage Trucks Travelling on Both Internal Forest Road Network and Public Road Network.

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Abstract

This GPSTRACK (acronym name) project has arisen as a result of a recommendation in the FITG (Forest Industry Transport Group) Code of Practice for Timber Haulage. "Encourage closer co-operation between consignors and hauliers to plan routes in a manner which optimises the economic returns within a legal framework." The project involved the installation of Bluetree GPS asset tracking systems onto 2 timber haulage trucks – an articulated Iveco Stralis 530 6*2 tractor unit with tri-axle road friendly air suspension flat bed trailer with a design gross vehicle weight (d.g.v.w.) equal to 44 000kg. The Scania 124 (400) was a rigid (3 axle) + trailer (3 axle) + crane combination with an equivalent d.g.v.w. of 44 000kg. This paper discusses the background and use of real-time asset tracking devices in the context of timber haulage in Ireland. The results analysis calculates the Horizontal root mean square (HRMS) 63% GPS accuracy of the both truck's travelled tracklog on both the public road network and the internal forest road network over a period of 4 weeks and totalling approximately 15,000 GPS data points. The HRMS accuracy values ranged from 2.55 m and 2.47 m for the public roads while the forest road accuracy ranged from approximately 27 m to 41 m for Iveco and Scania respectively.

Keywords; Real-time GPS, asset tracking, HRMS 63% accuracy, public roads, forest roads.

1. Introduction

Since the deployment of the first of 24 satellites by the United States Department of Defence (DoD) in 1978, Global Positioning Systems (GPS) have become a useful tool in forestry management with a need to geo – reference spatial information in terms of estimating forest road surveys (Martin et al. 2001, Holden et al. 2002), extraction of timber logs (Ronnqvist, 1999), transport control of forest fuels (Sikanen, 2005) and clarifying GPS performance under forest canopy and on industrial peat bogs (Holden et al. 1999, Holden et al. 2001).

Within the Irish forestry sector (both private plantations and state owned) there is a necessity to introduce Information Technology (I.T.) into the timber haulage sector (Optilog, 2003,). Information technology in this situation implies the use of GPS for tracking of timber trucks from a forest harvesting site to sawmill destination, and incorporating this positional information within Geographical Information Systems (GIS) to reference, for example, the timber truck on a map, to determine if the truck is located at the harvesting site, travelling on a national route or unloading within a sawmill (Frisk et al. 2005). Precision forestry is rapidly becoming an important practice, involving many aspects such as timber harvesting within the forests and subsequent timber transportation on both internal forest roads and the public road network (Devlin et al. 2007a). High GPS positional accuracy for internal forest applications can be used for updating the GIS forest roads database to assist in avoiding time consuming and erroneous digitising from paper maps.

Research has been carried out in an attempt to determine the effects of forest vegetation on GPS signals. Errors in a GPS signal occur due to the atmosphere (as the signal passes through the charged particles of the ionosphere and then through the water vapour of the troposphere). The signal can also bounce off local obstructions on the earth's surface still before it reaches the receiver, in this situation the local obstruction is the vegetation and canopy of the forests. This is known as multipath error (when a receiver arrives at a receiver with 2 or more paths), which is thus the cause of a loss in obtaining accurate position fixes of the tracked machines. Spruce et al. (1993) using a typical mapping-grade GPS receiver reported evidence that GPS successfully tracked forest machines under open sky conditions but under forest canopies, however, there were major decreases in accuracy, due mainly to the multipathing errors of GPS associated with forest vegetation. Also, Jalinier and Courteau, (1993) availed of GPS in an attempt to economically survey forest road networks by traversing forest roads with a vehicle fitted with a GPS receiver. The result reinforces what Spruce et al. (1993) concluded, in that areas with thick forest cover yielded questionable results when compared to a traditional method of surveying techniques to obtain greater accuracies. This paper documents the GPS performance accuracy of real-time asset tracking systems for timber haulage trucks travelling on both the internal forest road network and the public road network of Ireland and attempts to quantify the differences between performances under obvious varying canopy environments. The GPS accuracy is determined as a measure of Horizontal Root Mean Square (HRMS) at a confidence level of 63%. Results show that while the GPS accuracy vary considerably between public road data and forest road data, (thus emphasising the effects of forest canopy) the asset tracking systems still work adequately to the point where the user can still monitor the movements of the trucks in real-time without the loss of much GPS and General Packet Radio Service (GPRS) signal within the boundaries of the forests. Results for the public routes prove coherent with other studies of a similar nature (Devlin et al. 2007b).

