Decision Support System for Truck Route Modelling (D – TRM)

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1. Introduction

Since the 1970's Decision Support Systems (DSS) have become popular following the development in computer technology. A DSS aims to support in the solving of specific problems with both human and computer techniques. The purpose of this research was to design and develop a DSS for application involved with the cost calculations and revenue calculations of contracted timber haulage in Ireland. The DSS allows the costs and revenue of timber haulage to be calculated on a daily basis and a route specific basis. This implies that the user interface allows for certain criteria such as truck configuration, truck model, engine size, horsepower and design gross vehicle weight (d.g.v.w) to be selected. Both the revenue and running costs are directly related to the payload weight and the distance travelled. To generate the routes travelled and provide a sophisticated interface for spatial road map information a Geographic Information System (GIS) was used. ESRI's (Environmental Systems Research Institute) Arcview 8.3 was used which provides its own application programming in the form of Visual Basic for Applications (VBA). VBA was used to design and create the DSS while the GIS provides the spatial interface, database and route modelling component. A DSS by definition is a combination of databases, user interfaces and modelling components directed at solving a specific problem. For this *specific problem* a GIS alone is not a DSS. However, the GIS and DSS together combine to create a Spatial Decision Support System (SDSS) to extend the range of decision support through its ability to define route selection (using the Network Analyst tool (NAT) in Arcview 8.3) and also the display of spatial road vector data for the user interface can greatly enhance the decision making process.

The trend in routing systems in transport applications in general is to build and design the DSS around the geographical interface, where the user can interact with the problem and lead to better decision support. For this SDSS, interaction between the spatial road vector network of Ireland and other geographic data (cities, towns, X and Y co-ordinates of processing sawmill locations and timber harvesting sites, forest boundaries and internal forest road network) is needed. Use of the NAT to select the routes between the origin and destination is also required before the DSS can be implemented and interacted with. Human intervention in the actual routing process can substantially improve the route generated based on local knowledge. With this SDSS, the road network of scale 1: 50,000 forms part of a geometric network from which a "cost-weighting" can be applied when

using the NAT to predict the most likely and most cost saving route to be taken by the haulier.

The growth of SDSS is made possible by the growing availability of spatial data for GIS software. In comparison to the United States, United Kingdom and continental Europe, Ireland's availability of spatial data (both vector and raster) has been expensive and of poor quality. However, several private sector companies are now producing their own digital maps from satellite photography, remote sensing and GPS surveys. It is estimated that up to 80% of data needed for the activities of business and government is spatially related (Franklin, 1992).

In its most basic form, a routing problem involves travelling from origin to destination with a minimum of distance travelled. Within the GIS "cost-weights" can be applied when using the NAT which attempts to simulate the route to be taken in terms of shortest distance, road class, speed limits and the most probable route the haulier would take (Devlin et al. 2007). Each route returns a total distance travelled and the DSS can then be used to determine the cost of travelling such a route and compare results for routes of varying cost-weights.

The potential production of roundwood from the forests of Ireland will reach 5 million m^3 per annum by the year 2015 (Coford, 2001). Road transport will remain the most important mode of timber transport in Ireland, forming a substantial part of the timber industry's raw material costs and having a major influence on the sector's overall economic performance and competitiveness (Coillte, 2003). Within the Irish forestry sector, however, (both private plantations and state owned) there is a necessity to incorporate 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 forest harvesting site to sawmill destination and incorporating this positional technology with Geographical Information Systems (GIS) to reference the timber truck on a map. The GIS map is used 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). GPS and GIS technology have already been successfully implemented and utilised in many fleet management situations such as the effective management of ambulances (Derekenaris et al. 2001), hazardous material truck routing (Frank et al. 2000), milk collection (Butler et al. 2005) and real – time multi vehicle truckload pick-up and delivery problems (Yang et al. 2004). Thus the research is working towards a fully integrated pre-planning approach to timber haulage in an effort to optimise routes travelled in terms of, 1) haulage costs, 2) distance 3) time, 4) volume of timber transported and 5) savings from avoidance of empty return journeys and to create and develop flexible and cost effective haulage control system for the Irish timber haulage sector.

2. Development of a Spatial Decision Support System model (SDSS)

2.1 Decision support model designed with Visual Basic for Applications (VBA) within GIS

This involves designing and developing a Decision Support System (DSS) for route costing calculations. The DSS allows the cost of timber haulage to be calculated on a daily basis or route specific basis – cost per kilometre (CPK). Calculation of the CPK involves the use of the GIS in conjunction with the Network Analyst Tool (NAT), to generate and simulate the routes travelled and to provide a geographical user interface (GUI) for the spatial road network of Ireland (Devlin et al, 2007). The DSS is designed so that the user interface allows for certain criteria such as truck configuration, truck model, engine size, horsepower and

design gross vehicle weight (d.g.v.w) to be selected. ArcMap 8.3 provides its own application programming in the form of Visual Basic for Application (VBA). The VBA was used to design and create the DSS, while the GIS provides the spatial interface, database and route modelling component. A DSS by definition is a combination of databases, user interfaces and modelling components directed at solving a specific problem. For this *specific problem* a GIS alone is not a DSS. However, the GIS and DSS together combine to create a Spatial Decision Support System (SDSS) for route costing calculations.

2.2 Customising the ArcMap interface - GIS + DSS = SDSS.

ArcMap comes pre-installed with Visual Basic for Applications. VBA is not a standalone program. VBA provides integration into the Visual Basic Editor (VBE) that allows code to be written in the visual basic programming language. ArcMap has a main menu and a standard toolbar that appear by default. Although the main menu contains only menus and the standard toolbar contains menus, tools, combo boxes and edit boxes, both are still referred to as *toolbars*. One of the principal methods of tailoring the ArcMap interface is through the Customise dialog box that adds new toolbars and menus through simple drag and drop techniques. Customisation must be saved if the ArcMap interface is to be re-opened with more than just the default toolbars. These changes can be saved in 3 ways – 1) The current map document with .mxd file extension. Changes will only be present when this particular map document is opened. 2) A base template document with .mxt file extension. Templates are used as a quick method to create new map documents. 3) The normal template document with file name Normal.mxt. This template stores changes that are available every time ArcMap is loaded.

The VBE can be opened from the Tools menu and scrolling down to the *macros* tab (Alt + F11). This opens the VBE from within ArcMap. The code for the DSS was written and saved in the Normal.mxt template in order to make it available for all ArcMap documents. A custom command to automate the opening of the VBE was created through a UIButtonControl and added to the ArcMap interface. The image and text of the new buttoncontrol can only be edited once the Customise dialog box is open. The code attached to the macro automates the initialising of the DSS and is written as:

```
Private Sub UIButtonControl1_Click()
    Login.Show
    Login.txtpassword.Text = "" 'Clear the password
End Sub
```

This avoids having to continuously open the VBE, open the code of the DSS and then run the visual basic program before being able to manually operate the DSS. Clicking this buttoncontrol activates the Login screen to the DSS that requires the correct username and password in order to access it (figure 1).

