CBA and CEA on developed applications

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<td>A</td>
<td>Activity</td>
</tr>
<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
</tr>
<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
</tr>
<tr>
<td>C2C</td>
<td>Car to Car</td>
</tr>
<tr>
<td>C2I</td>
<td>Car to Infrastructure</td>
</tr>
<tr>
<td>CB</td>
<td>Cost Benefit</td>
</tr>
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<td>CBA</td>
<td>Cost Benefit Analysis</td>
</tr>
<tr>
<td>CC</td>
<td>Control Centre</td>
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<td>CEA</td>
<td>Cost Effectiveness Analysis</td>
</tr>
<tr>
<td>CI</td>
<td>Consistency Index</td>
</tr>
<tr>
<td>D</td>
<td>Deliverable</td>
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<tr>
<td>DGV</td>
<td>Dangerous Good Vehicle</td>
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<tr>
<td>DSS</td>
<td>Decision Support System</td>
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<tr>
<td>I2C</td>
<td>Infrastructure to Car</td>
</tr>
<tr>
<td>IO</td>
<td>Infrastructure Operator</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
</tr>
<tr>
<td>IVIS</td>
<td>In-Vehicle Information Systems</td>
</tr>
<tr>
<td>LC</td>
<td>Logistic Company</td>
</tr>
<tr>
<td>LN</td>
<td>Local Node</td>
</tr>
<tr>
<td>MCDC</td>
<td>Multicriteria Decision Making</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>OBU</td>
<td>Onboard Unit</td>
</tr>
<tr>
<td>OBU</td>
<td>On Board Unit</td>
</tr>
<tr>
<td>PBP</td>
<td>Pay Back Period</td>
</tr>
<tr>
<td>QoL</td>
<td>Quality of Life</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths-Weaknesses-Opportunities-Threats</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic Management Centre</td>
</tr>
<tr>
<td>V2V</td>
<td>Vehicle to Vehicle</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Messages Sign</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
</tr>
<tr>
<td>WTH</td>
<td>Willingness to Have</td>
</tr>
<tr>
<td>WTP</td>
<td>Willingness to Pay</td>
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Executive Summary

The current Deliverable, entitled D9.3: “CBA and CEA on developed applications”, is prepared in the context of WP9: “Dissemination and Exploitation” of the GOOD ROUTE project.

It presents the results of the Cost Benefit Analysis and the Multicriteria analysis. Both analyses have been based on the Business Cases identified for GOOD ROUTE project.

Starting with a description of the implementation of the scenarios, the application scenarios are being introduced as well as deployment and quantitative assumption scenarios.

The system modules and related costs are being analysed in means of investment, operation and maintenance costs in a next step.

In chapter 4 Operation efficiency impacts, are being described. Therefore, an overview of the GOOD ROUTE DSS functionalities is given. A focus is being placed also on passport sensitive infrastructure scenario evaluation, in which the GOOD ROUTE benefits to a DG transport in the Alpine region are being visualized. This use-case demonstrates the system opportunities towards daily operations in means of trip optimization due to the GOOD ROUTE passport.

One central part of this Deliverable is the CBA. The Cost Benefit Analysis allows to evaluate the GOOD ROUTE system impacts in economic terms. Therefore benefit-assumptions have to be adopted as basis for the GOOD ROUTE CBA. Benefit-assumptions and system module costs are being analysed in the following CBA. Main outcome of the CBA is the fact, that with respect to the made assumptions, several assumption setups can be identified, which return a positive benefit ratio.

The multicriteria analysis is focusing mostly on the assessment of GOOD ROUTE expected impacts from more generic socioeconomic aspects.

A SWOT (Strenghts-Weaknesses-Opportunities-Threats) analysis closes the Deliverable.
1 Introduction

The methodology for performing the CBA analysis will be defined, employing various indexes, such as Internal Rate of Return (IRR), Pay Back Period (PBP), Net Present Value (NPV), etc. CBA a priori and a posteriori questionnaires will be developed, focusing on issues such as users and experts Willingness To Have (WTH) regarding the proposed applications and Willingness To Pay (WTP) for them. A set of business oriented criteria and appropriate methodology for CEA will be selected. Relevant questionnaires for socio-economic data gathering, including data for SWOT analysis and intangible benefits and costs estimation will be prepared. The Analytical Hierarchy Process (AHP) multicriteria analysis will be introduced as a basis for incorporating expert-based priorities into the CEA.

The main objectives of this Deliverable are to identify costs and benefits of the GOOD ROUTE System and provide a cost benefit analysis which allows to value the effects of GOOD ROUTE in economic terms as well as to identify factors which have a strong impact on the economic performance of such a system.

In view of the GOOD ROUTE System and the available data and resources to identify economic effects, a simplified methodology is used which uses quantitative and qualitative economic approaches as well as scenario techniques to achieve the objectives.

At the beginning (Chapter 2) we recall the GOOD ROUTE Application scenarios (i.e. functions which are delivered by the system) and deployment scenarios (i.e. combinations of actors/roles which offer/use such functions) which also provide the economic context (voluntary and demand driven, infrastructure operator driven or regulation driven) in which they could occur. As most likely scenario the “Operation by specific IO’s for voluntarily use by LCs” is further pursued and a quantitative scenario is developed which allows alteron to estimate overall deployment costs for the system on the infrastructure operator side as well as for the involved truck fleet operators.

In a second step, investment, operation and maintenance cost all major system components are given, which are the basis for direct/internal economic cost of the system (Chapter 3).

Since the impacts and effects of the system are diverse and complex, a SWOT Analysis is made which identifies in a qualitative way key factors for system deployment (Chapter 6). In a separate chapter the specific benefits in particular for accident risk reduction from the GOOD ROUTE system are provided by the means of few examples (chapter 4), since no general assessment is possible within the means of this project.

Finally, a cost benefit analysis is made which uses those elements only, which are quantifiable for the system: system cost on the one hand and Logistic Company benefits in terms of time and operation benefits on the other. No external effects are taken into account (chapter 5).
2 Implementation Scenarios

The following application scenarios constitute the basic real-life case studies of GOOD ROUTE embedding its core functionalities (minimum risk route planning, guidance, monitoring, re-routing, incidents notification, priority passage and enforcement/emergency).

There are three application scenarios analysed below, aiming to clarify basic operational conditions and modalities of the system, which are necessary for the cost / benefit estimates to follow in the current Deliverable:

- Application Scenario 1: Minimum Risk Routing & Monitoring
- Application Scenario 2: Passport for Infrastructure Passage
- Application Scenario 3: Efficient enforcement of legal compliance

After the presentation of the above application scenarios, the potential of their deployment according to the standing business cases (hereby called deployment scenarios) is discussed in section 2.2.

2.1 Application scenarios

2.1.1 Application Scenario 1: Minimum Risk Routing & Monitoring

Current flow: A logistics company of a dangerous goods (DG) vehicle is planning and operating its trip. Depending on its characteristics it is not allowed to pass certain areas and infrastructure objects. It therefore plans its route depending on the operators’ knowledge of accessibility and/or refers to police/road authority support for trip planning. Once the route is planned, the driver operates the tour on the chosen route. If any events (e.g. traffic jam) occur, the vehicle driver either is stuck in the event, or has to deviate onto other roads, which may not be allowable or foreseen for such use.

GOOD ROUTE flow: The Logistics Company uses the GOOD ROUTE Portal for route planning for a specific vehicle/load and trip. It thereby receives a route planning in compliance with public authority/infrastructure operator restrictions for DG. The vehicle/load and the route are therefore known to the infrastructure operator in advance.

With the start of the trip, the driver starts its route guidance system and thereby activates the route for monitoring at the service centre. The trip is recalculated with the current traffic information and an up-to-date time of arrival is calculated. The driver is guided along the minimum risk route. In case of an event, the Control Centre (CC) logic monitoring the trip, can alert the vehicle/driver and directly propose a routing alternative in line with DG restrictions and minimal risk. A recalculated time of arrival is provided. The Logistic Company (LC) is informed and can reschedule the tour if necessary.

Functions
Following functions are operated by the GOOD ROUTE System in this scenario:

- minimum risk route planning (pretrip) (LC, CC)

---

1 We thereby assume, that not only risk but also legal restrictions are included in the DSS route optimisation process.
- route guidance (on-trip) (Driver)
- route monitoring and alert (CC, LC)
- minimum risk route re-routing (due to event and/or tour rescheduling) (LC)

The IO (Infrastructure Operator) would not directly be involved in this scenario. This scenario would usually be combined with the infrastructure passport scenario and/or enforcement scenario, where the IO/Police could be directly involved during the supervision of the trip.

Components involved:
- GOOD ROUTE Control Centre, DSS-for trip planning
- OBU & routing client- for route guidance and monitoring

<table>
<thead>
<tr>
<th>Actor</th>
<th>Relevant Costs</th>
<th>Relevant Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>• Investment costs (related to routing client and OBU and subscription to service, if own contractors)</td>
<td>• Lower accident risk&lt;br&gt;• Increased comfort (much less unexpected events and delays)&lt;br&gt;• Increased overall security of the trip (routing and re-routing, as provided by the Logistics Company, will ensure more adequate parking places and itineraries)&lt;br&gt;• Reduced stress; transit of responsibilities to the Logistic Company</td>
</tr>
<tr>
<td>LC</td>
<td>• Control Centre subscription and maintenance costs (for the service, the maps, …)&lt;br&gt;• Vehicles’ OBU’s and routing clients&lt;br&gt;• Higher operational costs and time delays (since there is possibility for prolonged route)</td>
<td>• More reliable tour planning and Estimated Time of Arrival (ETA), which implies better planning of the overall logistic chain and strengthening of the company profile (higher reliability)&lt;br&gt;• Early information on any type of obstacles ahead (monitoring &amp; alert)&lt;br&gt;• Continuous monitoring or the trip and increased compliance with law/rules: reduced fines, reduced drivers’ misbehaviour</td>
</tr>
<tr>
<td>External effects (Society)</td>
<td>• If the minimum risk route leads to increased trip length</td>
<td>• Lower accident risk (also for third party population)&lt;br&gt;• Lower risk for large-scale</td>
</tr>
</tbody>
</table>
Table 1: Application scenario 1 – Minimum Risk Routing & Monitoring (outside specific infrastructure)

2.1.2 Application Scenario 2: Passport for Infrastructure Passage

Current Flow: A LC plans a route for its DG vehicle/load, which would pass a critical infrastructure (tunnel, bridge) with restricted access.
- Option 1: passage not allowed: the LC has to plan alternative routes, usually involving significantly longer routes.
- Option 2: passage allowed, but only with special precautionary measures (escorting), taking significantly more time than usual.

GOOD ROUTE Flow: The DG vehicle (or the Logistic Company) plans the route via the GOOD ROUTE portal and, if applicable (according to the results of the Minimum Risk Route Guidance), requests for approval for passage through the critical infrastructure (i.e. tunnel, bridge, etc.). The IO either denies passage (leading to option 1 normal flow) or grants passage through the GOOD ROUTE portal (authorised part for the IO), leading to a GOOD ROUTE conform workflow for infrastructure passage.

In the first case, the minimum risk route guidance for the planned route is activated (identical to scenario 1). In the second case, the IO is able to identify in due time the vehicle, that has obtained passage approval and provide priority.

The most of the characteristics of each transport operation are verified in advance, from the time of passage request and the approval is provided upon the approval from the IO. However, as soon as the vehicle enters the control area of the enforcement node (local node is the specific case study in GOOD ROUTE), which covers the critical infrastructure surrounding area, the vehicle/load status is once again automatically verified (though the GOOD ROUTE enforcement system) upon the thresholds defined for the specific infrastructure (thresholds are regulated upon the local policies in each case); thus there is no need for escorting measures as in normal flow. Vehicles with alarms are separated for further check and vehicle without alarms can pass without disturbance, as scheduled, according to the priority rules set for this case by the IO. Further functionality is detailed in the following enforcement scenario.

Given the above, the passage through the infrastructure itself is expected to take less time and to be safer than without GOOD ROUTE.

Functions
Following functions are operated by the GOOD ROUTE System in this scenario in addition to Scenario 1:
- passport for infrastructure passage– LC, IO, (CC)
- Control Centre (Portal) – vehicle status monitoring (by police)
- automatic control (of vehicle compliance with rules) and enforcement – enforcement entity
- prompt/safe infrastructure passage - IO

**Components involved:**
- GOOD ROUTE Control Centre, DSS-for trip planning, passport
- Enforcement nodes, OBU & on-board driver HMI – for enforcement check
- OBU & routing client- for route guidance and monitoring

In addition to the relevant costs and benefits of Table 1 which apply also here with regard to the part of route planning, guidance and monitoring, the following table presents the additional costs and benefits related to the passport functionality in specific.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Relevant Costs</th>
<th>Relevant Benefits</th>
</tr>
</thead>
</table>
| Driver | As in Table 1 & upgrade of sensorial system if own contractor (for the enforcement functionality, which applies mainly for the following scenario). | • Additional reduction in unexpected delays due to the priority asset of the “passport” functionality.  
• Lower possibility for penalties for noticed violations (due to the in-advance check on planning phase pending the issue of “passport”).  
• Shorter, safer and more comfortable trips (in case wide deviation around special infrastructure is not necessary). |
| LC    | As in Table 1 & upgrade of sensorial system of the truck fleet (for the enforcement functionality, which applies mainly for the following scenario). | • Shorter, safer and more comfortable trips (in case wide deviation around special infrastructure is not necessary), which imply less accidents (fatigue related), less operational costs (shorter trips implying fuel and time savings), more attractive profile (less accidents; less delays; IT systems adopter), less costs due to penalties (in-advance enforcement). |
| IO    | System investment costs (subscription to the service).  
Enforcement costs (for enforcement nodes). | • Less resources spent for vehicles “escorting”.  
• Lower possibility for damage to the infrastructure (due to the in-advance check on planning phase pending the issue of “passport” and also the real-time enforcement check before entering the infrastructure). |
### Actor Relevant Costs Relevant Benefits

<table>
<thead>
<tr>
<th>Actor</th>
<th>Relevant Costs</th>
<th>Relevant Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>External effects (Society)</td>
<td>• It depends which is the actor that pays for the subscription to the GOOD ROUTE service (both for passport and enforcement). The relevant costs could be societal costs.</td>
<td>• Better planning, both on overall operation terms and emergency reaction plans (since they know in advance how many vehicles are expected and what they carry).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lower accident/incident risk which may lead to deaths, injuries, environmental and infrastructure damage (due to the in-advance check on planning phase pending the issue of &quot;passport&quot; and also the real-time enforcement check before entering the infrastructure).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Also, depending on deployment scenario: higher compliance rate /less rules violation and hence lower risk.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Less traffic side effects (due to avoidance of deviation routes).</td>
</tr>
</tbody>
</table>

Table 2: Application scenario 2 - Secured Infrastructure Passage.