2. Materials and Methods

2.1 Installation of GPS hardware

The independent GPS asset tracking provider was the company Bluetree. Installation of the GPS Blackbox with GPS tracker takes approximately 30 minutes to complete and is almost equivalent to the installation of a hands-free mobile phone carkit. The Blackbox and associated wiring is fixed under the dashboard on the passenger side of the truck (Figure 1).

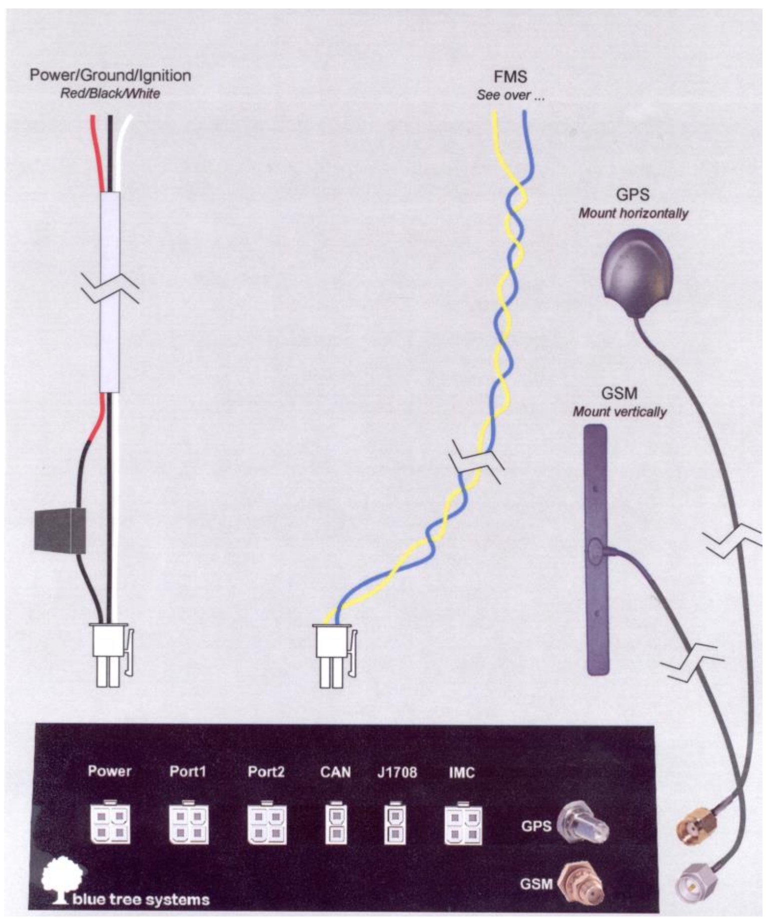

Figure 1 Schematic of GPS Blackbox wiring from Bluetree (FMS wiring included here but this is not needed for Fleetmatics).

The GPS tracker is positioned on the outer side of the dashboard so that it becomes visible through the front windscreen. The GSM / GPRS (Global System for Mobile Communications / General Packet Radio Service) magnetic antenna is fixed to the inside of the windscreen for optimum signal strength. The GPS Blackbox is fitted with a standard mobile phone SIM card and positional Latitude and Longitude information are recorded by the GPS and sent via the GSM / GPRS phone network to the data servers. This information can then be viewed through pc / laptop and internet web browser with username and password through the login page of the asset tracker providers. The amount of updated data depends solely on the time interval required by the user. This system operated at 3 minute intervals but any time interval whatsoever can be requested and subsequently set-up by the provider in question.