Within the VBA environment, as many forms, modules and class module can be added to complete the project. ArcMap has a default project that is listed in the Project Explorer as Project followed by the name of the open map document. Saving any work in this default project makes it accessible only to the associated map document. To make the project available with all ArcMap documents, the VBA work must be saved in the Normal.mxt project. A project is basically a collection of items to which code is added. A module is a set of declarations followed by procedures (instructions that the code performs). The user form is the container for designing the DSS user interface controls where command buttons, text
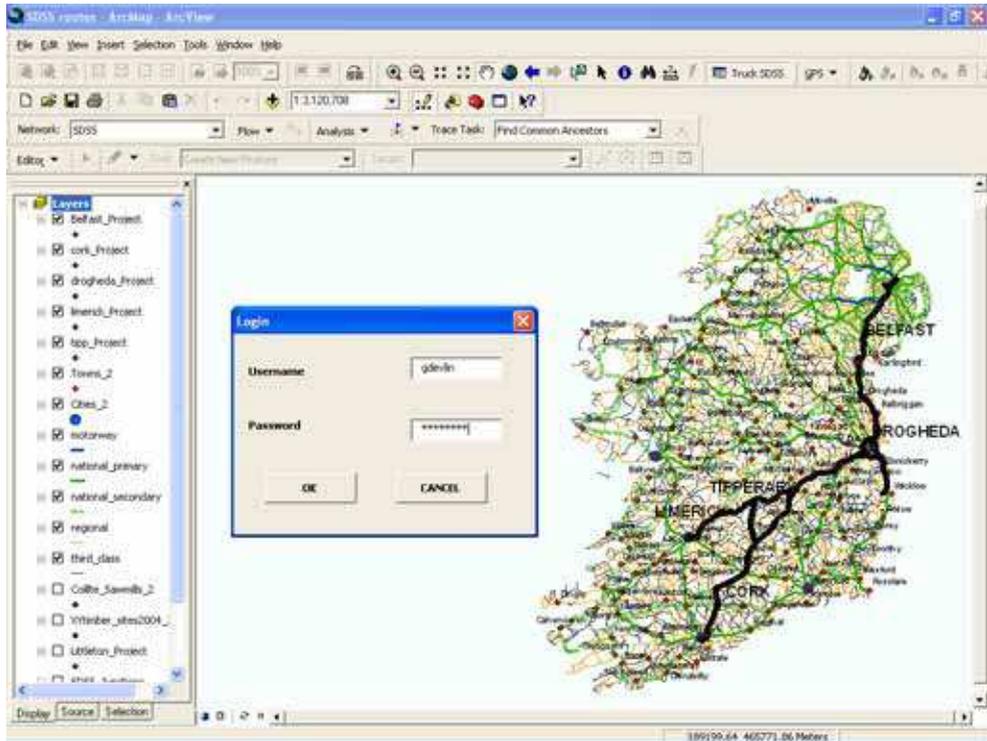
Fig. 1. Screenshot of ArcMap interface with Truck SDSS button control, DSS Login screen and GIS road map.

boxes, list boxes and combo boxes are added. The user forms are used because the user must be able to input information, display outputs and activate event procedures based on the context of each of the 5 user forms – Login, Truck Configuration, Route Calculations, Standing Variables and Costs and Results (figures 2 - 5). To insert a user form, firstly select the project where the form is to be saved – in this case the Normal.mxt, so that the DSS can be accessible from any opened map document. From the Insert menu, click UserForm. VBA inserts the user form and the Controls Toolbox for adding the controls to the user interface. Visual basic code can be added by simply double clicking each control and opening the code window. Once the code is written, it can be run within the VBA to test and debug the code for any errors. As mentioned earlier, the code is run automatically from clicking the *TruckDSS* buttoncontrol within the ArcMap interface, figure 1 above.

2.3 Determining the cost per kilometre (CPK)

It is essential for any transport company to know their vehicle operating costs, whether it is one or two vans, rigid trucks or articulated trucks. Operating costs should be available in some form or another, however, it is how the costs are formulated that allows a full understanding of the transport costs. Transport costs cannot be just a measure of time related costs and distance (kilometre) related costs. Vehicle operating costs (VOC) are a mixture of costs per day and cost per kilometre, simply because time related costs occur

Screenshots of the SDSS for Belfast GIS simulated route
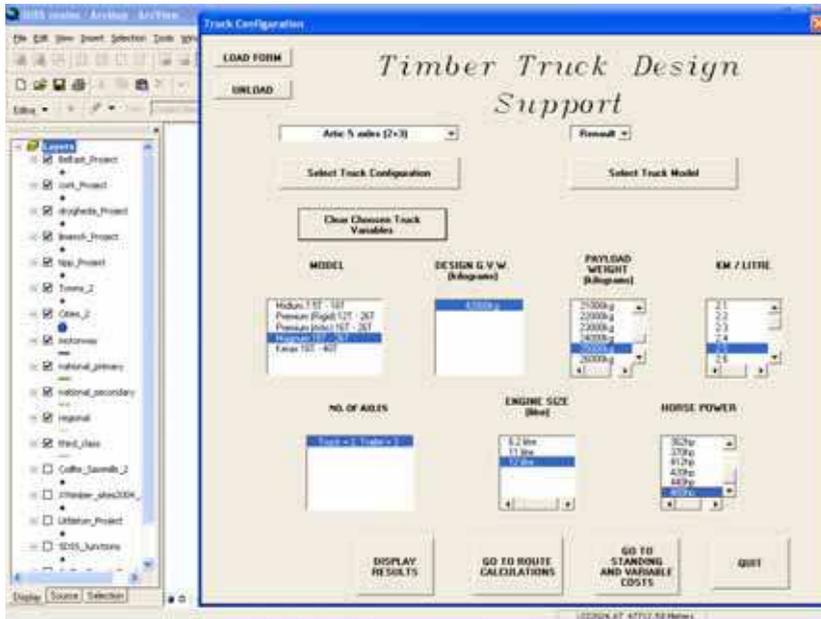