#### 2.1.3 Application Scenario 3: Efficient enforcement of legal compliance

**Current Flow:** Several dangerous goods vehicles pass through a toll station of a highway, soon after which a long bridge or tunnel starts. The vehicles either pass through the bridge/tunnel or are sent by a RO-RO ferry to the other side, loosing far too much time. If the police decides to make checks it needs to stop all heavy trucks, to check their speed (through the speedometer on-board) and pass them through a specific infrastructure to measure the load per axle. It should also check the type of load carried, etc. The overall check time per vehicle is from 10-30 minutes. The expected rate of rules violation is roughly 7-10%.

**GOOD ROUTE Flow:** A police car is parked just before the toll station and receives the signals sent by the enforcement data from OBU/local node module. All trucks that have a total weight and a weight per axle that is less than a threshold and carry dangerous goods that do not fall into certain types are allowed to cross the specific infrastructure, without the normal flow escorting measures. The rest few have to use the RO-RO ferry. The few ones for which a violation is self-reported are stopped at the toll station and fined. The necessary checks are less than 1/10 than before and every stopped vehicle is fined.

As aforementioned, the thresholds defined for each specific infrastructure are regulated upon the local policies in each case.

The following functions are operated by the GOOD ROUTE System in this scenario:
- automatic control (of vehicle compliance with rules) and enforcement – enforcement entity

**Components involved:**
- Control Centre (Portal) – vehicle status monitoring (by police and by I/O)
- Enforcement nodes, OBU & on-board driver HMI – for enforcement functionality

The following table presents the additional costs and benefits related to the automatic enforcement functionality.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Relevant Costs</th>
<th>Relevant Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>As in Table 1 &amp; upgrade of sensorial system if own contractor for the enforcement functionality.</td>
<td>• Passage through infrastructure (if approved to pass), leading to shorter, safer and more comfortable trips&lt;br&gt;• Lower time for passage, since there are fewer possibilities for enforcement control, and if there are any, are more targeted; in any other case, passage is automatic.&lt;br&gt;• Compliance with rules; reduced stress for penalties.</td>
</tr>
<tr>
<td>LC</td>
<td>As in Table 1 &amp; upgrade of sensorial system of the truck fleet for the enforcement functionality.</td>
<td>• Higher potential for shorter, safer and more comfortable trips (in case wide deviation around special infrastructure is not necessary), which imply less accidents (fatigue related), less operational costs (shorter trips implying fuel and time savings), more attractive profile (less accidents; less delays; IT systems adopter), less costs due to penalties (awareness for automatic enforcement).&lt;br&gt;• Equipped vehicles are exempt from manual controls if are compliant with regulations, which imply less delays (cost-related) related for trucks.</td>
</tr>
<tr>
<td>Police</td>
<td>System investment costs (subscription to the service).&lt;br&gt;Enforcement costs (for enforcement nodes), if this is the actor responsible for this.</td>
<td>• More prompt and efficient enforcement on reduced number of vehicles.&lt;br&gt;• Smaller effort from enforcement personnel for performance of daily tasks; raised productivity.</td>
</tr>
<tr>
<td>IO</td>
<td>System investment costs (subscription to the service).&lt;br&gt;Enforcement costs (for enforcement nodes), if this is the actor responsible for this.</td>
<td>• Less resources spent for vehicles “escorting”.&lt;br&gt;• Lower possibility for damage to the infrastructure (due to the real-time enforcement check before entering the infrastructure).</td>
</tr>
</tbody>
</table>
GOOD ROUTE Deliverable 9.3

Actor | Relevant Costs | Relevant Benefits
--- | --- | ---
responsible for this. | • More gain, since the possibility of accepting more vehicles is increased. | infrastructure.

External effects (Society) | Enforcement costs (for enforcement nodes), if this is the actor responsible for this. | • Lower accident/incident risk which may lead to deaths, injuries, environmental and infrastructure damage (due to the real-time enforcement check before entering the infrastructure).
• Also, depending on deployment scenario: higher compliance rate /less rules violation and hence lower risk.
• Less traffic side effects (due to avoidance of deviation routes).

Table 3: Scenario 3-efficient enforcement.

2.2 Deployment scenarios

There are three main Business Cases (deployment scenarios), envisaged currently for the GOOD ROUTE market penetration:

- Deployment Scenario 1: Voluntarily use for internal purposes.
- Deployment Scenario 2: Voluntarily use with additional benefits.
- Deployment Scenario 3: Mandatory use.

2.2.1 Deployment Scenario 1: Operation for LC’s internal purposes

In this case, a GOOD ROUTE system is implemented by a (group of) Logistic Company(s) to facilitate planning and monitoring of dangerous goods transports. It is adopted (on a voluntary basis) as an enhanced safety measure, to improve the efficiency and reduce the cost of the operation.

The GOOD ROUTE system can be conceived as a specialisation of client server systems for integrated tour planning, server guided\(^2\) truck navigation and monitoring, of which maps are extended for Dangerous Goods features and minimum risk evaluation algorithms.

Infrastructure operators have no or only a limited role in this scenario, being not the prime initiator of the system they might collaborate supplying up to date information on travel/passage times and events, as well as other details as far as in their interest and benefit from some knowledge on the specific trips of the DG vehicles monitored by the system.

\(^2\) The route is determined in the service centre (equivalent to GOOD ROUTEs Control Centre) and transferred to the navigation client.
Market penetration is expected to remain low (only large hauliers to be involved in otherwise private operation).

Application scenarios which may be deployed under this scenario:
- Minimal Risk routing & monitoring
- To a very limited extent: passport of infrastructure passage

![Figure 1: Value chain for deployment scenario 1.](image)

### 2.2.2 Deployment Scenario 2: Operation by specific IO’s for voluntarily use by LCs

In this case, the GOOD ROUTE system will be introduced by specific infrastructure operators in order to manage access or give priority of access or guarantee fast access (without escorting) or reduced fees, etc. The adoption of the system is voluntary and will be undertaken by selected transporters and dispatchers, of high volumes. The more infrastructure operators adopt such a (harmonised) system the more attractive it will become for transporters/dispatchers to adopt such a system.

As for Deployment scenario 1, the GOOD ROUTE system can be conceived as a specialisation of client server systems for integrated tour planning, server guided\(^3\) truck navigation and monitoring, of which maps are extended for Dangerous Goods features and minimum risk evaluation algorithms. In addition, OBUs (providing vehicle status information as well as billing functionalities) are supplied to DG LC as truck equipment and local node equipment is implemented at the infrastructure for vehicle status monitoring and enforcement support.

\(^{3}\) The route is determined in the service centre (equivalent to GOOD ROUTE’s Control Centre) and transferred to the navigation client.
A gradual market penetration is foreseen comparable e.g. to the introduction of automated tolling at Brenner or on French motorways, but focused on DG vehicles, which may choose to equip their vehicles and use GOOD ROUTE procedures (or continue without). The volume and growth is directly related with the number and the importance of the infrastructure operators involved.

All application scenarios may be deployed in this case:

- Minimal Risk routing & monitoring
- Secured (Safe) infrastructure passage
- Efficient enforcement of legal compliance may only implemented in a limited way, i.e. those vehicles equipped with OBU’s may be exempt from manual controls and may be offered more rapid processing (as incentive for GOOD ROUTE system use)

Figure 2: Value chain for deployment scenario 2.

### 2.2.3 Deployment Scenario 3: Mandatory use
GOOD ROUTE is introduced by specific infrastructure or for whole areas/countries as mandatory for all ADR vehicles or some classes of them.

The system is equivalent to that in Deployment Scenario 2, though extended for enforcement features.

Fast market penetration is expected in this case (from 50% to 100%, depending upon the type of law restrictions; i.e. local vs. national).
Scenarios/functions which may be deployed under this scenario:
- Minimal Risk routing & monitoring
- Passport for infrastructure passage
- Efficient enforcement of legal compliance

The value chain is very similar to Scenario 2.

Figure 3: Value chain for deployment scenario 3.

### 2.3 Quantitative Scenario Assumptions

In the following analysis of cost and benefits, the focus will be put on Deployment Scenario 2 for the following reasons:
- this introduction scenario driven by one or few Operators of critical infrastructure objects (tunnel, bridges) is considered the most likely;
- it implements a full GOOD ROUTE System and all major system components and functionalities.

In order to better be able to estimate investment cost for specific components, and in order to calculated economic benchmark values for the GOOD ROUTE system, some quantitative assumption on the introduction scenario need to be made.
2.3.1 Infrastructure and vehicle fleet assumptions

We assume that with one Control Centre installation one or more Infrastructure objects can be managed, as it is the case for the GOOD ROUTE Demonstrator.

As depicted in Figure 4, we assume that an origin and a destination area of (dangerous goods) are connected by a number of passages, which contain critical infrastructures. The more passages/critical infrastructures subscribe to the GOOD ROUTE scheme, the higher the share of vehicles in the total vehicle fleet ‘captured’ by the scheme is.

The number of passages per vehicle in a GOOD ROUTE site is increasing with the number of GOOD ROUTE sites and the share the bypassing traffic is consequently diminishing. Table 4 provides the quantitative assumptions on the DG vehicle fleet and passages in relation to the number of GOOD ROUTE sites participating. The quantitative assumptions made are inspired by figures provided by the Frejus tunnel site (Partner SITAF in GOOD ROUTE) on dangerous goods traffic at their site.

Figure 4: Origin and destination area, of which the critical infrastructures/passages are increasingly covered by GR Infrastructure management (top: one site participating in GOOD ROUTE Scheme, lowest, five sites participating).
The total fleet number in the area is assumed to be 25000 vehicles. Furthermore it is assumed, that each year, 4500 vehicles are being equipped with the OBU GR system to depict the gradual introduction of the system. Additional it is supposed, that the number of equipped trucks can only reach 80% of the maximum reachable number of vehicles by the sites. Regarding a scenario of 3 sites, a number of 20000 vehicles can be reached, i.e. 18000 vehicles (80% of 20000) are going to be provided with an OBU.

Table 4: Scenario assumptions for DG fleet, infrastructure sites and passages.

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of sites</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>No of vehicles involved</td>
<td>15000</td>
<td>20000</td>
<td>22000</td>
<td>22500</td>
</tr>
<tr>
<td>passages covered by GOOD ROUTE passages</td>
<td>2,0</td>
<td>2,0</td>
<td>2,0</td>
<td>2,0</td>
</tr>
<tr>
<td>DG passages per year/site</td>
<td>30000</td>
<td>30000</td>
<td>30000</td>
<td>30000</td>
</tr>
<tr>
<td>passages per vehicle</td>
<td>2</td>
<td>3</td>
<td>4,1</td>
<td>5,3</td>
</tr>
<tr>
<td>total passages</td>
<td>30000</td>
<td>80000</td>
<td>132000</td>
<td>180000</td>
</tr>
<tr>
<td>Share in total passages</td>
<td>12%</td>
<td>32%</td>
<td>53%</td>
<td>72%</td>
</tr>
<tr>
<td>ratio of vehicles passages with changed route to normally passing vehicles</td>
<td>0,264</td>
<td>0,204</td>
<td>0,1416</td>
<td>0,084</td>
</tr>
</tbody>
</table>

Figure 5: Number of vehicles equipped with OBU – introduction.
3 System modules & cost analysis

3.1 OBU

3.1.1 Investment cost

The OBU is a hardware component which needs to be implemented into the truck infrastructure, e.g. apply all cable connections, mount OBU. Thus, investment costs per OBU unit consist of hardware and software investment costs as well as installation cost.

From analogy with similar systems, it can be assumed that the price range for the OBU hardware is 200 - 300€. Furthermore, mounting costs for the OBU are supposed to be within a range from 200 – 250€.

3.1.2 Operation cost

Costs for OBU operation are assumed negligible.

3.1.3 Maintenance cost

Costs for OBU maintenance are negligible. OBU software-updates are one within the standard scheduled truck service.

3.2 Local Node

3.2.1 Investment cost

In order to have an estimation of local node infrastructure unit it is necessary to consider two different scenario typologies, the infrastructure enforcement and the mobile enforcement.

