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University of Antwerp - RUCA (Belgium)
Universidade Nova de Lisboa (Portugal)
University of Piraues (Greece)

EMOLITE

Evaluation Model for the Optimal Location of Intermodal Terminals in Europe

University of Antwerp - RUCA

Universidade Nova de Lisboa

University of Piraeus

<u>Content</u>

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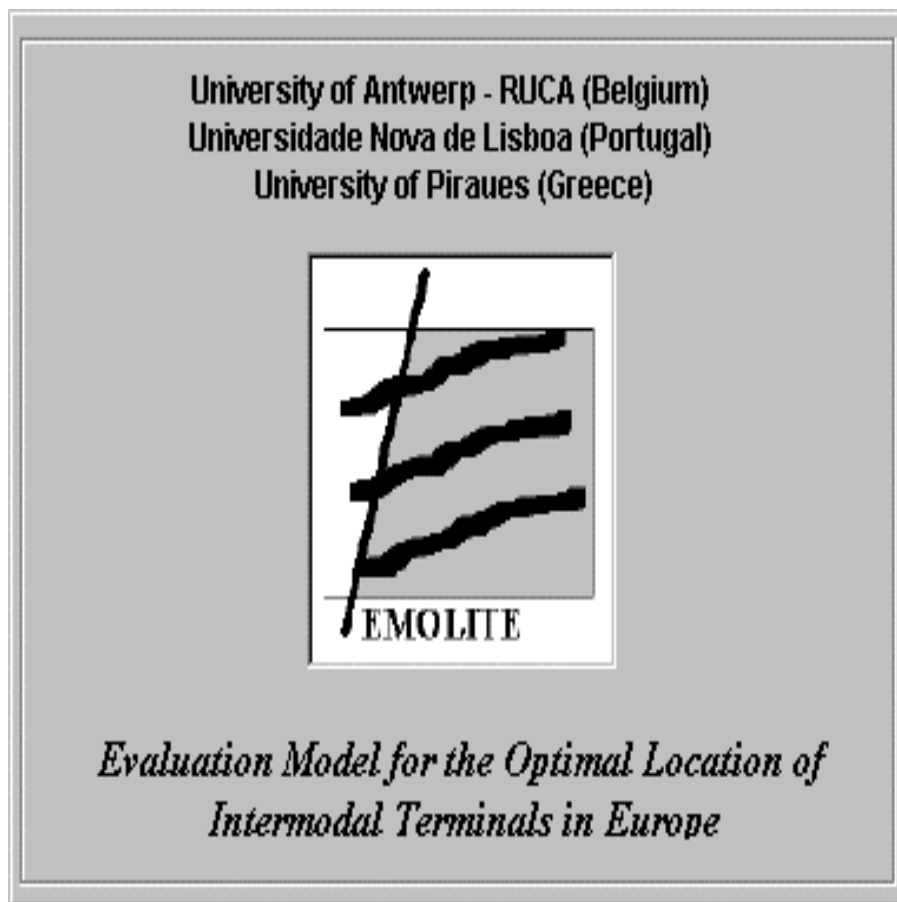
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2 Executive Summary

2.1 context

The continuously expanding number of privately owned vehicles and the ever increasing demand for (long distance) *road haulage* is leading to congestion of the European road network. Circumventing this congestion-problem by expansion of the road infrastructure is no longer possible in most cases. Moreover, road haulage is increasingly met with social disapproval because of the burden it puts on the environment (external costs).

The development of intermodal terminals at strategic locations on the Trans European Transportation Network is therefore important. However, the identification and evaluation of these potential locations should not be based solely upon transport-economic criteria at the level of the corporation (e.g., transportation costs and - distances). The use of an alternative approach should be considered which takes into account general and terminal-specific decision parameters, as well as public and private selection criteria.

In that context, the European Commission has, within the context of the 4th Framework R&D programme, awarded a contract (Contract nr. ST-96-SC.1018) to a research team, consisting of:

- University of Antwerp – RUCA (B)
- Centre for Intermodal Research – CIR (B)
- Universidade Nova de Lisboa (PE)
- Technical University of Athens (G)
- AND mapping (NL)

to develop a decision support model for the for the "**E**valuation **M**odel for the **O**ptimal **L**ocation for **I**ntermodal **T**erminals in **E**urope" (EMOLITE).

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2.2 EMOLITE framework

The objective of the project was to develop a decision support system that allows an integrated evaluation of potential terminal locations according to general and terminal-specific criteria, while simultaneously taking into account the dynamic and continuously changing transportation market. EMOLITE should provide comprehensive strategic information on the quality of potential locations for intermodal terminals.

EMOLITE is developed for non computer-experts, using computer-assisted data input, processing wizards and other applications that facilitate its use. EMOLITE therewith lowers the threshold to use computer modelling in the strategic decision-making process. The program therefore contains a multiplicity of data from different fields of interest. The information provides insights into the economic, social and infrastructure image of a country and is necessary at the level of strategic decisions.

The main sequence of tasks necessary to obtain the information is the following:

| User | → | Select destination Country | → | **Select Conditions** | → | **Select Weigts** | → | Rank Terminals |

The main features of the EMOLITE prototype are:

1. It ranks the alternative destination terminals according to attribute values and criteria (cost, flexibility and reliability).
2. It is a flexible system for handling terminal attributes, such as modifications and new insertions.
3. It contains a sophisticated, but simple, algorithm for solving the rating and ranking of terminals, using a fuzzy multiple attribute model.
4. The fuzzy multiple attribute model includes fuzzy attributes and fuzzy importance/weights and applies a weighted average aggregation procedure.
5. The construction of the fuzzy attribute membership functions is fully transparent to the user because the values to build them are automatically

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extracted from the database. This feature implies that with the increase of cases (terminals) in the database the attributes will better represent them.

6. EMOLITE is interactive and user-friendly in all dialogues with the user. It therefore contains two levels for weighting to allow the user to go more into detail only when wanted.

7. It incorporates a simulation facility, where the user can compare what are the results are of changes in his/her weights in the ranking of terminals.

2.3 Components Description

The **EMOLITE database** is implemented in Microsoft Access, according to the skeleton design, depicted in figure 1.

Figure 1: database skeleton
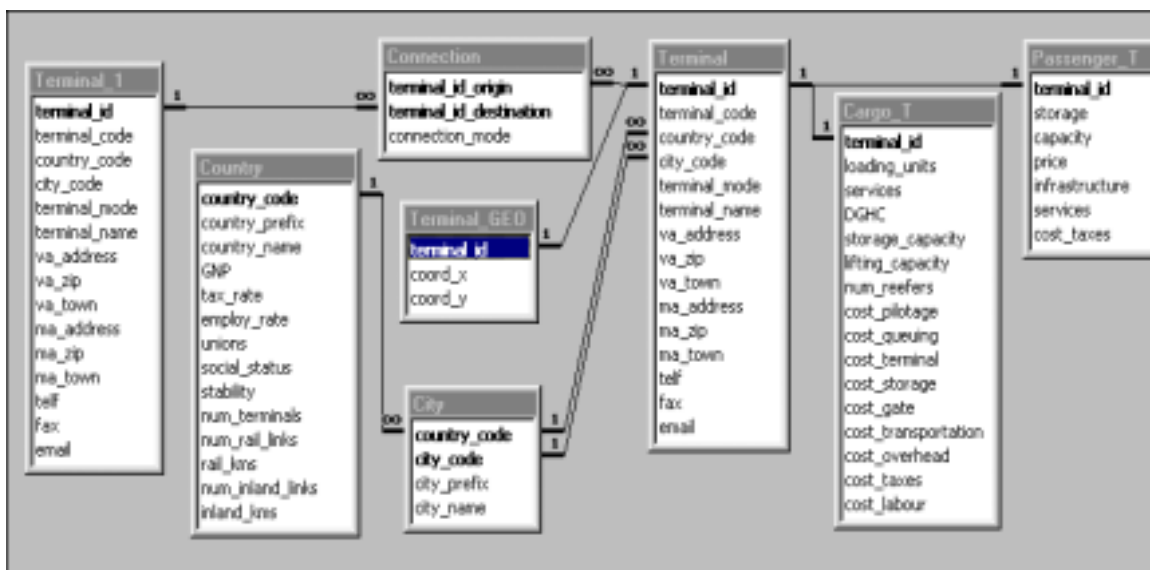
The database can be reached through the Database Wizard. In addition to the internal database, detailed information on terminals is available via an external database connection. This information remains property of AND Mapping (the Netherlands) and was provided to the EMOLITE research team only with the purpose of developing the EMOLITE prototype.

Wizards play a key role in EMOLITE application. They are intended to make users' life easier, leading them step-by-step through an unusually long, difficult, or complex task. Simulation Wizards help the user to define the transportation framework,

conditions and criteria/weights for a simulation session. The wizards are MDI (Multiple Document Interface) applications, where the main window provides a workspace for all the child windows in the application.

The **<u>EMOLITE simulation module</u>** is divided into classes, attributes and objects. The user weights each class and attribute by order of importance. The classes are:

- Cost

- Flexibility

- Reliability

<u>Cost</u> includes attributes such as overheads, pilotage, queuing time, terminal cost, storage, gate cost, taxes, labour cost, GNP and transportation. <u>Flexibility</u> consists of attributes like storage, cranes, fridge, connections, TEN accessibility and infrastructure. <u>Reliability</u> contains among others following attributes: unions, social status and stability.

The user will be able to display multiple documents at the same time, each displayed in its own window. In the case of EMOLITE, Project Specific information, charts, maps and reports are different types of documents. A crucial step is the definition of criteria / weights, see figure 2

<p align="center"><u>Figure 2: setting criteria / weights</u></p>

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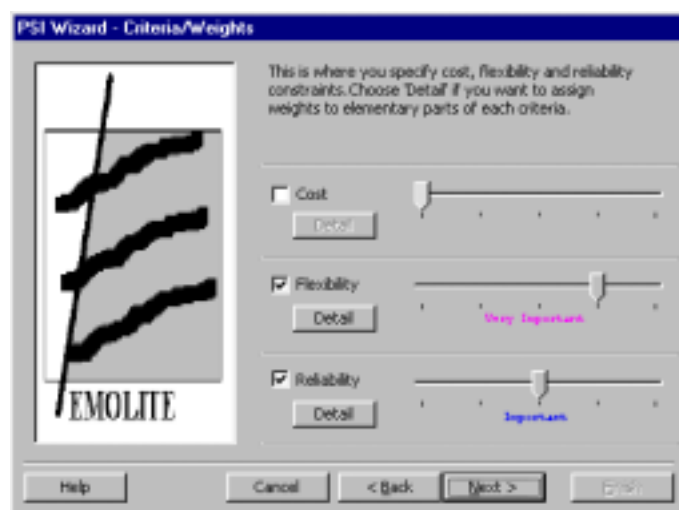
The weights for each class and for every attribute are identical and are determined by the user. The weight scale in EMOLITE is,

- Irrelevant
- Low importance
- Important
- Very important
- Extremely important

EMOLITE uses an innovative approach in criteria setting because the user can choose which constraints will be considered by (un)checking them.

The program allows the user to choose the presentation from of the results: Full Report, Summary Report, Graph, Map.

If all the criteria are introduced, the simulation can run and the results calculated. Running the simulation starts a calculation process for ranking terminals taking into account the conditions and criteria defined for the project under evaluation. A progress bar is shown during the calculation; once finished, the corresponding output windows (Summary Report, Full Report, Graph, Map) are updated to reflect the new results. The final results are presented to the user in different formats. An example of the graphics output is visualized in figure 3.

<u>Figure 3: Graphical presentation of results</u>
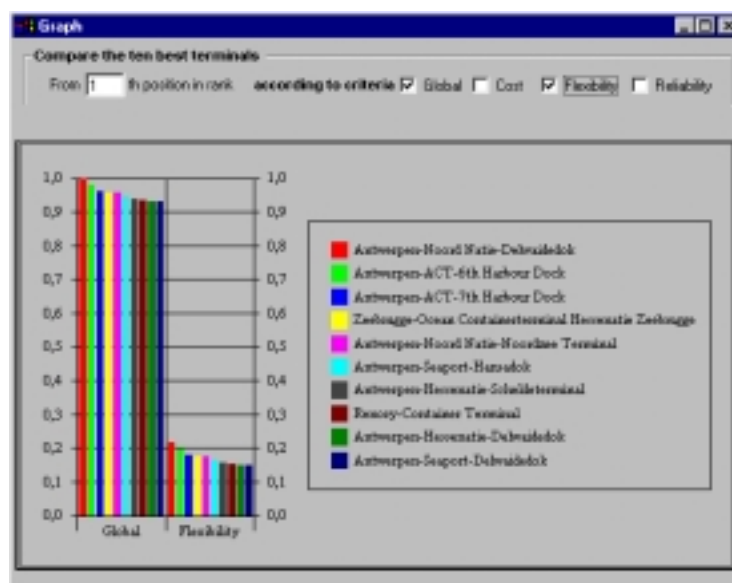
The results obtained from the simulation can be saved and re-used in future simulations.

2.4 Conclusions

The implementation of the EMOLITE prototype has been an interesting and rewarding experience in several ways. Undoubtedly, improvements can be made, e.g., in the user interface by including some additional functionality, in the database structure to accommodate more consistent data handling or in the fuzzy model by creating more fine-tuned algorithms in order to deal with more realistic / complex scenarios.

However, EMOLITE was a Prototype and should be considered only as a relevant step in the development of a system close to managers' real needs. The future "**EMOLITE 2000 system**" must be Web-based, for obvious reasons. The deployment of a Web-based architecture would result in much less maintenance effort and certainly in much easier and widespread utilisation, since users could access it simply as "another" Web page.

The EMOLITE prototype therefore has more value as a prototype rather than being already a practical computer model for strategic decision making.

However, the basic approach of EMOLITE already offers an interesting innovative feature, namely the **users interface**. Using the Wizards available in Windows and applying fuzzy logic to interact with the user can be considered an important step in closing the gap between high level managers and (logistics) computer models. The difficulties of entering data and conditions before running the simulations has been reduced to an easy "guided" methodology that enables non-experienced users to apply the method for their calculations.

3   Objectives of the EMOLITE project

The goal of the EMOLITE project is to provide a <u>valuable and reliable</u> tool to the decision maker, either public or private, to help him or her decide and consider the advantages and disadvantages of potential locations to develop an intermodal terminal.

To reach a sustainable decision, decision makers have to be adequately informed about the economical status of the country (and even better of the specific regions), the transport infrastructure and the transport flows, which means consequently that he or her needs an ever-increasing amount of information in order to draw up, assess and evaluate projects.

It is important to stress that **EMOLITE has not only to face as a probable user transport experts or researchers, but also managers and decision makers in the private sector**. Consequently, EMOLITE collected as many data as possible from various fields of interest and incorporates several presentation methods. All these data may not be useful to a particular user of a transport problem, but most of the data are very useful regarding the investment in a specific region. All these data constitute the economic, social and infrastructure image of a country.

Most of the decision support systems related to transportation are a direct or indirect application of operational research techniques. Many hidden assumptions and simplifications result to output, which may be the optimal solution from a mathematics point of view but in many cases not useful from the point of view of the investor. This is why **EMOLITE uses the fuzzy logic technology** to develop the prototype and paid particular attention to the **user interface**. Wizards are intended to make users' life easier, leading them step-by-step through an unusually long, difficult, or complex task. In EMOLITE, wizards are mainly used for creating and modifying simulation scenarios, accessing databases and getting help.

The goal of the prototype is to select a number of terminals in a given country (and optionally in a given city) which meets a defined number of quality conditions.

For the development of the EMOLITE-prototype, following assumptions have been made:

❑   The prototype will not deal with distances between terminals;

❑   The origin terminal is not relevant, only the destination terminal, its conditions and the connections it has with other terminals is considered;

❑   Intermediate terminals will also not be integrated; only the set of destination terminals will be taken into consideration;

❑   The model is developed both for goods. However, the prototype was developed in such a manner that it can easily be adapted for passenger terminal analysis..

❑   The multiple terminal choice models will be formalised and conceptualised, but not implemented in the prototype due to its complexity (it could be considered in a future project).

4 Means to achieve the objectives

The concept of EMOLITE is innovative given that it is designed for practical use at the managerial level. Although it is only a prototype, some practical application is possible. However, further development is required, in particular to integrate the application into new technologies such as the Internet.

To reach the objectives described in chapter 3, three elements were particularly important, namely

- the structure of the consortium and the exchange of information between the research partners;

- the hardware and software used for the development of EMOLITE;

- the dissemination.

The *structure* of the consortium took into consideration that there were two important issues in the project, which were the technical development and the strategic considerations. Therefore, a structure was designed were all tasks (both technical and strategic) were concentrated in one location. The writing of reports was also centralised in that location. In addition, the technical partners (Universidade Nova de Lisboa and the University of Antwerp – Department of Computer Science) were collaborating in the technical development and submitted a single technical report.

The approach is visualised in next figure.