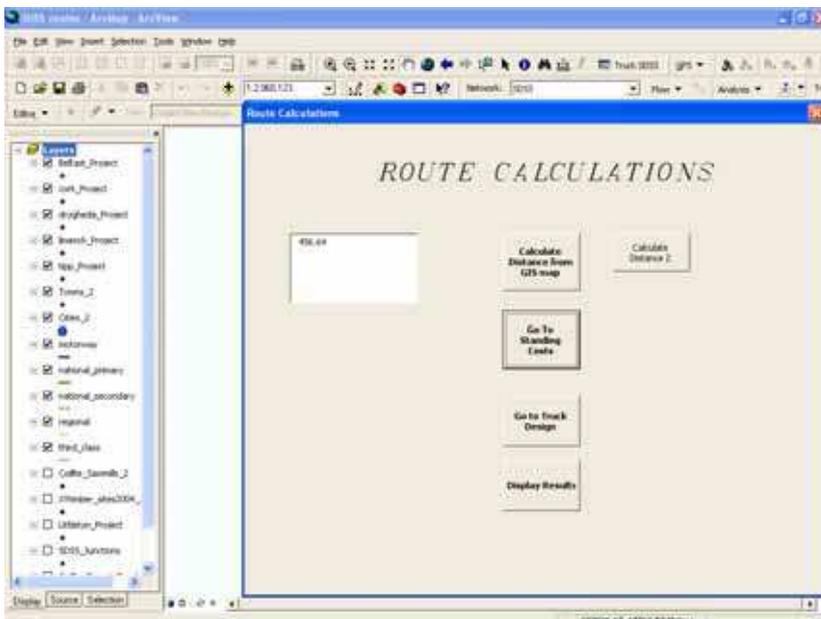Fig. 2. Screenshot of the Truck Configuration userform.

Fig. 3. Screenshot of the Route Calculation userform that reads the GIS distance of the simulated route.
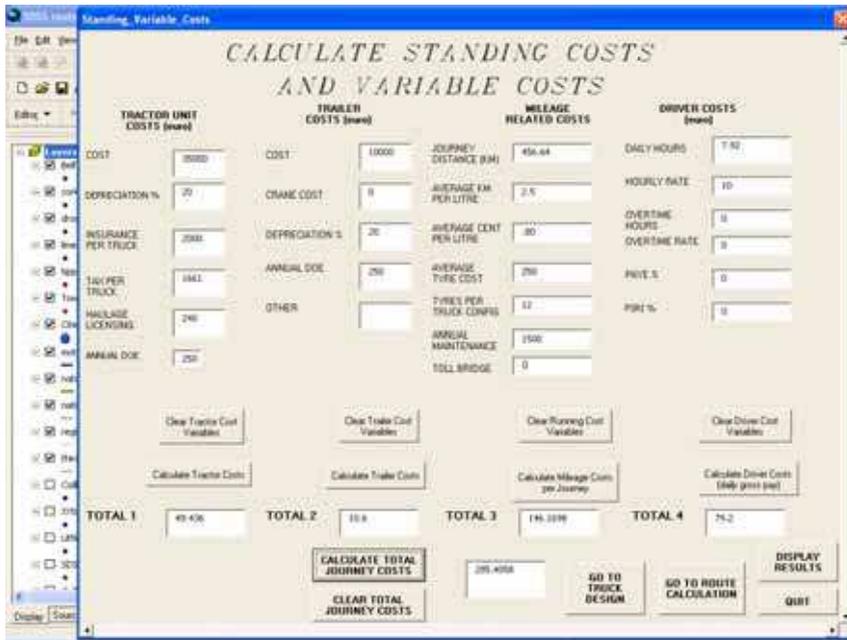
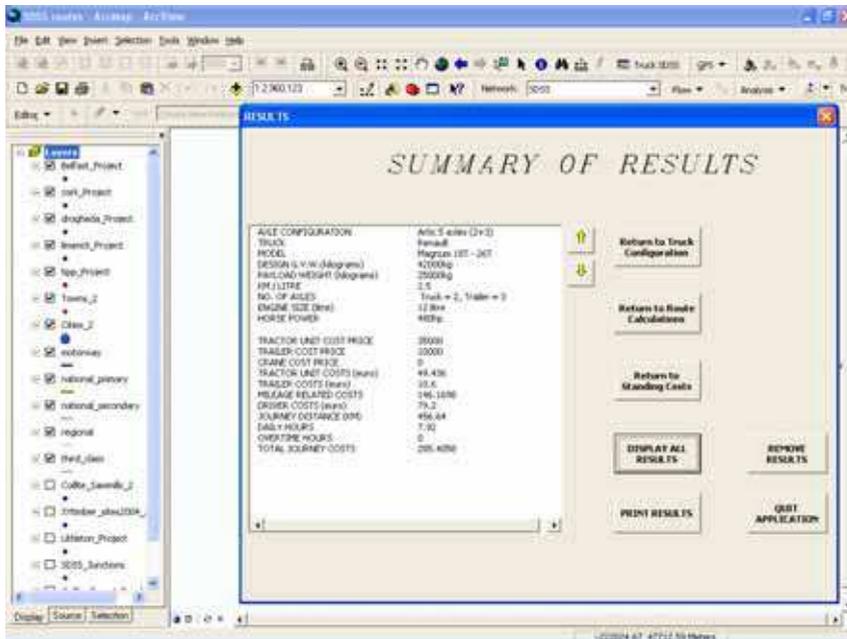Fig. 4. Screenshot of the Standing Variables and Costs userform

Fig. 5. Screenshot of the Summary of Results from all userforms.

even when the truck is not in use and distances will vary considerably depending on the eventual destination. A full understanding of transport costs will enable a company, family business or owner / truck driver to: 1) Identify operational changes such as route changes, being paid by the kilometre or being paid by the payload weight (kilograms); 2) Identify the most competitive route in terms of cost per kilometre versus revenue per kilometre; 3) Decide on the suitability of one truck configuration / truck model over another and 4) Compare costs to a 3rd party transport company – possibility of outsourcing the transport needs of a company.

The DSS was designed and the VB code written to formulate transport costs and calculate the CPK based on the explanation below:

- Capital costs (truck + trailer + crane)
- Time related costs (standing costs)
- Mileage related costs (running costs)

Capital costs;

- The initial cost of the truck and trailer purchased. The daily cost is calculated as 20% annual depreciation of the total initial cost over a 5 year period. The truck was second-hand at a value of €35,000. The trailer was also second-hand at a value of €10,000.

Time related costs include;

- Wages – Employee's gross daily pay based on the time taken for the particular journey – paid by the hour.
- Depreciation – Calculated as a percentage (20%) of the cost price over the depreciation period, normally 5 years.
- Insurance – Cost of insuring the vehicle and goods in transit insurance. Goods in transit insurance for hazardous chemicals are considerably higher.
- Tax – Goods vehicle road tax (based on the un-laden weight (u.l.w.) of the truck and trailer). Trailer tax is based on the u.l.w. also.
- Licence – National road freight carriers licence (renewed every five years). The cost per truck is higher if the haulage licence is International (for travel inside and outside of Ireland) as opposed to just National (only within Ireland).
- DOE – Trucks and trailers must pass an annual road-worthiness test. Without a road-worthiness certificate, no truck or trailer can be taxed. It is against road legislation to travel on public roads without appropriate road tax.