2.2 Truck Specifications

The Bluetree systems were fitted to 2 different axle configuration timber haulage trucks. The articulated truck was an Iveco Stralis 530 6*2 tractor unit with tri-axle road friendly air suspension flat bed trailer with a d.g.v.w. equal to 44 000kg (Figure 2). The Scania 124 (400) was a rigid (3 axle) + trailer (3 axle) + crane combination with an equivalent d.g.v.w. of 44 000kg (Figure 3). Even though both truck configurations have the same d.g.v.w due to the 6-axle configuration, the articulated Iveco has a higher payload weight than the Scania rigid simply because this rigid + trailer + crane combination increases the unladen weight and thus reduces the payload weight acceptable under weight legislation in Ireland. However, the idea behind the on-board crane is to offer flexibility to the driver when loading and unloading timber. Also, some crane technologies allow the weighing of timber on each lift when loading, therefore enabling an approximate measure and optimisation of the payload weight to within 500kg. This weighing facility is an added extra to basic timber crane functionality and costs in the region of €5,000.

Figure 2 Iveco Stralis 530 articulated configuration.

Figure 3 Scania 124 (400) rigid + trailer + crane configuration.

2.3 Software and data used

The GIS used in this research is ESRI's Arcview 9.1 (ArcCatalog, ArcToolbox and ArcMap) to explore, query and analyse the data geographically. Within the ArcGIS desktop software family are ArcView, ArcEditor and ArcInfo. ArcView provides data visualisation, query and analysis capabilities. ArcEditor has higher functionality than ArcView with powerful data creation and editing environment. ArcInfo includes all the functionality of both ArcView and ArcEditor and adds advanced data geoprocessing and data conversion capabilities that gives ArcInfo the highest GIS functionality within the desktop ArcGIS. The development platform was Windows XP for PC's. The main tools used to create, manage and edit the geodatabase are found in ArcCatalog and ArcMap.

ArcCatalog has the tools for creating and modifying the geodatabase schema while ArcMap is used to analyse and edit the contents of the geodatabase.

The data was recorded in the Irish National Grid (ING) datum in decimal degrees of Latitude and Longitudes, i.e. the asset tracking provider's GPS reference frame. Since the digital road map data within the GIS is in the ING datum in metres of Eastings and Northings, the GPS data was converted from decimal degrees into metres (Ordnance Survey Ireland, 1996; Ordnance Survey Ireland, 1999; Bray, 2001). This procedure is necessary in order to define the HRMS accuracy of the GPS data with the underlying GIS road vector network in units of metres. All data layers in the GIS must have the same co-ordinate systems (Irish National Grid) and the same units of measurement (metres). This data conversion was carried out with Grid Inquest 6.0 software, which is available as a free download from the Ordnance Survey Ireland website (Quest Geodetic Software Solutions Ltd). The digital road network of Ireland was used within the GIS. This comprised of motorway, national primary, national secondary, and regional and third class roads. The road network was represented as connections of 5917 nodes and 8941 links. The nodes represent the road intersections and the links represent homogeneous road segments. Geometric networks are built in the GIS model to construct and maintain topological connectivity.

3. Results and Discussions

The study was carried out over a 4 week period in which 10,669 data points were recorded for the Iveco and 9,500 data points recorded for the Scania. After filtering both sets of data for raw GPS X and Y co-ordinates, the amount of workable data to determine

HRMS accuracy becomes 8,360 data points for the Iveco (Figure4) and 5,049 data points for the Scania (Figure 5). It is important to note here, that the GPS tracklog for each truck cannot be accessed or downloaded by the user once logged onto the system itself. This data is stored on the Bluetree data servers and must be requested from technical support for each individual truck. The file can be sent as a .txt file via email and thus can be imported to an excel format and the GPS data filtered accordingly.