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Operational structure
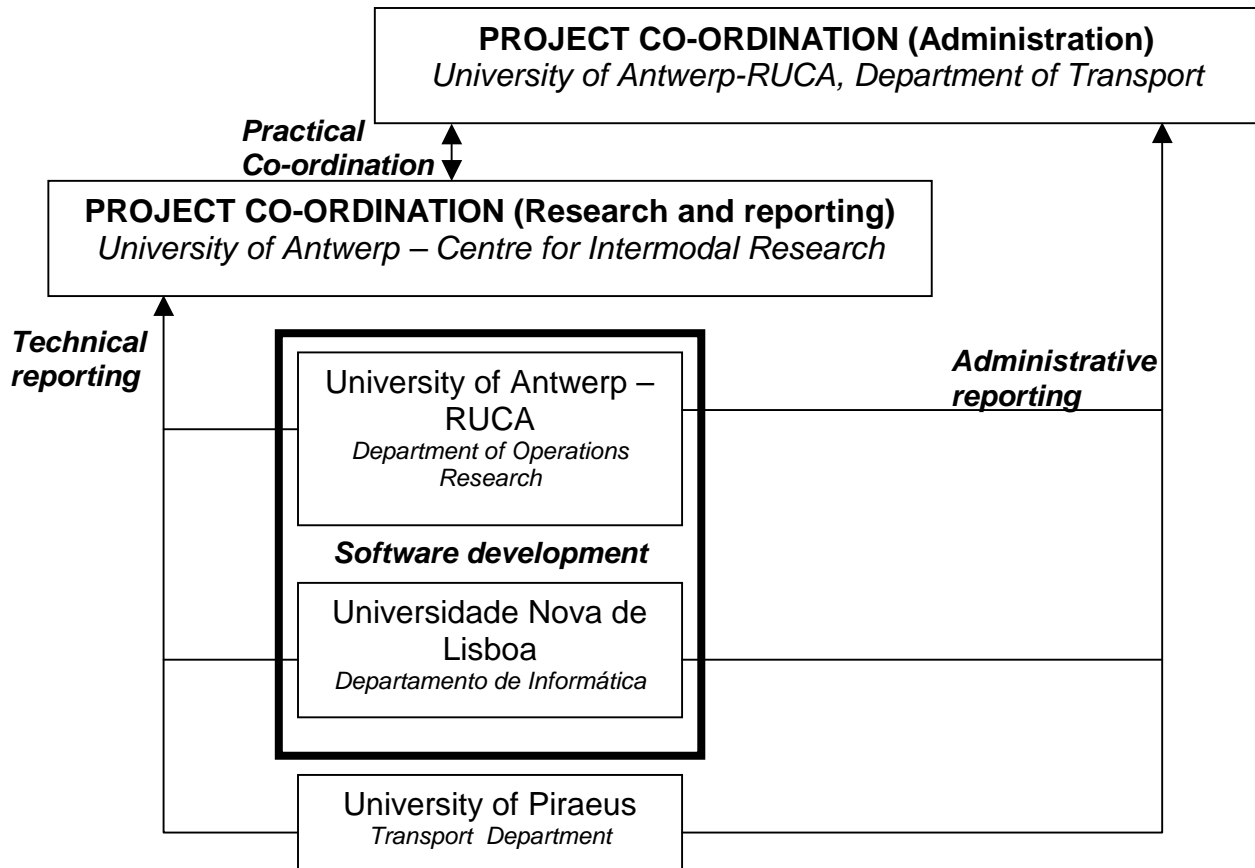
The *use of hardware and software* was an important element for the programme. In many cases, decision support systems are complex and written in propriety software or in complicated software packages. Given that simplicity was one of the important conditions for EMOLITE, the use of complicated software (and hardware) was not possible and "standard" software and hardware had to be selected.

After careful analysis, the EMOLITE partners decided for following software and hardware requirements:

- PC with Pentium processor.
- Microsoft Windows 95 or Microsoft Windows NT Workstation operating system version 4.0 or later.
- 16 MB of RAM (32/64 MB recommended).
- Microsoft Visual Basic/Visual C++ language and tools to implement the interfaces.
- DAO/ODBC to access databases from both languages.

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Finally, the success of EMOLITE will depend upon the efficient dissemination of the results. For that reason, the consortium partners decided that the prototype should be free of copyright to enable other persons / institutes / companies to use the EMOLITE results and extend / expand / improve the prototype.

In addition to academic papers that will be written by the university professors in the team, the dissemination will be focussing on the Internet. A resumé of the project results will be made available on the CORDIS website. In addition, more detailed information and a copy of the prototype will be made available trough the STRATECO website (www.strateco.org), in which the Centre for Intermodal Research is a founding partner.

5 Scientific and technical description of EMOLITE

5.1 Introduction

This research project was made possible under the **Strategic Sector of the Transport Research Programme of the 4th Framework Programme**, Task 1.3/22: Spatial Coordination for Intermodality and Modal Split.

The objective of the project was to develop an "Evaluation Model for the Optimal Location for Intermodal Terminals in Europe" (EMOLITE).

EMOLITE allows an integrated evaluation of potential terminal locations according to general and terminal-specific criteria. EMOLITE provides comprehensive strategic information on the quality of potential locations for intermodal freight terminals.

The development of EMOLITE is a joint effort of the University of Antwerp - RUCA (Belgium), Department of Transport Economics and Department of Operations Research, the University of Piraeus (Greece) , Department of Transport and the Universidade Nova de Lisboa (Portugal) , Departamento de Informática. The group was later in the project expanded with AND Mapping (the Netherlands).

The co-ordinates of the partners are given in Chapter 2.

5.2 Context

The current European transport environment faces a number of important problems, which urgently require a solution. The continuously expanding number of privately owned vehicles and the ever increasing demand for (long distance) road haulage is leading to congestion of the European road network. Circumventing this congestion-problem by expansion of the road infrastructure is no longer possible in most cases. Moreover, road haulage is increasingly met with social disapproval because of the burden it puts on the environment (exhaust gases, negative effects on the environment, etc…).

Freight transport services have evolved substantially in the last decade and encountered an increased demand for speed, reliability, optimum transportation costs and value added logistics. New developments in the field of telecommunication and technology (telematics) have contributed substantially to increase both speed and efficiency of transportation and made a tight control of commodity flows possible. The increased use of modern logistical concepts for the development of local, national, regional and Europe-wide distribution and transhipment centres for European and non-European freight are particularly important because patters are being laid down for the future which, once determined, will be difficult to change.

At present, distribution and transhipment locations designed for road or road/rail modes alone may be chosen unless the validity of the intermodal alternative as part of the offer can be demonstrated. Therefore, in order to fully develop modern European intermodal transportation networks the necessary supply and demand requirements of the distribution and transhipment centres need to be accurately determined. Supply-driven terminal requirements are controllable by the service provider while terminal operators cannot influence demand-driven terminal requirements.

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An integrated approach to the combination of supply and demand requirements enables to circumvent one of the major shortcomings of most intermodal research. Indeed, it is not sufficient to only address terminal-based requirements without reference to increasingly complex user requirements. Such approach would generate an optimised supply but would remain alienated from the true user needs.

However, concentrating exclusively on user requirements without taking into account specific supply-side availability, will inevitably lead to an unsustainable ad unattractive intemodal offer at the level of the transhipment area. It is only by means of simultaneously integrating into the analysis the demand and supply side conditions, that locations for the development of sustainable intermodal transhipment areas can be identified. Since terminals feature in a dynamic and complex transportation environment, the interrelations with this environment also need to be carefully considered. Therefore, the effect of changes in this external environment and their impact on customer needs (e.g. the need for value added logistics) and supply-side characteristics (e.g. changing terminal activity costs) need to be incorporated into the analysis.

5.3   Project description

5.3.1   Introduction

The goal of the Emolite prototype is to find a number of terminals in a given country (and optionally in a given city) which satisfy certain restrictions and criteria. In order to accomplish this, the following assumptions are made:

(i)   distances between terminals are not handled;

(ii)   the origin terminal is not important, it is only important the destination terminal, its conditions and the connections it has with other terminals;

(iii)   intermediate terminals are not handled, since here we only consider the set of destination terminals;

(iv)   multiple terminal choice models will be formalized, but not implemented in the prototype.

The main sequence of tasks necessary to obtain the destination terminals is the following (see figure 4):

Figure 4: Sequence of tasks
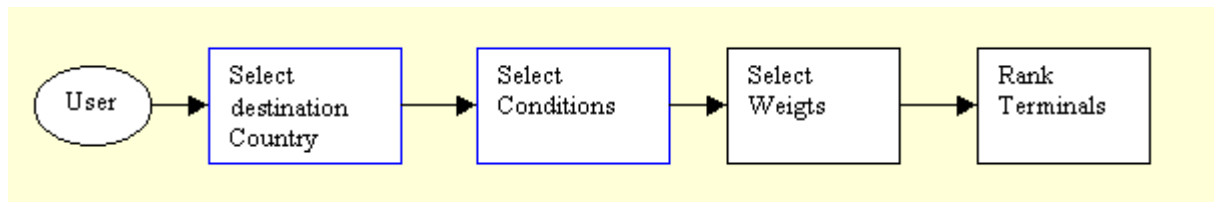
5.4 Development of the prototype

5.4.1 First prototype

The goal of the EMOLITE BETA Version was to select a number of terminals in a given country (and optionally in a given city) which meets a defined number of qualitative conditions. For the development of the first EMOLITE-prototype, following assumptions have been made:

❑ The prototype will not deal with distances between terminals;

❑ The origin terminal is not relevant, only the destination terminal, its conditions and the connections it has with other terminals is considered;

❑ Intermediate terminals will also not be integrated; only the set of destination terminals will be taken into consideration;

❑ The model is developed both for passengers and goods, although the concentration is on cargo transport, given that the case study will deal with cargo transport and not with passenger transport.

❑ The multiple terminal choice models will be formalised and conceptualised, but not implemented in the prototype due to its complexity (it could be considered in a future project).

The main features of the first EMOLITE prototype are:

8. It ranks the alternative destination terminals according to attribute values and criteria importance (cost, flexibility and reliability).

9. It is flexible system for handling terminal attributes, such as modifications and new insertions.

10. It contains a sophisticated, but simple, algorithm for solving the rating and ranking of terminals, using a fuzzy multiple attribute model.

11. The fuzzy multiple attribute model includes fuzzy attributes and fuzzy importance/weights and uses a weighted average aggregation procedure.

12. The construction of the fuzzy attribute membership functions is fully transparent to the user because the values to build them are automatically extracted from the database. This feature implies that with the increase of cases (terminals) in the database the attributes will better represent them.

13. EMOLITE is interactive and user-friendly in all dialogues with the user. It therefore contains two levels for weighting to allow the user to go into detail only when wanted.

14. it incorporates a simulation facility, where the user can compare what are the results of changes in his/her weights in the ranking of terminals.

The structure of the database was described in terms of a table containing a "field name", a "data type" and a "description". This can be seen in figures 5 to 13.

Figure 5**.** Details for table Terminal

Field Name	Data Type	Description
terminal_code	Number	
country_code	Number	
city_number	Number	
terminal_type	Text	"1"-Passenger ; "2"-Cargo
terminal_mode	Text	road/railway/maritime/inland/airway (e.g., "01001")
terminal_name	Text	
address	Text	

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Figure 6. Details for table Passenger_T

	Field Name	Data Type	Description
	terminal_code	Number	
	storage	Number	Storage units (mainly space for luggage - for now)
	capacity	Number	Capacity units (number of people)
	price	Number	Currency units (mainly storage costs - for now)
	infrastructure	Text	bank/hotel/shopping/car_rental/hospitality
	services	Text	repair/fuel/cleaning/maintenance/catering
	cost_taxes	Number	Currency units

Figure 7. Details for Cargo_T table

	Field Name	Data Type	Description
	terminal_code	Number	
	cargo_types	Text	roro/liquid_bulk/solid_bulk/container/lolo/cement
	specials	Text	piggy_back/swap_body/double_stack
	services	Text	water/fuel/maintenance/repair
	DGHC	Yes/No	Handles dangerous goods
	storage_capacity	Number	Storage units
	total_area	Number	Area units
	cost_pilotage	Number	Currency units
	cost_queuing	Number	Currency units
	cost_terminal	Number	Currency units
	cost_storage	Number	Currency units
	cost_gate	Number	Currency units
	cost_transportation	Number	Currency units
	cost_overhead	Number	Currency units
	cost_taxes	Number	Currency units
	cost_labour	Number	Currency units

Figure 8. Details for Cranes table

	Field Name	Data Type	Description
	terminal_code	Number	
	type	Text	Type designation
	qty	Number	# of cranes of type
	lifting_capacity	Number	Capacity units

Figure 9. Details for table Fridge

Figure 10. Details for table Terminal_GEO table

Figure 11. Details for table City table

Figure 12. Details for table Connection table

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Figure 13. Details for table Country table

Field Name	Data Type	Description
country_code	Number	
country_name	Text	
GNP	Number	
labour_cost_hour	Number	
tax_level	Number	%
employ_rate	Number	%
index_infrastructure	Number	1(worst) to 10(best) (mainly TEN accessibility - for now)
union	Number	Number of strikes/year
social_status	Number	1(worst) to 10(best)
stability	Number	1(worst) to 10(best)

For the first prototype, all "general information" was introduced in the EMOLITE BETA Version. Detailed information was collected and introduced in the general database. Information on the terminal specific database was depending upon the results of the AND Mapping co-operation and would be introduced in the final version of the EMOLITE prototype,

The algorithms and the simulation module were developed on the basis of the general database. depending again upon the information received from AND Mapping, adjustments would be made to finalise an operational prototype.

5.4.2 Final prototype

The following changes were made to the first prototype of the EMOLITE database and simulator:

1. Match AND Mapping fields with our EMOLITE attributes.
2. Feed the database with AND Mapping values.
3. Change some interface windows in order to make different groupings of information.
4. Guarantee correctness for CARGO; we only have information for this type of terminal.
5. Fuzzify in all cases. For example, all binary arrays must be fuzzified. All counting fields must be modified.
6. Add graphical views of the results obtained during the simulation.

7. Define a log file, so that the user can see and validate the values that are calculated.
8. Build a help on-line that can be used as a tutorial to help inexperienced users to get acquainted with the prototype.
9. Rearrange the main window so that, from there, we can access to a multi-criteria selection process.

All the above points were covered by the second version of the EMOLITE prototype. As the research team could only have access to information on cargo terminals, the passenger terminals were left unchanged. That is, the corresponding tables and fields still exist in the database, but the simulator ignores them in the second version. However, activating the passenger terminal evaluation model can be done without major difficulties and mainly depends upon the availability of relevant information.

The final prototype operates as demonstrated hereafter.

If cargo terminal is chosen from the window:

This is the second step of the PSI Wizard. The screen shown allows the user to specify the transportation framework, that is, to define the general characteristics of

the location(s) he/she is looking for. This step corresponds to the "Select destination country". The user must pick a country from the "Country" list box, where the countries available are the ones stored in the database. Optionally, the user may pick a city, which belongs to the selected country. The user must select at least one modality for the requested terminals. If the user selects more than one modality, the terminals extracted from the database will have at least one of the modalities selected.

Click <u>Back</u> to go to back and review/change the settings or click <u>Next</u> to proceed.

When proceeding, the following window appears:
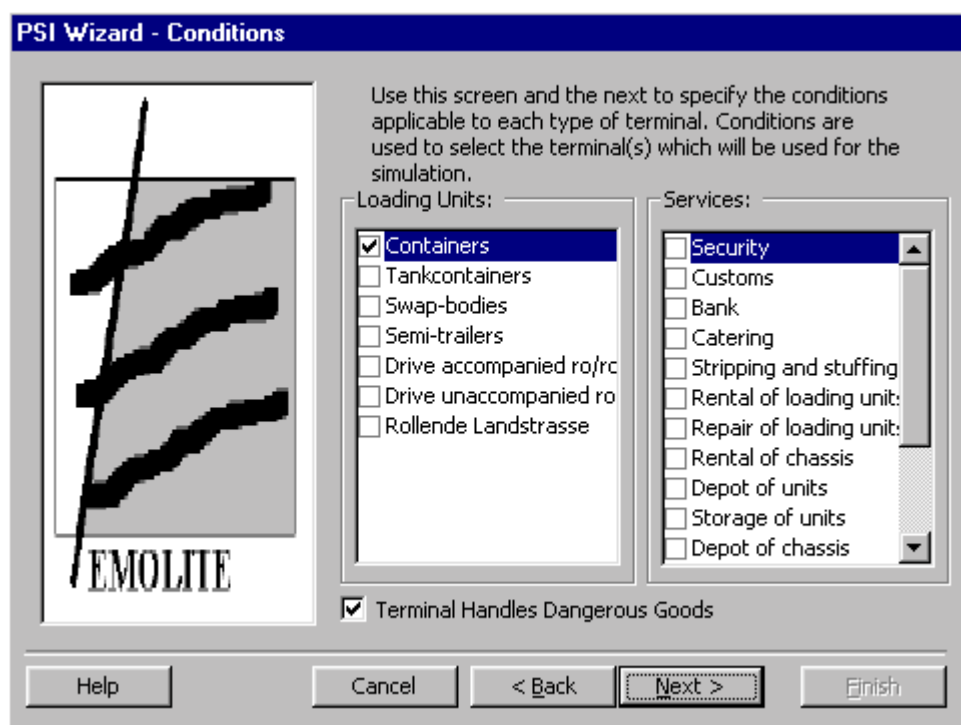
This is the third step of the PSI Wizard. The screen shown allows the user to specify the conditions applicable to each type of terminal. In other words, the user is able to narrow the set of terminals, evaluated for the intended purpose, through some conditional parameters. This step corresponds to the "Select conditions".

The user may select one or more types of loading units as well as services for the requested terminals. If the user selects more than one option, the terminals extracted

from the database will have all the capabilities selected.

Click Back to go to back and review/change the settings or click Next to proceed.

If we proceed, the conditions screen emerges:

This is the fourth step of the PSI Wizard. The screen shown allows the user to specify additional conditions applicable to each type of terminal. This step still corresponds to the "Select conditions".

The user may enter minimum values for terminals' capacities as well as maximum admitted costs for various items. If the user enters more than one value, the terminals extracted from the database will obey to all the restrictions specified.

Click Back to go to back and review/change the settings or click Next to proceed.

When Next is clicked, the fifth step is:
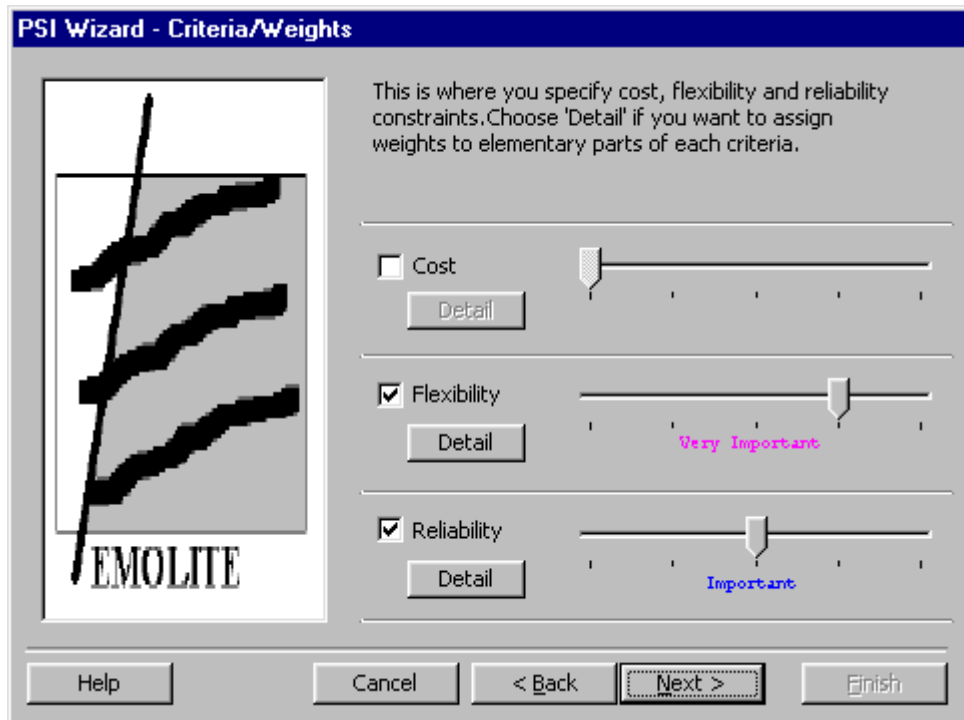
The screen shown corresponds to the main interface for the specification of criteria and weights that will apply to the terminals extracted from the database according to the conditions defined in the previous steps. This step corresponds to the "Select weights" task depicted in the Introduction.

