ITS APPLICATIONS TO FREIGHT TRANSPORT AND MANAGEMENT

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1. INTRODUCTION

Currently there is an increasing interest in improving and optimising transport of goods on short, mid and long distances as well as their management when inter-modality is concerned. This means design of Intelligent Transport Systems (ITS) should include Inter-modal Freight Villages (IFVs), devices on board the means of transport and the creation of Freight Traffic Control Centres (FTCCs).

The paper will describe a feasibility study to reduce waiting times of different means of transport (travelling on road, rail, water) gathering into Inter-modal Freight Villages thank to the installation and use of ITS applications. This will provide optimisation of the number of utilised means with a number of positive consequences such as money savings and reduction of goods delivery times.

The main aspects of this study will envisage:

- Automatic Vehicle Localisation (AVL) technique to track & trace all means of transport
- Radio Frequency Identification (RFID) technology to identify, classify, track & trace any kind of transported goods
- ITS installations at the Inter-modal Freight Villages that will regard:
    - Access control technologies (CCTV cameras and RFID beacons)
    - Automatic parking slot assignment/control,
    - IFV management
    - High-level FTCC able to manage all Vehicles-to-Centre communications as well as enormous amount of data regarding:
    - Traffic and viability information on motorways & national road networks
    - Sea and weather conditions
    - Ferries & boats and trains (sometimes air cargo too) timetables
    - Lorries & Heavy Goods Vehicles (HGVs) arrival/departure scheduled/estimated times.

Beyond installation of physical infrastructure on board the means of transport, at the IFV Control Centre and within the IFV area, a lot of data communication and data management is envisaged to ensure an effective and efficient result.

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2. ORIGIN AND DEFINITION OF THE "INTELLIGENT TRANSPORT SYSTEMS (ITS)" TERM

In the mid '80s a new discipline appeared on the market. Its name was Telematics, a fusion of two terms: Telecommunications and Informatics, where the latter includes science of information, practise of information processing and the engineering of information systems.
The first applications of telematic systems to road transport were identified as Advanced Telematic Transport (ATT).

In mid '90s ATT systems and projects increased in number and complexity. Therefore, the ATT concept evolved in Road Transport Traffic and Travel (RTTT) where not only pure technology was taken into account, but also the effects of its application on traffic and travels.

In the late '90s the concept of telematics evolved in a wider one named Information and Communications Technologies (ICT) and RTTT evolved into Intelligent Transport Systems (ITS) identifying an umbrella concept for a range of technologies including processing, control, communications and electronics that are applied to a transportation system (transport infrastructures, vehicles and users). It also includes an advanced approach to traffic management.

Nowadays there are ITS applications covering all modes of transport and providing a vast range of services regarding:

- management of road, rail, air, waterborne and urban traffic, including: travel and traffic information for users; traffic control; incident management; navigation, surveillance and guidance; and vehicle safety and control systems
- electronic payments and the enforcement of regulations
- management of Public Transport, freight movements and other fleet applications
- planning and policy-making activities

During the years across the 20th and the 21st century ITS expanded considerably from Light Vehicles and Public Transport to Heavy Goods Vehicles.
Today Intelligent Transport Systems are also a key enabler of the integration of different transport modes to provide door-to-door transport services.

3. DEFINITION OF INTER-MODAL/MULTI-MODAL TRANSPORT

The term "Inter-modal Transport" identifies the movement of goods whereby at least two different modes are used in a door-to-door transport chain.
Inter-modality is a quality indicator of the level of integration among different modes: more inter-modality means more integration and complementarity among modes, which provides scope for a more efficient use of the transport system.

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The most common transport modes involved in inter-modality are HGVs and trains or HGVs and vessels.

The integration among modes needs to take place at the levels of infrastructures and other hardware (e.g. loading units, vehicles, telecommunications), operations and services as well as regulatory conditions.

When more than two modes are involved in the logistic chain, the transport is said to be *multi-modal*.

The concepts of inter-modality and multi-modality are also applied to movements of people when using different transport modes to reach their final destination (e.g. car + train + buses).

4. THE "BLUE BANANA"

The "Blue Banana" (also known as the Hot Banana) is a discontinuous corridor of urbanisation in Western Europe. It stretches approximately from London in the north to Milan in the south. The curvature of this corridor (hence the 'banana' in the name) takes in cities such as Brussels, Amsterdam, Cologne, Frankfurt, Basel, and Zurich, and covers one of the world's highest concentrations of people, money, and industry. The curvature was coloured blue in maps produced by RECLUS, a group of French geographers managed by Roger Brunet.

The so-called "Blue Banana" belt, 75 million inhabitants, constitutes the economic heart of the European Community accounting for 2/3 of GNP.

The concept of "blue banana" is now widely recognised by any logistic company and offers the stimulus of thinking about homogenisation of services provided within that area including ITS applications.

In addition to this freight transportation axis there is another axis, known as "Latin Arc", which regards freight transport from the West to the East of South continental Europe.

