1. Overview

Logistics deals with everything involving planning, organising and managing activities that provides goods or services [1]. Complex logistics arrangements can result from the combination of different sorts of transportation like road, sea and air. For example, port operations are a complex arrangement in where road transportation can be seen as a feeder to sea transport. In regard of this, the UK is in a privileged position to generate and exploit the synergies associated to the logistics of port operations, in particular short sea routes. According to the European Commission (2007) sea routes (short sea) between neighbouring countries today offer high quality regular services that can be combined with other transport modes to provide efficient alternatives [2].

The logistics associated to port operations have a significant impact in the economy of a region. For example, in the UK’s northeast the North Sea represents a region with high potential to grow as a maritime region. According to the European Commission, in 2005, short sea shipping in the North Sea Region totalled some 591 million tonnes, with regular liner services and ferries operating fast, reliable and flexible connections that carry a wide range of cargos in a wide range of vessels,
including charter vessels that transport bulk steel and construction materials between terminals in the region as well as Roll On-Roll Off (RO-RO) operations. However the same Commission has identified road congestion in Europe as a major issue affecting the efficiency of sea transport. In the view of the Commission, the established benefits of short sea shipping as a sustainable part of the logistics chain creates demand for the extension of the North Sea short sea network. The “Motorways of the Sea programme” funded by the European Union [3] is looking at the increase of short sea shipping in the North Sea particularly on infrastructure (port infrastructures, infrastructures for direct land and sea access as well as inland waterway and canal infrastructures) and facilities (electronic logistics management systems, facilities to ensure and enhance safety and security, facilities to simplify administrative and customs procedures).

In the foreseeable future it has become evident that the use of new technologies will be required to gather the benefits associated to the high potential growth of short sea routes and on the other hand deal with the reliance of port operations’ logistics on road transportation. In the particular scenario of road transportation feeding port operations, novel Information and Communication Technologies (ICT) have the potential to solve many of the challenges faced today, guarantee the future sustainability of logistics operations in a specific geographic area and contribute to the generation of synergies that may lead towards better use of resources and waste reduction. In Europe, organisations like ERTICO [4] have recognised that the use of Intelligent Transport Systems and Services (ITS) combined with the appropriate investment in infrastructure, will result in reduced congestion and accidents while making transport networks more secure and reducing their impact on the environment.

Today, in logistics the use of internet-based applications such as web services, and technologies such as RFID, cellular networks, GPS-enabled devices, Wi-Fi and 3G among others have made possible to experience levels of visibility, control and connectivity never experienced before. In road transportation, applications based on WiMax, cellular infrastructure, Bluetooth and Wi-Fi have been adopted to provide certain connectivity. For example, by using the cellular infrastructure to reach the Internet network an embedded mobile phone in a given vehicle can get access to the network by using GPRS from a network operator such as ONSTAR®. However, still there are several limitations associated to current ICT technologies. For example, one main problem is that available services have to hop between different technologies like cellular networks, Wi-Fi, UMTS, 4G and WiMax, resulting in reliability and connectivity problems, not to mention problems associated to limited range, scalability and security. Therefore, by using heterogeneous ICTs there is a high risk of experiencing performance downgrade to the solutions designed to manage road transport logistics.

Road transportation logistics have specific needs in terms of ICT. According to the 2007 Commercial Vehicle Telematics Conference [5] some ICT-related issues affecting the sector include:
- An infrastructure where data and security layers ensure that all business critical data is not destroyed or corrupted
- Integrated application in replacement of commercial telematics with limited range and reliability
- For all fleet managers the elimination of expensive roaming and administered multicarrier agreements
- Increase visibility and productivity of a supply chain through integration with on-board GPS tracking systems leading to routing and traffic solutions
- The creation of a seamless supply chain where planning and replenishment activities will be completely automated
- Become a true interlinking technology that facilitate seamless interoperability
- Provide in-vehicle integration comprising location enabled services, communication capabilities, safety and security solutions, routing information and detailed management reporting
- Help fleet managers adhere to anti-idling rules

To address the issues listed above and in order to be able to run road transport logistics without the problems that have plagued current technologies in use, this research proposes one wireless solution which promises to be more reliable and which is still under development and subject to standardisation for massive deployment: Direct Short Range Communication (DSRC). DSRC promises to overcome the limitations associated to the use of heterogeneous technologies such as security, breakdown in IP mobility and lack of seamless handover. Up to now, this technology is still in development and in process of standardisation.