The user may choose which constraints will be considered by (un)checking them. Besides, for each constraint checked it is mandatory to assign at least one weight to its elementary criteria as it is depicted in the detailed cost criteria screen, detailed flexibility criteria screen and detailed reliability criteria screen (see further). The weights assigned at this (high) level will affect the criteria as a whole as explained in the context of the simulation model section.

Click Back to go to back and review/change the settings or click Next to proceed.

If all the detailed criteria are ok, then we can run the simulation. The final window allows us to choose the presentation of the results: Full Report, Summary Report, Graph, Map.
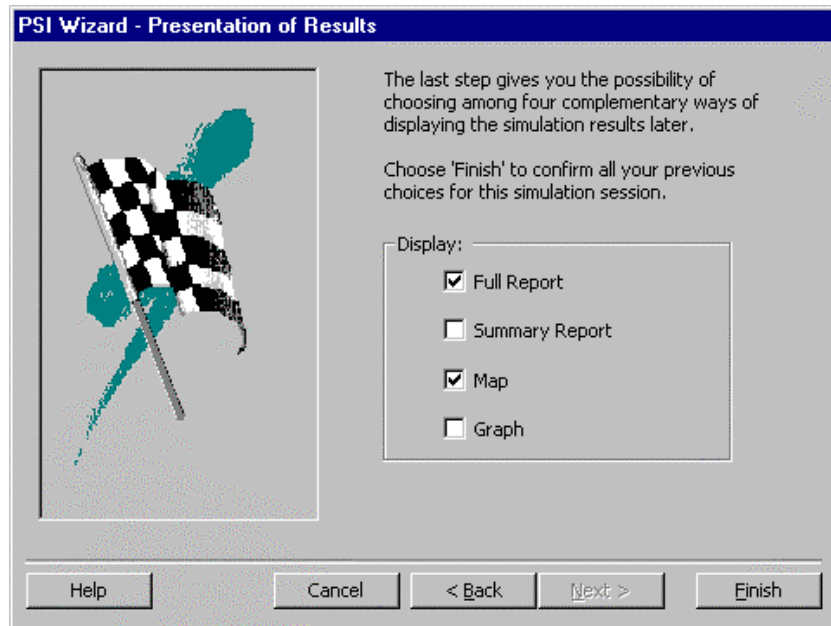
A summary report has the form:

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The screen shown is an MDI child, which displays the results from the Simulation in a tabular way. This window is shown and updated every time a simulation runs.

Graphs can also be used to better appreciate the results of the simulation. The screen shown is an MDI child, which displays the results from the simulation in terms of a graph. This window is shown and/or updated every time a simulation is run. For legibility reasons, only ten terminals are presented at the same time.

The following picture shows the global and flexibility criteria compared for the first ten terminals ranked:
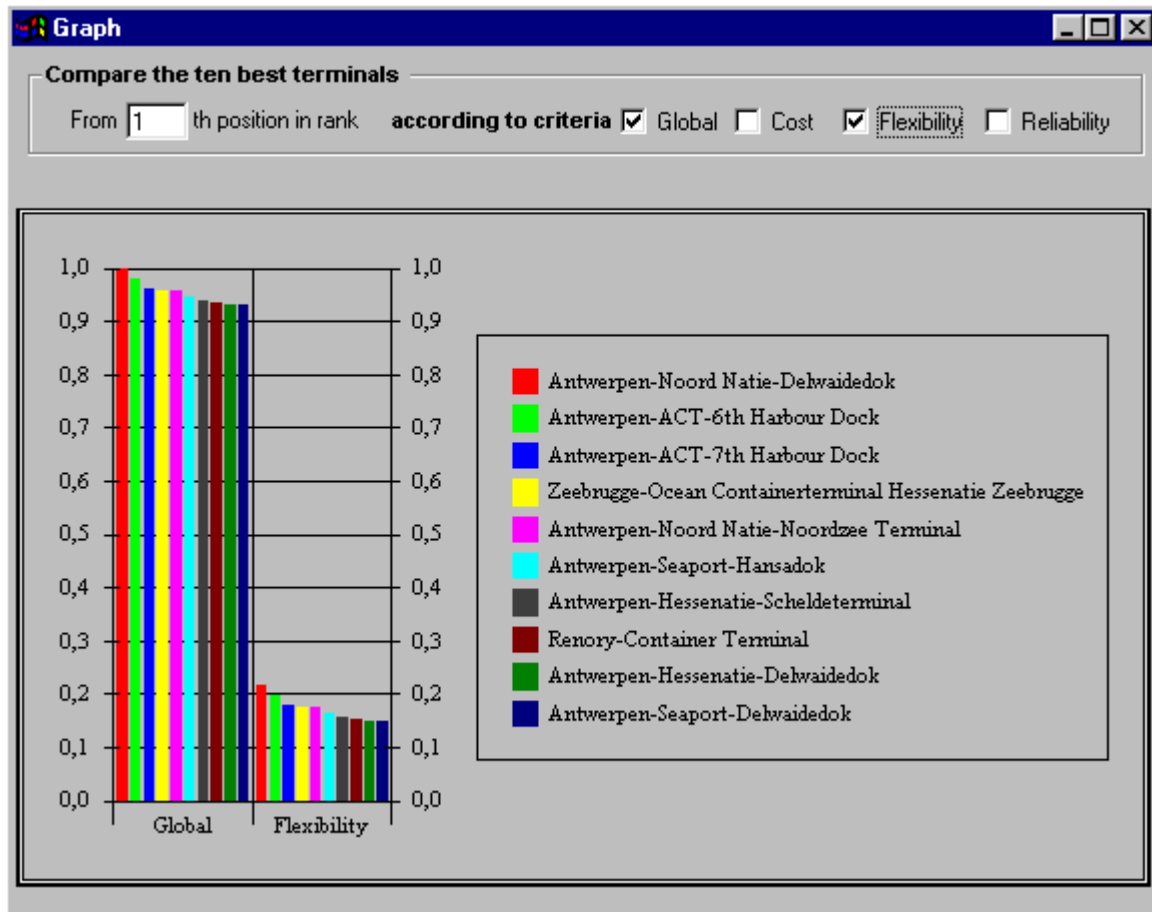
It is possible to double-click on every terminal presented to open the window showing its data, an example of such detailed information is demonstrated in next picture:

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Cargo terminals

Name: Aachen-West Ubf

ID: TD#t273   Code: DEU.AACH.WEST.0000

Visitors Address

Address: Republikplatz

Zip: [   ]   Town: Aachen

Mailing Address

Address: Republikplatz

Zip: [   ]   Town: Aachen

Contact

Tel: [   ]

Fax: [   ]

Email: [   ]

Coordinates

Latitude: 6,0688

Longitude: 50,7854

Country: GERMANY   City: Aachen

Capacity

Storage: 0

Lifting: 35

N. Reefers: 0

☐ Term. Handles Dangerous Goods

Cost of

Pilotage: 0

Queuing time: 0

Terminal: 0

Storage: 0

Gate: 0

Transportation: 0

Overhead: 0

Taxes: 0

Labour: 0

Modes:
- ☑ Road
- ☑ Rail
- ☐ Sea
- ☐ Inland Waterway
- ☐ Air

Loading Units:
- ☑ Containers
- ☑ Tankcontainers
- ☑ Swap-bodies
- ☐ Semi-trailers
- ☐ Drive accompanied ro/ro transport of semi-tr
- ☐ Drive unaccompanied ro/ro transport of sem

Services:
- ☐ Stripping and stuffing of containers
- ☐ Rental of loading units
- ☐ Repair of loading units
- ☐ Rental of chassis
- ☐ Depot of units
- ☑ Storage of units

OK   Cancel

The results obtained from the simulation can then be saved and used in the future.

5.5 The EMOLITE database

The EMOLITE program is based on two types of databases, an external and an internal one. EUROSTAT was chosen as main source for the *internal* database because EUROSTAT ensures availability in all Member-States, and has a uniform way of data-collection and data-presentation. The *external* database is based upon the database of AND Mapping (the Netherlands).

5.5.1 The general database structure

Although the capabilities of modelling problems by using fuzzy logic are interesting, it is necessary to go back to the basics and use sound basic information. Therefore the research team used data, cross-checked for their accuracy and their availability also in the (near) future. Consequently, EUROSTAT was chosen as main source of data because EUROSTAT ensures availability in all Member-States, and has a uniform way of data-collection and data-presentation.

The EMOLITE program is based on two types of databases, an external and an internal one. The databases are logically integrated in the system as shown in figure 14 below.

Figure 14: Database structure
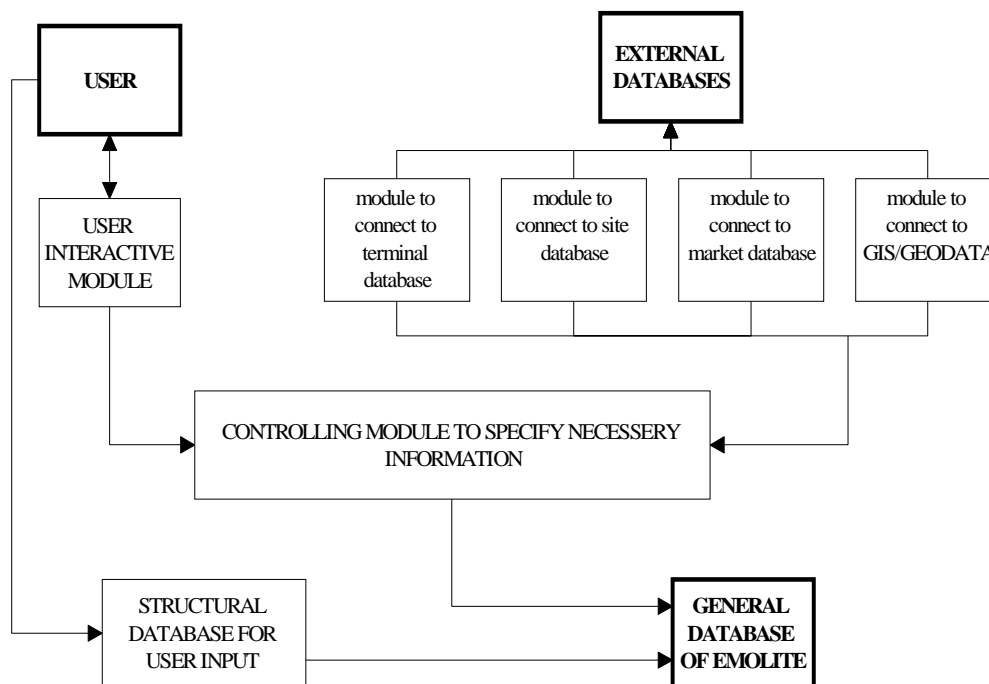
The *external* database is linked to four main built-in query modules of relevant data. The first module queries for a set of data referring to the terminal as such, the next group to the site, the other to the market and the last one provides geographical information. Thus the system extracts data of each sort in a robust and accurate way

whenever necessary. The database includes extensive data and the links channel the data into information for the internal needs of the system, i.e. of the algorithms.

The *internal* database is a more a general one, containing information related to the country and to economy. It will be analysed thoroughly, as separate section.

It is important to appreciate in figure 1 the user requirements logical box. The database should be considered as an encyclopaedia where data, facts and figures are stored. The user needs some but not all information available. This makes a selection procedure necessary.

The basic data structure is similar to relational databases and is visualised in figure 15 hereafter:

Figure 15: basic data structures

```
                        ┌─────────────────────────────────────────┐
                        │   E M O L I T E  G E N E R A L  D A T A B A S E   │
                        └─────────────────────────────────────────┘
                              │               │               │
                              ▼               ▼               ▼
                        ┌──────────┐    ┌──────────┐    ┌──────────┐
                        │  SET OF  │    │  SET OF  │    │  SET OF  │
                        │ RECORDS  │    │ RECORDS  │    │ RECORDS  │
                        └──────────┘    └──────────┘    └──────────┘
                              │               │               │
                              ▼               ▼               ▼
                        ┌──────────┐    ┌──────────┐    ┌──────────┐
                        │ RECORD   │    │ RECORD   │    │ RECORD   │
                        │   1      │    │   2      │    │   3      │
                        └──────────┘    └──────────┘    └──────────┘
                              │               │               │
                              ▼               ▼               ▼
                        ┌──────────┐    ┌──────────┐    ┌──────────┐
                        │ FIELD    │    │ FIELD    │    │ FIELD    │
                        │   1      │    │   2      │    │   3      │
                        └──────────┘    └──────────┘    └──────────┘
```
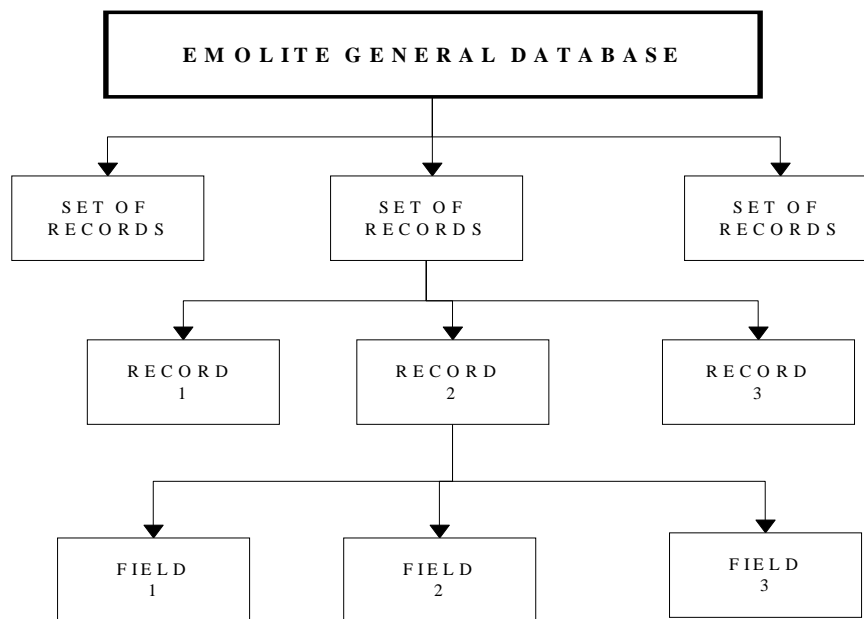
Every set of records contains records related to one another. Every record provides data broken down in individual data-fields. A simple example can be the transport set, where a record could be the country-roads and the fields several data, such as the length of the road network and the distribution between different road types (highway, local road etc).

Many figures are already included in the tables. The user must however perform the tedious task of updating these figures and complementing them.

5.5.2 The EMOLITE Internal database

The internal database contains six different groups of data, provided by EUROSTAT. The different tables represent groups of related information referring to all Member-States. The information can be broken down to macroeconomic and financial data, labour data, transport infrastructure, social status and origin-destination (OD) tables. All data are retrievable and can be integrated in any given application.

The macro-economic and financial data are providing an image of the fiscal status in the country. Figures of GNP, GNP per capita offer a comparison measure between different national economies. Along with the customer price index (CPI) and the short-term interest rates, the user can build an idea on the difference of costs related to the sites in one particular country compared to another country. In a simplified evaluation procedure, where two sites very close to each other but belonging to different countries are compared, such macro-data can act as first filter. Such indicators can provide important information before complex financial evaluations are conducted.

The EMOLITE database collects information from following available tables:

- Gross National Product in Millions of EURO
- Annual Growth
- Gross National Product in Millions of Purchase Parity Units
- Comparison of EURO and Purchase Parity Units
- Gross National Product per Capita in Purchase Parity Units [1000 Units]
- Consumer Price Index (base year 1985=100)
- Consumer Price Index Increase rate within 12 months
- Short term interest rates -Daily interest %

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The GNP measured in EURO or in "Purchase Parity Units" and their comparison provides interesting information about the growth and the investment potential of a country. The annual growth and the consumer price index along with the interest rates provide the general outline of the economy. The annual growth percentage indicates the growth or the expansion and the development of trade and commerce. The CPI along with the interest rates indicates the inflation and the local market of capital. Large-scale investment and transport infrastructure investments demand capital from the international financial markets and institutions, yet it is necessary to be aware, in almost all cases, of the local market as well.

A second set of interesting information is the information on labour and social protection. This information forms a separate table and provides an overview on employment conditions in the country. For the user of EMOLITE, these data reveal interesting information because they do not only support the system with data, such as unemployment rate but abet also figures about the percentage of labour missing due to illnesses or partial employment.

This set of data has actually four main objectives:

- to provide general employment information,
- to assist the user estimate the earnings of employees,
- to calculate the total working days per week,
- to estimate the total irrevocable days per year due to strikes, etc.

In order to achieve this goal the system draws out data out of these tables:

- Unemployment rates
- Unemployment in 1,000s (Totals)
- Net Earnings of employees (couple - no children) in the manufacturing industry EURO
- Net Earnings of employees (one salary - two children) in the manufacturing industry

- Social Protection per capita in EURO (1985 = 100)

- Social Protection per capita in Units

- Working hours weekly, full time occupation

- Percentage (%) of the labour force missing work due to illnesses

- Percentage (%) of the labour force missing work due to partial unemployment

- Lost working days due to strikes and disputes per 1,000 workers in the industry (all sections)

- Lost working days due to strikes and disputes per 1,000 workers in the manufacturing industry

These data concerning human resources labour force and their "habits" try to answer to questions such as the wages of the employment and labour force in the country and what is the expected evolution / attitude?

Figures of unemployment and net earnings of two major categories of workers are provided. In order to help the decision maker, the system must outline for him not only the official data regarding the average worker in a country but also the expected salary of a worker, the expected disputes and lost working days per year. The social protection figures and the official unemployment rates conclude this part. All these data may assist the user more by getting an idea about the actual status in human resources and calculate the cost with more accurate data keeping always in mind the necessary simplifications.

All this data are available from a single source, namely EUROSTAT.