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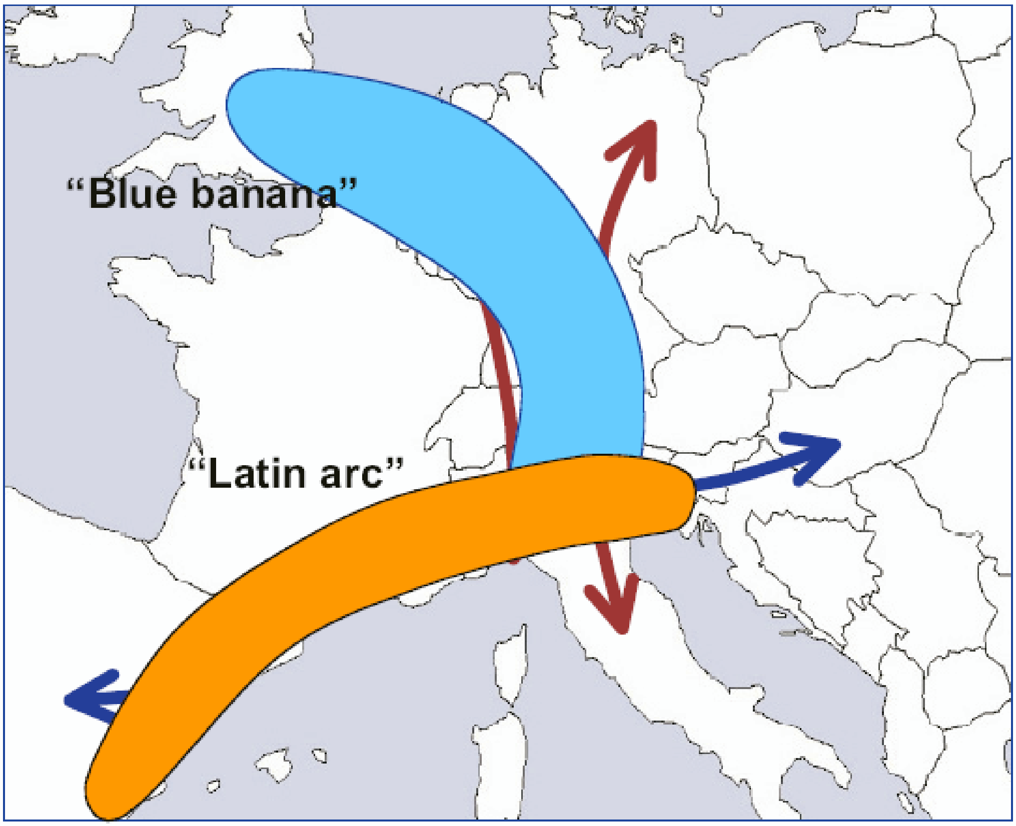

Figure 1 – Major European axes of freight transportation

5. INTER-MODAL FREIGHT VILLAGES

The continuously increasing amount of transported goods across one or more countries has caused the urgent need of improving the freight transport management.

Many big forwarders companies counting on a large fleet of vehicles have already got their own Freight Traffic Control Centre where each HGV is equipped with Automatic Vehicle Location (AVL)-enabled On Board Unit (OBU) that is in constant communication with the FTCC sending its instantaneous position, instantaneous speed, average speed, etc. This is currently obtained by a Global Positioning System (GPS) satellite device transmitting its data through GPRS wireless communication channel.

When receiving all data sent by vehicles in motion, the FTCC is able to display the real-time positions of all vehicles on a digital cartographic map. In addition,

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the Control Room is also able to open a vocal communication channel with HGV drivers in case of need.
Although briefly, this example helps understand how ITS improve the freight transport and management.

The peculiar benefits of Intelligent Transport Systems applied to freight transport and management, which can also be identified as logistics, can be perceived once arriving at Inter-modal Freight Villages (alternately known as Inter-modal Freight Terminals).

Before discussing all benefits, a concise description of IFV activities is necessary.

5.1 Activities performed at an Inter-modal Freight Village

An IFV is built on a vast flat land with real-time-controlled accesses and must have the ability to support many different telematic applications in the same time unit.
According to the geographical location where the IFV is installed it can deal with:

- land transport and/or
- waterborne transport and/or
- airborne transport

The difference in complexity between an inter-modal (at least two transport modes) and multi-modal (at least three transport modes) **F**V is not that much with regards to ITS applications management as they are modular. Conversely, major complexity will be found in installations of CCTV video-cameras networks, larger areas to control, more extended communications infrastructures and so on.

Further classification regards whether the IFV deals with national or international freight transport. In the latter case also customs control is required.

An IFV is managed by a Control Centre that has the duty of managing all activities performed within the IFV such as:

- Access Control (known as Gate In / Gate Out procedures)
  - Overland
    - i HGVs and/or lorries
    - ii Trains
    - iii Combined Transport (CT)[1]
  - Waterborne
- Customs (when IFV deals with international transport too)
- Freight management
  - IFV infrastructures
  - Containers (any size)
  - Pallets
  - Freight

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  - Dangerous Goods and Perishable Goods, which require different and special management procedures and storage areas
- Vehicles management
  - HGVs
  - Lorries
  - Trains
  - IFV management vehicles
  - Vessels, when IFV include (sea or river) ports
  - CT Management (procedures of loading/unloading HGVs on/from trains or ferries)
- IFV space management
  - Freight
  - Vehicles
- Timetables management
- Back office dealing with EDI (Electronic Data Interchange) regarding all transport documents
- Internet portal dedicated to IFV users that can carry out lots of admin/booking activities

In this paper inter/multi-modality dealing with air cargoes will not be taken into account.

6. STRUCTURE OF AN INTER-MODAL FREIGHT VILLAGE

The management of an IFV is very complicated as many activities are performed in the same time unit. That's why often IFVs are also known as *Logistic Cities*.

At the top there is an IFV Control Centre who is in charge of the complete management of the whole areas. In an IFV Control Centre (see figure 2) it is possible to identify the following sub-centres:

1. IFV Control Room
2. IFV Communication Management Centre
3. IFV Data Management Centre
4. IFV Management Services Centre
5. IFV Internet Portal
6. IFV Back Office

whose duties and functionalities will be described in the following paragraphs.

6.1 IFV Control Room

The Control Room (CR) supervises all activities described above and performed within the Inter-modal Freight Village. It should be manned 24 hours a day with a

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number of Control Room Operators able to control all the logistic journeys and activities procedures as well as talking to the lorries and trains drivers in case of need.
These operators will have some monitors directly connected to traffic and viability information systems in order to be timely aware of any disruptions along the journeys path and to plan the most suitable countermeasures. This means to have a continuous connection with different Control Rooms such as motorways patrols, (road) police, fire brigades, Traffic Control Centres (TCCs), etc.
Digital cartography using GIS technology will be used to control a wide geographic area where the specific IFV is located. On these maps the vehicles dealing with IFV operations and located with GPS technology will be displayed.
A robust IT system including a reliable Data Base Management System is then necessary to ensure the best service.