Mileage related costs include;

- Fuel – Calculate total kilometres for route driven (From GIS). Identify average km / gallon. This can be retrieved from the Infomax software.
- Tyres – Calculate by dividing the average cost per tyre by the total journey distance over a yearly period. The annual kilometres travelled for this truck is approximately between 100,000 – 120,000 kilometres. This implies a daily distance of between 400 and 500 kilometres per day, with approximately 250 working days per year. These figures comply with the readings of the digital tachometer on the truck.
- Maintenance – Calculate by dividing annual maintenance spend by total journey distance over a yearly period.
- Toll bridge – Some motorways in Ireland require a toll fee to be paid for travelling on it. The fee for a 5 axle truck configuration on the M50 toll bridge (most travelled) is €5.60.

For the purpose of this DSS there are 250 working days in the year. Therefore to calculate certain costs such as tyres and maintenance on a daily distance basis, the annual spend is

divided by the average distance travelled by the truck which is approximately 100,000 kilometres.

2.4 Engine diagnostic recording of Renault truck with Infomax 4.0 software.

This section of the study involved another period of GPS tracking of the truck. The articulated truck used was a Renault Magnum 480 4 * 2 tractor unit - two wheels on front axle and four wheels on the back, road friendly air suspension (driving) axle (figure 6). This truck replaced the DAF XF from the previous GPS tracking studies because it was not possible to record any engine diagnostics from the DAF XF. Renault Commercial Vehicles sell an *off the shelf* software package known as Infomax, for engine diagnostic management for any Renault truck model. DAF truck manufacturers, on the other hand, do not sell such a software package, hence the reason for switching trucks for the study.

Fig. 6. Photo of the Renault Magnum 480 (to the right). DAF XF is to the left.

2.5 Extraction of data

The Infomax used was version 4.0. Infomax is basically an assistance tool designed to optimise vehicle use. The software must be installed through the CD- ROM on a portable laptop. The adaptor cable must be connected to the serial port of the laptop and also to the default communication port on the truck. Infomax extracts data recorded by the trucks Fleet Management System (FMS). Extraction is carried out at the end of each working day. It is not necessary and not possible to extract data in real-time. The truck must be switched off and in a stationary position. Once the laptop is connected to the truck FMS with the adaptor

cable, the ignition must be switched on to proceed with the data extraction process. The extraction process consists of 4 stages:

- Preparation for communication – Infomax checks the connection to the vehicle and identifies itself to the vehicle.
- Identification of the vehicle – Infomax determines whether the vehicle has already been created in its database.
- If the vehicle is unknown in the database, then it must be first created in order to continue with the extraction.
- Infomax then reads the diagnostic data stored in the FMS and saves it to the database.

All modern trucks on continental Europe and Ireland are manufactured with an FMS as part of the design build. Infomax 4.0 provides detailed reports of the engine diagnostics on the truck's performance throughout each working day. It provides details such as distance travelled, diesel used, average consumption of diesel when moving and idling, average speed with engine running and the time with vehicle running as well as other information specific to the engine such as, cruise control, truck and trailer brakes, engine retarder and percentage of transported mass data.
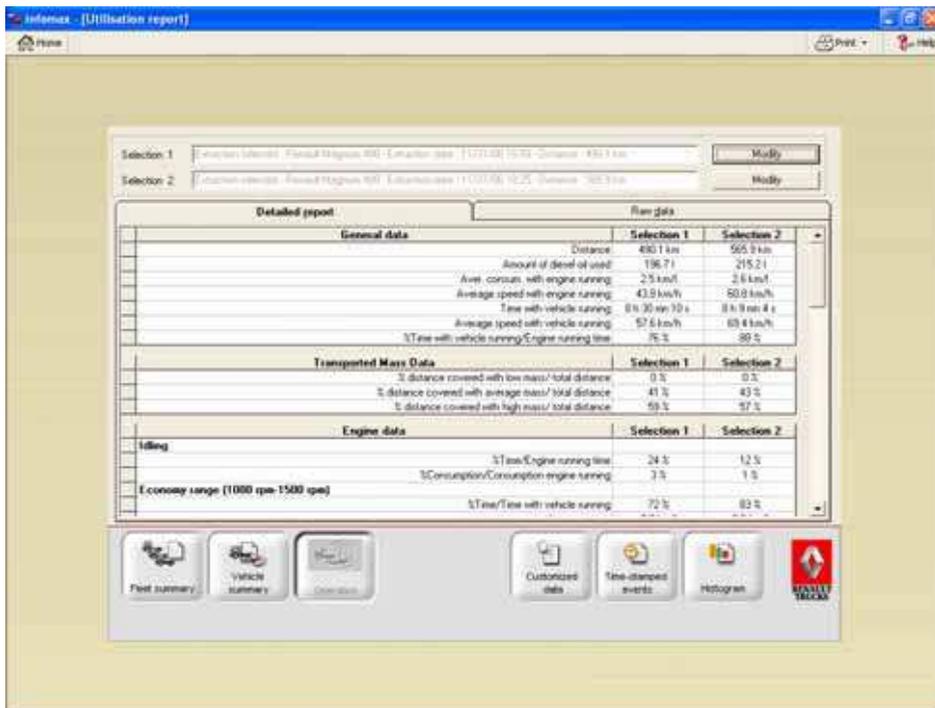

Fig. 7. Screenshot of the Infomax interface showing extracted data for the Belfast (selection 1) and Cork (selection 2) route

2.6 Combination of SDSS with Infomax 4.0 data to determine the CPK

The articulated Renault Magnum truck travelled 5 individual routes. Each route was also GPS tracked using the Trimble GeoXT. The GPS was set to record data every 20 seconds