The next group is the one containing information about the tax regime. The available income is about the taxation of the income and assets as percentage (%) of the GNP and the taxation of the production and the imports as percentage (%) of the GNP. Both data-sets are macroeconomic measurements but they give quite a clear idea about the tax regime.

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For simplicity and harmonisation reasons all monetary values are in EURO, as the common currency, which is the basis of calculation now and will be the common and dominating currency among Member States.

Collecting information regarding transport infrastructure and related information becomes more complicated because no uniform method of data-collection is existing. A breakdown per mode is available but the data provided by EUROSTAT are outdated and could therefore only be used as "indicators".

The EUROSTAT tables provide information regarding the infrastructure and in some cases also the current supply of transportation means. The breakdown is according to usual patterns.

Regarding the railways, breakdowns are available for tracks per narrow and normal gauges, per double or single lines and per electrified line or non-electrified. Subtotals and percentages provide informing on the current situation.

Unfortunately most of these data are of low value, since EUROSTAT does not publish small changes per year, e.g., the upgrading to a highway. Therefore, it is difficult to identify differences in the existing situation of the network.

In the EMOLITE database, several data groups have been collected covering both the "qualitative and quantitative aspects" of infrastructure to overcome the above described limitations.

More data is available for the road infrastructure, although these data can not be integrated in a single table since every country has different criteria and characteristics for road conditions. An additional problem is that the data are referring to 1990 (latest information available). Although there is no significant difference for developed countries such as Belgium, Germany or the Netherlands. In less developed countries such as Greece, Spain or Portugal, these figures can be misleading since many kilometres of highways have been constructed and national roads are transformed to highways in recent years.

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Data on the number of vehicles can provide useful information about the expected traffic but again, one should be careful because the figures are not reflecting the most recent situation.

An important factor is the fuel retail prices, as almost over of the 50% percent of the total road cost is the fuel cost. The user should update these tables as frequently as possible with the latest information available.

However and in spite of all these restrictions, the data can provide basic information, which demonstrate the quality of the EMOLITE model.

In the EMOLITE internal database, the road network is described with the following tables of data:

- Road Network
- Road Vehicles
- Stock of vehicles by category excluding motorcycles and caravans
- First registration
- Percentage of renewal
- Fuel - Retail Prices per 100 lt. [EURO]

The rail network is described with a consolidated table including all information about the gauges, number of tracks and electrification.

A very interesting group of data that has been integrated in the EMOLITE database is the one referring to inland waterways. High quality information is available in the EUROSTAT database, although it is not lately updated.

The following data are integrated in the EMOLITE database:

- Inland waterways - Number of enterprises servicing per country
- Inland Waterways
- Length and traffic density of the most important Inland Waterways
- Canals

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- Rivers

- Length of Navigable waterways by group

The tables providing information on seaport container terminals are outdated. However, the EUROSTAT information can be improved using another relevant source apart from EUROSTAT, which is the European Sea Ports Organisation (ESPO). The user can get an access through the web site: www.espo.be. However, accuracy remains questionable because most ports collect their own data and there is fierce competition among them making these ports reluctant to provide information. Nevertheless the structure of the available information allows the input of information according to a normal breakdown, as usually provided to the public. In many cases other information, such as the available infrastructure, superstructure and transit movements, is of greater importance, but it is only available in specialised publications. These publications can be found through ISL (www.isl.org) or via the magazine *Containerisation Today*.

Though the interest of freight movement by air is rather restricted to specific cargoes, it could be important to provide in EMOLITE the possibility of using the air facilities. For parcel shipping and JIT logistics, airports and airways provide the only alternative. Therefore, the option is included in the database but has not been elaborated in the prototype. The data include specific breakdown for parcel movements. Information on air traffic volumes in international airports is also provided.

Finally there are figures about the number of transport enterprises per each country, which could be an important starting point for marketing reasons and logistics chain development.

This information is completed with the general data used for calculations, such as the total surface and population of each country.

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Origin - Destination (O-D) tables were also foreseen in the EMOLITE database but generated more complications. The collection of O-D data is even more difficult since national borders disappeared in the EU. At present, there is almost no information available in the national statistics offices. Some specialised companies are collecting such data from trade unions, organisations and specialised agencies. However it might be very interesting to have this data in form of transport flows per mode and per SITC digit analysis among EU Member States. This feature is however not available in the EMOLITE prototype but could be considered for a later version if one is interesting in making detailed O-D surveys. Other flows, such as trade with third countries, are available by the national statistical departments and in many cases in electronic form. They could be used if the model is expanded with extra-European trade relations.

Finally, the EMOLITE database contains "general" information on the Member-States, which is stored in text format.

The text contains data on:

Geography
Location
Coastline
Maritime claims
International disputes
Climate
Terrain
Natural resources
Land use
Irrigated land
Environment
Geographic notes
People
Population
Age structure
Population growth rate
Birth rate
Death rate
Net migration rate
Sex ratio
Infant mortality rate

Life expectancy at birth
Total fertility rate
Nationality
Ethnic divisions
Religions
Languages
Literacy
Government
Name of the country
Data code
Type of government
Capital city
Administrative divisions
Dependent areas
Independence
National Holiday
Constitution
Legal system
Suffrage
Executive branch
Legislative branch

Judicial branch
Political Parties and leaders
Other political or pressure groups
International organisations participation
Economy
An economic overview
GDP
GDP real growth rate
GDP per capita
GDP composition by sector
Inflation rate (consumer prices)
Labour force

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Unemployment rate	Economic Aid	Airports
Budget	Currency	Heliports
Industries	Exchange rates	Communications
Industrial Production	Fiscal Year	Telephones
growth rate	Transportation	Telephone system
Electricity	Railways	Radio Broadcast stations
Agriculture	Highways	Radios
Illicit drugs	Waterways	Television broadcast
Exports	Pipelines	stations
Imports	Ports	Televisions
External Debt	Merchant marine	Defence
		Branches
		Manpower availability
		Defence expenditures

All these data can be considered and calculated in the selection process for the location(s) of intermodal terminals. Although some of these data seem to be rather *irrelevant*, several could be interesting indicators regarding the level of development of a country. For example, military activities in a country are indicative of the national wealth spend on the armed forces and the purchase power of such public service. The number of radios and TVs can be useful to users who needs direct information about the market penetration ability in audio-video. Additionally other information about the population and the government can affix to previous calculations or shape a first idea about marketing groups or the political environment.

5.5.3 Information sources and how to update the data

The aim of the EMOLITE research team was not only to assemble relevant data in the internal database but also to assure that the future user/developer of the EMOLITE decision support system could easily update the necessary data from several data sources.

Some 235 regions, comprising the entire territory of the European Union (EUR 15) and EFTA countries, feature in the four volumes of *Portrait of the regions.* The information includes maps and illustrations in colour, general and harmonised statistical tables, commentaries and analyses on territory, environment,

infrastructures, strengths and weaknesses of a region, changes in population, employment and unemployment and structure of economy (principle sectors of activity, salaries, list of companies or organisations employing the largest number of people, etc.). This publication is classified as "General Statistics".

The catalogue number is CA-74-91-00$-**-C, where $=1, 2, 3, 4 for each volume, i.e. volume 3 has the catalogue number CA-74-91-003-**-C.

Because the usual procedure is that EUROSTAT publishes the data after the collection and the checking operation by the National Statistic Offices. Consequently it costs time to concentrate all data from all Member States, but this is for the real benefit of the end-user. The EMOLITE team decided however to use the EUROSTAT data as basis because the information is consistent for every Member.

The publications of EUROSTAT used as sources are:

EUROSTAT code	ISBN
6120/007	ISBN 92-827-8845-8
6120/8201	ISBN 92-825-9734-2
6120/8201	ISBN 92-827-8360-X
6120/40401	ISBN 92-827-6756-6
6120/7101	

The first bulletin, 6120/007, is the Census Yearbook for 1996. "The people", "the land and environment", "the national economy", "trade and industry", the European Union": these five key chapters contain the main statistical data from EU countries from 1983 to 1993. This exhaustive statistical publication contains also detailed comparisons with the EU's main trade partners.

The user must be aware that, although this information is also offered in electronic format and in all languages (catalogue number the CA-81-93-204-**-C) as a CD-ROM it cannot be integrated to any system since it is a "read-only version". The last one, 6120/7101, is the EUROSTAT special edition on transport infrastructure, dated

1990. As discussed previously, it might be useful as basic information but the figures could be misleading.

Interesting information provided by EUROSTAT offices for free can be found in more than one publication. This information includes:

- Net earnings of employees in manufacturing industry in the EU, 1995
- Statistics in focus: population and social conditions. EUROSTAT, labour force survey, 1994
- Social protection and receipts, 1980-1994
- Statistics in focus: population and social conditions. Social Protection in the EU, 1995
- National Accounts ESA: aggregates, 1970-94
- General government accounts and statistics, 1970-93, 1993
- General government accounts and statistics, 1970-93, 1995
- Economy and finance, short term statistics, monthly publication
- Cost of living in the EU, 1995
- Money and finance (quarterly) III.3

Important transport related information can be found in the following EUROSTAT editions:

Title	Catalogue Number
EUROSTAT yearbook	CA-81-93-204-**-C
Portrait of the regions (4 volumes)	CA-74-91-00$-**-C where $ = 1, 2, 3, 4
Regions, statistical Yearbook	CA-91-95-924-4M-C
Money and Finance	CA-BQ-96-000-3A-C
ESA 1995	CA-15-96-001-**-C
National Accounts ESA – Aggregates 1970-1994	CA-94-96-154-3A-C
Labour Force Survey Results 1994	CA-92-95-877-**-C
External trade, Statistical yearbook, 1994	CA-83-94-628-5E-C

All these editions are reference tools that are regularly updated. In addition to the above reference tool interested persons could also examine the GISCO database. The GISCO database contains geographical information on themes such as administrative areas, infrastructures, hydrography, natural resources, industries, etc. By combing GISCO with the REGIO database, statistical information can be mapped at a regional level. REGIO is the first statistical, topographical software of the European regions. The real value of such a combination is to be seen in the

application of spatial analysis to areas like: the accessibility of European infrastructure networks, the degree of urbanisation or even the structural funds.

Regarding O-D tables, EUROSTAT provides in CD format a breakdown of cargo-flows per 8 digit SITC code for the intra- and extra EU trade. The data are analysed per month. Unfortunately, no breakdown per transport mode is provided.

The CD can be bought by EUROSTAT. Its code number is ISSN 1017-6594.

All information, described and used in the EMOLITE internal database, can be purchased as individual document or by annual subscription. Several publications are available in libraries, National Statistic Offices and relevant institutions.

An overview of existing statistical publications is available on the web (URL address: http://europa.eu.int/eurostat.html). The information can also be acquired in the 'EUROSTAT Data Shops':

Data Shop Brussels
Rue Joseph II, 121
1049 Brussels
tel.:+32-2-29-96666   fax:+32-2-29-50125
email: Piera.Calcinaghi@eurostat.cec.be

Data Shop Luxembourg
2, rue Jean Engling
1466 Luxembourg
tel.:+352-4335-2251   fax:+352-4335-22221
email: AgnesN@eurostat.datashop.lu

Data Shop Paris - c/o INSEE INFO Service
195, rue de Bercy
Tour Gamma A
75582 Paris Cedex 12
tel.:+33-1-53-17-89-32 or-45 fax:+33-1-53-17-88-22

Data Shop New York - c/o Haver Analytics
60 East 42nd Street - Suite 2424
New York, NY 10165, USA
tel.:+1-212-986-93-00 fax:+1-212-986-58-57
email: eurodata@haver.com

For the general data regarding all countries, which constitutes the last set of information in the EMOLITE database, the "Almanac of 1996" is a very interesting additional source. The EMOLITE research team also used it. This Almanac is on the World Wide Web on the site of the Central Intelligence Agency (CIA) of the United States Government. The database is updated frequently and is always accessible.

5.5.4 The external EMOLITE database

The external database used in EMOLITE is the Global transport database, an AND proprietary database. This database can either be licensed individually or in conjunction with the Global Geographic database. In the latter case the Unique Connection Points (UCP's) Terminals facilitates the connection.

The Global Transport database is continuously updated. New releases are made available to our clients twice a year, namely in January and July.

This database contains all information required for the transportation of cargo by standardised loading units like for instance containers. The database is divided into Transport Networks and Services.

Transport Networks	Contents
Terminals	1,031
Ferry Connections	190,500
Railway Network	323,200
Inland Waterway Network	14,500 km
Sea Network	85,500 km
Industrial areas	5,800

Transport Services	Number of
Ferry Services	3,000
Rail Services	19,500
Inland Waterway	25,400
Sea Services	7,500

Transport related	Number of
Organisations Europe	3,300

Transport Networks

All Transport networks are digital models of maps that can easily be linked together. When the Road Network Database is incorporated, extra information about tonnage restrictions for roads, toll roads, and border crossings open to freight transport will be included as well.

Terminal Network

Terminals are the turntables between different networks, the place where goods are transferred from one mode of transportation to another. The Terminal network consist of two files: the first file contains name, location and type of the terminal and the second file contains all specific characteristics of each terminal; like for example accessibility, names of operators ad loading equipment.

Ferry Network

The Ferry Network holds all data on ferry connections plus ferry coding points, as well as information like tonnage restrictions for freight transport. The ferry coding points can be used to link ferry timetables to this network (see Transport Services).

Railway Network

The Railway Network consist of freight and passenger lines and links to terminals with a rail connection. Passenger lines are also included as they are increasingly being used for freight.

Inland Waterway Network

The Inland waterway network contains river and canal waterways accessible to ships of over 50 meters in length and the links to terminals with a river or canal connection.

Sea Network

The European sea network contains transport routes between ports and the links to terminals with a sea connection. The sea networks of the Atlantic, India and Pacific Ocean are not linked yet to terminals on the surrounding continents.

Industrial Areas

The network of Industrial Areas contains information used by companies for industrial or other non – agricultural purposes.

Further details are described in Annex 1 of this final report. However, this information is confidential, given the commercial sensitiveness of the information.

5.6   Technical description of EMOLITE

5.6.1   Technical requirements

EMOLITE 2.0 is a prototype of a system, that is user friendly and not difficult to install. Also, since there was a limited budget available for the EMOLITE project, hardware and software choices reflect both large availability and low cost:

- PC with Pentium processor.
- Microsoft Windows 95 or Microsoft Windows NT Workstation operating system version 4.0 or later.
- 16 MB of RAM (32/64 MB recommended).
- Microsoft Visual Basic/Visual C++ language and tools to implement the interfaces.
- DAO/ODBC to access databases from both languages.

The selected hardware and software is sufficient because the goal of the EMOLITE project was only to produce a prototype version of the model. In order to produce a complete and complex system, software and hardware choices will have to be more demanding, at least in what concerns the database management system.

5.6.2 The EMOLITE framework

The EMOLITE framework can be seen from two different perspectives: data and simulation.

5.6.3 Data handling

An abstract and implementation free data model is shown in figure 16.

Figure 16. Data model
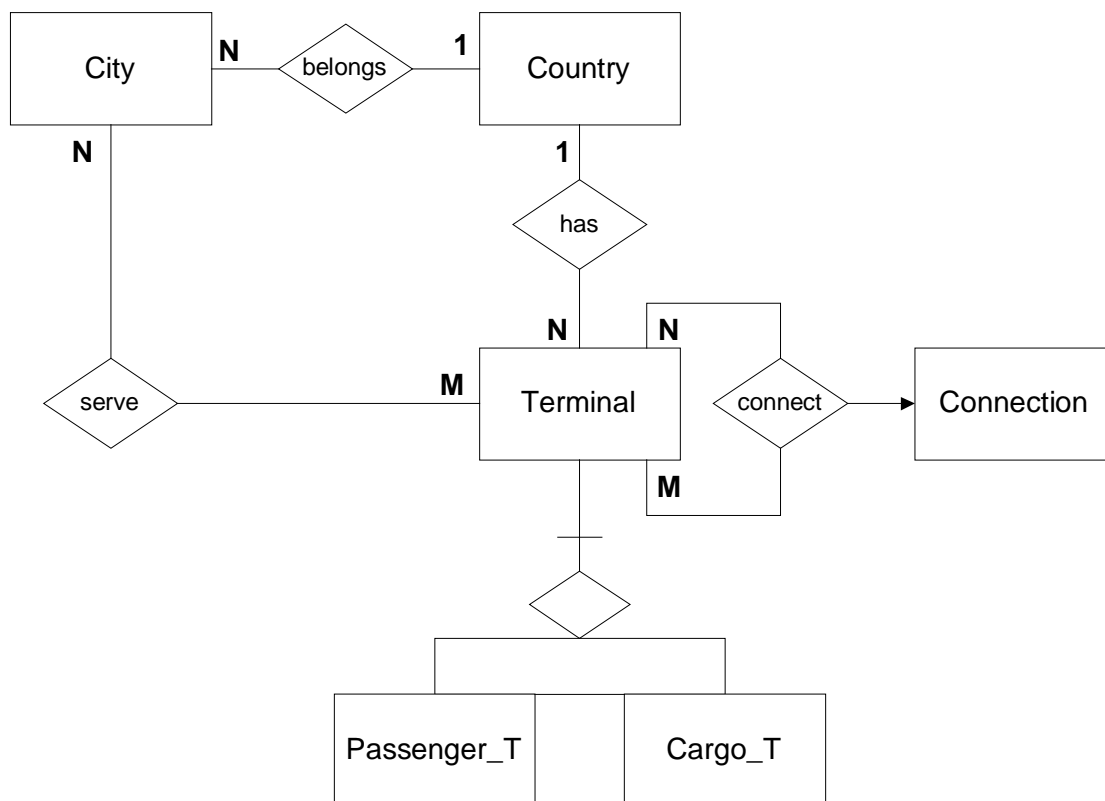
5.6.4 Simulation process for selection of destination terminals

The model for the developed prototype assumes that the user is located at an origin and that he wants to select a destination terminal to send his products. The

destination teminals are N, but all in one destination country. Figure 17 depicts this aspect.

Figure 17: Origin-destination decision model

```
+----------------+          +----------------+
|                |          |  Destination   |
| Country-origin |--------->|  Country:      |
|                |          |                |
+----------------+          +----------------+
```
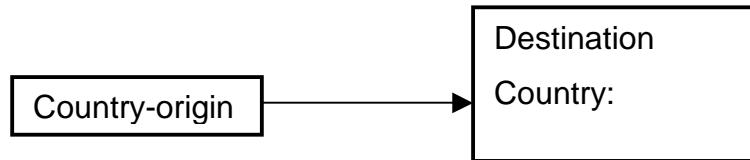
In order to select which of the destination terminals is the one that best satisfies the user conditions and criteria a simulation model was developed. This model is implemented in the prototype and includes two main phases:

Phase 1- Pre- Selection of possible destination terminals using the basic requirements (conditions) specified by the user.