The main supervised and controlled activities are:

- IFV Gate In / Gate Out procedures
- Means of transport coming to / leaving from the IFV as well as those one in loading/unloading procedures
- IFV parking spaces booking and occupancy
- Traffic and Weather conditions in the area where the IFV is located

The Control Room will be also responsible for managing information that will be sent to Variable Message Signs (VMS) installed in the geographic area (included motorways) where the IFV is located as well as inside the IFV itself.

These items of information will certainly regard the number of free parking spaces still available in the IFV (for those ones who didn't make their booking online due to whatever reason) as well as any kind of notice that could help haulers to reach the IFV in the most effective way.

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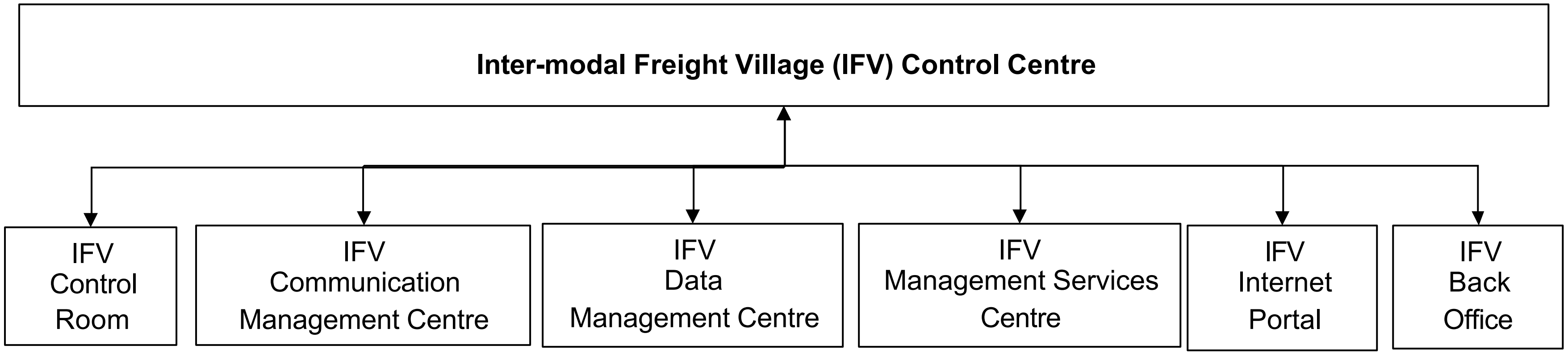

Figure 2 – IFV Control Centre structure (1st and 2nd layer only)

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6.2 IFV Communication Management Centre

The communication infrastructure is the core of all IFV operations. All different kind of communication must be linked to the IFV Communication Management Centre that is one of the activities managed by the IFV Control Centre.

It includes both wired and wireless infrastructure where the former consists of fibre optics and copper cable, dealing with data interchange and voice communication and the latter deals with the same topics but with a seamless coverage of the whole IFT area.

The most obvious coverage is that one for mobile telephony and data exchange (HSDPA, UMTS, EDGE, and GPRS)[2] but also Wi-Fi to allow operators to get connected in any part of the IFV area. When available, also Wi-Max coverage will serve the IFV area with advanced features.

6.3 IFV Data Management Centre

This Centre is made of two operational sub-systems dealing with data processing and data storage, both managed by a supervising system, which supervises the data processing and storage systems in order to ensure a 24/7/365 operability and be able to promptly inform the Control Room when some disruptions occur as well as perform (overnight) a daily back-up of all activities and data exchanged logs.

The *Data Processing System (DPS)* will deal with a vast amount of data and together with the IFT Communication Management Centre they represent the most important part of the IFV Control Centre.

Data flows regard real time information concerning:

- Vehicles (land and sea transports) localisation, journey timetable, origin and destination
- Freight type, quantity, localisation, journey timetable, origin and destination
- Allotted parking spaces for HGVs & lorries and related occupancy status (on/off)
- Electronic Data Interchange (EDI) regarding all transport documents included Customs ones
- All activities performed through the IFV Internet Portal (described below)

Harmonised communication standards, procedures and transport documents (waybills) on EDI basis will increase the use of electronic transaction in transport that will bring further time saving.

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In addition to what described above regarding real time information, a robust *Data Storage System (DSS)* is vital for all procedures performed by the Inter-modal Freight Village.
The most common and effective solution consists of using a Relational Data Base Management System (RDBMS) which allows to extract data in high number of different options in order to get any kind of statistics, to use stored data merged with real time ones, to prepare workload forecast, to manage IFV daily management operations and so on.
To prevent stored data from losses due to any kind of system crashes, a Redundant Array of Independent Disks (RAID)[3] must be put in place where data redundancy and data split on a number of discs offer a higher level of security.

6.4 IFV Management Services Centre

This Centre will have the following main duties:

- To perform the daily IFV management, such as infrastructures, workers shifts, vehicles maintenance, building and infrastructures maintenance, parking space availability, security, et cetera
- To manage all data sent from IFV operators' handheld wireless devices concerning unloading/loading procedures of specific jobs
- To manage the IFV General Timetable
- To manage and update the IFV Internet Portal

Special attention deserves the *General Timetable management*.
This activity is peculiar as the higher the Level of Service (LoS) provided, the larger the amount of saved time, which is the one of the added values that ITS application bring to the overall IFV activity, thus to each means of transport involved in IFV operations.

The system merges scheduled transport timetables with the real time transport situation comparing them with the scheduled operations written in the logistic calendar. Depending on the system accuracy and on the IFV operators' professionalism it will be possible to optimise waiting times among different means of transport.

The key expression for this activity is "Timetables Coordination" across modes at both national and international level.
The items of information considered create an Information Network concerning:

- Transport Operators
- Infrastructures Managers
- Service Providers

This coordination will be very important for cross-border hauls and high-density & fast-flowing corridors where different modes contribute to an inter-modal transport chain.

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6.5 IFV Internet Portal Management Centre

The development of an Internet Portal is essential to provide IFV customers (e.g. transporters and forwarders) with a tool that can remarkably reduce waiting times when involved in IFV operations. They will be able to input their scheduled journey timetable, transported freight and people, to specify whether a transport is carried out by HGV or by a Combined Transport, to book a HGV parking space, to make any kind of payments, to fill in Customs electronic forms and any other forms that, once arrived at the IFV, will be only verified and signed with a considerable time saving for the transporters and the IFT management staff.