along each of the routes. Each route provided between 1200 and 1300 sample points, of which approximately between 700 and 900 points were dynamic. There was on average 7
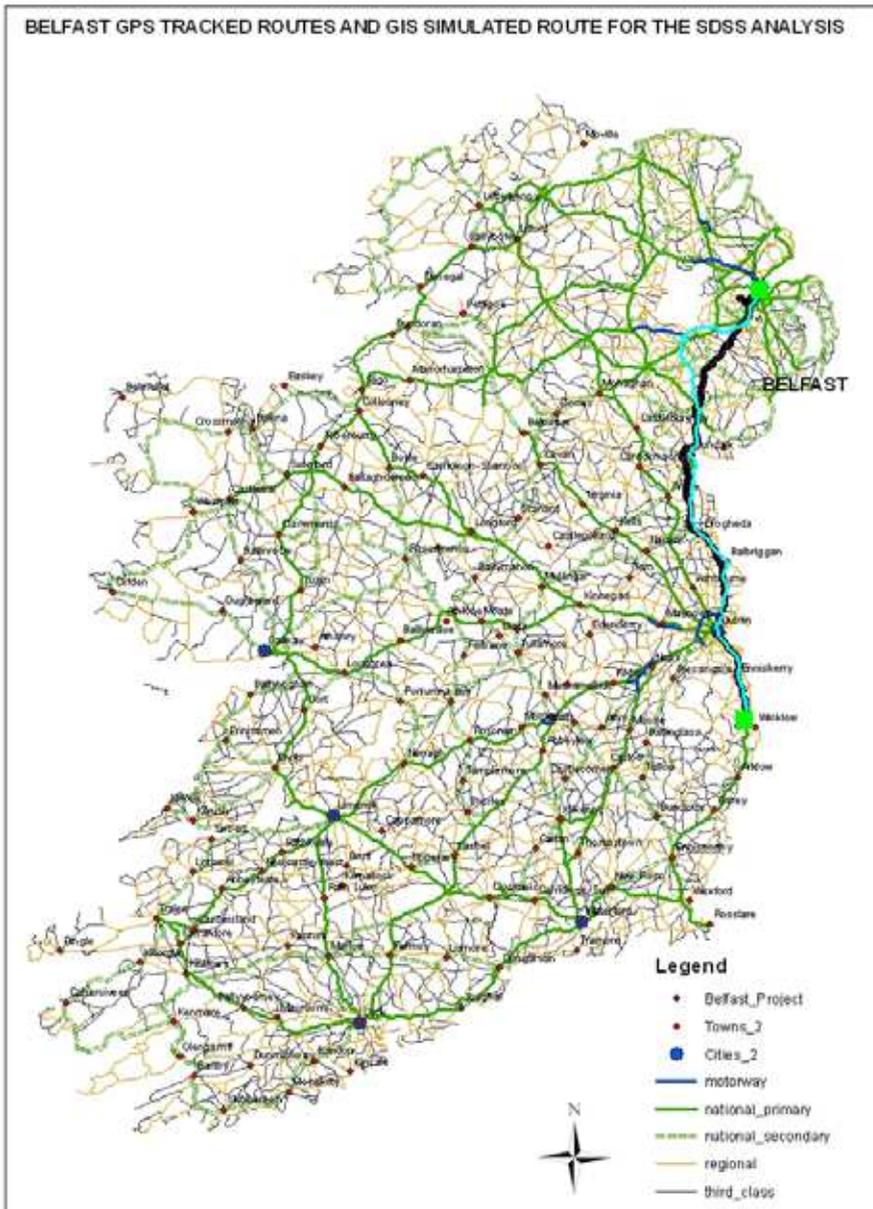

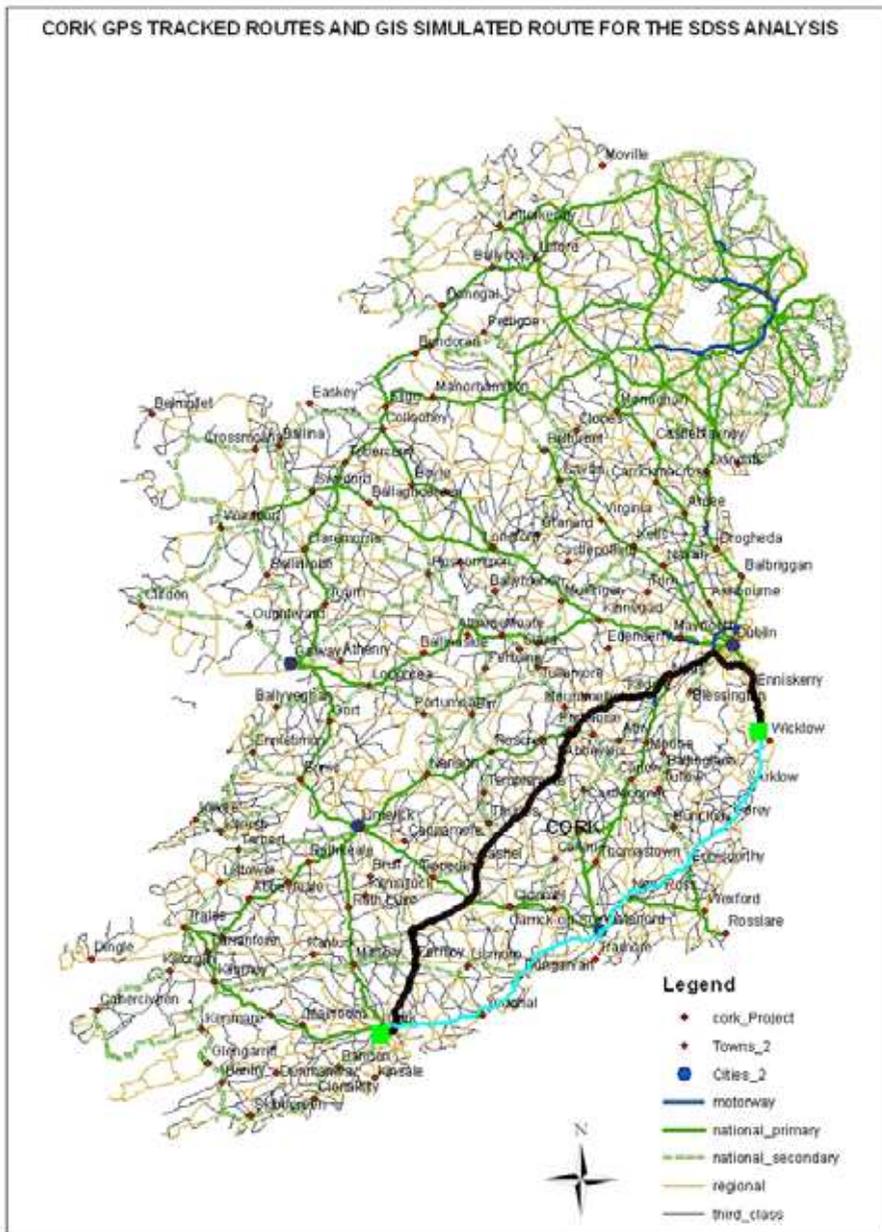Fig. 8a. Belfast GPS and GIS route.