The first is based on a fixed local node unit placed at the wayside of the highway.

Each site in which we can suppose to implement the infrastructure enforcement, then all strategic points as country frontiers, bridge, tunnel and so on, need to provide two local node units, ones for each road side direction.

The local node infrastructure costs depend on the following factors:

- Local node unit composed by:
  - DSRC unit
  - Antenna
  - Laptop PC
  - Mobile phone
- Insulate box in order to house the local node and in according to the highway law dispositions

The cost of the prototype local node unit used during the pilot tests has been expensive mainly because of the use of a pc-laptop instead of a specific hardware platform that could accomplish just to the enforcement specified task. The same is for the UMTS connection to Control Centre. A
mobile phone has been used, but it could be possible to have a device who includes a modem to manage this connection without make use of a mobile phone.

The total cost of the local node infrastructure used during the pilots can be round up to 1100€, it means that for each strategic point the cost should be on 2200€. The industrialization mass productions of this product could significantly lower the price cost since it is possible to realize a specify hardware smaller and with an adapted hardware minimizing the costs till roughly to 800 € for each strategic point.

3.2.2 Operation cost
The local node operational costs are substantially related to the internet connection that it must provide for Control Centre connection, in order to send it all trucks information in any time and to allow Control Centre responsible to update the local node policies every time it is required. The connection needs to be protected, quite fast and uninterrupted. The cost of connection will depend to the network company used and can be estimated round to 30 € per month.

3.2.3 Maintenance cost
The maintenance cost should be limited to a sporadlic but constant supervision of the local node unit in order to assure the correct functioning of the antenna and the others hardware device. A supplementary cost can also derive from the necessity to update some software configuration that is not directly accessible from the local node web service. The total maintenance cost can be round from 200€ to 400€ per year.

3.3 Routing client

3.3.1 Investment cost
The Routing Client is expected to be an existing business navigation which includes communication means. It includes a feature which allows ‘guided routing’, i.e. Routing and navigation along waypoints which are sent from a server. Similar applications are estimated to cost about 500€, but this cost is not accounted for, since the navigation service and benefit is considered outside the system boundaries.

3.3.2 Operation cost
The operation costs for the Routing Client are composed of cost for data communication and fees for the routing service. Taking into account, that a common data flat rate communication costs 5€ / month, total communication costs will be 60€ / year.

The GOOD ROUTE client application is expected to be a pay per use application, i.e. the user pays not a static fee per month, but for each route he calculates.

3.3.3 Maintenance cost
Maintenance costs are negligible due to the fact, that maintenance and updates are only done to the main business application.
3.4 **Portal/Control Centre**

It should be noted that the GOOD ROUTE Portal consists of the Control Centre, the DSS and the Conflict Resolution modules; thus the following costs include the respective costs of all participating modules.

3.4.1 **Investment cost**

The investment costs are costs for development, integration and testing the software. They amount to a total of 500,000€.

3.4.2 **Operation cost**

The system is being operated on 4 servers: 1 Frontend Server, 2 Backend Server, 1 Database Server.

Each server costs a hosting fee of 400€ / month. In these operation costs, map licences, map integration, DG content collection and training of staff are included. We assume that the needed personnel is available and saved otherwise by improved infrastructure operation efficiency, so the system is overall neutral in personnel.

3.4.3 **Maintenance cost**

As a typical rate for software maintenance costs, 20-30% of the investment is expected. Thus, the annual maintenance costs per unit will be 100,000€ / year. The amount of maintenance costs includes costs for regular software updates and content maintenance, e.g. DG content.

4 **Operation efficiency impacts**

4.1 **Impacts of different types of routes**

For every transport request, the GOOD ROUTE DSS can provide

i) the minimum economic cost route,

ii) the minimum risk route or

iii) the minimum combined cost route.

We will examine the impact that each of the aforementioned routes has on the route length, the route duration, the overall economic cost and the overall risk of the route.

In our example, a DGV carrying propane will start from point (8.57233, 47.2617), ending at point (8.38335, 46.96736), with an intermediate stop at point (8.41313, 47.107). The start, end and intermediate points are displayed in Figure 6. All points are in Switzerland.
The DGV is expected to reach its destination at 10:30 on 20/11/2008, as shown in Figure 7.

Figure 7: Dialog box of the Good Route simulator for the routing case in Switzerland.
The three different routes (minimum economic cost, minimum risk, minimum combined cost) are shown in Figure 8, Figure 9 and Figure 10 respectively. The weighting factor of the combined cost equals to 0.5.

Figure 8: Minimum economic cost route for the routing case in Switzerland.
Figure 9: Minimum risk route for the routing case in Switzerland.
In the table below, we can see the total distance, travel time, economic cost and risk of each of the three routes, as well as the difference of those values when compared with the corresponding values of the first route (minimum economic cost route).

<table>
<thead>
<tr>
<th></th>
<th>Minimum Cost</th>
<th>Minimum Risk</th>
<th>Difference %</th>
<th>Minimum Combined Cost</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>53,841</td>
<td>96,449</td>
<td>79,14%</td>
<td>57,076</td>
<td>6,01%</td>
</tr>
<tr>
<td>Travel Time</td>
<td>1:46:59</td>
<td>2:17:29</td>
<td>28,51%</td>
<td>1:52:32</td>
<td>5,19%</td>
</tr>
<tr>
<td>Cost</td>
<td>36,211717</td>
<td>58,629746</td>
<td>61,91%</td>
<td>37,952114</td>
<td>4,81%</td>
</tr>
<tr>
<td>Risk</td>
<td>49,023407</td>
<td>10,061643</td>
<td>-79,48%</td>
<td>15,857708</td>
<td>-67,65%</td>
</tr>
</tbody>
</table>

Table 5: total distance, travel time, economic cost and risk

In the case of the minimum risk route, the overall distance and the total economic cost are greatly increased (79,14% and 61,91%), while the total risk is almost equally decreased (79,48%). The travel time is also increased (28,51%) but not so much as the aforementioned values. Thus, the minimum risk route achieves the minimisation of the risk with the price of an equally big increment of the cost.
In the case of the minimum combined cost route, however, we experience a similarly big reduction of the total risk (67.65) with only a slight increment of the overall distance (6.01%), travel time (5.19%) and economic cost (4.81).

Therefore, we conclude that the minimum combined cost route is the optimal one, when we take into account the overall risk, as well as the business needs. It is also easier to be adopted by the interested parties than the more costly minimum risk route.

**GOOD ROUTE as a passport for sensitive infrastructure**

Nowadays, most DGVs are not allowed to pass through sensitive parts of the infrastructure, such as tunnels and bridges. In those cases, they are forced to follow big deviations, greatly increasing the cost of route, pollution and maybe even the overall risk. In this section, we will examine such an example, when a DGV is not allowed to pass through a restricted tunnel, while those restrictions wouldn’t apply to a similar DGV that makes use of the GOOD ROUTE system.

In our example, two DGVs carrying ammonia will start their journey from point (8.59464, 46.71109) to point (8.83106, 46.45424), at the same time. The first one does not use the GOOD ROUTE system, while the second does. The GOOD ROUTE equipped DGV is allowed to pass through the Gotthard Tunnel, while the other one is not. The restricted tunnel is displayed in yellow colour, in Figure 11.
We will compare the minimum cost route of the non-equipped DGV (Figure 12) to the minimum combined cost route of the equipped DGV (Figure 13). Due to the area being underpopulated, the two routes differ only in the restricted tunnel, which is part of the latter only, while the former follows a deviation around it.
Figure 12: Minimum cost route of the non-equipped DGV.
In the table below, we can see the total distance, travel time, economic cost and risk of each of the two routes, as well as the difference of those values when compared with the corresponding values of the first route (minimum combined cost route of the equipped DGV).

<table>
<thead>
<tr>
<th></th>
<th>Equipped DGV</th>
<th>Non-equipped DGV</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>44,282</td>
<td>56,938</td>
<td>28.58%</td>
</tr>
<tr>
<td>Travel Time</td>
<td>0:50:58</td>
<td>1:24:29</td>
<td>65.76%</td>
</tr>
<tr>
<td>Cost</td>
<td>26,397811</td>
<td>37,127104</td>
<td>40.64%</td>
</tr>
<tr>
<td>Risk</td>
<td>0.215229</td>
<td>0.623061</td>
<td>189.49%</td>
</tr>
</tbody>
</table>

It is obvious that the deviation which the non-equipped DGV is forced to follow has a very negative impact to all the observed values. The distance increases by 28.58%, the travel time by 65.76%, the total economic cost by 40.64% and the total risk by 189.49%.

From the above, we conclude that the use of the GOOD ROUTE system cannot only reduce the overall risk, but the total economic cost as well, when sensitive parts of the infrastructure are concerned.
5 Cost-Benefit-Analysis

This Cost-Benefit-Analysis is utilising a simplified approach. Only internal cost to GOOD ROUTE operation, i.e. cost incurred by the GOOD ROUTE Infrastructure Operator and/or the Logistic Company, is accounted for in the calculation. No societal cost and benefits are included within this cost benefit analysis, i.e. neither benefits resulting from reduced accident/risk, nor time savings due to reduced traffic jams and no reduced environment effects are being included.

Furthermore, no external benefits are taken into account; only internal benefits to the Logistic Company and the infrastructure operator are being used (Figure 14).

Necessary cost assumptions and input data are based on information given in chapter 3.

![Figure 14: System boundaries and cost and benefits accounted for in the CBA.](image)

5.1 Benefit assumptions

External/societal benefits, e.g. accident risk, environmental effect etc. are not used for this cost benefit analysis, only internal benefits to LC are used here.

The Logistic Company has to pay investment costs for equipping their trucks with hard and software. In daily operations, the Logistic Company has to pay on the one hand the system operation costs and on the other, it has to pay fees for using the service. In return, the Logistic Company benefits from the GR system in improved passage processing. Especially time cost savings for those trucks passing once they are equipped, resulting in a shortened trip length, fuel cost savings and operation cost savings due to simplified operations are main benefits of the GR system to the Logistic Company.
The shortened trip length for bypassing vehicles is a characteristic benefit of the GR system to the Logistic Company. Once a truck is equipped with GOOD ROUTE system, it is allowed to use the tunnel, where it is not allowed to pass without.

Assumptions concerning time costs, operation costs and fuel costs are based on the German CBA guidelines (Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen).

The Infrastructure Operator benefits from the system in matters of reduced passage processing costs, e.g. personnel and equipment costs, which are not accounted for in detail. We assume that the GOOD ROUTE system operation is neutral in personnel cost compared to current operations without. The Infrastructure Operator has to pay costs which result from Control Centre and Local Node investment, maintenance and operations.

### 5.2 Cost-benefit calculation

Main target of the CB analysis is to provide information, whether the investment is cost effective or not. Therefore, we calculate CB ratio as main information value. In case the returned CB ratio is >1, the system yields more benefits than it costs within the chosen time frame.

In case of a ratio <1, the system costs surpass the benefits. Cost and benefits during the time frame are ‘normalized’ to a net present value.

**Net Present Value (NPV)**

The Net Present Value of an investment is defined as the difference between the present values of its future cash inflows and outflows. This means that all annual cash flows should be discounted to the start time at a predetermined discount rate (discounted inflows minus discounted outflows for each one of the years of the evaluation period).

The evaluation period for the financial evaluation is selected to be 5 years. In our context we calculate a separate NPV for all negative cashflows (cost) and for all (monetarised) benefits.

The calculation of the NPV is given in the German CBA guidelines:

\[
NPV = \sum_{a=1}^{n} \frac{N_a}{(1+10^{-2} * p)^a}
\]

where:

- \(N_a\) = benefits in year \(a\)
- \(p\) = discount rate
- \(n\) = the number of years

In practice, several countries have an official agreed discount rate, which even it may not be theoretically precise, does have the advantage that all projects can be measured by the same benchmark. Typically these official discount rates fluctuate within an interval with 10 % as maximum and 3 % as minimum.
As an example, 1 € invested at 3% annual rate, will become 1+3% after 1 year;  
\[(1+3\%) \times (1+3\%) = 1.0609\] after 2 years;  
\[(1+3\%) \times (1+3\%) \times (1+3\%) = 1.0927\] after 3 years, etc.

Regarding the economic present value of 1 € that will be spend or gained 2 years later is 
\[1 / (1+3\%) \times (1+3\%) = 0.9426\].

### Calculation

For the GOOD ROUTE system, the CB is shown for 1 sample scenario, calculating 3 sites participating in the scheme (mid scenario in Table 4).

Respecting cost assumptions and input data given in chapter 3, all costs (investment, operation and maintenance) are listed for each involved partner in table 1 for the time interval of 5 years.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Centre</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>investment cost</td>
<td>500.000 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintenance cost</td>
<td>100.000 €</td>
<td>100.000 €</td>
<td>100.000 €</td>
<td>100.000 €</td>
<td>100.000 €</td>
</tr>
<tr>
<td><strong>Local Node</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>investment cost</td>
<td>6.000 €</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>operation cost</td>
<td>2.160 €</td>
<td>2.160 €</td>
<td>2.160 €</td>
<td>2.160 €</td>
<td>2.160 €</td>
</tr>
<tr>
<td>maintenance cost</td>
<td>1.800 €</td>
<td>1.800 €</td>
<td>1.800 €</td>
<td>1.800 €</td>
<td>1.800 €</td>
</tr>
<tr>
<td><strong>Routing clients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>operation cost</td>
<td>270.000 €</td>
<td>540.000 €</td>
<td>810.000 €</td>
<td>1.080.000</td>
<td>1.080.000</td>
</tr>
<tr>
<td>maintenance cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OBU</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>investment cost</td>
<td>1.800.000</td>
<td>3.600.000</td>
<td>5.400.000</td>
<td>7.200.000</td>
<td>7.200.000</td>
</tr>
<tr>
<td>operation cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintenance cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Cost table (Scenario 3).