There will be an IFV Webmaster responsible for keeping the Portal always operational and promptly intervening in case of disruption. All data entered by users will then be managed by the IFV Back Office.

6.6 IFV Back Office

The Back Office processes all data coming from the Internet Portal, and from the IFV Data Management Centre.
It is in constant contact with at national and international Customs and it deals with all transport documents management.

It also allows managing certain IFV operations, such as

- HGV parking space availability
- Containers space availability
- IFV Management Vehicles
- Advanced booking of national/international Combined Transports
- etc.

according to specific dates and times once is verified the positive output of payment procedures.
The Back Office will be equipped with powerful accountancy software and a number of employees whose work contributes to the optimisation of the logistic operations performed in the IFV.

In figure 3 the IFV Control Centre activities are represented in an organisational chart, whereas in figure 4 the IFV Control Centre's main activities are represented.

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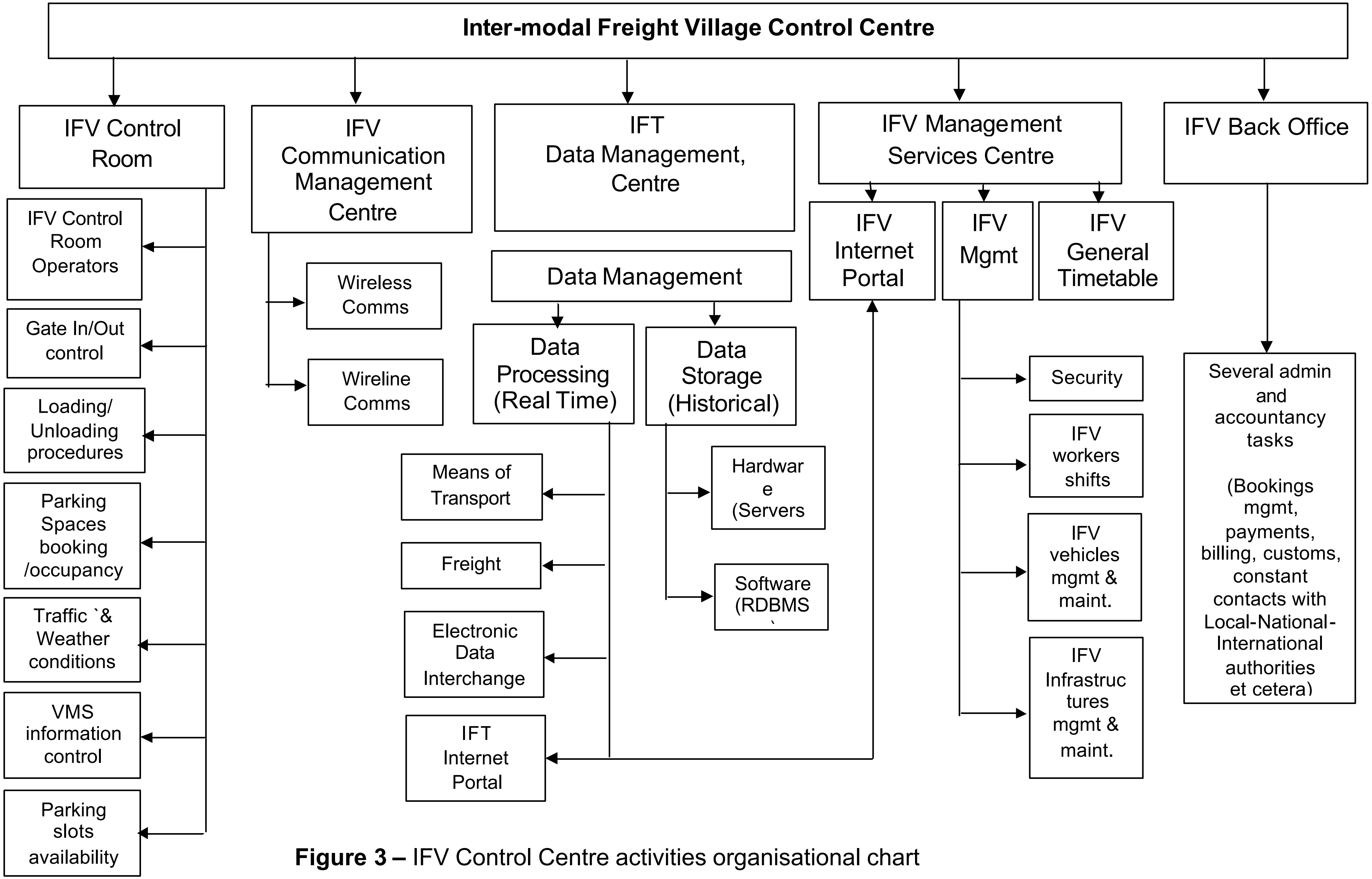