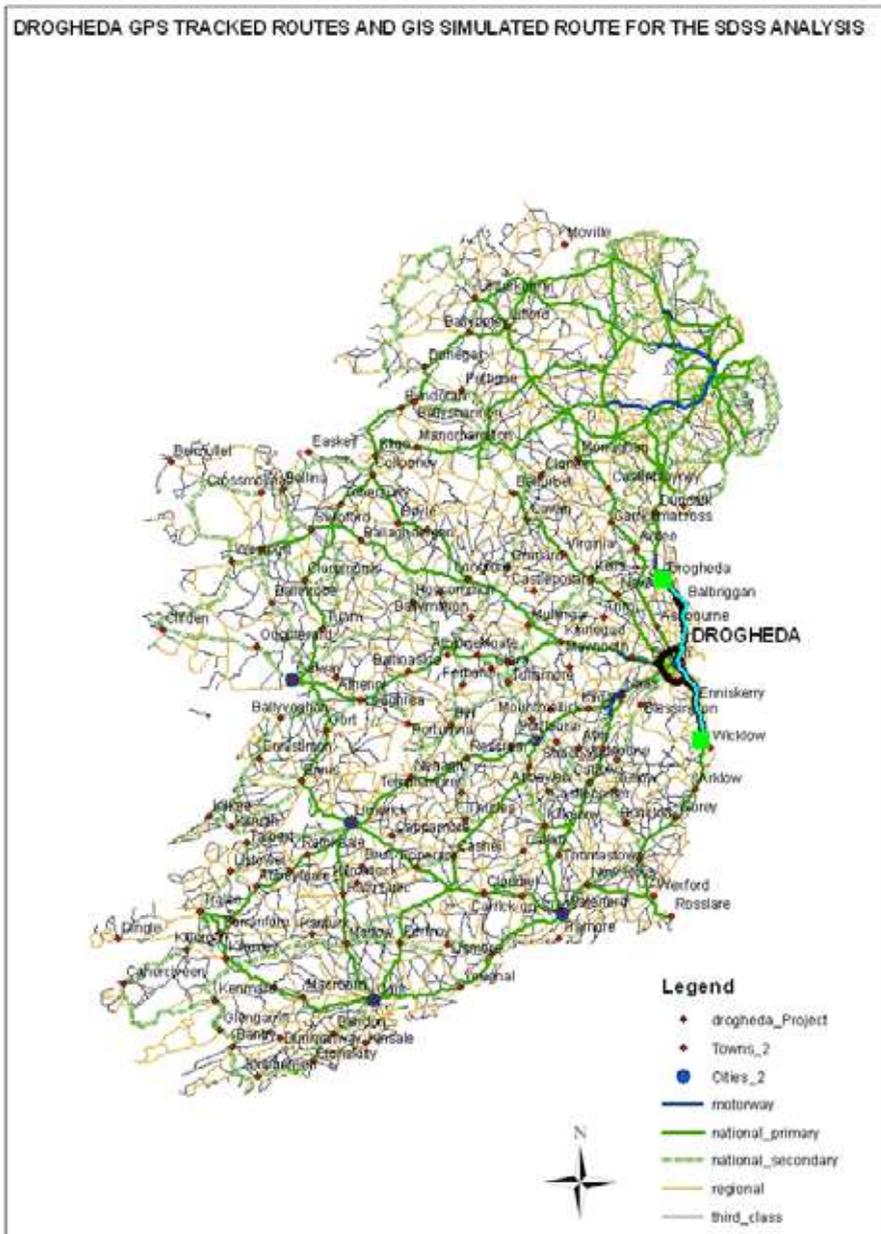Fig. 8b. Cork GPS and GIS route.
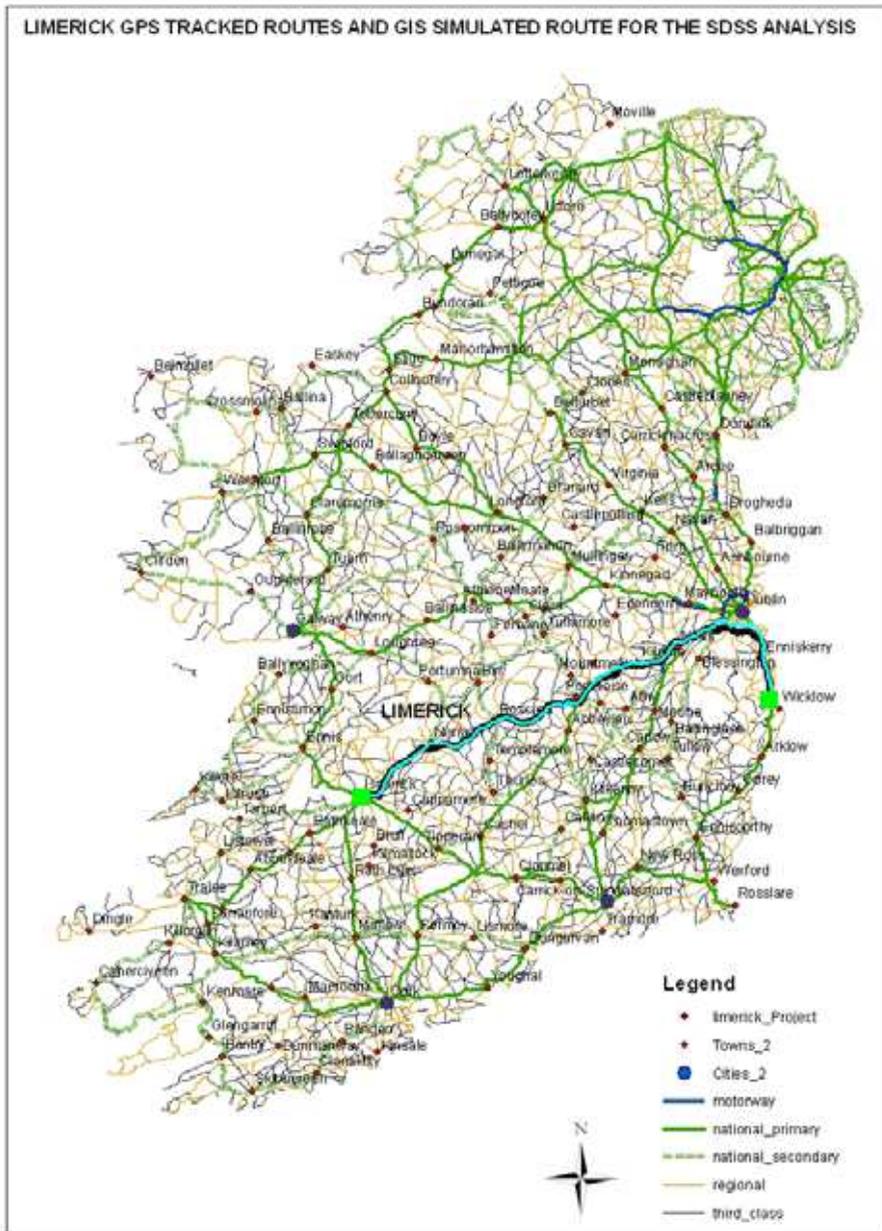
Fig. 8c. Drogheda GPS and GIS route.
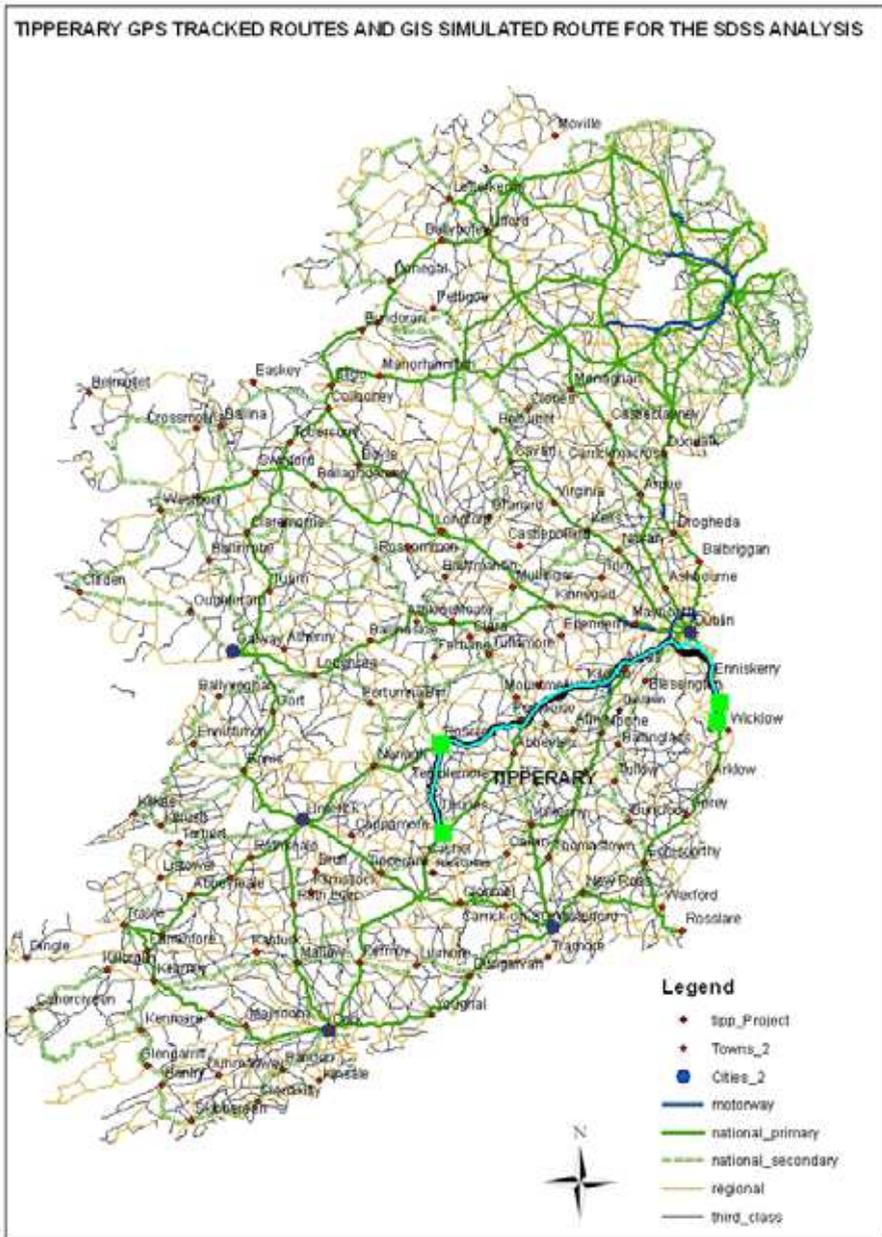
Fig. 8d. Limerick GPS and GIS route.