DSRC is a promising technology based on the standard IEEE 802.11p and which is designed to handle different types of service applications, including the transmission of both safety and non-safety
messages into two modalities: vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). DSRC is allocated at the 5.9 GHz frequency band and is designed to support high vehicular velocities in a radio transmission range up to 1000 m with a data rate up to 27 Mbps [6] per channel including two control channels and seven service channels. Within this technology two types of messages are transmitted: Wireless Access for Vehicular Environment (WAVE) Short Messages (WSM) and IPv6 traffic. WSM messages involve low latency and critical safety-related messages assuming a real-time propagation while IPv6 traffic is generally related to commercial services such as download or streaming of data. To allow internet Protocol (IP) traffic, the discovery of IP addresses [7] is performed by generating a global IP address with the Media Access Control (MAC) address and the IP prefix advertised by the current roadside infrastructure. A timer value is assigned to this IP address so when the timer expires, the IP address is no longer valid. If the vehicle attaches to a new roadside infrastructure, a new IP address based on the new IP prefix must be generated. Figure 1 shows the components of a vehicular network.

Figure 1. Vehicular Network Components

According to the vehicle-to-infrastructure integration VII report [8] the main network elements are briefly described as follows:

**On-Board Unit (OBU).** This element comprises a hardware module installed within the vehicle which includes a 5.9 GHz DSRC transceiver; a GPS location system; a processor for application services; and a human machine interface (HMI). A wide range of applications generated at the OBU can be formatted as IP traffic and propagated by using an available DSRC service channel. According to the estimations made on WAVE [6] in the USA.

**Roadside Unit (RSU).** This element is considered to be the gateway between the fixed infrastructure and vehicles. RSUs comprise a DSRC transceiver (RSU), a GPS location system, an application processor and a router that is attached to the fixed network. The RSU periodically broadcasts advertisement messages within its radio transmission range to aware neighboring vehicles of its presence. Any exchange of information coming from a vehicle is verified at RSU’s processor and forwarded by the router to reach the core network.

**Message switch (MSW).** Its main function is to handle and parse all the data intended to reach any network element. It also performs message management and subscription operations according to the message’s priority for efficient bandwidth distribution. All RSUs must be registered with their assigned MSW and associated to a specific region.

**Network Management (NM).** The management of the network will be carried out by centralised entities known as network operation centers (NOC). These centers are responsible for the analysis of all the information retrieved from the MSW, as well as, operation and maintenance of the vehicular network infrastructure.
Certification Authorities (CA). All messages passing through the network must be digitally signed so the CA is responsible of the distribution of key certificates to secure all the exchange of information and minimize the risk of a network attack.

Map Server (MS). Its function consists of maintaining the accuracy of map databases and it is logically connected to the MSW. Once an update in the position parameters has been performed in the map database, the updated information is released and sent back to the MSW, RSU and OBU.

The exchange of messages between vehicles and the fixed infrastructure can be implemented in either broadcast or geocast transmission modes. In the broadcast protocol, periodic messages are advertised to neighboring vehicles by the roadside unit with its radio transmission range. In the geocast protocol messages are transmitted according to specific geographical regions. This latter is suitable when the message need to be propagated beyond a limited radio transmission range. Moreover, the exchange of information can be performed in a single-hop or in a multi-hop based routing. For the first case, the communication is carried on exclusively between the OBU and the RSU while the second involves the collaboration of vehicles to propagate the message.

2. Novelty of Research
The research described in this proposal fits the EPSRC call on Feasibility Studies in novel ICT developments which allow early user adoption, supporting highly speculative and risky short term research activities. The research presented in this proposal is a unique speculative feasibility study on the use of DSRC to manage road transport logistics acting as feeder of port operations. DSRC is an innovative technology still under development and with huge potential benefits. In fact, DSRC promises to overcome the shortcomings of present ICT used in road transport logistics whilst at the same time it will play a key role to ensure the sustainability and competitiveness of a region.