Figure 3 – IFV Control Centre activities organisational chart

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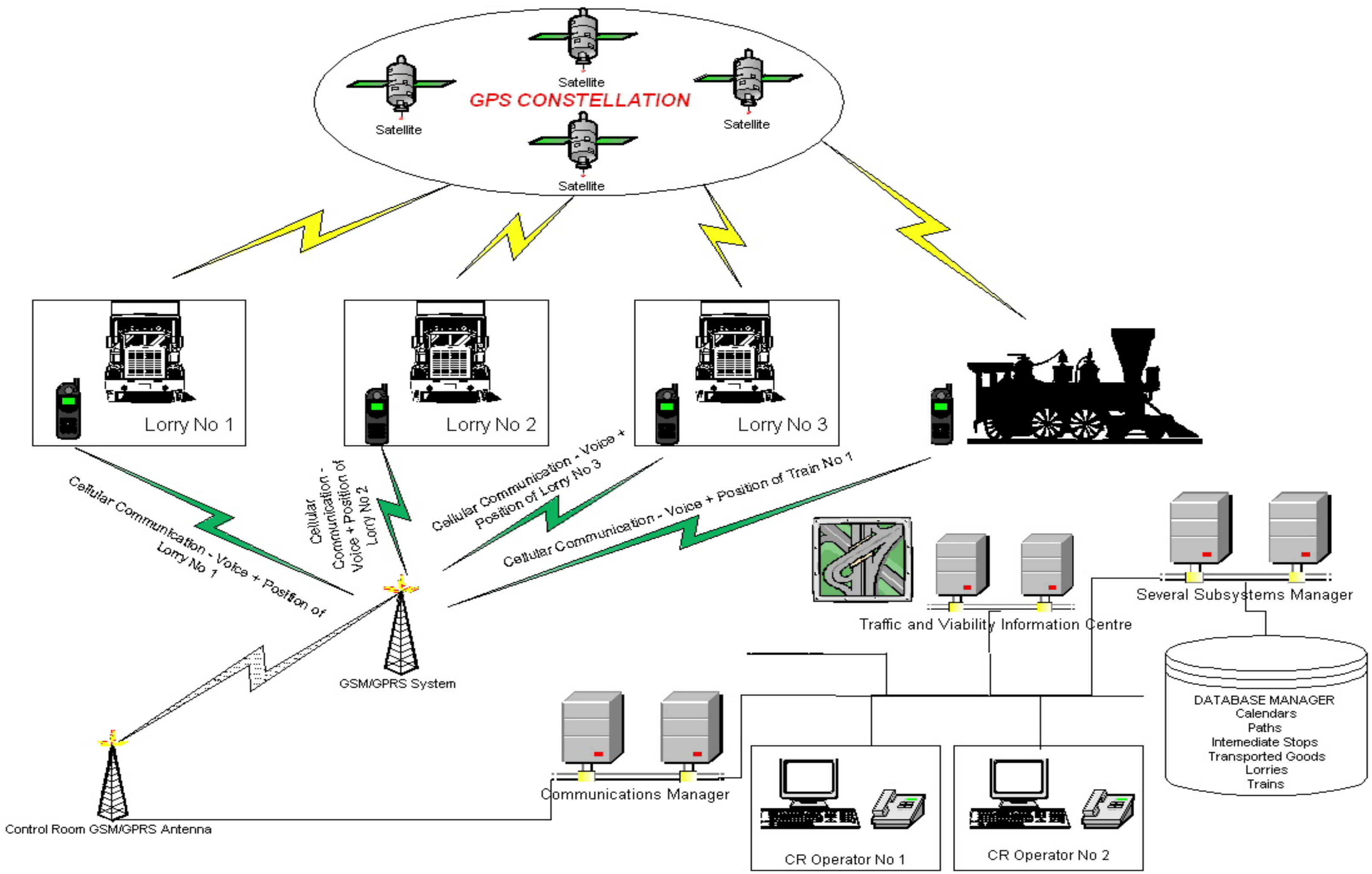

Figure 4 – IFV Control Centre's main activities

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7. TECHNOLOGIES

So far it was explained the IFV from an organisational point of view with some references to technologies. In the following paragraph more technological aspects and their applications will be described.
To implement ITS solutions some technologies have to be utilised in order to effectively and efficiently process all data conveyed to the IFV Control Centre.
These are as follows:

- Localisation technologies
  - GPS (Global Positioning System)
  - GSM-R (GSM for Railway)
- RFID
- Magnetic sensors
- CCTV
- ICT (Information and Communications Technologies)
  - Communications
    - i Wired
      - Fibre Optics
      - Copper wires
    - ii Wireless
      - HSDPA/UMTS/EDGE/GPRS[2]
      - Wi-Fi (Wireless Fidelity)
      - Wi-Max (Worldwide Interoperability for Microwave Access, when commercially available)
  - Data Processing Systems
  - Data Storage Systems
    - iii RDBMS (Relational Data Base Management Systems)

7.1 Localisation Technologies

To ensure the best efficiency of IFV management through ITS solutions the whole vehicles situation should be constantly updated and checked/managed by the IFV Control Room.

The most widely used technology is the satellite localisation using currently the GPS constellation (in the future also the GALILEO one).
This implies that vehicles have an On-Board Unit (OBU) installed where not only vehicle positioning can be transmitted through GPRS wireless communication channel as mentioned above.
As a matter of fact, the OBU could be designed to include also Electronic Toll Collection (ETC) module enabled to pay road usage in the UK and abroad.
What described can be mainly referred to HGVs as vessels have been using satellite localisation for long time.

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With regards to trains, they use GSM-R, a wireless communication platform which includes also localisation features.

In February 2007 it was reported that UIRNET, an Italian company grouping 20 Italian IFVs together, has been preparing an operational plan to launch the first Italian satellite-controlled logistic platform able to control, monitor and survey all freight transport within the Italian territory.

This will help define better freight transport itineraries to optimise travel times as well as the number of vehicles involved in the transport chain, reduce road traffic, better track and trace freight movements to increase security whose all countries have a great need nowadays.

7.2 Radio Frequency IDentification (RFID)

Radio Frequency Identification is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum[4] to uniquely identify object, animal or person.

RFID is coming into increasing use in industry as an alternative to bar codes. Main advantages of RFID is that it does not require direct contact or line-of-sight scanning and it is less affected by dust and dirt.
A RFID system consists of two/three components: an antenna and transceiver (often combined into one reader) and a transponder (the tag).
The antenna uses radio frequency waves to transmit a signal that activates the transponder. When activated, the tag transmits data back to the antenna. The data is used to notify a programmable logic controller that an action should occur. The action could be as simple as raising an access gate or as complicated as interfacing with a database to carry out a monetary transaction.

Within an Inter-modal Freight Village, RFID can have many application specially related to freight with control and management of goods boxes as well as containers. By having an easier cataloguing of:

- which type of goods is contained in each box and on which vehicle this box is loaded onto
- which kinds of goods are loaded into each container
- which position the container has got inside the huge inter-modal centre area

the whole organization is better run as in any moment it is possible to know the exact position of any type of goods as well as to make all kinds of statistics about volumes and types of transported goods. The added value brought by the use of this technology becomes peculiar when dangerous or perishable goods are processed.