Adapted from the German EWS (Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen), Ausgabe 1997, assumptions for time costs, fuel costs and operation costs have been scaled-up utilizing a discount rate of 3 % as follows.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time costs [€ / vehicle h]</strong></td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td><strong>Operation costs [€ / 100km * vehicle]</strong></td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td><strong>Fuel costs [€ / 100 km]</strong></td>
<td>-</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 7: Cost assumptions.

Table 8 lists the resulting time saving benefits regarding a scenario of 12 passages per vehicle per year (all sites) and a time saving of 1 h.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of passages</strong></td>
<td>54000</td>
<td>108000</td>
<td>162000</td>
<td>216000</td>
<td>216000</td>
</tr>
<tr>
<td>time saving per vehicle passage (h)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>cost saved</td>
<td>1.417.500 €</td>
<td>2.835.000 €</td>
<td>4.252.500 €</td>
<td>5.670.000 €</td>
<td>5.670.000 €</td>
</tr>
</tbody>
</table>

Table 8: Time saving benefits.
Table 9 lists the trip reduction benefits with respect to table 2.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trips with reduced length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>trip length reduction (km)</td>
<td>1620</td>
<td>3240</td>
<td>4860</td>
<td>6480</td>
<td>6480</td>
</tr>
<tr>
<td>time saving (h)</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>additional equipment cost</td>
<td>-62.100 €</td>
<td>-124.200 €</td>
<td>-186.300 €</td>
<td>-248.400 €</td>
<td>-248.400 €</td>
</tr>
<tr>
<td>time cost saved</td>
<td>42.525 €</td>
<td>85.050 €</td>
<td>127.575 €</td>
<td>170.100 €</td>
<td>170.100 €</td>
</tr>
<tr>
<td>operation cost savings</td>
<td>16.200 €</td>
<td>32.400 €</td>
<td>48.600 €</td>
<td>64.800 €</td>
<td>64.800 €</td>
</tr>
<tr>
<td>fuel cost savings</td>
<td>28.350 €</td>
<td>56.700 €</td>
<td>85.050 €</td>
<td>113.400 €</td>
<td>113.400 €</td>
</tr>
</tbody>
</table>

Table 9: Trip reduction benefits.

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Cumulative Value (NPV)</th>
</tr>
</thead>
</table>

Table 10: Total cost and savings.

Results of table 6 are visualized in Figure 15:

Figure 15 shows the GR system in deficit. Thus, a profitable operation of the GR system is not possible using the chosen setup parameters. A variation of the ratio of the possible settings underlines the importance of 2 parameters.

- passages per vehicle and year
- time saving per vehicle passage (h)
Subsequent, different parameters are varied. The influence of this variation to the sensitivity analysis is shown in the graphics below.

Using a setup as follows:

**variation of time saving per vehicle passage**, 3 sites, 12 passages per vehicle and year, rest remains constant.

![Variation of time saving per vehicle passage](image)

**variation of No of passages per vehicle and year**, 3 sites, 1h time saving per vehicle passage, rest remains constant.

![Variation of number of passages per vehicle and year](image)
The results, demonstrated in figure 16 and 17 return several possible profitable scenarios. A combination of both variations is illustrated in Table 10.

Table 7 displays a result matrix of the cost benefit ratio dependent on time savings per passage and per vehicle [h] and No of passages per vehicle and year [N].

<table>
<thead>
<tr>
<th>No of passages per vehicle and year [N]</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.46</td>
<td>0.51</td>
<td>0.57</td>
<td>0.62</td>
<td>0.67</td>
<td>0.73</td>
<td>0.78</td>
<td>0.83</td>
</tr>
<tr>
<td>11</td>
<td>0.51</td>
<td>0.56</td>
<td>0.62</td>
<td>0.68</td>
<td>0.74</td>
<td>0.80</td>
<td>0.86</td>
<td>0.92</td>
</tr>
<tr>
<td>12</td>
<td>0.55</td>
<td>0.62</td>
<td>0.68</td>
<td>0.74</td>
<td>0.81</td>
<td>0.87</td>
<td>0.94</td>
<td>1.00</td>
</tr>
<tr>
<td>13</td>
<td>0.60</td>
<td>0.67</td>
<td>0.74</td>
<td>0.81</td>
<td>0.88</td>
<td>0.95</td>
<td>1.01</td>
<td>1.08</td>
</tr>
<tr>
<td>14</td>
<td>0.64</td>
<td>0.72</td>
<td>0.79</td>
<td>0.87</td>
<td>0.94</td>
<td>1.02</td>
<td>1.09</td>
<td>1.17</td>
</tr>
<tr>
<td>15</td>
<td>0.69</td>
<td>0.77</td>
<td>0.85</td>
<td>0.93</td>
<td>1.01</td>
<td>1.09</td>
<td>1.17</td>
<td>1.25</td>
</tr>
<tr>
<td>16</td>
<td>0.74</td>
<td>0.82</td>
<td>0.91</td>
<td>0.99</td>
<td>1.08</td>
<td>1.16</td>
<td>1.25</td>
<td>1.33</td>
</tr>
<tr>
<td>17</td>
<td>0.78</td>
<td>0.87</td>
<td>0.96</td>
<td>1.05</td>
<td>1.15</td>
<td>1.24</td>
<td>1.33</td>
<td>1.42</td>
</tr>
<tr>
<td>18</td>
<td>0.83</td>
<td>0.92</td>
<td>1.02</td>
<td>1.12</td>
<td>1.21</td>
<td>1.31</td>
<td>1.41</td>
<td>1.50</td>
</tr>
<tr>
<td>19</td>
<td>0.87</td>
<td>0.98</td>
<td>1.08</td>
<td>1.18</td>
<td>1.28</td>
<td>1.38</td>
<td>1.48</td>
<td>1.58</td>
</tr>
<tr>
<td>20</td>
<td>0.92</td>
<td>1.03</td>
<td>1.13</td>
<td>1.24</td>
<td>1.35</td>
<td>1.45</td>
<td>1.56</td>
<td>1.67</td>
</tr>
</tbody>
</table>

Table11: Sensitivity Analysis Matrix.

5.3 Summary

No societal cost and benefits are included within this cost benefit analysis, i.e. neither benefits from reduced accident/risk, nor time savings from reduced traffic jams and no reduced environment effects are being included.

Furthermore, no external benefits are taken into account; only internal benefits to the Logistic Company and the infrastructure operator are used.

On the one hand, the system itself takes a minimum investment of 2.66 Mio. € in case of 1 year operation and 1 site. Within a time horizon of 5 years, the system costs reach a total of +27 Mio. € in case of 1 site. The main reason for this economic situation is massive investment and operation cost in the OBUs of the DG vehicle fleet, which therefore can hardly be justified for a single infrastructure object.

On the other hand even one site can be theoretically being operated with overall benefits under certain assumptions. Nevertheless, it is recommended, not only for economic efficiency, but also for safety reasons, that the system is being introduced for all/most critical infrastructures in a region (+2 sites).

To be internally profitable, some ratio-levels within the setup configuration need to be varied. The highest effects on the system profitability have the ratio-levels of:

- passages per vehicle and year
- time saving per vehicle passage (h)
Regarding those 2 critical factors for cost/benefit ratio, a sensitivity analysis returns several ratios >1. Thus, there are scenarios, in which the system can be operated in way that it yields significantly more benefits than it costs.

Using a specific interval range for the 2 critical factors, 0,8-1,5h time saving per vehicle passage and 10-20 passages per vehicle and year, a CB ratio >1 can only be reached within the interval, when factor “time saving per vehicle passage (h)” is at minimum 0,9h. Furthermore, it is required that that factor “passages per vehicle and year” is at least 12.

From the analysis it is clear, that the specific situation at the infrastructure sites with regards to traffic, delays and fleet involved needs to be known in detail to understand the cost benefit situation.

Taking the factor “time saving per vehicle passage (h)” as constantly 1; 18 passages per vehicle and year are needed, to reach a CB ratio >1 (1,02).

Taking the factor “passages per vehicle and year” as constantly 12, to reach a CB ratio of 1, 1,5h of time savings per vehicle and passage are needed.

Modifying both setup-parameters, a possible CB ratio >1 can be reached with a setup of 15 passages per vehicle and year and a time saving per vehicle passage of 1,2h (1,01).

The matrix in Table 7 displays the CB ratio levels depending on the ratio level in 3 colors, red, yellow and green.

As mentioned before, no external benefits were taken into account. Nevertheless, additional benefits e.g. reduced societal cost, time savings by reduced enforcement effort, reduced need of personnel for manual checks and a lower compliance rate influence the systems value positively.

For a possible investment decision, the external effects should be taken case dependent into account, if the CB ratio is not explicitly positive.
6 Cost Effectiveness Analysis (CEA)

6.1 Methodology for Multicriteria Analysis

The framework for multicriteria analysis as defined within ADVISORS (GRD1-1999-10047) project (De Brucker et al, 2001) has been adapted for use in GOOD ROUTE project. The multicriteria analysis (MCA) sensu stricto starts with the construction of the so-called evaluation matrix and then continues with the aggregation of the information contained in it. The MCA sensu stricto finally yields a ranking of the application areas. In this way, the sensitivity of this ranking can be tested as well.

The evaluation table forms the input for the synthetic phase of the multicriteria analysis framework. Generally, this table can be visualized as indicated below. Each alternative, c.q. each deployment scenario in our case (a1), is evaluated on each criterion (ci). The result of each of these partial evaluations is represented in the table by “e”.

<table>
<thead>
<tr>
<th></th>
<th>c1</th>
<th>c2</th>
<th>...</th>
<th>ci</th>
<th>...</th>
<th>cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>a1</td>
<td>e11</td>
<td>e12</td>
<td>...</td>
<td>e1i</td>
<td>...</td>
<td>e1m</td>
</tr>
<tr>
<td>a2</td>
<td>e21</td>
<td>e22</td>
<td>...</td>
<td>e2i</td>
<td>...</td>
<td>e2m</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>al</td>
<td>el1</td>
<td>el2</td>
<td>...</td>
<td>eli</td>
<td>...</td>
<td>elm</td>
</tr>
<tr>
<td>an</td>
<td>en1</td>
<td>en2</td>
<td>...</td>
<td>eni</td>
<td>...</td>
<td>enm</td>
</tr>
</tbody>
</table>

Table 12: Evaluation table (general case).

Whereby:  
- ci = a criterion (expected impact) (i = 1, ..., m)  
- m = the total number of criteria;  
- ai = an alternative (i.e. application area) (l = 1, ..., n);  
- n = the total number of alternatives (application areas);  
- eli = the evaluation of alternative (application area) l on criterion i.

When the criteria included in the evaluation table above are constructed for each level of analysis, it is possible to arrange them into different groups so that each specific group corresponds to the objectives of a specific level. This means that the evaluation table can be partitioned into specific parts, as shown in Table 13 below.

Within the evaluation matrix, however, clusters of criteria may be distinguished. One cluster may be related to effects that can be expressed in monetary units; another cluster may be related to non-monetary safety effects, etc.

The information represented in the evaluation matrix seldom makes it possible to select one alternative in an unambiguous fashion. In most cases, the scores obtained by the alternatives on the various criteria (partial evaluations) are conflicting, which means that they so not unanimously point to a single “best” alternative, that would be superior in terms of all criteria. This situation is
sometimes referred to as the “multicriteria imbroglio” (Scharlig, 1985:4). An aggregation method is therefore needed in most cases, to synthesise the conflicting information. Each aggregation method relies on specific assumptions regarding the comparability of the partial evaluations and the relations between criteria. In most cases, criteria should be given explicit weights. Within each aggregation method, several MCA approaches can be used to aggregate the partial evaluations.

The partial evaluations (i.e. the criterion scores) are expressed in different units, using different evaluation scales. In order to permit comparisons between criterion scores, these scores should be normalised, especially when cardinal MCA methods are used. Various normalisation procedures can be applied. Normalisation methods and MCA methods are intrinsically related. The specific normalisation procedure used may affect the results of the final aggregation procedure.

The normalisation procedure selected in our case is the Normalisation by dividing each score by the column total. This normalisation procedure is shown in the following formula.

$$e_{ij} = \frac{e_{ij}}{\sum_{i=1}^{n} e_{ij}} \quad (1)$$

With this normalisation procedure, the sum of the normalised scores is always equal to 1. Both cardinality and proportionality are respected. The normalised scores in this method are concentrated, since they span a more narrow range of possible values. This normalisation method is used in the standard AHP method (analytic hierarchy process), presented in the following section.

Not all objectives pursued in the policy process have the same importance. The criteria included in the evaluation matrix, should therefore, be weighted. A larger number of weighting procedures are closely related to the MCA method used. A widely used method for determining weights is the pairwise method, which is used in the AHP of Saaty (1988). In the pairwise method, criteria are compared in pairs. For each pair, the decision maker (in this case, 10 experts coming from ELPA) has to state whether the first criterion is as important as the second one or whether the dominance in terms of importance of the first over the second criterion is moderate, strong or “complete”. The pairwise comparison is a widely used subjective method and useful for obtaining one sound weight vector for a sole decision maker as well as for a group, like in our case, in an uncertain decision context, and while respecting the different individual opinions in case of a participating group as much as possible.