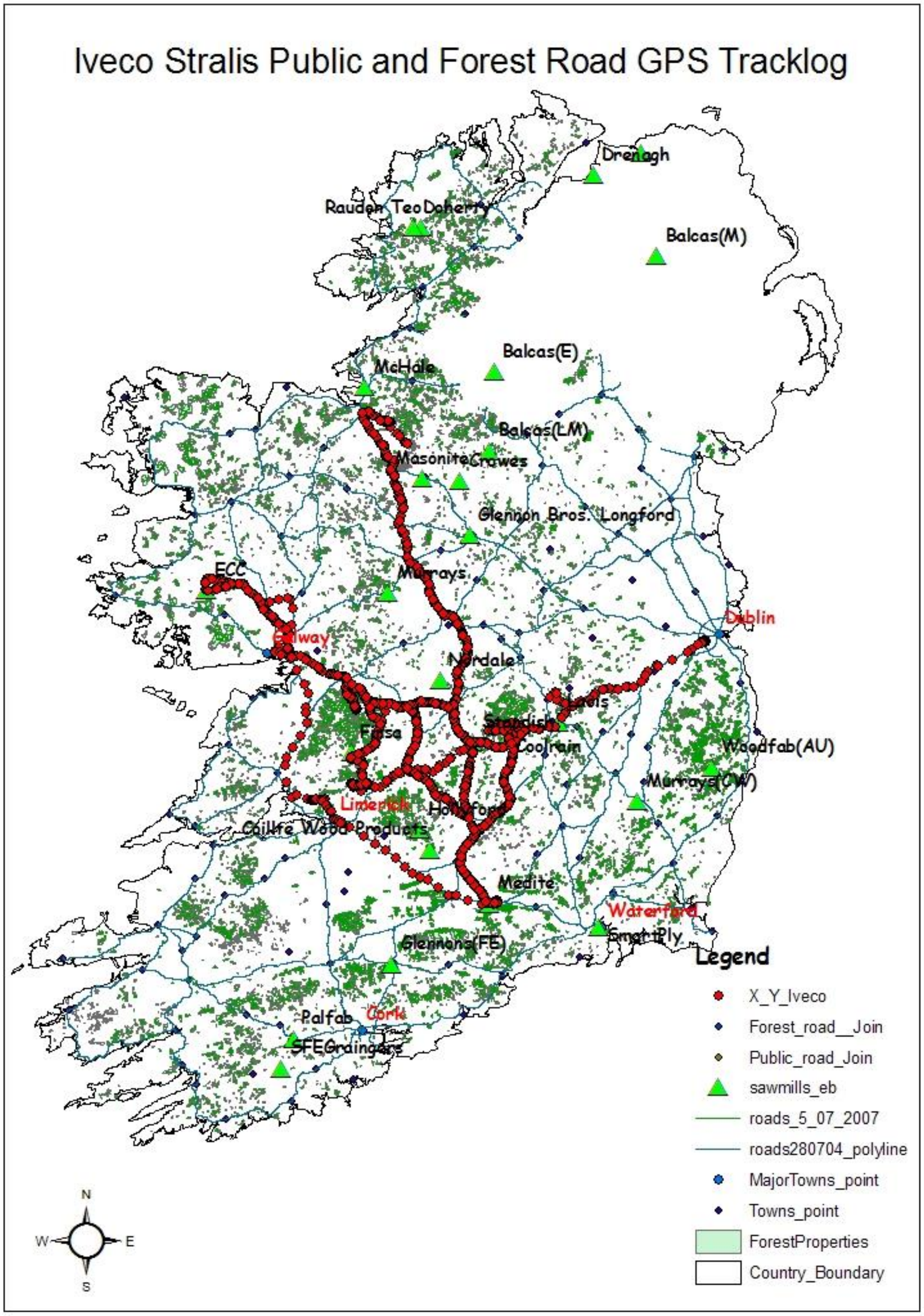

Figure 4 Iveco Stralis public and forest road GPS tracklog created in GIS.