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Using this technology some RFID-reader-equipped posts have to be installed in strategic places of the IFV area in order that incoming lorries can be identified as well as their load. According to a suitable parking plan where each incoming lorry has got its assigned parking lot, it is possible to retrieve all information in real time and through magnetic sensors it will be possible to know whether the allotted parking space has been occupied from the assigned vehicle.

7.3 Magnetic Sensors

These devices can be used in conjunction with the RFID technology as far as vehicles parking areas are concerned. They will be installed in each numbered parking slot (or bay) and will be part of a magnetic sensors network directly connected to the IFV Communication Management Centre.

It is possible to have a digital map of the parking space area where each bay can assume different colours according to the occupancy status:

- green, free bay
- yellow, booked bay
- red, occupied bay by booked vehicle
- flashing red, occupied bay by not booked/wrong vehicle

IFV Control Room operators will promptly check the situation through the CCTV Pan-Tilt-Zoom video-cameras controlling the parking space area.

7.4 CCTV (Closed Circuit TeleVision)

In such a huge area as an Inter-modal Freight Village is laid on, surveillance is of paramount importance so the creation of a dense network of video-cameras will be realised.
Some of them can also have an Automatic Number Plate Recognition (ANPR) feature that it could be used for the IFV gates access control and IFV parking space areas.

All signals coming from the CCTV video-cameras will be conveyed to the Control Room where operators will promptly react when some irregularities will be detected.

7.5 ICT (Information and Communications Technologies)

This field involves a huge number of technologies ranging from pure telecommunications to data processing and storage units.

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The former regards both wired and wireless communications to ensure a communications mesh able to cover every corner of the IFV allowing everybody (indoor and outdoor) to send data and make phone calls with any kind of device.
The latter deals with data processing units that must have high computing capacity and data storage units that must have huge memory size, redundant data storing techniques and a high-level security protection.

8. BENEFITS OF INTRODUCING "ITS" APPLICATIONS TO IFV

As listed above, the IFV Control Centre has to accomplish and control a lot of tasks in the same time unit. That's why ITS and advanced technologies such as Closed Circuit TeleVision (CCTV) video-cameras networks and Radio Frequency Identification (RFID) give a remarkable added value to the IFV management.
Final goal of installing ITS applications in Inter-modal Freight Villages is to reduce waiting times of all means of transport going to/leaving from a specific IFV thank to electronic management of several duties included bureaucratic papers processing. Therefore, major benefits introduced by ITS applied to IFV activities are:

- Optimisation of the number of means of transport utilised in the logistic chain
- Time saving
- Cost saving
- Less congestion
- Respect of environment

In figure 5 and 6 flow charts reporting the cause-effect relationships are displayed. IFV sub-centres where ITS applications are introduced are in blue, IFV activities are in black upper case characters, cause-effect relationships are in black lower case characters and benefits introduced by ITS applications to the transportation chain are in red lower case characters.

Last, but not least, benefit is the:

- Increased Level of Security

concerning means of transport (mainly HGVs) and freight while both on-trip and within the IFV area. As ITS could be seen as more oriented to ensure security to vehicles and freight, ICT could be identified as ensuring security to communications infrastructures and data processed and stored.

As ITS are interconnected to ICT, the result is a global increase of security over the whole freight transport chain.

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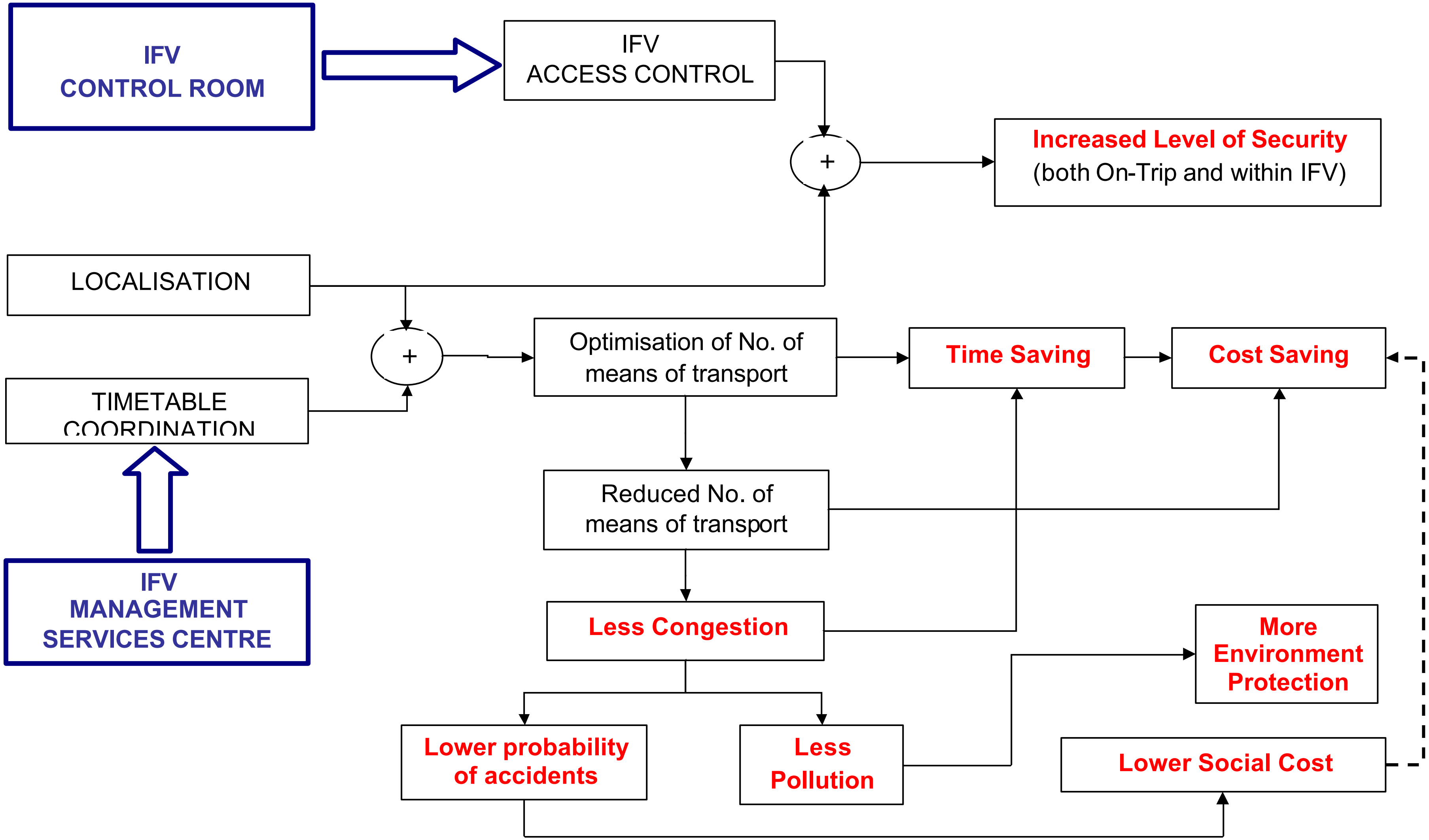