Phase 2- Selection of the best terminal using a fuzzy rating and ranking of the possible terminals to provide the best choices to the user.

Phase 1

In this phase the user must select the basic requirements his/her destination terminals should have. These requirements are divided in two sections (corresponding to two windows in the prototype).

First, the user has to click on which of the following items the destination terminals should handle to transport the products:

- Type of cargo «solid bulk, general cargo, containers, liquid bulk commodities, cement»,
- Specials «piggyback, swap body, double stack»,
- Services « water, fueling, maintenance, repair»

Second, the user should introduce the values for the following conditions:

- Capacity « minimal storage, minimal crane, Fridge»
- Price «overhead, pilotage, queing time, terminal cost, storage, gate cost»

After, the prototype performs the selection of the destination terminals that fulfill the specified requirements (conditions). The result is a set of POSSIBLE destination terminals.

Phase 2

In this phase a rating and ranking process are performed to obtain a final classification for each of the possible terminals (previously selected in phase 1). This selection process includes the following elements: (1) an aggregation algorithm for rating the terminals; (2) a raking process for the selection of terminals (from best terminal to worst from the set of possible ones), (3) Importance/weights for the three evaluation criteria (cost, flexibility, reliability) and for their respective attributes; (4) Fuzzy attributes;

The structure of the fuzzy multiple attribute decision model, implemented in the prototype is shown in Figure 2. This figure depicts the three main classes of attributes (costs, flexibiltity, reliability) and their respective attributes. The figure also shows the weights that will be assigned to the classes and attributes (Weight_X, W_Y), as well as the membership values for each attribute (M_Y).

The inputs required from the user for the whole process are just the importances (weights) that they assign to each class and to each attribute(Weight_X, W_Y). To introduce this weights the prototype provides user-friendly windows with bars wre the user moves the bar to the desired importance level. The importances range go from extremely unimportant to extremely important (more details about the importances will be provided later). The fuzzy membership values (M_Y) are obtained automatically from the database using the fuzzy membership function for the respective attribute. The latter functions are embeded in the prototype and its construction process will be addressed later.

After obtaining the weights the rating and ranking process are performed by the prototype to obtain the final classification as follows:

(1) Rating

The rating process for any terminal A is obtained by a weighted sum formula. Using the labels depicted in figure 18 generates:

Rating (A) =

Weight_C* (M_ov*W_ov+ M_pi*W_pi + M_qt*W_qt + M_tc*W_qt + M_tc*W_tc + M_tr*W_tr + M_gc*W_gc + M_tx* W_tx + M_lb* W_lb + M_st* W_st) +

Weight_F* (M_cr*W_cr + M_str* W_str + M_fr*W_fr + M_co*W_co + M_ten* W_ten + M_inf* W_inf) +

Weight_R* (M_un*W_un + M_soc* W_soc + M_sta*W_sta).

Figure 18: Multiple attribute decision mode
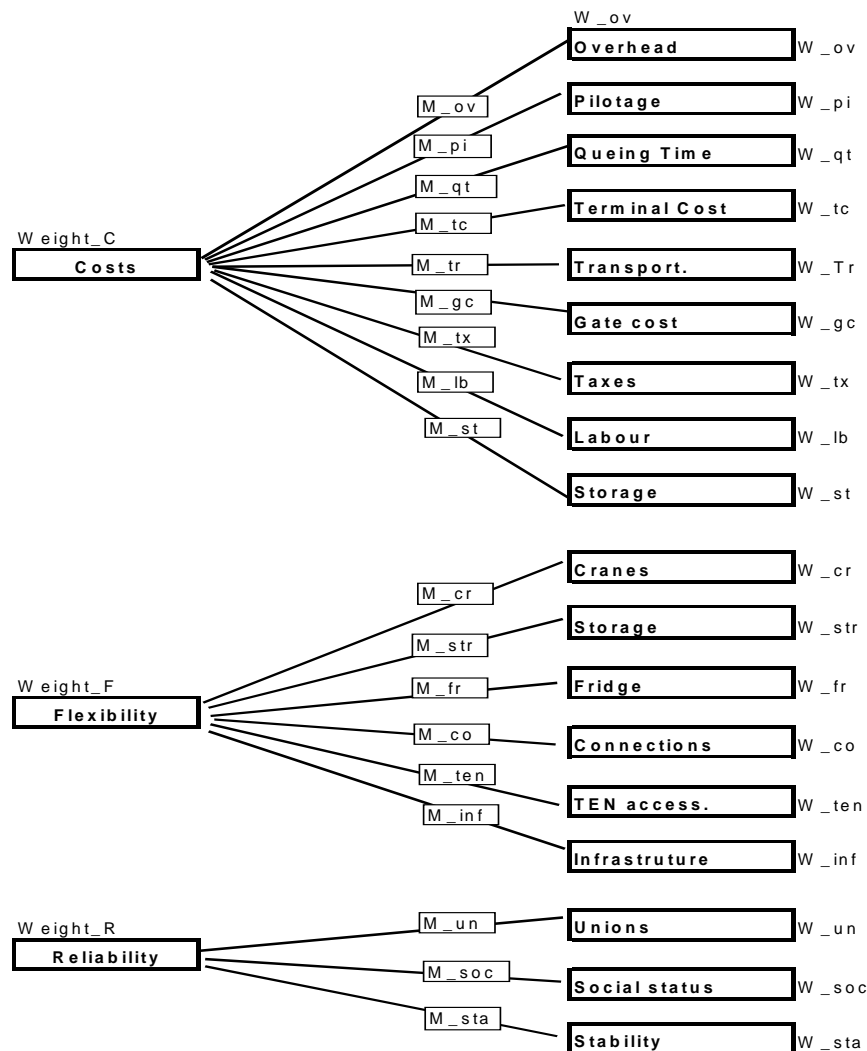
Formally the aggregation formulas are:

$$Rating(C_j) = \sum_i W_i \times SC_i$$

$$Rating(Term_K) = \sum_j W_j \times C_j$$

Where C_j is a criterion (Cost, Flexibility or Reliability), SC_i are the sub-criteria (fuzzy attribute value) of each criteria, W_i is the importance of that sub-criteria, W_j is the importance of criteria C_j and $Term_k$ is the terminal being evaluated.

 (2) Ranking

After obtaining the rating for each possible destination terminal the ranking process begins. The ranking is done by using an "ideal" terminal concept, i.e. the rating is matched with a fixed ideal terminal to obtain a classification. An ideal terminal is one with membership value of 1 for all attributes, where 1 corresponds to the highest (smallest) membership value for the attribute data range. In addition, the summary report (output of the prototype) also shows the fuzzy rating as well as the rating with the ideal.

The value obtained in the rating of terminal is than matched against the "ideal" value to obtain a measure of how far away from the ideal that choice is. The "ideal" is calculated with the above formulas using for all attributes a membership value (µ) of 1 (best possible). This is an original measure, proposed in this project, which accounts for the importances given by the user to each sub-criteria and criteria, to obtain a final ideal value for the terminal being evaluated. Hence, the final ranking value, per terminal, is obtained as follows:

$$FuzzyRaking\,(\text{Terminal}_A) = Rating\,(\text{Terminal}_A) \div Ideal$$

As can be observed, the operators for aggregation used in the EMOLITE prototype are the algebric product and algebric sum and they belong to the set of t-nomrs and t-conorms. These type of operators satisfy the axioms of boundary, associativity, monotone non-decreasing and comutativity (similarity). Many other operators from the classes of t-norms and even compensatory operators could have been used, but for reasons of simplicity the prototype only used the simple algebric product and sum.

The final ordering of the terminals, which corresponds to the *Ranking* phase of the FMA approach is the descending order of the values obtained in the FuzzyRating. I. e. the best terminal is the one with the highest value, the second best is the one with the second highest value and so forth.

As mentioned, the prototype shows, in the summary report, the *FuzzyRaking* value and the *Rating(A)* to provide the total value obtained and its relation with an "ideal" value. The classification are presented in a decreasing order of classification, i.e. from the best classification to the worst.

With the results obtained with the prototype the user has a rating and ranking of all possible terminals (the ones selected with the Conditions module) and if he is not satisfied he can always change some of the weights to perform a "what-if" analysis (simulation capability).

(3) Importance/weights

The importance/weights for the three criteria (cost, reliability and flexibility) and its respective sub-criteria (see respective menus) is defined as a discrete fuzzy set with the following labels and respective membership values:

[irrelevant: 1, low: 3; important: 5, very important: 7, extremely important: 10]

The prototype presents the user a scale-bar with the above labels where each tick corresponds to the above membership values. The user introduces his/her importance/weights for the three upper level criteria (Costs, Flexibility, Reliability) and, when desired, for each of the detailed sub-criteria. By default the value is *irrelevant*.

(4) Fuzzy Attributes

There are two types of representation for the fuzzy attributes: discrete or continuous. The attributes of the EMOLITE are depicted in the second level of Figure 2. These fuzzy attributes are embedded in the software and the user does not need to provide any information for its construction, once they are build automatically. Hence, the construction process for the continuous attributes was the following:

1. First the Minimum and the Maximum of each attribute is extracted from the database of terminals.

2. Second the type of function for that criteria (ascending or descending) is obtained from a database table. For example, for costs it is always descending (the lower the value the better).

3. The corresponding fuzzy sets are built with triangular functions, such as:

4. When a specific terminal criteria is being evaluated, the membership value (μ) for each attribute, is calculated with the respective database value for that attribute, x, as follows:

   Ascending:

   $$\mu(x) = (x-min)/(Max-Min) \text{ for } Min <= X <= Max ;$$
   $$\text{for } X <= Min \text{ is } 0$$
   $$\text{for } X => Max \text{ is } 1$$

   Descending:

   $$\mu(x) = (Max-x)/(Max-Min) \text{ for } Min <= X <= Max ;$$
   $$\text{for } X => Max \text{ is } 0$$
   $$\text{for } X <= Min \text{ is } 1$$

   where $\mu(X)$ lies in the interval [0, 1].

   It should be noted that this construction is transparent to the user. All that is required from him/her is the introduction of importances/weights for the evaluation criteria.

5. The membership value (μ) obtained is later used to calculate the final evaluation aggregation procedure for ranking the terminals (using the respective importance/weights for the evaluation criteria).

5.7 The user interface to increase user accessibility

When the application starts, a logo screen is shown:
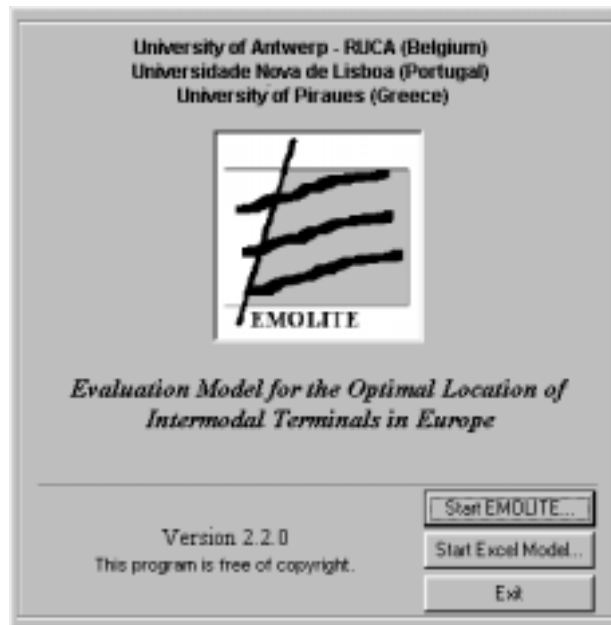
Start EMOLITE...

This button allows going to the main EMOLITE window, by giving the user the possibility of creating or opening a Project Specific Information.

Start Excel Model...

This button opens an Excel model, from where we can access to a multicriteria selection process.

Exit

This button exits the application.

After closing the logo screen, a dialog box pops up, allowing the user to choose between loading a project file saved previously or creating a new one from the scratch.
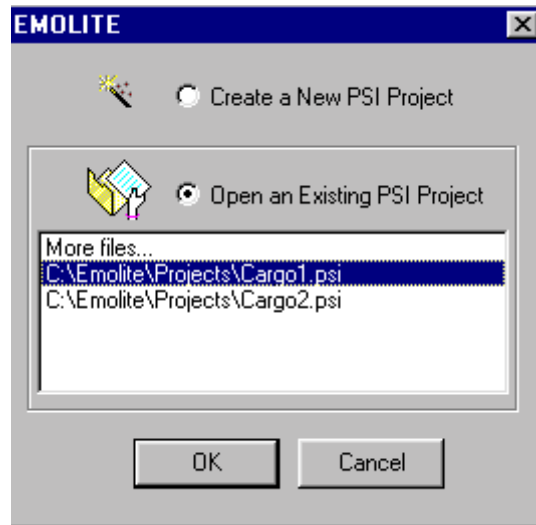
Create a New PSI Project

By selecting this option and clicking on OK, the user goes to the PSI Wizard in order to build a new project.

Open an Existing PSI Project

By selecting this option and clicking on OK, the user goes to the EMOLITE Main Window with the settings of the project selected.

Wizards play a key role in EMOLITE application. They are intended to make users' life easier, leading them step-by-step through an unusually long, difficult, or complex task. In EMOLITE, wizards are mainly used for creating and modifying simulation scenarios and accessing databases.

The purpose of the Simulation Wizard is helping the user to define the transportation framework, conditions and criteria/weights for a simulation session.
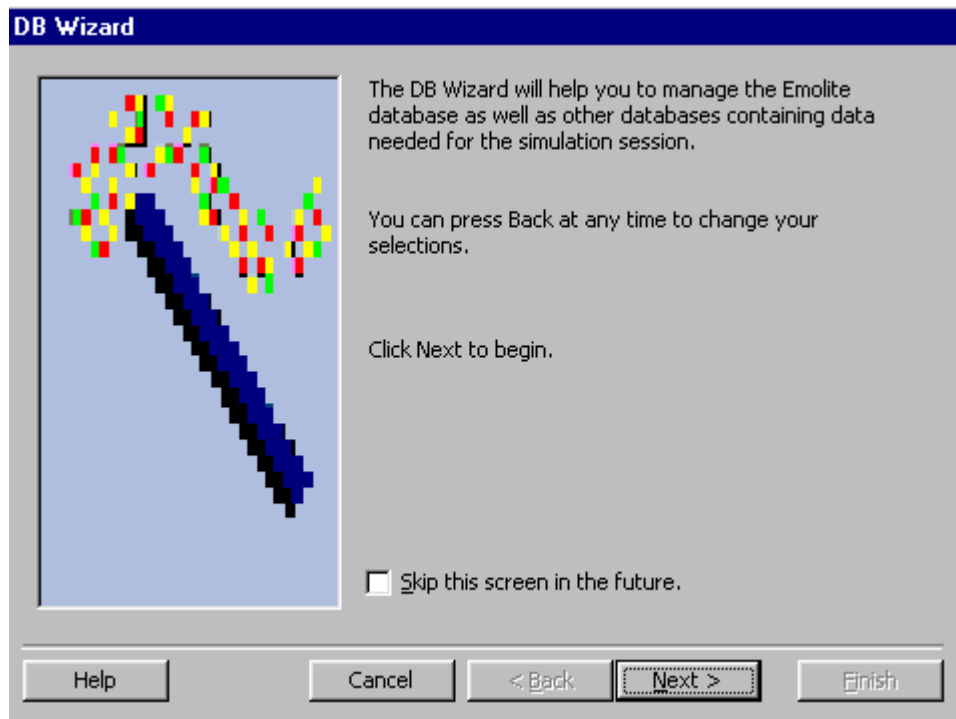
This is an MDI (Multiple Document Interface) application, that is, the main window will provide a workspace for all the child windows in the application.

The user will be able to display multiple documents at the same time, with each document displayed in its own window. In the case of EMOLITE, Project Specific Info, charts, maps and reports are different types of documents.

Project Specific Info

- Transportation Framework
    - Type of terminal:
        - Cargo
    - Destination terminal:
        - (Belgium)
    - Modalities:
        - (Road)
        - (Rail)
- Conditions
    - Capacity (Minimum required):
        - Lifting capacity of crane (metric tones) = (30)
- Criteria/Weights
    - Flexibility
        - TEU's = (Irrelevant)
        - Lifting capacity of cranes = (Few important)
        - Reefers = (Important)
        - Connections = (Important)
        - TEN accessibility = (Few important)
        - Infrastructure (Services + Loading Units) = (Irrele
    - Reliability
        - Unions = (Few important)
        - Social Status = (Very Important)
        - Stability = (Extremely important)
        - GNP = (Few important)
- Presentation of Results
    - (Summary Report)
    - (Graph)

The *Project Specific Info* window contains the parameters defined for the project currently in use.

The menus will provide the usual commands for managing PSI files, customizing windows, displaying documents, getting help, starting wizards and running simulations.

File Menu
>   **New**
>   **Open...**
>   **Close**
>   **Save**
>   **Save As ...**
>   **Properties...**
>   **Print Preview**
>   **Print...**

Exit

Edit Menu
>**Cut**
>**Copy**
>**Paste**

View Menu
>**Toolbar**
>**Status Bar**
>**Log**

Simulation Menu
>**PSI Wizard**
>**DB Wizard**
>**Fuzzy Set Range**
>**Run...**

Window Menu
>**Cascade**
>**Tile Horizontal**
>**Tile Vertical**
>**Arrange Icons**

Help Menu
>**Contents**
>**Search**
>**About Emolite...**

All the underlined entries have graphical interfaces defined.

There is also a *Toolbar* - from which the user can issue some commands in a quicker way – and a *Status bar* – where relevant messages are displayed showing the status of the application when certain operations are being performed.