This information gathered from the corresponding templates is then transformed into a numeric scale. On the basis of this information, the relative priorities or weights are calculated, using, the eigenvector method. Since a number of pairwise comparisons are redundant, the overall consistency of the pairwise comparisons can be determined. The implied meaning of weight in the standard AHP procedure is the relative value attached to the scores on the different criteria.
Table 13: Partitioned evaluation table.

Whereby:  
\( s_k \) = a stakeholder \((k = 1, \ldots, h)\);  
\( h \) = the total number of stakeholders;  
\( c_i \) = a criterion \((i = 1, \ldots, m \text{ or } m' \text{ or } m'' \text{ according to the stakeholder considered relevant})\);  
\( m \) = the total number of criteria used by a particular stakeholder \((\text{this number can be different for each individual stakeholder})\);  
\( a_l \) = an alternative \((\text{i.e. deployment scenario})\) \((l = 1, \ldots, n)\);  
\( n \) = the total number of alternatives;  
\( e_{lik} \) = the evaluation of alternative \((\text{deployment scenario})\) \(l\) on criterion \(i\) of stakeholder \(k\).
6.2 The Analytical Hierarchy Process (AHP) for socio-economic evaluation

The analytical hierarchy process (AHP) (Saaty, 1982, 1988 and 1995) is probably the most widely known and widely used MCA method in decision-making. The AHP method is based on three principles, which form the subsequent steps of the method, namely: (1) construction of the hierarchy, (2) priority setting and (3) logical consistency.

6.2.1 Construction of the hierarchy

Humans have the ability to perceive things and ideas, to identify them, and to communicate what they observe. For detailed knowledge, our minds structure complex reality into its constituent parts, and these in turn into their parts, and so on hierarchically. A hierarchy is, therefore a complex system in which the constituent parts are hierarchically structured. An example of a simple hierarchy is given below.

![Figure 18: Example of a hierarchy in the AHP method.](image)

The top of the hierarchy consists of one single element, which represents the overall objective or focus. The intermediate levels represent the sub-objectives and their constituent parts (if possible, as measured by operational criteria). The lowest level of the hierarchy consists of the final alternatives that are considered. The arrows represent the causal relationships within the hierarchy. This causal relationship means e.g. that the lower level element ("children" node) contributes to the higher level element ("parent" node) or that it contains a property included in the higher level element. The AHP involves system thinking. Each "parent" node in the
hierarchy together with all its “children” nodes can be considered as a subsystem of a larger system (or hierarchy).

There is no general rule for developing hierarchies, they can be constructed top-down or bottom-up (Olson, 1996, pp. 11-13). Often, a combination of both is applied. The top-down method starts at the top, identifying the decision maker’s fundamental objective and develops subelements of value, proceeding downward until all measures of value are included (weeding out redundancies and measures that do not discriminate among available alternatives). At the bottom of the hierarchy, available alternatives can be added. The aim of this approach is to gain as wide a spectrum of values as possible. Once they are attained, the process of weeding and combining can begin. This approach is comparable to what Keeney (1996, pp. 47-52) considers as “value-focused thinking”.

The bottom-up approach starts with given alternatives and asks the decision makers (or the stakeholders) those features which make these alternatives good or bad choices. For instance, the decision maker would be asked for a list of those attributes that distinguish between available alternatives. The bottom-up approach will generate a large unstructured list of attributes, which can be clustered into groups of common elements (subsystems), leading to potentially the same hierarchy (system) as the top-down approach.

The top-down approach is most likely best when dealing with strategic decisions, where the available alternatives are not necessarily yet identified. The bottom-up approach works well when the set of alternatives are fairly well fixed and given, and the decision problem is to select from among them (Buede, 1986; Olson, 1996, pp. 12).

### 6.2.2 Priority setting

The relative priorities of each element in the hierarchy are determined by comparing all the elements of the lower level in pairs against the criteria with which a causal relationship exists. The pairwise comparison expresses how much more strongly an element does contribute to (or possess, etc.) the property of the criteria studied than does the element with which it is being compared. The decision maker is therefore provided with a comparison mechanism which has a pairwise set-up as indicated in the following tables.

<table>
<thead>
<tr>
<th></th>
<th>$a_1$</th>
<th>$...$</th>
<th>$...$</th>
<th>$a_i$</th>
<th>$...$</th>
<th>$a_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_1$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$...$</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a_i$</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$...$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>$a_n$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14: Pairwise comparison of elements in the AHP.
<table>
<thead>
<tr>
<th>Intensity of importance $P_{ci}(a_i,a_{i'})$</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Both elements have equal importance</td>
<td>Both elements contribute equally to the criterion under consideration</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of the row element over the column element</td>
<td>Experience and judgment reveal a slight preference of the row element over the column element</td>
</tr>
<tr>
<td>5</td>
<td>Strong importance of the row element over the column element</td>
<td>Experience and judgment reveal a strong preference of the row element over the column element</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance of the row element over the column element</td>
<td>The row element is very strongly favoured over the column element, and its dominance has been demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Absolute importance of the row element over the column element</td>
<td>The evidence favouring the row element over the column element is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediary values</td>
<td>A compromise between two assessments</td>
</tr>
</tbody>
</table>

Reciprocals (1/2, 1/3, 1/4, ..., 1/9) When the column element is compared with the row element, it is awarded the reciprocal value of the row/column element comparison

Rationals Ratios arising from the scale If consistency were to be forced by obtaining $n$ numerical values to span the matrix

1.1-1.9 For tied activities The row element and the column element are nearly indistinguishable; moderate is 1.3 and extreme is 1.9.

Table 15: Pairwise comparison scale in the AHP.

Table 14 gives the preference intensity ($P_{ci}$) for a specific pair of (sub)objectives (i.e. $a_1$, $a_2$) whereby the decision maker prefers the row element ($a_i$) to the column element ($a_{i'}$) in terms of the higher level objective under consideration (if possible, measured by an operational criterion $c_j$) under consideration. The preference intensity is expressed on a scale from 1 to 9, derived from Saaty's subjective comparison scale (see Table 15). A similar approach is taken for the constituent components within each objective and subobjective (in case the hierarchy would have more than three levels). Finally, there is also a pairwise comparison of the alternatives (the elements of the lowest level in the hierarchy) against the criteria ($c_j$) (on the next higher level).

Within each subsystem, the relative priorities of the elements are determined through the pairwise comparison mechanism described above. The relative priorities are calculated using the theory of eigenvectors and eigenvalues. The relative priorities (weights) are given by the eigenvector corresponding to the highest eigenvalue. In case the pairwise comparison matrices are completely consistent, then the highest eigenvalue
(λ_max) always corresponds to the number of elements (n) compared in the matrix. In case of complete consistency, the eigenvector corresponding to the highest eigenvalue (λ_max=n), i.e. the vector containing the relative priorities, can simply be obtained by normalizing any column of the pairwise comparison matrix (by dividing each element by column total). One will always obtain the same vector with relative priorities. In the paragraphs below, the eigenvector method will be briefly illustrated.

The pairwise comparison matrix is represented by the letter A. Its standard element is Pci(ai,ai'). The vector containing the relative priorities (weights) is represented by W. Its standard element is wi. According to the eigenvector method, the following relation holds (Formula 2).

\[ AW = nW \]  \hspace{1cm} (2)

Whereby: A = the pairwise comparison matrix;
W = the vector with the relative priorities (or weights);
n = the number of elements compared in the pairwise comparison matrix A (which, in case of complete consistency, is equal to the highest eigenvalue of A, n=λ_max).

When the matrix A is filled in directly with the ratios of the weights (wi/wi'), instead of the subjective expert evaluations given by the scale of Saaty, Pci(ai,ai'), which form an estimator of this ratio, one will obtain the following relation (Formula 3).

\[ \begin{bmatrix} W_1 & W_1 & \cdots & W_1 \\ W_1 & W_2 & \cdots & W_1 \\ W_2 & W_2 & \cdots & W_2 \\ \vdots & \vdots & \ddots & \vdots \\ W_n & W_1 & \cdots & W_n \\ W_1 & W_2 & \cdots & W_n \\ \vdots & \vdots & \ddots & \vdots \\ W_1 & W_2 & \cdots & W_n \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} = n \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} \]  \hspace{1cm} (3)

In order to synthesize the various priority vectors are weighted by the global priorities of the parent criteria and synthesized. One starts this process at the top of the hierarchy. By doing so the final or global relative priorities for the lowest level elements (i.e. the alternatives) are obtained. These final or global relative priorities indicate the degree to which the alternatives contribute to the focus. These global priorities form a synthesis of the local priorities (i.e. the priorities within each subsystem), and as such they integrate the decision making process.

As regards the sequence of the pairwise comparisons, one can follow two procedures, namely the top-down procedure or the bottom-up procedure. In the former, the subobjectives are compared in pairs in terms of their contribution to the focus. Next, the constituent components of each subobjective are compared in pairs in terms of their contribution to the subobjective with which they have a causal relation, etc. This procedure continues until one reaches the lowest level of the hierarchy. The latter procedure starts at the bottom of the hierarchy by comparing the alternatives in terms of...
contribution to the elements of the next higher level, etc. Next, this procedure is repeated at the next higher level. Finally one arrives at the top, comparing the subobjectives in terms of their contribution to the focus.

It is important that the decision maker or the expert to whom the task of making the pairwise comparisons has been delegated, is constantly aware of the exact content of the elements for which he/she is making pairwise comparisons. Therefore, the bottom-up method may be more suitable because of the learning character of its procedure. One starts at the lowest level, and subsequently moves to the higher levels, i.e. the levels at which the lower level elements are represented in a more aggregated form. However, when decision makers and stakeholders are involved in the decision making process from the beginning, both procedures may be considered equivalent.

6.2.3 Consistency check

In each pairwise comparison matrix, a number of the pairwise comparisons are redundant. When e.g. a₁ is compared to a₂ and a₂ is compared to a₃, the comparison of a₂ and a₃ becomes redundant from a theoretical point of view. In fact, in case of complete consistency, the following relation (Formula 4) holds.

\[ P_{ci}(a_i, a_{i'}) = P_{ci}(a_{i'}, a_i) \cdot P_{ci}(a_i, a_{i'}) \forall i, \ell \] (4)

Whereby: \( P_{ci}(a_i, a_{i'}) \) = the preference intensity for alternative \( a_i \) over alternative \( a_{i'} \) according to criterion \( i \).

However, the redundant comparisons are made, for two reasons. First, the redundancy makes it possible to neutralise estimation errors that may have occurred in the other pairwise comparisons of the same matrix, given the calculation of the eigenvector, described in the former section. Second, the redundancy makes it possible to check the consistency of all the pairwise comparisons within one matrix.

When the pairwise comparison matrices are completely consistent, the priority (or weight) vector is given by the right eigenvector (W) corresponding with the highest eigenvalue (\( \lambda_{\text{max}} \)). In that case, the latter is equal to the number of elements compared (n). In case the inconsistency of the pairwise comparison matrices is limited, \( \lambda_{\text{max}} \) slightly deviates from n. This deviation (\( \lambda_{\text{max}} - n \)) is used as a measure for inconsistency. This measure is divided by n-1. This yields the average of the other eigenvectors (Forman, 1990, p. 301). Hence, the “consistency index” (CI), is given by formula 5.

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \] (5)

Whereby: CI = the consistency index;
\( \lambda_{\text{max}} \) = the highest eigenvalue of the pairwise comparison matrix (A);
\( n \) = the number of elements compared in the pairwise comparison matrix (A).

The final consistency ratio (CR), on the basis of which one can conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the consistency index
(CI) and the random consistency index (CI*), as indicated in Formula 6. The random consistency indices (the CI*s) are given in the following table. They correspond to the degree of consistency that automatically occurs when filling in at random reciprocal matrices with the values given below.

<table>
<thead>
<tr>
<th>n</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI*</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
<td>1.51</td>
<td>1.48</td>
<td>1.56</td>
<td>1.57</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Table 16: Random consistency indices (CI*s).

\[ CR = \frac{CI}{CI^*} \] (6)

Whereby: CR = the consistency ratio; CI = the consistency index; CI* = the random consistency index.

The consistency ratio in some applications (namely the computer program Expert Choice<sup>TM</sup> developed by Forman, 1998), is called inconsistency ratio (ICR), because it provides a measure for inconsistency and not for consistency.

Saaty (1982:82) argues that the inconsistency should not be higher than 10% (CR ≤ 0.10). Inconsistency higher than 10% means that the consistency of the pairwise comparisons is insufficient.

The consistency ratio for the whole hierarchy (CRH) is determined on the basis of the consistency indices for each pairwise comparison matrix. The CI of each of these matrices is then multiplied by the relative priority of the parent element in terms of contribution to the parent of this parent element. This process is repeated for each level of the hierarchy (except for the lowest level). The values obtained are summed. This yields the consistency index for the hierarchy (CIH). This value is then compared to the value that one would obtain by repeating the same process using the random consistency index (CI*). This yields the random consistency index for the hierarchy (CI*H). The consistency ratio for the hierarchy (CRH) is then given by the ratio of the CIH and the CI*H, as shown in Formula 7.

\[ CRH = \frac{CIH}{CI*H} \] (7)

Whereby: CRH = the consistency ratio (CR) for the whole hierarchy; CIH = the consistency index (CI) for the whole hierarchy; CI*H = the random consistency index (CI*) for the whole hierarchy.