Figure 5 – Simplified scheme of benefits introduced by ITS applications to IFV (1/2)

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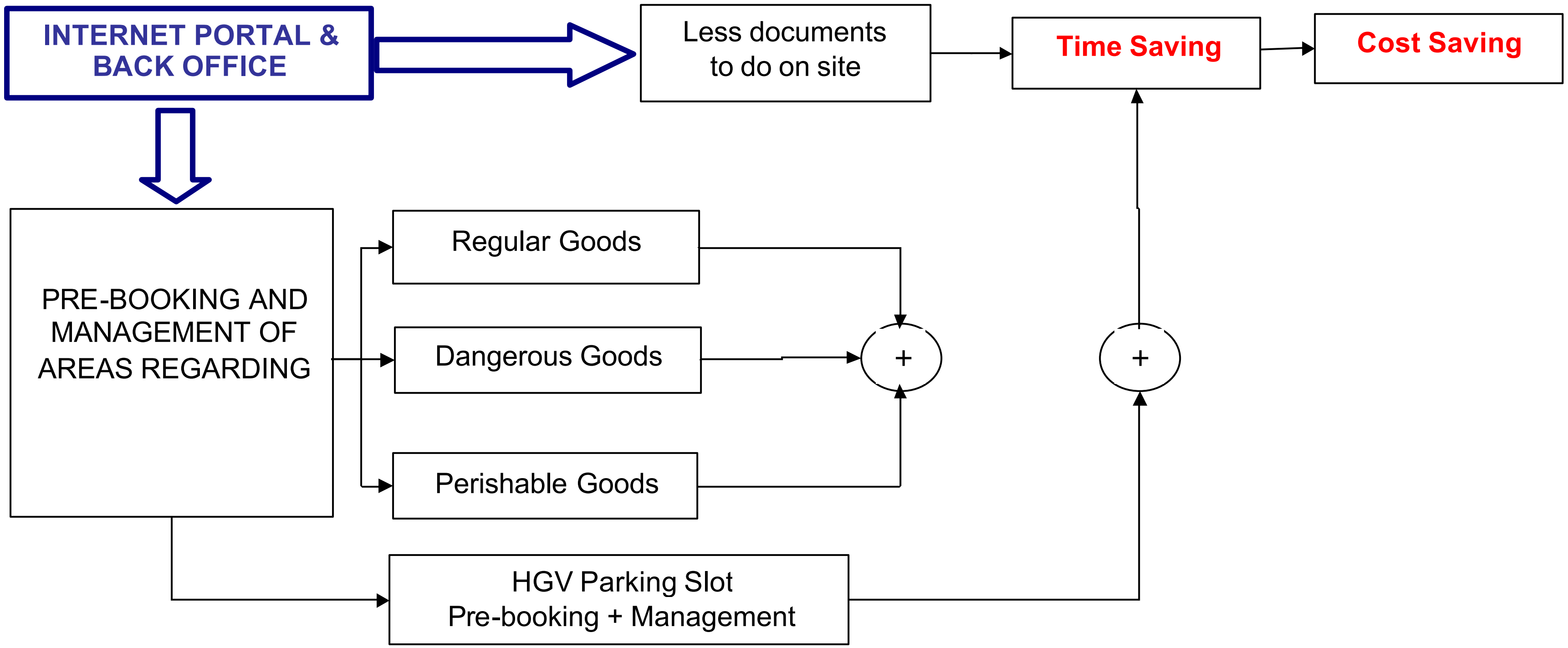

Figure 6 – Simplified scheme of benefits introduced by ITS applications to IFV (2/2)

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9. CONCLUSIONS

In Europe there is a number of very good experiences of ITS applications applied to freight transport and management.
Nearly all major forwarders companies have got their HGV fleets satellite-controlled and managed by Control Rooms. Some other companies have equipped their carriers with handheld devices which not only transmit in real time all performed actions (good delivered, not delivered, rejected, etc.) but also the consignee's signature. So tracking and tracing the good-to-be-delivered itinerary is now possible from the forwarder's side as well as from the sender's side.

As described in this paper, ITS technologies can also bring a relevant benefit to Inter-modal Freight Villages where concrete results were measured about the improvement of the Quality of Service offered to haulers companies and time saved during inter-modal operations. The future trends will envisage standardisation of ITS solutions categorised by IFVs size in order that, at least at European level, haulers will find same kind of service whichever IFV of destination.