The Log window is provided as a debug tool, that is, it displays the contents of the EMOLITE log file. This is useful in some situations, where something goes wrong or tracing an operation in a detailed way is important.

```
View Log                                                    _ □ ✕

Find what:  [                              ]        Refresh

  ----------------------------------------------------
  Run Simulation
  ----------------------------------------------------

  Condition:
  SELECT * FROM ((Country INNER JOIN City ON Country.country_code =
  City.country_code) INNER JOIN Terminal ON (City.city_code = Terminal.city_code)
  AND (City.country_code = Terminal.country_code)) INNER JOIN Cargo_T ON
  Terminal.terminal_id = Cargo_T.terminal_id WHERE  Country.country_name =
  'Belgium'  And (Mid(Terminal.terminal_mode, 1,1) = '1'  Or
  Mid(Terminal.terminal_mode, 2,1) = '1' ) And Cargo_T.lifting_capacity > 30 ORDER
  BY Terminal.terminal_id

  # Terminals selected: 33

  PG_Cost: 0

  PG_flexib: 7

  PG_reliab: 5

  xxxxxxxxxxxxxxxxxxxxx
  0.Terminal: Mouscron-DPMLI(TD#t2201)
  xxxxxxxxxxxxxxxxxxxxx

  -------------------Flexibility
```

Another important window is provided as an auxiliary way to view the current range for the various criteria parameters used by the simulation algorithm.

Criteria	Delta	Min	Max
Cost			
Overhead	−	0,00	0,00
Pilotage	−	0,00	1200,00
Queutime	−	0,00	0,00
Termcost	−	0,00	0,00
Transport	−	0,00	1250,00
Gatecost	−	0,00	0,00
Taxes	−	0,00	0,00
Labcost	−	0,00	0,00
Storage	−	0,00	0,00
Flexibility			
Storage	+	0,00	678,00
Cranes	+	0,00	2000,00
Fridge	+	0,00	0,00
Connect	+	0,00	100,00
Tenaccess	+	0,00	11056,00
Facilities	+	0,00	24,00
Reliability			
Unions	−	0,00	1671,00
Social	+	0,00	0,00
Stability	+	0,00	0,00
Gnp	+	0,00	46380,70

The **Criteria** field shows the name of the criteria.

The **Delta** field shows a plus sign if "Min" is the lower limit and a minus sign otherwise.

The **Min** and **Max** fields show the range values.

To run the simulation we need to choose **Run...** from the menu. This step corresponds to the "Rank terminals" after the simulation.

To run the simulation, the user has three alternatives:

- by clicking the option **Run...** from the Simulation menu in the main window
- by clicking the appropriate button at the Toolbar in the main window
- by clicking **Yes** in the Confirmation box shown after leaving the PSI Wizard

Running the simulation starts a calculation process - that takes into account the conditions and criteria defined for the current project - for ranking terminals.
A progress bar is shown during the calculation; once finished, the corresponding output windows (Summary Report, Full Report, Graph, Map) are updated to reflect the new results.

5.8   Setting weights and criteria

Setting the weights and criteria can be done at the general level and at the detailed level (see figure 18)

Figure 18. Definition of general criteria
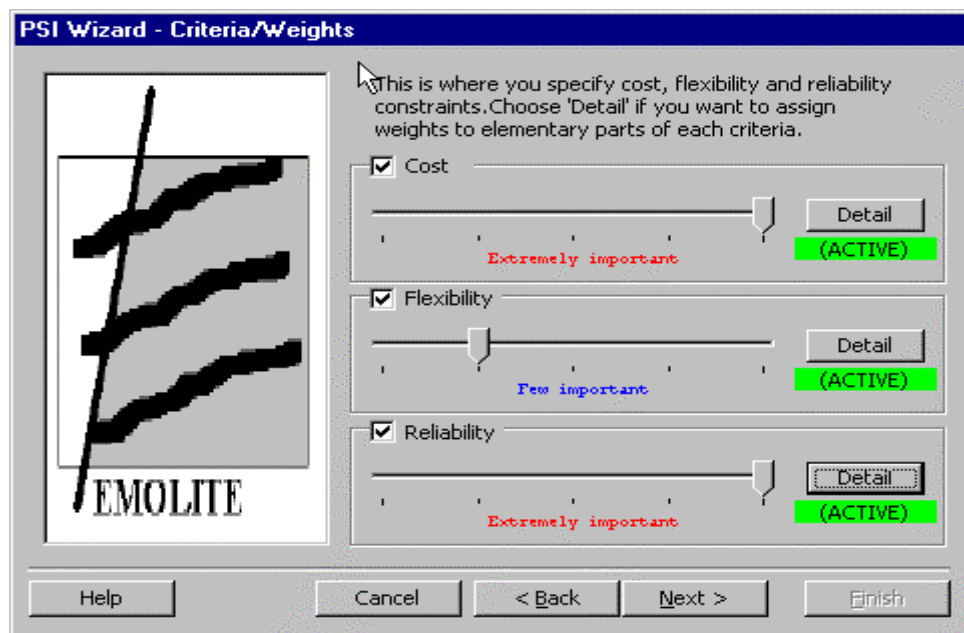
Next step in preparing the simulation is defining the criteria. Here, the window represented in figure 18 is used. The main criteria that are used to evaluate the quality of the terminal are: cost, flexibility and reliability. Each of these can be given a total value, for example a total cost. In case more specifications are required by the user, the button *Detail* is pressed and specifications for each element which compose the three main values can be entered. Figures 19, 20 and 21 demonstrate the composition of each of the three criteria.

University of Antwerp - RUCA

Universidade Nova de Lisboa

University of Piraeus

Figure 19. Definition of detailed cost criteria
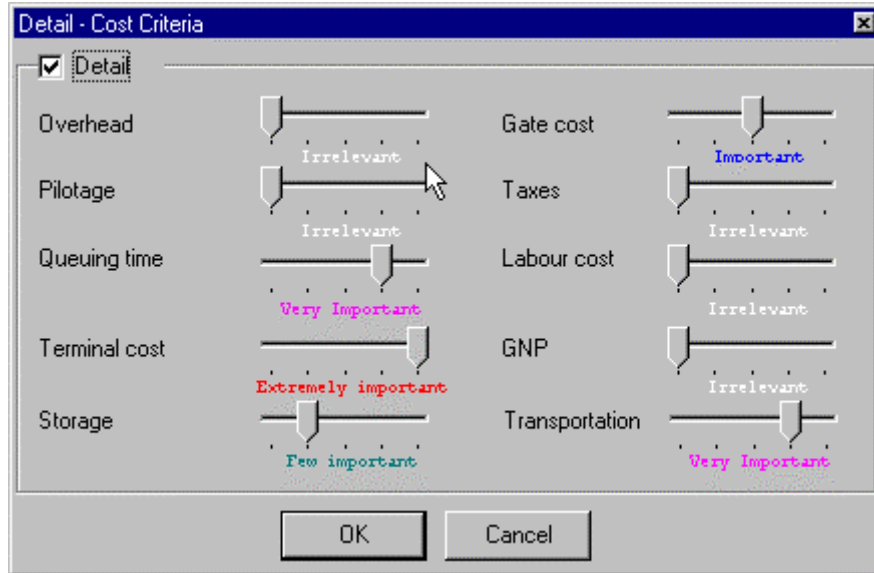
Figure 20. Definition of detailed flexibility criteria
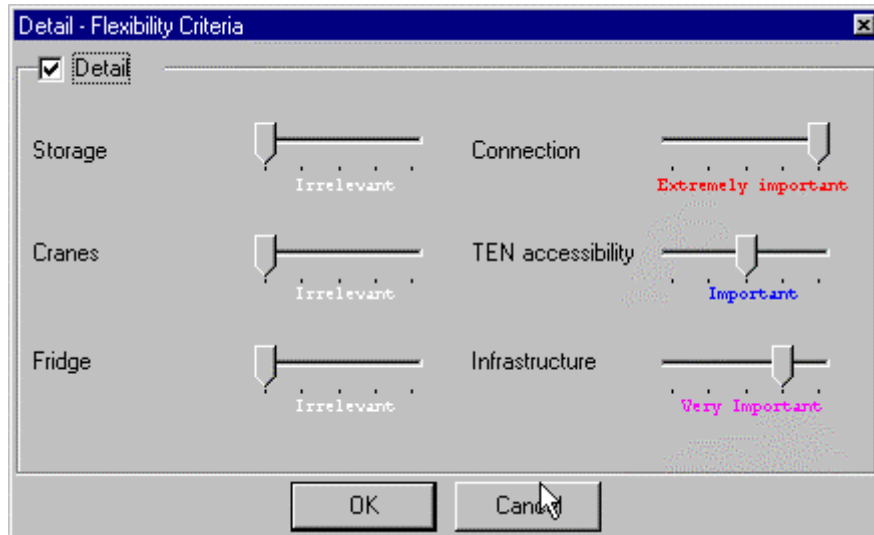
Figure 21. Definition of detailed reliability criteria
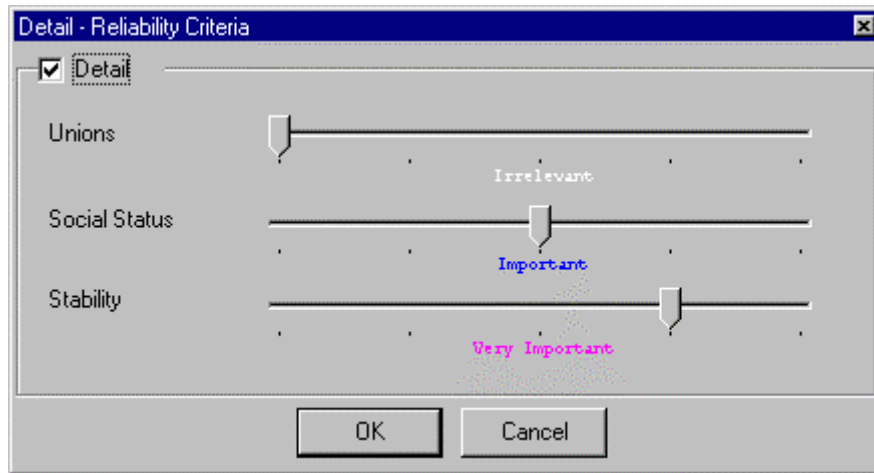
At this moment, all the information necessary for the prototype to run has been entered. However, in order to see the simulation results, also the type of output (representation) that is required can be specified (cfr. *Supra*)

5.9 EMOLITE Algorithms

5.9.1 The models of EMOLITE

EMOLITE includes two types of models: Terminal Evaluation Models and Terminal Choice Models. The former category aims to evaluate a terminal at a specific location, or a set of terminals at specific locations. The latter category aims at choosing a terminal or a set of terminals out of a set of specific locations.

Within EMOLITE three concepts have been worked out in detail:

1) the Terminal Evaluation Models provide a measure expressing the degree to which a terminal suits the user's preferences,

2) the Single Terminal Choice Models solve a Fuzzy Multiple Attribute Decision problem, choosing one alternative out of a set of feasible alternatives, using as single goal the degree to which a terminal suits the user's preferences; and

3) the Multiple Terminal Choice Models solve an optimisation problem, choosing a free or predetermined number of alternatives out of a set of feasible alternatives.

It can be seen that the three models make up a hierarchy. The third model calls the second model multiple times to be solved, while the second model uses as basis for its choice the evaluation method developed in the first model.

Before elaborating more on the three models, the terminology is presented, which is taken from Starr and Zeleny (1977) and proposed in the review article by Ribeiro (1996):

1) Alternatives. A set of objects, products, actions, items of choice or strategies . For instance, a list of cars considered for purchase or a list of sites for a new building, or, in our case, a terminal at a specific location.

2) Attributes. Each alternative is defined by a set of characteristics. These may represent physical characteristics such as weight or colour, or, in our case, labour cost, pilotage cost, accessibility to TEN, country stability.

3) Objectives. A collection of attributes selected by the decision-maker to be used as a goal. For example, buying a car (objective) includes attributes such as price, maximum velocity and comfort, price, in our case, the evaluation is done on aggregated attributes as cost, flexibility and reliability.

4) Preferences/weights. The relative importance of each attribute across all attributes or, the relative importance of the instances of an attribute. In our case, the decision-maker can give more or less importance to either cost, or flexibility, or reliability.

Many times it is difficult to obtain precise concepts for features, attributes, criteria, such as how to define comfort as an attribute for buying a car, or how to measure accessibility to Trans European Networks. Several types of uncertainty can arise and many methods and theories have been proposed to solve this problem in the realm of decision making. However, the most important theories addressing uncertainty in decision making are probability and fuzzy set theories.

In a fuzzy environment attributes, weights and objectives can all be fuzzy sets. Further, the attributes may be fuzzy linguistic variables as, for example, the 'social status' attribute can have three fuzzy subsets 'low', 'moderate' and 'high'.

The Single - or Multiple Terminal Choice problem is very similar to a classical problem in Operations Research, called the Warehouse Location problem. The Warehouse Location aims to locate one or more warehouses at a number of distinct pre-specified locations in such a way that a cost function is minimised. In the following paragraphs we will briefly discuss the Warehouse Location Problem in terms of its opportunities and limitations for our problem. An extensive review of the scientific literature on location including more than 1500 titles can be found in Domschke ad Drexl (1985).

5.9.2 The Objective Function

The main objective used in OR models for location is distribution cost. In its most simplistic version it even reduces to a weighted sum of distances, assuming a linear transport cost structure. If only one warehouse has to be located, the omission of the fixed operating cost of the warehouse assumes that this cost is equal in all locations. This is a situation that is, in Europe, certainly not correct. More sophisticated models include multiple costs and other terms can be added as long as they are expressible in monetary units. In such a way models are obtained which minimise either total facility cost, or total transport cost, total fixed and operating cost, or total user cost. As a result the vast majority of the models available examine and optimise on one single objective, be its cost minimisation or profit maximisation.

In our case, cost is an important issue but certainly not the only one. Two other aggregate objectives are high flexibility and high reliability. Also, a number of researchers have recognised that the problem of locating facilities has a number of different facets - for example cost, customer service, risk and environmental impact. These facets are not necessarily measurable in comparable ways, e.g. money, and the optimum result for each factor is unlikely to be achievable simultaneously in the

same site. Min and Schilling (1990) give an analysis of several papers examining multiple objectives.

Location models can be distinguished not only by the type of objective function but also by the attitude taken towards the choice of location. The approach may be either 'continuous' or 'discrete'. The continuous models basically assume that the facility may be located anywhere, whereas in discrete models, a list of pre-selected sites is required from which to choose the best subset to use. In our case, we certainly deal with the discrete case as we make a choice of already existing terminals. Even if we put ourselves in the position of thinking about building a new terminal, only a limited number of locations have to be taken into consideration.

Algorithms for optimising discrete models frequently use mathematical programming [e.g. in Khumawala (1972) and in Erlenkotter (1978)]. EMOLITE, however, cannot use mathematical programming because its objective function cannot be expressed in a single term, e.g., costs. The simplest of all continuous models, namely the centre-of-gravity model, is still advocated by some authors, although the model has serious modelling restrictions, - for example, the method locates only one facility, and ignores any interaction with other facilities.

5.9.3 The Optimising Process

The objective function of EMOLITE aims to maximise the degree of satisfaction with a (set of) terminals given by the user, where this degree is represented by the degree of membership to a fuzzy set. This means that in fact, a single objective function exists, but this function itself is consists of many factors.

The Single Terminal Choice Problem can be solved in a straightforward way. Out of the potential sites residing in the databases those sites are selected which are feasible according to the user's requirements and constraints. At first it is assumed that the constraints are crisp. This means that upper or lower bounds put by the user on some characteristics cannot be violated. However, it could be that the user puts

forward such a set of constraints that no feasible solution exists in the database. Therefore, fuzzy constraints can be included in the DSS, meaning that the constraints can sometimes be violated to a certain degree. In this way, a terminal is no longer either 'feasible' or 'not feasible', but has a degree of feasibility.

Assuming that out of one hundred potential locations in the database, ten feasible locations (or in the fuzzy case with a high enough degree of feasibility) are selected. Ranking the ten alternatives according to the fuzzy objective function and choosing the site with the highest ranking solves the Single Terminal Choice Problem. This procedure is similar to the earlier mentioned Multi Attribute Decision Making (MADM) procedures.

Multiple attribute decision making (MADM) deals with the problem of choosing an alternative from a set of alternatives which are characterised in terms of their attributes. Usually MADM consists of a single goal, but this may be of two different types. The first is where the goal is to select an alternative from a set of scored ones based on the values and importance of the attributes of each alternative. The second type of goal is to classify alternatives, using a kind of role model or similar cases. MADM is a qualitative approach due to the existence of criteria subjectivity. Both type of goals require information about the preferences among the instances of an attribute and the preferences across the existing attributes [MacCrimmon, 1973]. The assessment of these preferences is provided either directly by the decision-maker or based on past choices. Further, the decision-maker might express or define a ranking for the criteria as importance/weights. There are many forms for expressing the importance. The most common are: (a) utility preference function; (b) the analytical hierarchy process and (c) a fuzzy version of the classical linear weighted average. In addition, even for a fuzzy decision, the criteria could be fuzzy or crisp.The aim of the MADM is to obtain the best alternative, that is the one with the highest degree of satisfaction for all the relevant attributes or goals. In order to obtain the best alternative a ranking process is required. If the rating for each alternative is crisp, there is no problem and the best alternative is the one with the highest support.

When the rating is itself a fuzzy set, a more sophisticated ranking procedure is required. Further discussion of potential ranking procedures can be found in Ribeiro (1996).

5.9.4 The Multiple Terminal Choice Problem: a Heuristic Approach

The procedure that is proposed for the Single Terminal Choice Problem is inefficient for the more complex problems. Theoretically, it should be possible to evaluate all subsets out of the set of feasible sites, but this number grows in an exponential way with the number of sites. It is known that if N sites are selected, the number of subsets is equal to 2^N. Assume, as above, that ten feasible sites are selected, 1024 evaluations have to be made before a ranking can be obtained.

For all problems - and terminal choice is no exception - there are two approaches to optimisation: exact procedures and heuristic procedures. Exact solution procedures are defined as those procedures that can be demonstrated as always giving the optimal solution to a problem. Heuristics are essentially rules of thumb, which will usually give a good if not optimal solution. However, counter examples to heuristic procedures can be found; that is, a problem (in many cases a pathological one) for which the method clearly gives a bad solution.

Obviously most people would prefer an optimal solution, which leads to the use of an exact procedure. Unfortunately, the choice is not always so straightforward. Let us consider the classical warehouse location problem, with total fixed and operational cost as the objective function to be minimised. The principle technique for obtaining an exact solution is a form of mathematical programming called mixed integer programming. This method requires the costs to be linear, that is, that they increase directly with the level of activity. So, this idea completely ignores the notion of economies of scale. Often non-linearities occur, which can be accommodated in some ways by using a piece-wise linear cost curve. But this makes the mathematical programming formulation so complex that with current optimisation packages it is virtually impossible to solve it optimally.