Fig. 8e. Tipperary GPS and GIS route.

Fig. 8. GIS map of each GPS and GIS route – Belfast, Cork, Drogheda, Limerick and Tipperary.

satellites acquired for each of the sample points recorded. In 3 out of the 5 routes the number of satellites acquired reached as high as 11. Data was assigned its geographic co-ordinate system (TM65) and its projected co-ordinate system (Irish National Grid) with the tools in ArcToolbox. The GPS routes could then be layered onto the GIS road vector map (figure 8). Each route is simulated within the GIS using the Network Analyst Tool (NAT) and assigned the same cost – weightings (Devlin et al, 2007). The SDSS is used to calculate the CPK for each of the GPS (Infomax) route versus the CPK for the simulated GIS route. The costs involved for each route were broken down into both variable and fixed costs. The fixed costs relate to the capital costs of the truck and trailer. These values remain the same for each route cost calculation. The variable costs include both the mileage costs and driver costs for the time taken for the journey. These values change for each of the 5 routes travelled. The time taken for each journey, the exact travelling distance and the kilometre per litre is data that must be extracted from the Infomax software to use in the DSS calculation of the CPK for each route – 5 GPS tracked routes and 5 GIS simulated routes (figure 8).

3. Results and discussions

This SDSS was used to calculate the costs of each of the 5 specific routes taken by the truck i.e. how much it costs to travel a certain distance. The costs involved for each route were broken down into both variable and fixed costs. The fixed costs relate to the capital costs of the truck and trailer. These values remain the same for each route cost calculation. The variable costs include both the mileage costs and driver costs for the time taken for the journey. These values change for each of the 5 routes travelled. The time taken for each journey, the exact travelling distance and the kilometre per litre are data that can be extracted using the Infomax software. This data is used to calculate the variable costs. Table 1 shows the related costs for each GPS route based on the distance extracted from the Infomax software.

INFOMAX ROUTE	BELFAST	CORK	DROGHEDA	LIMERICK	TIPPERARY
Infomax Distance (km)	490.10	565.90	235.40	545.30	406.00
kilometre / litre	2.50	2.60	2.50	2.30	2.30
Journey Time (hrs)	8.50	8.15	4.96	8.56	7.00
Journey Costs (€)	162.48	174.17	80.97	189.71	141.26
Driver Costs (€)	85.00	81.50	49.60	85.60	70.00
Tractor Unit Costs (€)	49.44	49.44	49.44	49.44	49.44
Trailer Costs (€)	10.60	10.60	10.60	10.60	10.60
TOTAL COSTS (€)	307.52	315.71	190.61	335.35	271.30
Infomax Cost per kilometre (€)	0.63	0.56	0.81	0.61	0.67

Table 1. Details of GPS route.

Table 2 shows the corresponding costs for the distance extracted from the GIS.

GIS ROUTE	*BELFAST*	*CORK*	*DROGHEDA*	*LIMERICK*	*TIPPERARY*
GIS Distance (km)	456.64	517.08	189.82	537.50	405.46
kilometre / litre	2.50	2.60	2.50	2.30	2.30
Average Speed (km/ hr)	57.60	69.40	47.30	63.60	57.90
Journey Time (hrs)	7.92	7.45	4.01	8.45	7.00
Journey Costs (€)	146.17	159.15	60.79	187.00	141.07
Driver Costs (€)	79.20	74.50	40.10	84.50	70.00
Tractor Unit Costs (€)	49.44	49.44	49.44	49.44	49.44
Trailer Costs (€)	10.60	10.60	10.60	10.60	10.60
TOTAL COSTS (€)	285.41	293.69	160.93	331.54	271.11
GIS Cost per kilometre (€)	0.63	0.57	0.84	0.62	0.67

Table 2. Details of GIS route.