10. USEFUL LINKS

Centros de Transporte intermodal - Spain
http://www.centrosdetransporte.com/def_int.htm

CILT – Chartered Institute of Logistics and Transport - UK
http://www.ciltuk.org.uk/pages/home

EIA – European Inter-modal Association
http://www.eia-ngo.com/

EIRAC – European Inter-modal Research Advisory Council
http://www.eirac.net/

EURIFT – European Reference Centre for Inter-modal Freight Transport
http://www.eurift.net/en/index.html

FIATA – International Federation of Freight Forwarders Associations
http://www.fiata.com/

GSM-R – GSM for Railways
http://gsm-r.uic.asso.fr/specifications.html

Inter-modal Freight Villages in Europe
http://www.freight-village.com/

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Inter-modal Freight Villages in Italy
http://www.interporto.it/

IRU – International Road transport Union
http://www.iru.org/

Logistics – European Commission/Transport
http://ec.europa.eu/transport/logistics/index_en.htm

Logistics in Germany
http://www.invest-in-germany.de/en/research/logistics/

Network of National ITS Associations
http://www.itsnetwork.org/

UIRR - International Union of combined road-rail transport companies
http://www.uirr.com/

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NOTES

[1] Combined Transports (CT) are usually classified as Accompanied (ACT) and Unaccompanied (UCT).The former identifies the complete lorry loaded onto special wagons (this operation is called "horizontal loading") whereas the lorry driver travels in a reserved wagon-lit. One advantage of adopting this solution consists of having a relaxed lorry driver according to specific national laws (a number of rest hours are compulsory after a specific number of travelling hours). Another advantage is that this solution does not require particular loading/unloading techniques nor highly-equipped logistic terminals. Briefly, this solution is suitable for short-range, mid-range trips (from 200 to 400 km) (124 to 248 miles).

The latter is the most efficient technique to integrate roads and railways. This integration increases the enterprises productivity and their transport capacity. Moreover, it creates beneficial effects on the social system as regards the reduction of pollution and roads congestion. The units of UCT loading are the semi-trailers with pliers and mobile case which are vertically moved by a crane. These units allow the door-to-door service covering the longest central trip stretch by train and the shortest stretches by lorry.

[2] Different technologies for mobile communication are listed below (where G stands for Generation)

Acronym	Acronym explanation	known as
HSDPA	High Speed Downlink Packet Access	3.5G
UMTS	Universal Mobile Telecommunications System	3G
EDGE	Enhanced Data rate for Gsm Evolution	2.75G
GPRS	General Packet Radio Service	2.5G
GSM	Groupe Spéciale Mobile, better known as Global System for Mobile comms	2G

[3] RAID (Redundant Array of Independent Disks) is a way of storing the same data in different places (thus, redundantly) on multiple hard disks. By placing data on multiple disks, I/O operations can overlap in a balanced way, improving performance. Since multiple disks increases the mean time between failure (MTBF), storing data redundantly also increases fault-tolerance. A RAID appears to the Operating System to be a single logical hard disk.
RAID employs the technique of "striping", which involves partitioning each drive's storage space into units ranging from a sector (512 bytes) up to several megabytes. The stripes of all the disks are interleaved and addressed in order. In a single-user system where large records, such as medical or other scientific images, are stored, the stripes are typically set up to be small (perhaps 512 bytes) so that a single record spans all disks and can be accessed quickly by reading all disks at the same time.
In a multi-user system, better performance requires establishing a stripe wide enough to hold the typical or maximum size record. This allows overlapped disk I/O across drives.

There are several types of RAID (Standard and Nested levels) plus a non-redundant array (RAID-0):
Standard RAID levels

- RAID-0. This technique has striping but no redundancy of data. It offers the best performance but no fault-tolerance.
- RAID-1. This type is also known as *disk mirroring* and consists of at least two drives that duplicate the storage of data. There is no striping. Read performance is improved since either disk can be read at the same time. Write performance is the same as for single disk storage. RAID-1 provides the best performance and the best fault-tolerance in a multi-user system.
- RAID-2. This type uses striping across disks with some disks storing error checking and correcting (ECC) information. It has no advantage over RAID-3.
- RAID-3. This type uses striping and dedicates one drive to storing parity information. The embedded error checking (ECC) information is used to detect errors. Data recovery is accomplished by calculating the exclus ive OR (XOR) of the information recorded on the other drives. Since an I/O operation addresses all drives at the same time, RAID-3 cannot overlap I/O. For this reason, RAID-3 is best for single-user systems with long record applications.
- RAID-4. This type uses large stripes, which means you can read records from any single drive. This allows you to take advantage of overlapped I/O for read operations. Since all write operations have to update the parity drive, no I/O overlapping is possible. RAID-4 offers no advantage over RAID-5.
- RAID-5. This type includes a rotating parity array, thus addressing the write limitation in RAID-4. Thus, all read and write operations can be overlapped. RAID-5 stores parity information but not redundant data (but parity inform ation can be used to reconstruct data). RAID-5 requires at least

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three and usually five disks for the array. It's best for multi-user systems in which performance is not critical or which do few write operations.

- RAID-6. This type is similar to RAID-5 but includes a second parity scheme that is distributed across different drives and thus offers extremely high fault- and drive-failure tolerance. There are few or no commercial examples currently.

Nested RAID Levels (numbers must be read as sum of two digits, i.e. 10 is not ten but 1+0)

- RAID-10. This type offers an array of stripes in which each stripe is a RAID-1 array of drives. This offers higher performance than RAID-1 but at much higher cost.
- RAID-51 (or 53). This type offers an array of stripes in which each stripe is a RAID-3 array of disks. This offers higher performance than RAID-3 but at much higher cost

More information concerning Nested RAID levels can be found at http://en.wikipedia.org/wiki/Nested_RAID_levels

[4] RFID systems are classified according to the range of frequencies they operate:

- Low-Frequency (LF) RFID (30 kHz to 500 kHz), which have short transmission ranges (generally less than 2 meters)
- High-Frequency (HF) RFID systems (13.56 MHz), which are widely for non-contact smart payment and credit cards
- Ultra High-Frequency (HF) RFID systems (850 MHz to 950 MHz), which offer longer transmission ranges (more than 25 meters). This kind of RFID are widely used in logistics such as pallet and shipping containers tracking
- Super High Frequency (SHF) RFID systems (Giga Hertz) used for long range access control for vehicles. They could be used for IFV Gate In / Gate Out procedures

In general the higher the frequency the more expensive the system

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