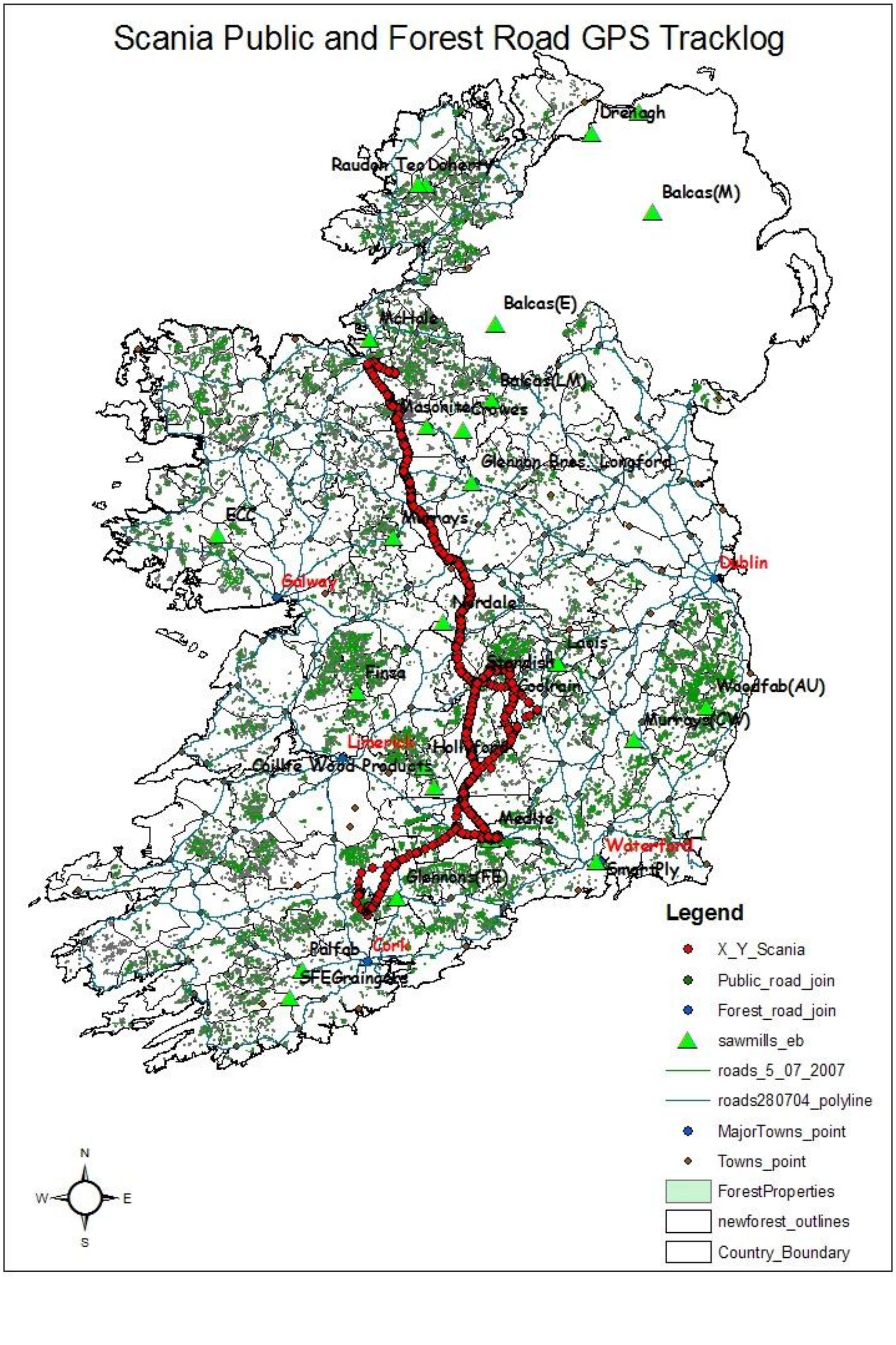

Figure 5 Scania public and forest road GPS tracklog created in GIS.