This distance reflects the most probable route that is defined within the geometric network. Graphically, the routes look very similar and indeed they are except for small differences in the actual distance. In an effort to reflect the actual time taken for the GIS routes to be travelled, the average kilometre per hour was extracted from the Infomax software. This value for each route was used to estimate the approximate travelling time based on the formula Speed = Distance / Time.
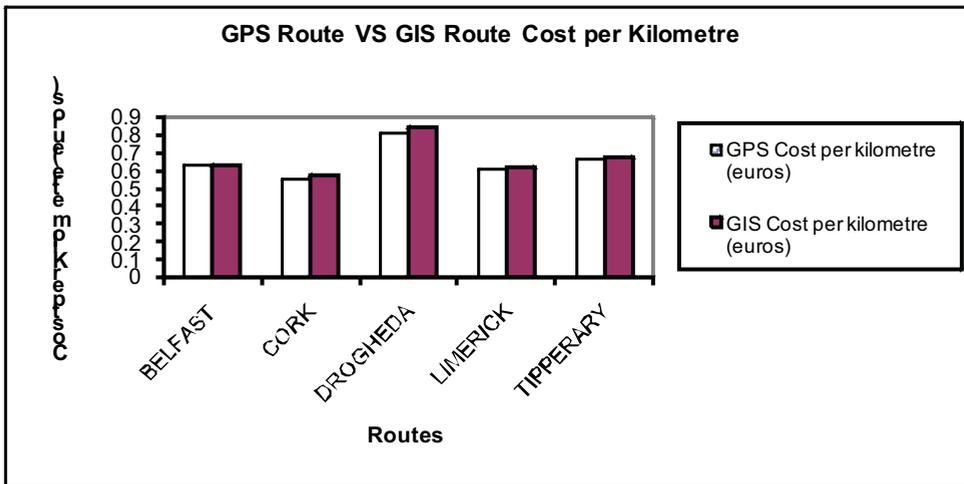

Fig. 9. Graph of CPK for GPS vs GIS routes.

From the Cork route (figure 8b) it can be seen that the GIS actually defined an entirely different route from the GPS route that was travelled, with a difference in distance of 48.82km. The actual difference in cost per kilometre (CPK) was in fact negligible at €0.57 and €0.56 respectively. An important point to note here is that the GPS actually tracked the truck on the return journey to be the same route defined by the GIS.

Another point to note is the route defined by the GIS for the Drogheda journey (figure 8c). This route travels through Dublin city and returns this route also. The truck travelled through the city early in the morning simply because of no traffic congestion at that period of the day. The GIS route is in fact shorter than the route travelled home through, but there is the added bonus of avoiding the toll charges for use of the ring road known as the M50 around Dublin city. Notice, however, that the GPS route returned through the toll bridge. The reason for this is the fact that the ring road does provide a faster journey than through the city in the afternoons. This is in fact the normal travelling procedure for the truck driver when travelling to the north of Ireland and leaving the depot early in the morning, usually around 4am. From table 1, the CPK for the GPS Drogheda route was €0.81 while the CPK for the GIS route through the city was in fact a higher value of €0.84. This actually proves that by avoiding the city on the return trip the CPK is decreased even with having the added charge of the toll bridge of €5.60 for 5 axle truck configurations. City driving can be full of stopping and starting, gear changing and braking, all of which can lead to an increase in CPK despite the actual shorter distance being travelled. The Belfast route (figure 8a) was a similar situation as regards the use of the toll bridge but the CPK remained consistent at €0.63.

New legislation from February 2007 in Ireland no longer permit heavy goods vehicles (HGV) to travel through Dublin City between the hours of 7am and 7pm. All trucks must use the outer ring road known as the M50 or the Dublin Port Tunnel. All HGV's that work in Dublin port must now use the Port Tunnel to avoid travelling in the city. The Tunnel is 4.5km long and takes approximately 6 minutes to travel through, joining Dublin Port with the M50 outer ring road that provides convenient access to all other major national routes. It is estimated that the Port Tunnel will remove approximately 6,000 trucks a day from Dublin City. This newly constructed tunnel under Dublin City is the longest urban tunnel in Europe. It is toll free for trucks and was opened on the 20th December 2006 at a cost of €751 million to the Irish economy (Department of Transport, 2006).

4. Conclusion

The introduction of Information Technology (IT) into the Irish Forestry sector is becoming ever increasing. During the Gudrun hurricane in Sweden in January 2005, thousands of cubic metres of timber were clearfelled by the ferocity of the storm. Irish timber harvesters and hauliers travelled to Sweden to aid in the recovery effort. The Irish workers experienced the impressive use of IT in the Swedish Forestry Industry at first hand for perhaps the first time. There is a strong belief now that the same technology can be implemented into the Irish forestry situation for an increase in efficiency in harvesting and haulage operations. This work is another step into the overall integration of IT into the timber sector in Ireland. The development of this Spatial Decision Support System can be used to calculate the costs per kilometre associated with timber haulage. It works in conjunction with a GIS road map and the Network Analyst tool. The NAT is used to define routes most probable for the timber haulier and the DSS can then analyse the CPK associated with these routes. Routes were verified through GPS tracking of the truck. The CPK were compared to the GPS route and the GIS simulated route. The results of the study certainly discovered some interesting facts. For example, the GIS Drogheda route that defined its route through Dublin City had a higher CPK of €0.84 as opposed to the GPS route. Even though the GPS route was longer and travelled the ring road around Dublin City at an extra cost of €5.60, the GPS route

returned a lower CPK of €0.81. All of the other GPS routes were longer in distance than the GIS routes but the difference in CPK was only approximately €0.01.

To take this study further, funding has just been secured to analyse the movements of the truck on the internal forest road network. The project aims to use the SDSS to define CPK on the forest roads and combine these values with the CPK of the public roads. The truck will also GPS tracked and its positional accuracy will be quantified within the more difficult terrain of the forest canopy. It is well documented that GPS performance becomes degraded under forest environments. For this reason, it is predicted that other GPS services such as Differential GPS and the European Geostationary Navigation Overlay Service (EGNOS) will be used to optimise the GPS performance while tracking the truck.

5. References

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Decision Support Systems Advances in

Edited by Ger Devlin

This book by In-Tech publishing helps the reader understand the power of informed decision making by covering a broad range of DSS (Decision Support Systems) applications in the fields of medical, environmental, transport and business. The expertise of the chapter writers spans an equally extensive spectrum of researchers from around the globe including universities in Canada, Mexico, Brazil and the United States, to institutes and universities in Italy, Germany, Poland, France, United Kingdom, Romania, Turkey and Ireland to as far east as Malaysia and Singapore and as far north as Finland. Decision Support Systems are not a new technology but they have evolved and developed with the ever demanding necessity to analyse a large number of options for decision makers (DM) for specific situations, where there is an increasing level of uncertainty about the problem at hand and where there is a high impact relative to the correct decisions to be made. DSS's offer decision makers a more stable solution to solving the semi-structured and unstructured problem. This is exactly what the reader will see in this book.

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