3. Aim and objectives
The aim of the proposal is to accomplish a feasibility study on the implementation of DSRC to provide an environment with the highest degree of security, reliability and quality to manage road transport logistics acting as feeders of port operations. Total visibility, seamless interoperability and vehicle integration are some of the characteristics provided by DSRC that will facilitate the generation of the required synergies to run logistics operations in a way that can contribute to an increase of short-sea transportation, ensure future sustainability of road transportation/port operations, as well as securing a positive impact on the regional economy. Also DSRC may help fleet operators to adhere to anti-idling rules set by government initiatives. The proposal on DSRC presented here aims at linking different port sites by creating a DSRC zone of influence. A cluster of four ports in the river Humber has been considered for this purpose; this means that eventually vehicles coming into the DSRC zone of influence will be able to exchange messages/information between them and the fixed roadside infrastructure in place.

This project has the potential to contribute to the creation of one of the first purpose-built electronic architectures for the support of logistics operations in the UK. Specific objectives of the research include.

1. To identify and map principal logistics activities involving vehicle utilisation in road transport serving port operations—a case for Humberside region ports- and to identify the present state of current ICT for road transport in the Humber port region.

2. To determine the specification and topology of DSRC required to implement the technology within a road transport environment serving a port site – network of ports in the Humber region. This step requires defining the technical characteristics of the main network elements, as well as estimation costs on the design of the network, documentation, deployment, testing, evaluation, training, scalability and maintenance.

3. Simulate the behaviour of the DSRC network for the Humber region, model the exchange of messages between vehicles and the roadside infrastructure and to register, assess and make adjustments to specifications.

4. To investigate the possibility of building a web portal/web services solution as the logistics application built on DSRC that will be used to process exchanged logistics-related messages between transport vehicles and the roadside DSRC fixed infrastructure (information exchanged may include destination, ownership, types of goods, weight, value, insurer, time-window restriction for deliveries, road warnings and traffic updates) and to identify potential enablers and barriers to the adoption of DSRC and DSRC-based solutions for road transportation feeding port operations and to promote awareness on the use of DSRC-based solutions.
5. To share and disseminate experiences, methodologies, and tools associated to the implementation of DSRC with the wider academic and industrial communities in the UK. The purpose of this task is to define a series of steps that may be used to replicate the experience of defining the specifications of DSRC in the Humber region in other port/maritime regions.

4. Methodology
The methodology involves a four-stage approach over a period of twelve months. This four-stage approach comprises two work packages with their associated research themes.

I. Examine the current state of major logistics processes involving the use of vehicle transporters acting as feeders to sea transport/port operations. This action includes examining the movements of materials and the corresponding information. This stage contemplates examining the current state of the processes used to handle the move of materials/goods and its related information by road transporters to a port site. This will be achieved through accessing datasets from the road transporters and port operators. In order to have a broad picture, the work to be undertaken will have to identify the processes in place to deal with fast, medium and slow moving products.

II. Document the current state and functionality of ICT. From the information provided by road transporters and port operators match to what extent logistics needs identified by the 2007 Commercial Vehicle Telematics Conference are addressed by the current ICT in place. Determine what will be the requirements to be addressed by the DSRC-based logistics application for road transporters feeding port operations. Define a set of metrics applicable to the current and future performance associated to the use of ICT.

III. Modelling of the DSRC infrastructure. Once it has been possible to identify the limitations of the current ICT infrastructure but also the limitations of existing logistics applications; the next step is to model the characteristics of the DSRC infrastructure (wireless communication linking vehicles to the roadside) and simulate the exchange of messages between vehicles and the roadside.

IV. Investigate the possibility of building a web portal application. Functionality and data requirements specification will determine the characteristics of the logistics application to be built upon the DSRC-infrastructure for the purpose of processing exchanged logistics-related messages and information.

5. Work Packages and Research Themes

Mapping principal logistics activities involving vehicle utilisation and current state of ICT solutions used to manage the logistics of road transporters

The use of tools such as value stream mapping applied to the supply chain will provide a picture of the flow of materials/good and the flow of information. In order to have a broad view of the processes involved, mapping tasks will look at fast, medium and low moving materials/goods. In this stage it will be necessary to evaluate the functionality provided by current ICT solutions and the support given to the exchange of information “messages” between vehicle transporters and the port operators. This exercise will help to generate a list of requirements that will have to be considered in the design of a DSRC-based logistics solution. Data collection is a key activity for this project in the sense that issues and patterns identified will be key to specify first, the requirements of DSRC to operate a vehicular network serving port operations and second, the functionality of logistics applications to be built upon DSRC. This stage will make possible to identify logistics needs. Techniques envisaged to help in the data collection include:

- Using the Delphi technique to get expert opinion from industry collaborators regarding enablers and barriers for the implementation of DSRC-based vehicular networks and on the functionality of information systems required to address the needs of logistics involving road transportation and port operations.
- Meeting groups of experts in ICT and logistics operations

Determine the elements and specifications of DSRC required to implement the technology within a road transport environment serving a port site

The activities associated to this work package include: a) Defining the technical characteristics of the main network elements such as OBU, RSU, MSW, NM, CA and MS, as well as b) estimation costs on the design of the network, documentation, deployment, testing, evaluation, training, scalability and maintenance.
Modelling of a DSRC network for the management of road transport logistics feeding port operations
The main activity associated to this work package comprises the use of a modelling tool to simulate the configuration required for the DSRC network. Because the project presented is a feasibility study, purchase of the infrastructure elements required to install a DSRC network such as OBU, RSU, MSW, NM, CA and MS is prohibitive. Instead, a tool for modelling a DSRC network has been considered using the IEEE 802.11p standard. The tool considered for this purpose is OPNET’s Modeller Wireless Suite, which allows wireless network modelling and simulation. According to OPNET [10], the use of this suite provides “the industry's most flexible and scalable wireless network modelling environment, and includes a broad range of powerful technologies for accelerating simulation run-time”. Also in the view of OPNET the software offers full protocol stack modelling capability with the ability to model all aspects of wireless transmissions, interference, transmitter/receiver characteristics, including RF propagation, node mobility including handover, and the interconnection with wired transport networks.

Investigating the possibility of developing a web portal/web services solution as the logistics application built on DSRC
This work package investigates the possibility of developing a web portal/web services tool as the logistics application to be built on DSRC and which will be used by transport vehicles to exchange logistics messages between them and the roadside DSRC fixed infrastructure. The functionality, requirements and development of the application will have to be specified here. Information exchanged may include destination, ownership, types of goods, weight, value, insurer, time-window restriction for deliveries, road warnings and traffic updates. The use of the .NET platform has been considered for the development of the tool. Development of the application will be outsourced to developers through online project bidding.

Sharing and disseminating experiences associated to DSRC involving road transport logistics and port operations
This work package will have to organise and gather experiences, methodologies, and tools associated to DSRC within members of the organisations participating as industrial partners and with the wider academic and industrial communities in the UK. The purpose of this task is to define a series of steps that may be used to replicate the experience of defining the specifications of DSRC in the Humber region in other port/maritime regions.

6. Current Research Work

The Effects of Handoff on the Elasticity of Logistics Applications in Mobile IP Networks
The current research on the project is focussed on the maximum response time of an IP network application as determined by the DSRC radio interface. The link between these two seemingly unrelated aspects of a mobile IP network is handoff (also called handover), and in particular, the loss and consequent retransmission of packets because of delays in handoff. It is understood that in a wireless environment where there are large obstructions such as buildings and machinery, the maximum range of communications is severely limited, and may be well below the DSRC maximum of 1000m. In order to achieve uninterrupted mobile network access, it becomes necessary to locate network access points (roadside stations) at short separation distances that are no greater than the maximum radio wave propagation range. It is important to note that the efficacy of a logistics IP network application is incumbent on a minimal information update period. These observations have motivated our current study on the effect of the IP network infrastructure on the time it takes to communicate messages between the haulage vehicles and a fixed repository.

OPNET® Modelling Wireless Suite is being used to evaluate the maximum response time of a logistics network application as a function of the maximum communications range. The network simulation involves defining a predefined trajectory that is traversed by haulage vehicles along which access points have been placed at the maximum communications range.
Mapping the flow of information and materials in logistical operations involving road hauliers feeding ports

Research work has been undertaken to map the flow of materials and information involving process of a customer order. The approach presented in figure 3 follows a layer representation, where vehicle layer represents basic layer, followed by the operator layer, the integrator layer and the operator layer as the uttermost layer of this representation. Communication at the vehicle and operator layer is limited because the use of GPS and SMS text. Under the present scheme two-way communication takes place between the operator layer and its own fleet of trucks fitted with GPS units. One-way communication via SMS text takes place between the road hauler and outsourced trucks.