From within the GIS, the data recorded from each route can be added as a shapefile (.shp) layer to the map (Figures 4 and 5). The map contains the underlying road network in Irish National Grid (ING) coordinates. The GPS points are converted from decimal degrees Latitude and Longitude into ING metres in order to correctly overlay and align with the road network.

Within the tools of the GIS, a spatial join was carried out on both the internal forest road network and public road network separately (Table 1). This implies calculating how close each GPS point is to the underlying road vector. To measure accuracy, it is necessary to have a known location. If there is no known location then *precision* can only be quantified. In this study, the known truth location is the road network. The distance of the GPS fix from the known location was then calculated. From the statistics tools within the GIS, the mean and the standard deviation of the distance values between the recorded GPS points and the underlying road vector data can be calculated accordingly. The root mean square is determined from the square root of the sum of the squares of the mean and standard deviation. This calculation is repeated for varying buffer distance zones of 5 m and 10 m for public road HRMS and 50 m and 100 m for forest road HRMS. Research has previously shown that the HRMS 63% of dynamic GPS data on public roads is less than approximately 10 m hence justification for these limits (Devlin et al. 2007b). The increased distance buffer zones for forest road analysis of 50 m and 100 m are indicative of the degradation of GPS accuracy under certain forest canopy conditions.

ROUTES	**STANDARD DEVIATION**	**MEAN**	**MAX**	**MIN**	**$(mean)^2 + (SD)^2$**	**HRMS (63%)**
Iveco forest road <100m	21.275144	17.112563	100	0.03423	745.4715646	27.30332516
Iveco forest road <50m	12.172874	11.579401	50	0.03423	282.2613889	16.80063656
Iveco public road < 10m	2.612783	3.540893	10	0.014916	19.36455824	4.400517952
Iveco public road < 5m	1.41605	2.129473	5	0.014916	6.53985286	2.557313602
Scania forest road <100m	27.999054	29.952698	100	0.2848942	1681.111142	41.00135537
Scania forest road <50m	13.785317	17.637685	50	0.2848942	501.1228969	22.38577443
Scania public road <10m	2.80209	3.753173	10	0.011468	21.93801594	4.683803576
Scania public road <5m	1.397929	2.047586	5	0.011468	6.146813916	2.479276894

Table 1 HRMS 63% accuracy of public and forest road.

As mentioned previously, the accuracy is expressed as a Root Mean Square (RMS) and is a measure of the spread of data around the known location (i.e.) Horizontal RMS (HRMS). The RMS value represents the horizontal distance from the truth (road network) for which 63% of the position errors are predicted to be less.

Another related accuracy specification is 2dRMS or twice the distance RMS. The confidence level for 2dRMS is 95%. A third accuracy specification is Circular Error Probable (CEP), which has a 50% confidence level. These three different measures can be used to describe a GPS receiver's accuracy. They all describe the same spread of errors, but in different ways. Figure 6 shows the graph of varying HRMS 63% accuracy.