### 6.3 GOOD ROUTE Multicriteria Analysis

#### 6.3.1 Introduction

This section presents the set-up and the results of the multicriteria analysis performed in the context of GOOD ROUTE. The Cost Effectiveness Analysis in GOOD ROUTE has been performed for the three different deployment scenarios (or business cases),
identified, which are already described in section 2.2 of the current document and have constituted the basis also for the Cost-Benefit analysis presented above.

In contrast to cost-benefit analysis (CBA), based on neoparetian welfare economics, multicroteria-analysis has its roots in a different discipline, namely operations research. MCA does not necessarily rely on welfare economics concepts but compares a number of actions or alternatives in terms of specific criteria. These criteria represent an operationalisation of the objectives and subobjectives of decision makers. This seems especially useful in the context of GOOD ROUTE (and GOOD ROUTE like systems), where multiple, often conflicting, evaluation criteria can be identified.

6.3.2 Evaluation Criteria, Deployment Scenarios (Alternatives) & Hierarchical Decision Tree

The first thing to be defined for the socio-economic assessment according to the methodology described in section 6.2 is the hierarchical decision tree as well as the linkages between the several levels of the hierarchy (Figure 19). The first step for this is to identify the interacting items, which in our case is the deployment scenarios (as alternatives), and the criteria/impacts (objectives), upon which each of these scenarios has been rated by the decision makers. The focus in this case is the assessment (in qualitative terms) of the socio-economic impacts of the GOOD ROUTE system across its three different deployment scenarios.

The deployment scenarios, also aforementioned and described, which serve as the “alternatives” and thus the basis of our analysis are the following:

- **Deployment Scenario 1 (Business Case 1):** Voluntary use for internal (Logistic Company) purposes
- **Deployment Scenario 2 (Business Case 2):** Voluntary use (by Logistic Companies) with additional benefits (for Infrastructure Operators)
- **Deployment Scenario 3 (Business Case 3):** Mandatory use

The criteria, upon which, these scenarios/business cases have been rated are as follows:

- Road Safety
- Environmental Safety
- Societal Safety
- Operational Costs
- Transport Operation efficiency
- Drivers’ comfort and Quality of Life
- Jobs and revenue creation

On the basis of the above definition of the evaluation criteria and the alternatives (deployment scenarios), the hierarchical decision tree, which constitutes the basis of the multicriteria analysis, is easy to be constructed.

The upper level of the hierarchical decision tree is the focus of the analysis, namely the GOOD ROUTE socioeconomic impacts. In the right lower level, the main clusters of the impacts are discerned, namely the societal and the economic/monetary impacts. The
third level of the hierarchy consists of the expected impacts, as identified by the GOOD ROUTE Consortium (the analysis objectives/criteria) and their clustering as “societal” or “economic” is evident through the relevant links. In specific the “Jobs and revenue creation”, is linked to both clusters, however is considered in this case mainly as a societal impact, despite its economic dimensions (weaker linkage with “economic” impacts). The last level of the hierarchy consists of the deployment scenarios (or alternatives of the analysis), which are linked to all criteria. All three deployment scenarios are correlated with all evaluation criteria. The specific impact of each deployment scenario (as envisaged by the decision makers) on each of the identified criteria/expected impact (i.e. road safety, …) is depicted in Figure 23, as a result of the multicriteria analysis.

As already presented in section 10: “Definition of expected impacts (pre-assessment)” of D7.1: “Final Pilot Plans”, submitted since the first year of the project, there is a series of stakeholders that are considered actors of the overall logistics chain of GOOD ROUTE and interact with each other. The following table (coming from D7.1) provides an overview of the expected impacts magnitude for each actor.

<table>
<thead>
<tr>
<th>Impact Target group</th>
<th>Road safety</th>
<th>Environmental protection</th>
<th>Societal safety</th>
<th>Transportation cost</th>
<th>Transport operation efficiency</th>
<th>Drivers’ comfort and QoL</th>
<th>Jobs and revenue creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety advisors/trainers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Drivers</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Transportation companies/ADR goods companies</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Road operators</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Special infrastructure operators</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>OEM’s</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>ADAS/IVIS, sensors and communications devices developers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Middleware, digital maps and service providers</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Road Safety Authorities</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipalities and of the local actors</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Citizens representatives, such as automobile clubs and journalists</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Table 17: Definition of expected impacts of GOOD ROUTE system for different target groups of users (++ very positive; + positive; 0 neutral/uncertain; - negative; -- very negative; empty cells signify non relevant impacts).
Figure 19: Hierarchical decision tree for GOOD ROUTE Socioeconomic impacts.
Looking at the above evaluation criteria, which actually reflect the expected impacts of the GOOD ROUTE system, as identified by the GOOD ROUTE Consortium, it is obvious that most of them are self-explanatory, whereas in some cases could be also conflicting.

Definitely, the most considerable impacts of the system are foreseen to be those ones of the societal and road safety. It is clear that the adoption of the GOOD ROUTE system will lead to enhancement of road safety, since there will be less accidents, or at least less severe accidents, since all involved actors (e.g. TMC’s, infrastructure operators, enforcement and emergency services) will be able to monitor the operations and react (the authorised ones in each case) if a dangerous situation/operation due to any reason (driver’s fault, unexpected environmental conditions, vehicle’s failure, risky cargo transportation due to several reasons) is detected. Beyond road safety, societal safety remains the core expected impact of GOOD ROUTE, since not only drivers and road users but also other, 3rd party population safety is targeted (this is the main innovation of GOOD ROUTE).

However, there are cases, when the public safety increase does not coincide with transportation companies’ and ADR companies benefit, since an alternative decision that would be advantageous and less risky for safety from several aspects may prove to be cost ineffective for these actors. On the other hand, the most possible case seems to be that the financial benefits coming from the prevention of the accidents, which in this transportation sector usually mean great losses (also for insurance costs) and the efficient management of the fleet (passage on time, avoidance of routes with heavy traffic, early reaction at vehicle, cargo or driver failure) with the assistance of all connected nodes (infrastructure, local enforcement nodes, TMC’s) would prevail over the eventual additional costs. In parallel, the enhancement of the reliability of the transportation missions due to GOOD ROUTE promote the image of the ADR goods companies and the transportation companies, which is a contributing factor to their business success.

Furthermore, the GOOD ROUTE system constitutes a new product and creates a number of new services; thus, if considered successful, may bring more sales to the OEM’s as well as to Middleware (digital maps and service) providers and to ADAS/IVIS, sensors and communications devices developers concerning its respective sub-modules. As a consequence, new jobs will be created to support the sales, installation, maintenance and the provision of the relevant emerging services. However, in some cases, this may have the opposite results, such as in the case of the special infrastructure operators, some current tasks of which (such as escorting) may be replaced by the new services; however the new services may create in this case as well a series of new tasks for them. On the other hand, the special infrastructure enterprises are to have a financial benefit from the introduction of the new system, since they will be able to save the cost of the services they have foreseen currently to support the relevant procedures. In a similar way, the tasks of all aligned services (police, fire brigade, etc.) will be facilitated and this could imply comfort and wealth as a whole.

In the meanwhile, the drivers’ comfort and QoL will be improved, since they will not have to seek for the appropriate route or be concerned about changes that could affect their trips and cause delays and problems in submitting on time their delivery. Moreover, the GOOD ROUTE monitoring and emergency services are to prevent them from thefts and other security threats, which is beneficial for the companies as well. The monitoring of the drivers’ travel and rest hours will protect them from illegal workload,
which will be positive for both the road safety and their own quality of life. In addition, since the communication of the key info will be done automatically, the language barriers will be eliminated and their communication throughout Europe will be facilitated.

Finally, the GOOD ROUTE system penetration in the relevant market will also prospectively create the need for adaptation of the training curricula of the drivers and their safety advisors, which will have to be qualified also in new technologies and services that will be related with the drivers’ tasks. The training standards may increase and persons with expertise in the new technologies may be required.

The above criteria are typically selected by the GOOD ROUTE Consortium. This method, which is usually applied in practice, is called “alternative-focused” thinking method (Keeney, 1996:47ff).

### 6.4 GOOD ROUTE Multicriteria Analysis Results & Discussion

#### 6.4.1 Methodology followed

The methodology followed is the one described above, in section 6.1, with the necessary adaptations in order to serve the scope of the specific analysis.

The analysis started with the pairwise comparison of the aforementioned evaluation criteria. This comparison was performed through a relevant table, especially constructed for this reason, which is shown below, and according to the guidelines of Table 14 and Table 15.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Road Safety</th>
<th>Environmental Safety</th>
<th>Societal Safety</th>
<th>Operational Costs</th>
<th>Transport Operation Efficiency</th>
<th>Driver’s comfort &amp; QoL</th>
<th>Jobs and Revenue Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Societal Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Operation Efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver’s comfort &amp; QoL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jobs and Revenue Creation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 20: Template for pairwise comparisons of evaluation criteria.

The pairwise comparisons were performed by 10 experts coming from ELPA (the Automobile Club of Greece). Their pairwise comparisons led to 10 completed templates like the above. The corresponding values were averaged, leading to one template at the end, which was normalised, leading to the final ranking of the evaluation criteria, as depicted in Figure 22. Thus, this figure depicts the ranking or, in other
words, the importance of each criterion in relation to the other. It should be stressed, that the decision makers were asked to rank the objective importance of each criterion, avoiding to take the side of any of the aforementioned stakeholders. This explains, for example, the fact that societal and road safety are found in the top of the ranking of Figure 22.

After the realisation of the pairwise comparisons of the evaluation criteria, the same experts were asked to identify what would be the impact of each deployment scenario in specific on each of the different dimensions, reflected by each evaluation criterion. The deployment scenarios were analysed to the experts and after that, pairwise comparisons, similar to the above, were held, but in this case, taking into account the specific conditions implied by each deployment scenario (see following example figure).

<table>
<thead>
<tr>
<th>Deployment Scenario 1</th>
<th>Road Safety</th>
<th>Environmental Safety</th>
<th>Societal Safety</th>
<th>Operational Costs</th>
<th>Transport Operation Efficiency</th>
<th>Driver's comfort &amp; QoL</th>
<th>Jobs and Revenue Creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Societal Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver's comfort &amp; QoL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jobs and Revenue Creation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 21: Example template used for pairwise comparisons of evaluation criteria per deployment scenario.

Once again, the pairwise comparisons by the 10 experts were averaged leading to three templates (one for each deployment scenario) that were normalised and led to the combinational Figure 23.

However, this combinational figure is not enough, since it does not incorporate the individual weights of each criterion that resulted from the first pairwise comparisons. Thus, according to the method explained in section 6.1, the overall ranking of the deployment scenarios, taking into account the specific weights given to each criterion (reflecting their objective importance) was estimated and is provided in Figure 24.

6.4.2 Results & Discussion

The ranking of the importance of GOOD ROUTE evaluation criteria (or expected impacts) is shown in the following figure.
As it is obvious from the above figure, “societal safety” ranks first among the other criteria, which is absolutely expected, since one of the main research questions posed for GOOD ROUTE is how is going to affect the societal safety in general (the reader should be reminded that besides the Individual Index, the Decision Support System takes into account also the Societal Index, referring to third party population safety).

“Road safety” and “environmental safety” follow right after the societal safety (very close to each other), which is again very reasonable, since GOOD ROUTE is placed in the context of “road safety”, whilst it indirectly addresses the “environmental safety” (in terms of nature and infrastructure safety both). The other criteria, namely the “operational costs”, the “transport operation efficiency”, the “driver’s comfort and QoL” and the “jobs and revenue creation” are the last criteria in the ranking, reflecting the fact that, most probably, it has not been very evident to the decision makers in which way and up to which level, GOOD ROUTE influences each of them or that they consider them much less important than the core anyway expected impacts, namely the societal, road and environmental safety. However, their selection as major evaluation criteria/expected impacts by the GOOD ROUTE Consortium is justified by the fact that its participants, being involved in is development and knowing the system, better than the external experts, are convinced for the importance of these dimensions and their relevance to the GOOD ROUTE scope. For example, although the decision makers were explained the scope and the functionality of the GOOD ROUTE system, inevitably, since they have not watched the system operating, could not be convinced imagine how much easier the transport operation would be for the logistic company or how much more comfortable would feel the driver with the intelligent system that would take all decision and risk burden off him. In the same way, not having the Cost Benefit Analysis available (the two analyses were performed in parallel), they could not know the exact impact on the operational costs of the logistic company. However, this is exactly the scope of this multicriteria analysis, which is mainly a qualitative analysis, aiming to reflect the average feeling of an external decision maker. It should not be neglected that this decision making, performed by ELPA experts in this case, could be performed-and this could be the actual case in the future, prior to the adoption of GOOD ROUTE on national/European level-by other governmental actors, which will have even less expertise to understand in depth the GOOD ROUTE. Finally, to avert any implication of the weights provided by the decision makers, a sensitivity analysis has been performed, the results of which are presented below.
The ranking of each GOOD ROUTE deployment scenario on each of the criteria reflecting the expected impacts is shown in the following figure, whereas the overall ranking of the GOOD ROUTE deployment scenarios, incorporating the individual weight of the evaluation criteria (depicted in Figure 22) is shown in Figure 24.