The adoption of DSRC as the infrastructure to support road haulage and port operations will enable the exchange of information between trucks approaching the port perimeter and different parties involved in the logistics process at the operator layer including: terminal operator, shipping line, port authority and of course the road hauler, which in some cases has become a 3PL responsible also for integration of logistics jobs. Figure 4 shows information sharing through the existence of DSRC links. At the integrator and operator layers, information exchange between high level logistics applications will be possible through DSRC-enabled links.
Figure 3. Current state of information flow in road haulage/port operations

Figure 4. Future state of information flow in road haulage/port operations
Information services requirements for road haulers supported a DSRC-based infrastructure

One key aspect of DSRC is that it has been contemplated as the infrastructure in place to support high level applications. Common information services requirements for road haulers [11] include the following:

- Map Services
- RiskTriLicense Management
- Contract Management
- Responsibility Management
- Timetable Management
- Logistics Operator Management
- Route Management
- Resource Management
- Order Management
- Vehicle Positioning
- Vehicle Monitoring
- Vehicle Identification
- Handling Instructions Management
- Wireless IT
- Loading Management
- Shipment Management
- Party Identification Management
- Exception Management
- Unloading Management
- Reclamation Management
- Tracking Data
- Tracking Data Monitoring
- Tracking Target Creation
- Production Management
- Production List Management
- Product Management

Based on the above list of information services requirements for road haulers, hence it is possible to suggest load information presented in Table 1.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ToL*</td>
<td>Type of load*</td>
</tr>
<tr>
<td>DT</td>
<td>Departure Time</td>
</tr>
<tr>
<td>EaT</td>
<td>Expected arrival Time</td>
</tr>
<tr>
<td>OL</td>
<td>Origin of load</td>
</tr>
<tr>
<td>DP</td>
<td>Destination port</td>
</tr>
<tr>
<td>DQ</td>
<td>Destination quay</td>
</tr>
<tr>
<td>WoL</td>
<td>Weight of load</td>
</tr>
<tr>
<td>SL</td>
<td>Shipping line identifier</td>
</tr>
<tr>
<td>RH</td>
<td>Road hauler identifier</td>
</tr>
<tr>
<td>OID</td>
<td>Operator identifier</td>
</tr>
<tr>
<td>LTV</td>
<td>Load total value</td>
</tr>
<tr>
<td>IID</td>
<td>Insurance identifier</td>
</tr>
<tr>
<td>CPO</td>
<td>Current position</td>
</tr>
</tbody>
</table>

**Table 1.** Road haulier load information
Using OPNET® ACE™ it is possible to model the exchange of messages containing the above description through the proposed DSRC-based network put in place.

**Secure access architecture for logistics operations – future considerations**

In common information services architectures, the deployment of Authentication, Authorization and Accounting (AAA) models constitute a fundamental part for the deployment of services mainly used by network operators and e-commerce applications [12]; [13]. For allowing access to the network, user authentication and authorization might include two levels: first, authorization to access a radio channel at the roadside antenna; second, authorization to access a specific service application at the fixed network domain. Once the user has been successfully authenticated and authorized the user becomes eligible with the right to access specific applications, usually in the form of service credentials. Additionally, an accounting infrastructure might be required for charging purposes, as well as for estimation of resource consumption.

![Diagram of Secure Access Architecture](image)

**Figure 5. Future state of information flow in road haulage/port operations**

In figure 5, a secure access architecture capable of supporting supplicant’s authentication is proposed, also this architecture is capable of providing on-demand security features, as well as authorization and accounting. In general, authentication is performed in the security module which relies in the presence of multiple certificate authorities (CA). From this proposed architecture, it is guaranteed the certainty of the communicating participants by providing on-demand security attributes during the initial communication setup between a requester truck and a shipping line premise. It is worth to emphasize that CAs are responsible for the generation, distribution and management of certified cryptographic keys among communicating parties. Additionally, the security module is responsible for keeping control of road haulers’ records, as well as shipping liners’ records.

Latest update: November 2008
Website: [http://members.lycos.co.uk/aec572/DSRC-Hull-Logistics.html](http://members.lycos.co.uk/aec572/DSRC-Hull-Logistics.html)
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8. Sponsors
This research work is supported under EPSRC grant number EP/F067119/1 Feasibility of implementing Direct Short Range Communication (DSRC) technology for the management of road transport logistics feeding port operations. Industrial collaborators include Associated British Ports (ABP) and DSV Road Limited.

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