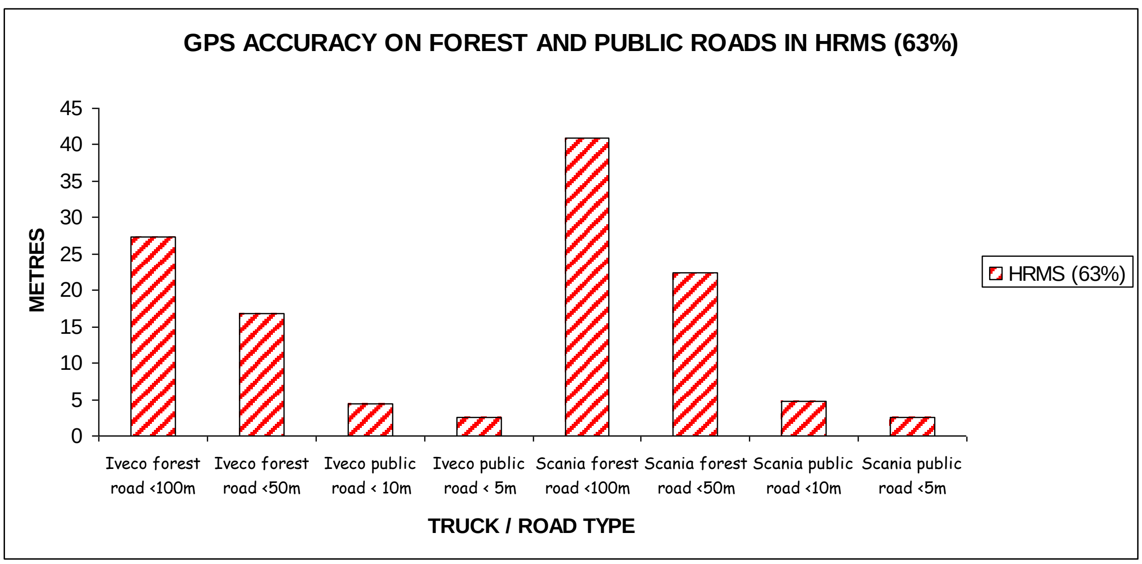

Figure 6 Graph of HRMS 63% accuracy for public and forest roads for Iveco and Scania.

From Table 1 and Figure 6 it can be seen that the HRMS 63% accuracy on the forest roads increases to as much as 41 m for the Scania data and approximately 27 m for the Iveco. The data for the public roads proves much more favourable with accuracy values of 2.55 m for the Iveco and 2.47 m calculated for the Scania. Recent developments in forest inventory GIS data include the X and Y co-ordinates of all entry and exit points for all Coillte forest boundaries. With the advancements of in-car satellite navigation (sat-navs) systems, it could be possible to in-corporate sat-navs into the cab of the truck for the drivers to use. Sat nav systems such as the Garmin Nuvi 770 allow X and Y co-ordinates to entered and routed accordingly. This can be done for all timber haualge contracts. Once the forest boundaries are known, the entry and exit points can be typed into the Garmin Nuvi and the optimised routes generated from starting point to destination. Another interesting add-on to this approach optimised routes from a driver perspective is that, if the X and Y locations of the in-forest timber stacks are also known and available, then the Garmin Nuvi could be used to route the truck beyond the entry point of the forest boundary and directly to the location of the timber stack that are to be transported.

4. Conclusion

The results of the field work prove that HRMS 63% accuracy does indeed become degraded under forest canopy but the important thing to note here in relation to the asset tracking systems, is that the systems do work very well from a monitoring point of view. The GPS signal is still tracking the truck in-forest and the user can monitor movements within the forest which is what is required. It would be a different situation if the signal was being totally lost and no position fixes were being acquired at all. The forest canopy is simply inducing multipath effects and thus reducing the eventual HRMS accuracy to the recorded values as high as 27 m and 41 m for the Iveco and Scania respectively. However, with the continuing development of new European GPS satellite system, Galileo and use of EGNOS (European Geostationary Navigation Overlay Service), it is hoped that greater precision and accuracy will be obtained under difficult canopy conditions and higher altitudes in the near future. Within the Irish forestry sector attempts are in progress to fully optimise the transportation of timber from forest harvesting site to sawmill based on route planning and destination planning incorporating GIS and GPS technology. In an environment where operating costs such as diesel fuel and labour are rising continuously, the timber haulage sector must implement the existing technology in order to remain competitive and maximise the time a truck is travelling while loaded in order top maximise the revenue per km.

Acknowledgements

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