![GOOD ROUTE Deployment Scenarios vs. evaluation criteria (expected impacts)](image)

**Figure 23: GOOD ROUTE deployment scenarios vs. evaluation criteria (expected impacts).**

The above figure demonstrates the level up to which each of the deployment scenarios is expected to influence road safety, environmental safety, societal safety, etc., always according to the decision makers. It should be noted that for the extraction of the above figure, the decision makers in each case, were asked to evaluate the impact of the system if each of the deployment scenarios were applied, but always in comparison to the existing situation and not in comparison to another deployment scenario. In more detail, when a decision maker was asked to evaluate the impacts of the mandatory use of GOOD ROUTE, s/he was not supposed to imagine as pre-existing situation, the one implied by the voluntary use of the system with additional benefits or by the voluntary use of the system for internal purposes. In each case, the reference situation was the current-without GOOD ROUTE- situation.

As it is shown from the above figure, the mandatory adoption of GOOD ROUTE is expected to influence more that any of the other deployment scenarios road safety, societal safety and environmental safety. This seems to be rather reasonable, since it is obvious that if the GOOD ROUTE system is applied as a mandatory one for all logistic companies and all infrastructures in the whole national traffic network, it will minimise at the maximum possible extent the risks inherent in Dangerous Goods transportation for the drivers and road users, for the third party populations, for the infrastructures and the environment, etc. In the same sense, the intermediate conditions (Deployment scenarios 2 and 3) are expected to influence less the road, societal and environmental safety.
On the other hand, it seems that the second deployment scenario (“Voluntary use with additional benefits”) is expected to bring about the most radical change (always in comparison to the existing situation) in terms of the transport operation efficiency. This is considered a reasonable result, since the efficiency of the transport operations is considered to be well improved in Business case 1 and 2, however, in the context of the mandatory use of the system, a much more complex framework is created and further investigation should be held. For example, the potential analyst should take into consideration what would happen if all logistic companies would have the right to book a passport for passage through infrastructures, or if their fleets (travelling on the same route) were all redirected to the safest route (which is always the same for any vehicle having the same or similar origin and destination…). In this case, very careful business rules and conflict resolution schemes should be designed in order to allow the most efficient possible exploitation of the system in a wide scale. Operational costs, on the other hand, are expected to be influenced more in the case of the voluntary use for internal purposes. It is a fact that the operational costs of the company will increase in such a case, taken into account the investment costs on vehicle equipment, Control Centre services operation and maintenance (perhaps new personnel has to be employed for these purposes), which is counterbalanced, however, by the fact that less accident costs and less costs related to delays, etc. will most probably occur. Nevertheless, this is also valid in the other two Business Cases. The difference is that in the other two cases (in the second Business Case and much more in the third mandatory case), operational costs seem to have much less significance in relation to other criteria.

Finally, the following figure has emerged, which provides the overall ranking of the deployment scenarios, having incorporated, the individual weight of each criterion (Figure 22) and the ranking of each deployment scenarios upon each criterion (Figure 23). It seems that the mandatory use of the system seems to be the most desirable scenario in terms of expected impacts in comparison to the other two, whereas the voluntary use of the system for internal purposes for the company is the last one in the ranking, expected to bring about the less impacts.

![GOOD ROUTE Deployment Scenarios Overall Ranking](image)

Figure 24: GOOD ROUTE deployment scenarios overall ranking.
The final result may be different when these inputs would change. It is, therefore, useful to test to which extent the final ranking is sensitive for a change in one or more of these inputs. The most crucial inputs are the criteria weights, since a small change in the weights may possibly result in a different final ranking.

Such changes would also offer the possibility to check whether, under different criteria weights, the final deployment scenarios ranking would be modified, for example if some options of low priority would become first and the opposite. This also applies to what is aforementioned, about the profile of the decision makers. For example, if the decision maker is a governmental stakeholder, the priorities may change, as in the case that the decision is made by the infrastructure operator, the logistic company, or any of the stakeholders presented in Table 17.

Therefore, there are two types of sensitivity analysis conducted, namely (1) sensitivity analysis for each criterion separately, (2) stakeholder analysis.

In the first type of sensitivity analysis (namely sensitivity analysis for each criterion separately), the sensitivity of the final ranking is tested for each of the seven criteria separately. It is tested if the final ranking would be different from that obtained in the basic scenario, when the weight of one separate criterion would be increased or decreased, while the relative weights of all the other criteria remained the same. The figures provided below represent the several versions of the final ranking according to each of the evaluation criteria increase or decrease. In each case, we have used the half and the double score for one specific criterion, leaving the rest of the criteria scores stable. It should be noted that in this case (the sensitivity analysis), the normalisation procedure is bypassed for the sake of the analysis and the maximisation of the impact incurred by the changes.

Observing the results below, we easily realize that the final ranking of the deployment scenarios is surprisingly stable. Of course, the scores may change, though slightly, but the priority ranking itself remains in all occasions the same. This implies, that even if the experts evaluation was different than the one presented in this document, the final ranking of these specific fields would remain the same, which strengthens the reliability of the result.

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4 The sum of the weights of all evaluation criteria is always equal to 1. However, when we double, or half the normalised weight of any criterion and we keep the other weights stable, it is obvious that the sum of the weights is more or less than 1. But this enables to show the impact of the change up to the maximum possible extent.
Figure 26: GOOD ROUTE deployment scenarios overall ranking (half score for Road Safety).

Figure 27: GOOD ROUTE deployment scenarios overall ranking (double score for Environmental Safety).

Figure 28: GOOD ROUTE deployment scenarios overall ranking (half score for Environmental Safety).
Figure 29: GOOD ROUTE deployment scenarios overall ranking (double score for Societal Safety).

Figure 30: GOOD ROUTE deployment scenarios overall ranking (half score for Societal Safety).

Figure 31: GOOD ROUTE deployment scenarios overall ranking (double score for Operational Costs).
Figure 32: GOOD ROUTE deployment scenarios overall ranking (half score for Operational Costs).

Figure 33: GOOD ROUTE deployment scenarios overall ranking (double score for Transport Operation efficiency).

Figure 34: GOOD ROUTE deployment scenarios overall ranking (half score for Transport Operation efficiency).
Figure 35: GOOD ROUTE deployment scenarios overall ranking (double score for Driver’s comfort and QoL).

Figure 36: GOOD ROUTE deployment scenarios overall ranking (half score for Driver’s comfort and QoL).

Figure 37: GOOD ROUTE deployment scenarios overall ranking (double score for Jobs and revenue creation).
In the second type of sensitivity analysis, the criteria used for the analysis, reflecting the main expected impacts of GOOD ROUTE are clustered into two groups, namely the ones that are related to societal impacts and the ones that are related to rather monetary impacts (affecting mainly stakeholders like the logistic companies, etc.), as follows:

**Societal impacts**
- Road Safety
- Societal Safety
- Environmental Safety
- Drivers comfort and QoL
- Jobs and revenue creation (this one is considered as a societal impact in this case, despite its monetary dimensions, since it refers to public benefits)

**Monetary (economic) impacts**
- Operational Costs
- Transport Operation Efficiency (in terms of time delays, fuels consumption, affecting also company costs, etc.)

In each case, the weights of the criteria belonging to one of the above clusters were maximised, whereby the criteria of the other cluster were ignored, i.e. their weight was set equal to zero. The results for the first and the second case are depicted in the following figures. The scores have been maximised to the value 0.415, which is the highest one in the main final ranking normally corresponding to the “societal safety” criterion (Figure 22).
The results of the stakeholder analysis reveal a more significant variation of the final ranking in comparison to the first sensitivity type results. This may be due to the fact that the weight set was very different from the one used in the basic scenario as well as from those used in the first sensitivity analysis type. Although in the first case (maximisation of the societal impacts), the priority of the scenarios remains the same, in the second case (maximisation of the monetary impacts), the priority is changed, placing as first one in the ranking the voluntary use of the system for internal company purposes. This is absolutely justified, since this is indeed the scenario that would be mostly beneficial from the logistics company’s strict point of view, if no societal impact was taken into consideration.

What is really important, however, is that the deployment scenario ranked first in all other cases is the mandatory use of the system, which constitutes a very useful information for all interested decision makers, who would probably have to evaluate
which is the most beneficial business case, under several combinations of given circumstances.

The AHP provides a convenient approach for solving complex Multicriteria Decision Making (MCDM) problems in many areas including the area covered by the GOOD ROUTE project. However, there is sufficient evidence to suggest that the recommendations made by the AHP should not be taken literally, i.e. the closer the final priority values are to each other, the more careful the user should be. This is true with any MCDM method. An apparent remedy is to try to consider additional decision criteria which, hopefully, can assist in further discriminating among the alternatives.

The above observations suggest that MCDM methods should be used as decision support tools and not as the means for deriving the final answer. To find the truly best solution to a MCDM problem may never end, however the AHP method is in our case the most reliable way available, to evaluate the GOOD ROUTE business cases.
7 SWOT Analysis & expected impacts (HIT)

7.1 Methodology

SWOT Analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture. It involves the specification of the objective of the business venture or project and the identification of the internal and external factors that are favourable and unfavourable towards the achievement of that objective.

- **Strengths**: attributes of the organization that are helpful for the achievement of the objective.
- **Weaknesses**: attributes of the organization that are harmful for the achievement of the objective.
- **Opportunities**: external conditions that are helpful for the achievement of the objective.
- **Threats**: external conditions which could do damage to the business's performance.

![SWOT Analysis Diagram](image)

Figure 41: Illustrative diagram of SWOT analysis.

If, on the other hand, the objective seems attainable, the SWOTs are used as inputs to the creative generation of possible strategies, by asking and answering each of the following four questions, many times:

- How can we Use each Strength?
- How can we Improve each Weakness?
- How can we Exploit each Opportunity?
- How can we Mitigate each Threat?

Ideally a cross-functional team or a task force that represents a broad range of perspectives should carry out the SWOT analysis. For example, a SWOT team may include an accountant, a salesperson, an executive manager, an engineer, and an ombudsman.
Internal and external factors

The aim of any SWOT analysis is to identify the key internal and external factors that are important for the achievement of the objective. These come from within the company's unique value chain. SWOT analysis groups key pieces of information into two main categories:

- Internal factors – The strengths and weaknesses internal to the organization.
- External factors – The opportunities and threats presented by the external environment to the organization.

The internal factors may be viewed as strengths or weaknesses depending upon their impact on the organization's objectives. What may represent strengths with respect to one objective may be weaknesses for another objective. The factors may include all of the 4Ps5; as well as personnel, finance, manufacturing capabilities, and so on. The external factors may include macroeconomic matters, technological change, legislation, and socio-cultural changes, as well as changes in the marketplace or competitive position. The results are often presented in the form of a matrix.

SWOT internal issues are sorted into the programme planning categories of:
1. Product (what are we selling?)
2. Process (how are we selling it?)
3. Customer (to whom are we selling it?)
4. Distribution (how does it reach them?)
5. Finance (what are the prices, costs and investments?)
6. Administration (and how do we manage all this?)

By sorting the SWOT issues into the 6 planning categories one can obtain a system which presents a practical way of assimilating the internal and external information about the business unit, delineating short and long term priorities, and allowing an easy way to build the management team which can achieve the objectives of profit growth.

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5 Product - A tangible object or an intangible service that is mass produced or manufactured on a large scale with a specific volume of units. Intangible products are often service based like the tourism industry & the hotel industry. Typical examples of a mass produced tangible object are the motor car and the disposable razor. A less obvious but ubiquitous mass produced service is a computer operating system.

Price – The price is the amount a customer pays for the product. It is determined by a number of factors including market share, competition, material costs, product identity and the customer's perceived value of the product. The business may increase or decrease the price of product if other stores have the same product.

Place – Place represents the location where a product can be purchased. It is often referred to as the distribution channel. It can include any physical store as well as virtual stores on the Internet.

Promotion – Promotion represents all of the communications that a marketer may use in the marketplace. Promotion has four distinct elements - advertising, public relations, word of mouth and point of sale. A certain amount of crossover occurs when promotion uses the four principal elements together, which is common in film promotion. Advertising covers any communication that is paid for, from television and cinema commercials, radio and Internet adverts through print media and billboards. One of the most notable means of promotion today is the Promotional Product, as in useful items distributed to targeted audiences with no obligation attached. This category has grown each year for the past decade while most other forms have suffered. It is the only form of advertising that targets all five senses and has the recipient thanking the giver. Public relations are where the communication is not directly paid for and includes press releases, sponsorship deals, exhibitions, conferences, seminars or trade fairs and events. Word of mouth is any apparently informal communication about the product by ordinary individuals, satisfied customers or people specifically engaged to create word of mouth momentum.
7.2 SWOT in GOOD ROUTE

7.2.1 Strengths

- **Minimum Risk Route Guidance**
  The major innovation and strength of GOOD ROUTE is the fact that calculates the minimum risk route (route with the minimum cost, with the maximum safety, combined route with minimum cost and maximum safety) and that, in comparison to existing conventional fleet management systems, which are operating on the basis of the fastest or shortest route. In this way, it is the first time that a system, placed actually in the fleet management segment, does take into consideration the safety aspects of the drivers all road users, as well of the 3rd party population.

- **Automatic Minimum Risk Re-routing**
  In addition to the estimation of the minimum risk route, the minimum risk re-routing is also enabled through GOOD ROUTE. All conditions (business reasons, traffic jam or accident, weather conditions, other) are automatically identified by the system and the minimum risk re-routing is directly estimated, according to the rules set behind (depending upon the deployment scenario, it could be the company, the infrastructure operator or other entities that set these rules) and acknowledged to all actors of the logistic chain. All the decision and execution burden related to the change of route is taken off the driver, who is assisted with an easy to use navigation system, easily installed in his/her vehicle.