The basics question in EMOLITE is related to the degree of accuracy with which the EMOLITE-program needs to model the terminal evaluation or choice system. A simplified model may be used to provide an exact solution, but to optimise accurate representations of most real intermodal transport systems means using a heuristic procedure.

For reasons of efficiency, not all the 2N potential subsets should be evaluated. As mentioned before, the objective is to reduce the search, and this is exactly what is meant by a heuristic. As Herbert Simon said about heuristics; they denote "any principle or device that contributes to the reduction in the average search to a solution" [Newell, Shaw and Simon, 1958]. Therefore using heuristics as an approach to problem solving will be applied, where the emphasis is on working towards optimum solution procedures rather than optimum solutions. Heuristic techniques are most often used when the goal is to solve a problem whose solution can be described in terms of acceptability characteristics rather than by optimising rules [Tonge, 1961].

Given that the number of potential sites will be high due to computational requirements, a heuristic approach is the only feasible solution in EMOLITE. Among the more successful heuristics is the Add algorithm introduced by Kuehn and Hamburger (1963). Using their ideas, a heuristic for the Multiple Terminal Choice Problem will be developed in the next phase of EMOLITE.

The heuristic that is proposed in EMOLITE for identifying the best set of terminal sites consists of two parts:

- *the main program*, which adds terminals one at a time until no more additional terminals can be added which increase the degree of satisfaction of the transport user,

- *the bump-and-shift routine*, entered after the main program, which attempts to modify solutions arrived at in the main program by evaluating the degree of satisfaction implications of dropping individual terminal sites or of shifting them from one location to another.

The heuristic is considered valid based on the following elements:

- most geographical locations are not promising sites for a 'best' terminal site. Locations with promise are either located close to the source or close to the destination or in a corridor in between those two places;

- near optimal sets of terminals can be developed by locating terminals one at a time, adding at each stage of the analysis a terminal which produces the greatest increase in degree of satisfaction for the entire terminal set ;

- only a small subset of all possible terminal locations need be evaluated in detail at each stage of the analysis to determine the next terminal to be added.

The main program begins with the source (or sources) connected to one central terminal. Each possible terminal site is then evaluated by determining the increase in degree of satisfaction that would be achieved by placing a terminal at that location. The location giving the greatest increase in degree of satisfaction is then selected for the first placement of a terminal. With the new terminal in place, the process is repeated for the next location. When no further improvement in degree of satisfaction is achieved, the main procedure yields to the second routine.

The bump-and-shift routine is designed to check the solution in two ways:

- any terminal which is no longer really increasing the degree of satisfaction because some traffic has shifted to newly located terminals is eliminated (bumped) and the traffic reassigned,

- attempts are made to interchange each remaining site with other in the territory it serves.

During the implementation a second heuristic is also taken into consideration, called the Drop algorithm, which is basically the reverse of the Add algorithm, terminals are initially assumed to be at all possible locations, and customers are assigned to multiple terminals. The procedure is then to eliminate the terminal whose elimination gives the biggest increase in degree of satisfaction. The process is repeated until no further increase is possible.

6 Improvement potential of EMOLITE

Due to several administrative setbacks during the project, the development of EMOLITE remained limited to the qualitative evaluation of intermodal terminals in Europe.

However, the implementation of the EMOLITE prototype has been an interesting and rewarding experience in several ways. The research team is aware that some aspects could have been done in different ways leading perhaps to a better solution.

The lack of feedback from professional users during the analyses and development process was regrettable. Their contribution could have helped finding an even better user interface. It might also have lead to include additional functionality, more adapted to specific user needs. Possibly, the database structure might have been improved to accommodate consistent and more relevant data. Finally the participation / validation by the end user could have helped the research team to fine-tune the fuzzy model in order to deal with more realistic scenarios.

However, given that the proposed EMOLITE model is only a first prototype, it will be up to the researchers that further develop and improve the initial model to generate a truly validated model that can be tested by the end users.

Despite all these setbacks, the EMOLITE researchers strongly believe that the present structure constitutes a relevant step for the final development of a decision support system that meets the real managers' needs.

There are several aspects of the present prototype that could be scrutinised for further improvement. The issues are discussed hereafter.

6.1 EMOLITE for passenger terminals

The EMOLITE model can be considered as an innovation in the field of strategic decision making in the selection and qualitative assessment of intermodal freight terminals.

However, EMOLITE could easily be expanded to passenger with only limited efforts. In the final prototype there is a basic evaluation structure foreseen for the assessment and selection of passenger terminals. If a database with relevant information on passenger is created in the future, the model could be easily expanded as demonstrated hereafter.

In a first window a selection can be made between the type of terminal (passengers, freight). Next, the set of alternative modes of transportation (e.g. railway, road, train, maritime, airway) has to be identified by the EMOLITE user. Supposing that a passangers terminal is selected, then, by selecting *Next* a window as visualised in figure 22 could allow the user to identify the maximum number of people, maximum price, the required services and infrastructure.

Figure 22: Selection of passengers terminals' conditions

By pressing the button *Next* a new window, represented in figure 23, could define the connections and the alternative modes.

Figure 23: Selection of terminal's connections
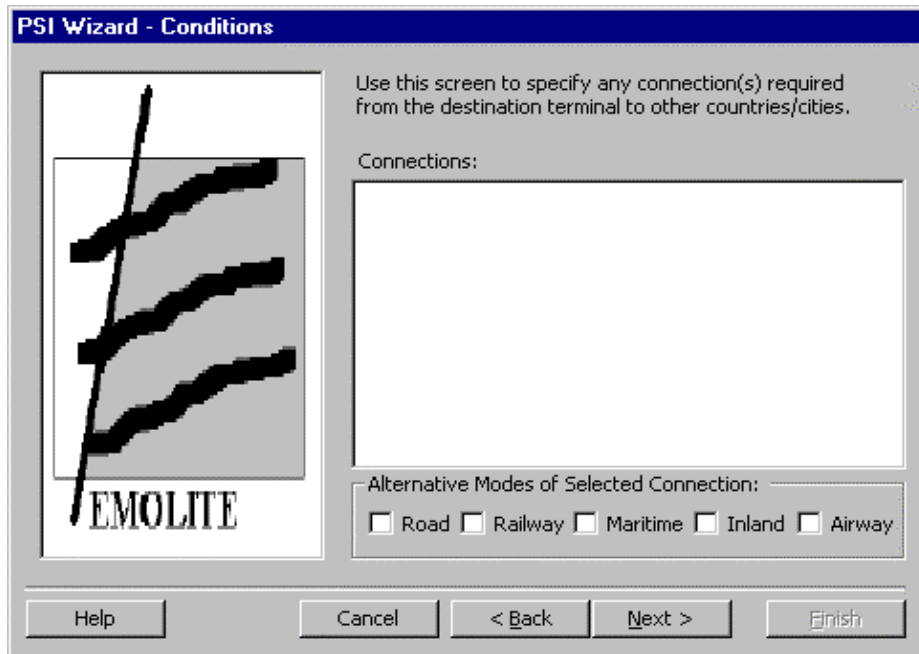
At this moment, all the information necessary for the passenger prototype to run has been entered.

The calculations and algorithms are similar to the examples provided for intermodal freight terminals.

6.2   EMOLITE 2000 : The internet version

In all cases, the new version of EMOLITE must be Web based. The following figure illustrates roughly what could be the "Web Architecture" for the EMOLITE 2000 system.

EMOLITE - Web System Architecture
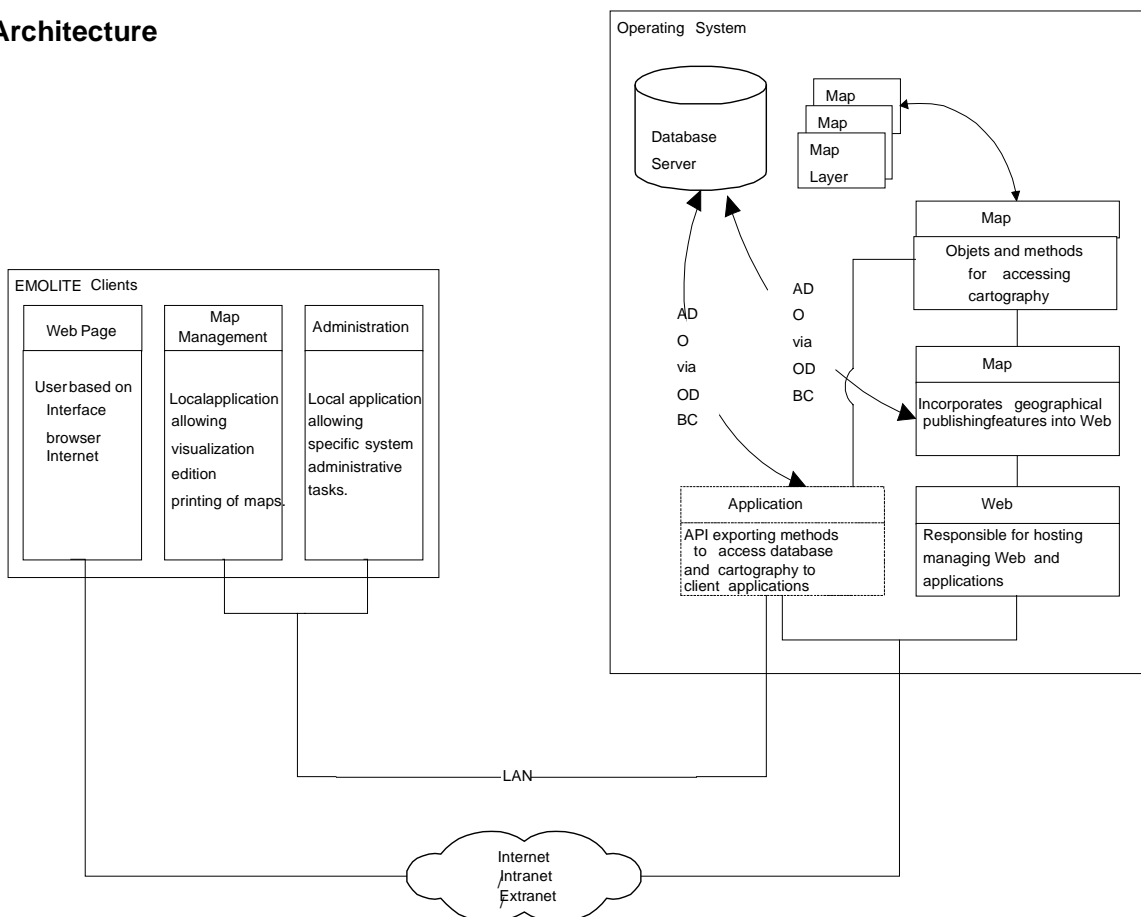
The deployment of such architecture would result in much less maintenance efforts and certainly in much easier and widespread utilisation, since users could access it simply as "another" Web page. The concept is visualised in the next figure.

Geographical Server

Database Server

WWW Server

EMOLITE Server

Local Network/ Intranet

Browser

EMOLITE Client

EMOLITE Client

Browser

Router/Firewall

Internet / Extranet

Browser

EMOLITE Client
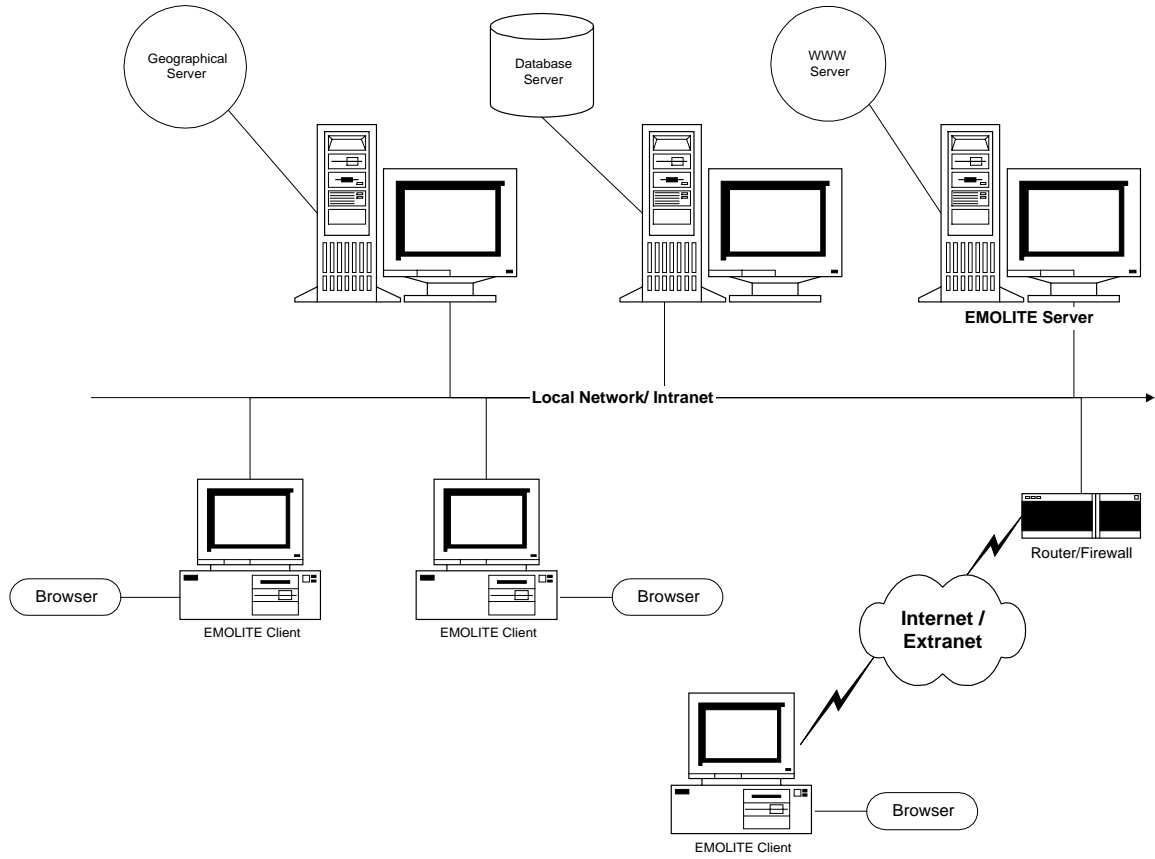
6.3   Some strategic considerations

6.3.1   introduction

The present EMOLITE design, development and implementation is based on the systems development life cycle (SDLC) concept and rapid prototyping. Because of the unstructured nature of a DSS, the development methodology differs from the traditional SDLC in several ways. The process itself is shorter and iterative, i.e., the stages are not strictly sequential. DSS designers have long recognised the need for departure from the traditional SDLC and recommend an iterative approach, with extensive use of prototyping [Sprague and Carlson, 1982].

Any future EMOLITE development requires the active participation of various specialists (transport economics, logistics management, operations research, computer science) in all stages and employs a development strategy that allows for working concurrently on design and development. A fundamental assumption of the traditional SDLC methodology is that the requirements can be completely specified during the analysis phases. This does not translate well to DSS development. The process of requirement specification for a DSS is best characterised as a learning experience that takes place continuously during development. Since formal methodologies do not exist for DSS development to the same extent as for information systems, a framework is proposed, which consists of the following phases: project assessment, problem analysis, design, development, testing, and documentation, implementation and maintenance.

6.3.2   Project assessment

In this phase three major tasks are defined: (1) define the problem, (2) determine the project feasibility; and (3) develop a project proposal.

Projects are initiated in response to a problem or an opportunity to employ new technology. The first task in project evaluation is to carefully define the problem and to determine if the problem is appropriate for a DSS. The problem should be neither too trivial nor too complex. If heuristic problem-solving techniques exist, it is likely to

be appropriate. We consider our decision problem as a semi-structured problem (this idea is elaborated further on), and for this type of problem a DSS is suitable. Whether it is feasible for the Transport Company depends not only on the suitability evaluation but also needs technical, operational and economic feasibility.

Technical feasibility is used to determine if the technology (hardware, software and expertise) exists to solve the problem. If, like in our project, the DSS is intended to be used by multiple users, it is necessary that it is developed on a widely-used platform. It seems quite natural that in a today's small business environment a personal computer is common hardware, and that a DSS should run in a Microsoft Windows environment to allow for widely distribution among potential users. In terms of expertise, we are convinced that the nature of solving the decision problem is not difficult, but the difficulty appears in the huge amount of technical and economic data. These data could possibly be kept in memory of the human user, or in various books at different places. But it is easily understood that the integration of these data on one place together with simple calculating or optimisation models, can greatly improve the decision-making process of the transport manager. The project is operationally feasible if the new system can be introduced with little disruption to current operations, can be operated by current staff, and can be integrated with current systems. Comparing costs versus anticipated benefits can test economic feasibility. But, in practice, a DSS offers intangible benefits like:

- better decisions,
- more consistency in decision-making,
- better use of resources,
- superior service,
- enhancement of the company image.

In the case of a future EMOLITE application, it is not expected that current operations will suffer from the installation of the DSS. But the tasks of deciding which terminal(s) to use have changed. It can however be expected that the user will accept these changes in a positive way. It facilitates work in terms of searching for

data and calculating. The user also will feel greater responsibility. By making simulations, either with changed parameters or changed objective functions, a 'best' solution can be obtained in an interactive way while, using a manual system, it is technically or economically impossible to compare various scenarios. If the whole project seems feasible, the company can make up a project proposal for the development and installation of the DSS.

6.3.3 Problem Analysis

This stage consists of an in-depth study of the key elements of the problem, which should provide the developer with more insight into the decision-making process. The partners in any future EMOLITE-project per definition need different backgrounds. One part of the group should act as transport and logistics specialists providing information on which data and decision techniques are relevant for the decision-making process; the other part represent the computer science and the problem solving (modelling and algorithmic) people gathering information from the transport experts. It is known that results are highly dependent on the developer and his/her ability to understand the problem domain.

The next step is the development of a more advanced prototype to assist in identifying more detailed systems requirements. Here, the difference with large-scale systems is clear. In a large-scale system, the analyst attempts to understand the entire system before any development is started. For a small scale DSS, the process is less rigid with prototyping beginning early in the development process.

6.3.4 Design

The first step in the overall logical design of the future EMOLITE DSS is to construct the main menu and the menu structure. Since the DSS is a dynamic system, plans to incorporate changes are made during the design. A modular design will facilitate the addition of new features and modification of existing features is essential. Object-oriented design is another option that will support future enhancements. The detailed design will focus on the database, the model (base) and the user interface.