- **Passport for infrastructure passage**
  The “passport” for passage function, through several infrastructures, is another major strength of GOOD ROUTE. Time delays, related also to additional costs for the company and the infrastructure, are being averted in this way, whereas the infrastructure achieves to have an overview of its traffic network and manage the transport operation much more efficiently. The same is valid also for the company, that is enabled to plan the itineraries of the vehicles in advance and estimate a very close to reality time of arrival to destinations, which enhances the flow of the overall logistic chain. Finally, the driver is very much enhanced in his/her daily employment tasks, since s/he knows in advance the schedule of the day and may plan his/her trip in the most convenient for him/her way.

- **Enforcement/emergency**
  Automatic enforcement and emergency support are also considered as strengths of the system. Automatic enforcement comes to replace conventional escorting held in infrastructures nowadays, and to achieve higher level of compliance to the valid in each case regulations. The operators of the infrastructure know in advance what is transferred in their site, which also enables them to allow the passage of more vehicles through it, since they will be assured that it is safe and since they will be prepared on how to mitigate potential risks (enforcement functionality). This will enhance also the transport operation as a whole, since unnecessary deviations, leading to longer and thus more costly trips, will be averted, which is beneficial for both the companies and the drivers. Finally, this comes to be also beneficial for the society as a whole, since routes through densely population areas will be avoided. The emergency functionality in specific will allow prompt detection of malfunctions and failures of any type and respective reaction
by the corresponding entities. In this way, loss of human lives and large scale damages to the infrastructure are prevented.

- **GOOD ROUTE Control Centre: an info point for the whole logistic chain**
The feasibility of all the above use cases, which require the involvement of all parties related to the transport operation, is achieved through the GOOD ROUTE Control Centre. All actors with different accreditation rights are enabled to monitor the transport operation of the equipped fleets and any changes occurring to that through a portal, which notifies them on the interesting and significant for them events in real-time. Thus, depending on the emerging situation, quick decisions are made from the side of the infrastructure operators and the companies and prompt reaction is enabled from the respective entities in case of problems (reasons for enforcement or emergency). In this way, even customers benefit directly, since they are also authorised to monitor the operation status of their own goods.

- **Driver always in the loop**
The driver, from his/her side, is also enabled in his/her daily tasks, through the navigation client, via which s/he is notified automatically for any changes in his/her route, as well as through the in-vehicle display, through which s/he is notified for any violations made (regarding his/her vehicle and its cargo). The on-board unit also enables the communication in emergency cases. In this way, the driver is always kept in the loop.

- **Instantiation of GOOD ROUTE Decision Making according to local rules and stakeholders weighting factors**
The local rules imposed by each infrastructure in normal flow constitute the framework, upon which the GOOD ROUTE Decision Support System operates and provides the minimum risk route. A great flexibility of the system is the fact that any change in the local rules or addition of new ones, corresponding to new infrastructures subscribed, is easily followed by change of the framework set behind the decision process of the system. In a similar manner, the weights imposed to each contributing factor for the estimation of the combined minimum risk route (minimum cost and maximum safety for drivers and third parties) can be also modified, depending upon the priorities in each case. Thus, a different weighting system may be applied, following the deployment context of the system (local, national, European context), the main actor behind the system (dispatcher, infrastructure, contractor, public entity), the governmental priorities each time, etc.

- **Common Ontological Framework**
The basis for the communication principles in GOOD ROUTE has been set in the ontological framework, developed from its early beginning. The ontological framework is developed in such a way, so as to include, if needed, more attributes corresponding to more parameters (related to vehicle, cargo, transport operation as a whole) as well as to more context of use, beyond road transport. It is open to be interfaced by other ontologies, enabling the connection of GOOD ROUTE to existing systems. It is the main asset of GOOD ROUTE that will allow its wide scale adoption and its compliance to the existing systems, raising in this way its penetration potential and viability.

- **Compliance with emerging technologies**
As evident through D8.3: “Towards required standards”, GOOD ROUTE complies with all relevant to it standards, which strengthens its penetration potential. It is well placed in the context of the European Directives for Dangerous Goods transportation; it complies with C2C, I2C, C2I and TMC standards, security standards, etc.

- **Benefits for all**
GOOD ROUTE constitutes win-win business proposition to all involved stakeholders. The company, the drivers, the infrastructure, the customers, the enforcement and the emergency units and, above all, the whole society, benefit in terms of safety, comfort and even operational costs.

- **Vast potential for added value services**
GOOD ROUTE context may be easily extended in many aspects. The decision making may anticipate more dimensions than the ones already considered (i.e. security, overall environmental safety indices), the telematic system could include more functionalities (like driver monitoring systems and other Advanced Driver Assistance Systems), more actors, if applicable, could be involved and access the Control Centre, whereas the context of use could be enlarged, including other transportation segments, besides the Dangerous Goods transportation, as well as other transportation modes, besides road transport. The cooperative principles embedded in the system architecture would allow more advanced communication potentials, which have not been demonstrated in the context of GOOD ROUTE, like communication with other vehicles or other infrastructure items (VMS, beacons, V2V, etc.).

### 7.2.2 Weaknesses

- **Need for instantiation/update of map data**
The map data utilised by the Decision Support System of GOOD ROUTE need to be constantly updated, whereas each time a new infrastructure is subscribed to the GOOD ROUTE service, the population and safety related map data of the region needs to be constructed and added in the back-end.

- **Missing real time accident and updated population data**
The GOOD ROUTE Decision Support System, among other data, utilises accident and population data in order to calculate its indices. In case such data are missing, historic data need to be utilized instead, which are, however, not always representative of the recent reality.

- **Need for medium to large scale deployment of the system**
As it is evident from the above CBA analysis results, the more infrastructures do subscribe in the system the more beneficial the system proves to be for the Logistic Company. Else, the systems, at least from monetary aspects, does not pay off the investment required on behalf of the company, which may constitute a barrier for its initial penetration in the market.

- **Need for scope widening**
The Minimum Risk Route Guidance of GOOD ROUTE takes currently into account the minimum risk route in terms of costs and safety (on individual and on combined basis). Although, in this way, it already addresses a great share of risks related to transport operations, aspects like security, overall environmental protection, etc. are factors that
are not at the moment anticipated in the decision making process and comprise a recommendation for further enrichment of the system. A further enrichment would be also related to the application of the service in a wider segment of the transport operations, dealing with the transportation of other types of goods (i.e. high value goods) or even public transport. In this way, the target market for GOOD ROUTE would be enlarged significantly.

7.2.3 Opportunities

- **High societal and business risk**
  In the last 10 years more than 200 people have died in Europe’s tunnels and the direct cost of these accidents were about 210 million Euros per year. Meanwhile, 0.5% of total accidents occur in bridges, 3% of which are fatal ones. And the number of such critical infrastructures (i.e. urban tunnels, highway tunnels, long bridges, etc.) is expected to increase by 35% until 2010. The societal and business risk is evident and constitutes the main rational for research and deployment of GOOD ROUTE like systems.

- **ERA-NET Transport Action Group, ITS Action Plan, UNECE, relevant Directives and initiatives relevant to GOOD ROUTE**
  There is a series of Directives and Action Plans that constitute the appropriate regulatory framework for GOOD ROUTE, to fit in and comply with. The most outstanding and relevant to GOOD ROUTE, which prove that the project has been in line with the European and international trends and priorities in the area, are outlined below.

  The ERA-NET TRANSPORT Action Groups are aiming at coordinating national research policies in the field of transport. Sixteen partners (mainly ministries) from thirteen countries are working together towards this coordination. The final objective is to create a strong and unified European Research Area in the field of transport. Therefore, various European countries are searching the ways and means to launch a common research project to find out what would be the requirements for a European system, which would make interoperable different local, national and regional systems.

  In specific, the Action Group 12 (ENT12) is trying to coordinate national policies of research in the specific field of the transport of dangerous goods. In addition, within the framework of this Activity, an inventory of the norms used by different actors for the collection and exchange of data are drawn. Relevant norms identified include: ISO 17687 concerning “Transport Information and Control Systems (TICS); General Fleet Management and Commercial Freight Operations; Data Dictionary and Message sets for electronic identification; Monitoring of Hazardous Materials/Dangerous goods transportation; and DATEX2. The final list of standards will be composed within this activity.

  Furthermore, the ITS Action Plan, entitled “An Action Plan for the Deployment of Intelligent Road Transport Systems for More Efficient, Safer and Cleaner Transport” is meant to identify the contribution which ITS can make for improving road transport efficiency, safety and security, and for reducing the negative impacts of transport on the environment and is in line with GOOD ROUTE priorities.
Finally, the recently emerged Directive 2004/54/EC, on minimum safety requirements for tunnels in the trans-European road network creates a comprehensive regulatory framework addressing both administrative practices and infrastructure and technical standards. 512 tunnels will be affected in the European Union, mostly in Austria and Italy.

In addition, the United Nations Economic Commission for Europe (UNECE), the major international forum regarding tunnel safety should be mentioned. 55 international agreements and conventions have been elaborated (ADR signed in Geneva in 1957, UN Convention on Road Traffic-Geneva 1949, …).

Another initiative has emerged by the UNECE Working Party on Road Traffic Safety in 1999 (a group of experts developed “recommendations for minimum requirements concerning safety in tunnels of various types and lengths”). In addition, an Ad-hoc Interdisciplinary Group of Experts on Safety in Tunnels under the aegis of UNECE Inland Transport Committee (2000) has been established. In December 2001, the UNECE group presented 43 recommendations concerning road users, tunnel operation, infrastructure and vehicles.

Finally, the study by the OECD and PIARC (World Road Association) produced in 2001 on the transport of dangerous goods through road tunnels, is actually picturing GOOD ROUTE. It is reviewing past tunnel accidents and national legislations, and proposing three tools for a better management of risks: harmonised groupings of dangerous good loadings, a risk quantification model, and a decision support model.

Thus, GOOD ROUTE provides the answer and an enabling platform to many different policy initiatives and legislative actions.

7.2.4 Threats

• Dangerous Goods Vehicles Drivers Acceptance
It is common knowledge that the drivers of heavy vehicles do not always respond in the most eager way to the adoption of new, innovative technologies and services that would change their daily business routine and thinking. The concept of continuous monitoring and even more of enforcement may not be well accepted, especially by drivers with long experience in the field. Before the system commercialization, a deeper investigation on the User Interface aspects, especially those ones concerning the drivers, should be realized, to assure intuitiveness and user acceptance.

In the meanwhile, and as already stated in the Pan-European workshop of GOOD ROUTE-EURIDICE in Lucerne, it will be difficult to approach the drivers that work for themselves (and not on behalf of a company), which, however, comprise a considerable share of this market.

• Research focus on European and international level shifting from safety to the environmental protection
Due to the large scale environmental damage of the last decade and the multiple impacts for the quality of all kinds of life, research and business interest has been shifted from safety and the “0 accidents” vision to environmental protection and the “0 emissions”
vision. The GOOD ROUTE system, as it currently stands, does not yet focus on environmental issues, although any DG accident may have extremely negative environmental impacts. However, the possibility of widening its scope, to take into account environmental aspects as contributing factors for the estimation of the (combined) minimum risk route, is a promising asset of the system.

- **Economic recession**
  Economic recession will reduce the available social and private funds that could be used for setting up and maintaining GOOD ROUTE-like services. On the other hand though, it will enhance the need for reducing the costs related to transport operation delays, fuel consumption, loss of human lives and infrastructure damage, thus it may also constitute an opportunity for GOOD ROUTE.

- **Competition**
  Several other competing platforms are there in the cooperative safety systems area, even if they do not address the exact same targets (i.e. those of CVIS, SAFETUNNEL), while some Fleet Management Systems may provide part of the GOOD ROUTE solutions, thus good consolidation, synergies and common interfaces rather than fierce antagonism and further market fractionisation are required.
8 Conclusions

As analysed in the previous chapter, the major innovation and strength of GOOD ROUTE is the fact that GOOD ROUTE, in comparison to existing conventional fleet management systems, which are operating on the basis of the fastest or shortest route, calculates the minimum risk route (route with the minimum cost, with the maximum safety, combined route with minimum cost and maximum safety).

In addition to the estimation of the minimum risk route, the minimum risk re-routing is also enabled through GOOD ROUTE.

All conditions (business reasons, traffic jam or accident, weather conditions, other) are automatically identified by the system and the minimum risk re-routing is directly estimated, according to the rules set behind (depending upon the deployment scenario, it could be the company, the infrastructure operator or other entities that set these rules) and acknowledged to all actors of the logistic chain.

This offers each user group a very high process automation and guidance level in means of daily operations and decision finding.

Taking into account that GOOD ROUTE constitutes a win-win business proposition to all involved stakeholders, everyone involved benefits in terms of safety, comfort and even operational costs.

There is also a noticeable potential for added value services to which GOOD ROUTE can be extended with, e.g. (security, overall environmental safety indices). This opens the opportunity to have a further improvement for the system and to keep it as state of the art for the next years.

Besides investment costs, especially the driver acceptance is being identified as critical parameter to the GOOD ROUTE SYSTEM. In a possible roll out scenario, driver training can minimize acceptance discrepancies.

As visualized in the Sensitivity Analysis Matrix (table 10) several positive cost-benefit ratios can be identified for a 3 site scenario.

This implies also, that a system implementation of the GOOD ROUTE system to less than 3 sites seems critical justified in high investment costs for a basic setup and lower benefits due to a reduced area of effectiveness.
References