For the database design, a database model is selected. In today's environments, it is comm2on to use the relational database model for real-life applications. The model or model subsystem will be designed to provide the user with the ability to create, access, catalog and integrate mathematical models easily. The new EMOLITE should use Evaluation Models, which assess locations or sets of locations, based on the transport decision-maker's preferences. A second type of models to be provided are Optimisation Models, in which a location or a set of locations is found according to a preference function put forward by the user.

User-interfaces are also required and must include pull-down menus and graphical user interfaces (GUIs) which will meet the needs of all potential users. The menus present the choices in a clear and consistent manner, and the format of the results will facilitate decision-making, and are consistent with the user's conceptual approach of the system.

6.3.5 Development, testing and documentation

During development, the application is constructed, databases are established and implemented, the user interface is refined, and the analytical models are developed and tested. The development stage of the DSS is considerably shorter than that of a traditional information system since the tools used are typically application generators which free the programmer to think about the 'how to' of systems functions. One successful development strategy is to identify a key module and develop it completely, deferring development of other modules. The rationale is that if the appropriate module is developed first, the logical structure of other modules are similar to the key module and successful development of the key module is a good indication of overall system success.

The user of the future EMOLITE model (or in this case the transport specialists) must provide feedback on the user interface and the help screens, validate the decisions made by the system, evaluate the menu navigation logic (how to move between

screens) and refine the system specifications, if necessary. This element was left out in the original EMOLITE program due to managerial problems.

The evaluation of a future EMOLITE DSS could therefore turn out completely bad. It could be that the wrong development tool is selected, the prototype must be thrown away, and the design process restarted. This sounds dramatic, but a more serious error would be to proceed with a wrong development environment.

Testing the DSS focuses on validation of the system product, the expected results and user acceptance. Results from analytical models and heuristics should be validated using historical data to check if system results are consistent with past decisions. A useful strategy is to load a file containing test cases (e.g. data on one specific country in Europe) at the beginning of the development and continuously test, as different components for the DSS are developed.

Documentation is developed during this stage, with an emphasis on clarity of presentation. DSS documentation should consist of project description, input and output screens, reports, model descriptions and formulas, database schema, menu navigation diagrams, results from test cases and source code. This is a technical documentation that cannot serve as a user's manual.

6.3.6 Implementation

It should be recognised that the implementation of an improved EMOLITE model is a process of organisational change. The implementation changes the way tactical or operational decisions are made. The major concern is here the successful implementation. Different organisational models have served as a basis for a theory of successful implementation. A review on the scientific literature can be found in Alavi and Joachimsthaler (1992). They have linked successful implementation of a DSS to user situational variables (user involvement, training and experience). They estimated that when users were involved in the development process and provided with the appropriate training and experience, the rate of implementation success could increase by as much as 30%.

6.3.7 Maintenance

As decision-making strategies will evolve over time, the DSS will require changes. The present EMOLITE model is only a prototype model that can be distributed on a large scale, but the potential user should be aware that this package would not solve his problems forever. In a real commercial implementation a plan for system maintenance is required. The design of the system, choice of development tool, and programming skills of the developer, will affect maintenance costs. If the system is developed by outside contractors, it is recommended that an individual within the organisation be responsible for monitoring the system. An important part of the maintenance effort is a post-implementation evaluation during which the system users and management discuss strengths and weaknesses of the DSS. Users should report problems and request for new features to the individual who is responsible for managing the maintenance effort. Security should be added to lock out unauthorised changes.

6.3.8 Note on Semi-structured decisions

Consider the transport operator being confronted with the decision of choosing one or more terminal locations. It can be stated that

(1) considerable data on the available alternatives and their characteristics exist;
(2) information is known about his past decisions (or of the decisions made by his predecessor);
(3) experts who know about the transport and handling services are available. Still it seems that the decision of choosing the right terminal is a difficult one.

The society as a whole knows a lot about this type of decision, but a given decision-maker might know relatively little or not enough about the particular problem. Thus the decision problem can be almost perfectly structured from the point of view of society as a whole and relatively unstructured from the point of view of the decision-maker. This type of problem is called a semi-structured decision problem [Jacquet-Lagrèze and Shakun, 1984]. In the well-known textbooks of Keen and Scott Morgon (1978), of Sprague and Carlson (1982), and of Bonczek, Holsapple and Whinston (1981) it is suggested that semi-structured decision problems are a fruitful area for

DSS. The ultimate goal of the DSS for our semi-structured decision problem has to enable the decision-maker to learn in an efficient way what his preferences and goals are in relation to what is available on the market and thus to make the decision. The information is located in a database on the existing alternatives and their characteristics. Into the DSS a set of goals (or criteria) is built which decision-makers and experts in the field have commonly used. This is what we have called earlier the knowledge available in the society. Further, we must be able to assess the preference function of a particular decision-maker.

In multi-objective decision-making problems, multiple objectives are mostly non-commensurable and cannot be combined into a single objective. Moreover the objectives usually conflict with each other in that any improvement of one objective can be achieved only at the expense of another. Consequently the aim is to find a compromise of satisfying solution of a decision-maker which is also Pareto optimal based on his/her subjective value judgment. When formulating the multi-objective optimisation problem that closely describes and represents the real decision situation, various factors of the real system should be reflected in the description of the objective functions and the constraints. Naturally these objective functions and the constraints involve many parameters whose possible values may be assigned by the experts. In the conventional approaches, such parameters are fixed at some values in an experimental or subjective manner through the experts' understanding of the nature of the parameters. In most practical situations, it is natural to consider that the experts often only ambiguously know the possible values of these parameters. In this case, it may be more appropriate to interpret the experts' understanding of the parameters as fuzzy numerical data which can be represented by means of fuzzy subsets of the real line known as fuzzy numbers [Dubois and Prade, 1978]. The resulting multi-objective optimisation problem involving fuzzy parameters would be viewed as the more realistic version of the conventional one [Orlovski, 1984].

7 Conclusions and recommendations

7.1 Why EMOLITE?

At present, the EMOLITE software is strongly determined by the availability and quality of the information that feed the algorithms. This aspect is directly related to one of the core problems of location analysis. Uncertainty and mathematical fuzziness govern information in the decision-making process. Objectives and criteria are often difficult to be measured by crisp values, and thus regularly neglected. Also the lack of accurate data increases the fuzziness of the analyses.

Transport problems are per definition complex. Therefore, any approach that translates qualitative objectives in crisp parameters and fixed data is inaccurate and insufficient. Even if all information used is quantifiable the selection process is subjective in nature. Decision-makers therefore find any analytical approach too restrictive and use subjective knowledge (business intuition) during the final phases of the decision-making process. In most cases, computers are no longer used and are even considered obsolete because user interfaces are generally to complex to handle.

The implementation of the EMOLITE prototype has been an interesting and rewarding experience in several ways. Some aspects could have been done in a different way leading perhaps to a better solution than the present prototype. The hardest problem was the lack of feedback from potential users during the whole analysis and development period. Such a contribution could have

- improved the user interface,

- identified additional functionality more suited to specific user needs,

- optimised the database structure to accommodate consistent data

- validated and fine-tuned the fuzzy model in order to deal with more realistic selection scenarios.

Despite all that, the research team strongly believes that the present structure is a relevant step towards implementing a system close to the true managers' needs.

7.2   EMOLITE and the decision making process

Decisions related to the location of freight and passenger terminals are complex and require careful consideration because they generally involve a long term allocation of substantial (financial) resources. Once such decisions are taken, they also become very difficult to reverse without losing a considerable part of the initial investment. Decision makers should therefore analyze all relevant elements which could influence both the short term and the long term consequences of selecting specific locations.

The various existing models to identify optimal locations can be positioned in one of the four quadrants of <u>Figure 24</u>, in which the horizontal axis refers to the complexity of the applied analytical model (high or low) and the vertical axis identifies the value of the results for public and private decision makers (high or low) in their final decision. Conventional location models usually do not meet the requirements of decision makers. These models are either too complex or too general.

Figure 24: Policy Relevance of Location Decision Models

Complex models generally consist of mathematical and/or geometrical algorithms. The complex algorithms generate very detailed results on very specific problems, e.g., the optimal location in terms of minimising costs, taking into account

transportation costs and distances. These solution models are very important from an academic point of view, but have only a limited relevance in managerial decision making processes because these mathematical algorithms require so many abstractions and conditions that the final results are extremely difficult to be translated into real-life decisions. They are therefore located in quadrant 4. However, many decision criteria in the selection and evaluation of specific locations are characterised by uncertainty, subjectivity, imprecision and ambiguity. The inaccuracy is not only related to the data but also to the evaluation process itself. In certain cases, accurate data are available and decision makers have a well defined opinion as regards the importance of specific parameters. Mathematical algorithms can be applied in order to analyse these specific problems. However, accurate data will not always be available and existing inter-relationships between decision factors may be unclear. In addition, decision makers have the tendency to evaluate parameters not according to objective standards but according to personal experience, intuition and on the basis of a subjective assessment of the importance (weight) of the criterion in the overall decision making process. The problem of inaccuracy has to be taken into consideration and a methodology developed that enables to translate this inaccuracy and uncertainty into a reliable decision making framework.

General models, on the contrary, include a large number of uncertain decision factors in the analysis. But the actual evaluation of the individual factors is in most cases very limited and rarely based upon reliable evaluation models. General site evaluation models also have a tendency to overlook existing inter-dependencies among the set of relevant decision factors. Such type of general analysis seems useful in the managerial decision process to overcome the problem of inaccuracy but it is doubtful whether the results of such superficial evaluation are reliable and generate the best solution possible. The general models are therefore located in quadrant 2 of Figure 24.

In principle, it is possible to develop *custom made* models for the identification of the optimal location to establish freight and passenger terminals. However, time and

resources generally are lacking in order to develop these individualised models which are located in quadrant 3 of Figure 24.

The development of an alternative selection and evaluation model for the location of intermodal terminals is proposed in this research project. The **Evaluation Model for the Optimal Location of Intermodal Terminals in Europe** (EMOLITE) proposed in this research project, allows an accurate evaluation of potential sites for the development of freight and passenger terminals according to both *internal* and *external* requirements, taking into consideration the dynamic and continuously changing environment of freight and passenger transport. The model also combines mathematical accuracy and user-friendliness and can therefore be positioned in quadrant 1 of Figure 24.

7.3 The usefulness of EMOLITE

The EMOLITE prototype has several interesting features that could be useful to other applications. Consider the prototype in accordance to its functions and the conclusion is that in itself, the present model has more value as academic tool rather than a practical and useful model for strategic decision making. However, digging deeper in the concept of EMOLITE, on can conclude that several sections constitute the basis of further research possibilities.

EMOLITE is constructed in a modular manner as visualised in figure 25.

Figure 25: modular approach of EMOLITE
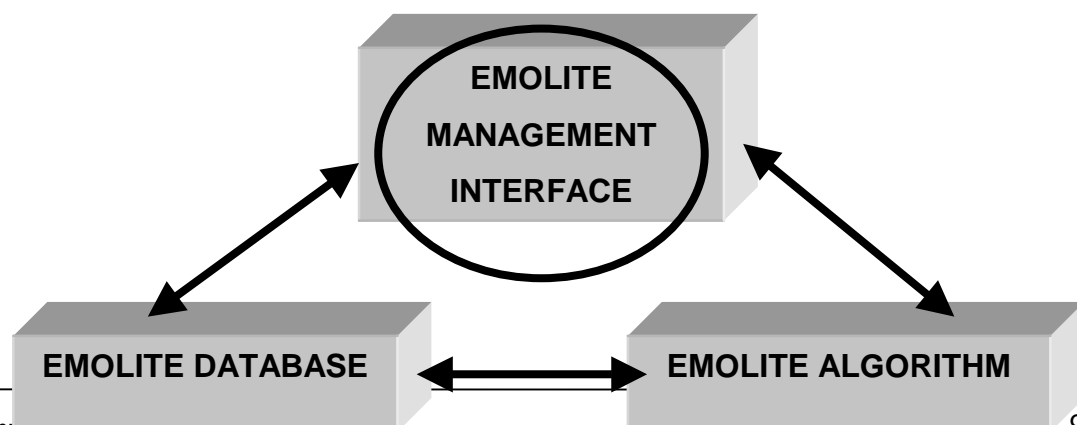
In particular the EMOLITE Management Interface is important. Using the Wizards available in Windows and applying fuzzy logic to interact with the user creates a first user friendly approach between operational computer models and their users. The difficulties of entering data and conditions before running the simulations has been reduced to an easy and "guided" method that enables non-experienced users to apply the method for their particular purpose.

Also the two other sections, namely the Database and the Algorithm are innovative and offer possibilities to expand most existing approaches to site location selection and analysis. The mixed use of socio-economic, geographical and economic data in combination with a multi-criteria analysis offers a wider perspective to the computer assisted site location decision making process.

Further research will be necessary to explore the possibilities of EMOLITE, not only in relation to site location and selection procedures but also and even more to the possibilities of further elaborating the EMOLITE approach to other evaluation models.

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9 Annex 2: The External Database of EMOLITE

9.1 Global Transport Data

The Global transport database is an AND proprietary database. This database can either be licensed individually or in conjunction with the Global Geographic database. In the latter case the Unique Connection Points (UCP's) Terminals facilitates the connection.

The Global Transport database is continuously updated. New releases are made available to our clients twice a year, namely in January and July.

9.1.1 Global Transport Database

This database contains all information required for the transportation of cargo by standardised loading units like for instance containers. The database is divided into Transport Networks and Services.

Transport Networks	Contents
Terminals	1,031
Ferry Connections	190,500
Railway Network	323,200
Inland Waterway Network	14,500 km
Sea Network	85,500 km
Industrial areas	5,800

Transport Services	Number of
Ferry Services	3,000
Rail Services	19,500
Inland Waterway	25,400
Sea Services	7,500

Transport related	Number of
Organisations Europe	3,300

Transport Networks

All Transport networks are digital models of maps that can easily be linked together. When the Road Network Database is incorporated, extra information about tonnage restrictions for roads, toll roads, and border crossings open to freight transport will be included as well.

Terminal Network

Terminals are the turntables between different networks, the place where goods are transferred from one mode of transportation to another. The Terminal network consist of two files: the first file contains name, location and type of the terminal and the second file contains all specific characteristics of each terminal; like for example 2accessibility, names of operators ad loading equipment.

Ferry Network

The Ferry Network holds all data on ferry connections plus ferry coding points, as well as information like tonnage restrictions for freight transport. The ferry coding points can be used to link ferry timetables to this network (see Transport Services).

Railway Network

The Railway Network consist of freight and passenger lines and links to terminals with a rail connection. Passenger lines are also included as they are increasingly being used for freight.

Inland Waterway Network

The Inland waterway network contains river and canal waterways accessible to ships of over 50 meters in length and the links to terminals with a river or canal connection.

Sea Network

The European sea network contains transport routes between ports and the links to terminals with a sea connection. The sea networks of the Atlantic, India and Pacific Ocean are not linked yet to terminals on the surrounding continents.

Industrial Areas

The network of Industrial Areas contains information used by companies for industrial or other non – agricultural purposes.

Notes:

Km	total length of all segments
Links	total number of segments
-	mode does not exist
0	no information available
Railway Network	consist if lines for passenger and freight transport
Inland waterway Network	are counted twice when border between countries is in the middle of the river
Services	connections operating on the network; numbers are subject to heavy changes
Organisations	numbers are subject to heavy changes

9.1.2 Transport Networks

Sea Links

Sea Shipping	Links	Km
Europe	1,100	85,500
Atlantic Ocean	606	255,100
Indian Ocean	260	120,800
West Pacific	830	246,300
East Pacific	291	226,100

Ferries

No	Code	Country	Links	Km
		International ferries	869	109,16
355	AL	Albania	0	0
374	ARM	Armenia	0	0
43	A	Austria	24	3
994	AZ	Azerbaydzhan	0	0
32	B	Belgium	0	0
387	BIH	Bosnia and Herzegovina	0	0
359	BG	Bulgaria	0	0
375	BY	Byelorussia	0	0
385	HR	Croatia	153	2,952
357	CY	Cyprus	0	0
420	CZ	Czechia	4	3

45	DK	Denmark / Faeroe	217	1,030
372	EW	Estonia	12	80
358	FIN	Finland	156	1,370
33	F	France	144	5,276
995	GE	Georgia	0	0
49	D	Germany	420	1,584
30	GR	Greece	630	19,838
36	H	Hungary	93	20
354	IS	Iceland	27	368
353	IRL	Ireland	46	100
39	I	Italy	495	15,887
371	LV	Latvia	0	0
411	FL	Liechtenstein	0	0
370	LT	Lithuania	3	1
352	L	Luxembourg	0	0
389	MK	Macedonia	0	0
356	M	Malta	3	6
373	MD	Moldavia	0	0
377	MC	Monaco	0	0
31	NL	Netherlands	143	112
47	N	Norway	1?962	17,076
48	PL	Poland	192	46
351	P	Portugal / Madeira /	54	3,100
40	RO	Romania	12	159
7	RUS	Russia	9	305
421	SK	Slovakia	0	0
386	SLO	Slovenia	0	0
34	E	Spain / Canary Island	60	3,845
46	S	Sweden	198	767
41	CH	Switzerland	9	9
90	TR	Turkey	123	1,631
380	UA	Ukraine	0	0
44	GB	United Kingdom	540	5,718
381	YU	Yugoslavia	12	4
		TOTAL	**6,610**	**190,45**

Each ferry connection between a pair of ports consist of 3 links (segments) with 2 ferry coding points in between, one for each direction.

University of Antwerp - RUCA

Universidade Nova de Lisboa

University of Piraeus

Terminals, industrial areas, railways and inland waterways

Nr	Cod	Country	Terminal	Industri	Railw		Inland	
			Location	Location	Links	Km	Links	Km
35	AL	Albania	1	0	32	503	-	-
37	AR	Armenia	0	0	8	467	-	-
43	A	Austria	30	0	2,055	5,776	9	312
99	AZ	Azerbaydzhan	0	0	17	1,519	-	-
32	B	Belgium	44	534	994	3,061	192	967
38	BIH	Bosnia and	0	0	58	1,695	-	-
35	BG	Bulgaria	11	0	135	3,763	2	461
37	BY	Byelorussia	1	0	128	5,074	-	-
38	HR	Croatia	9	0	112	2,583	1	133
35	CY	Cyprus	4	0	-	-	-	-
42	CZ	Czechia	20	0	1,038	9,092	27	259
45	DK	Denmark /	38	0	592	2,620	-	-
37	EW	Estonia	1	0	61	1,159	-	-
35	FIN	Finland	18	0	368	5,778	-	-
33	F	France	94	0	4,453	31,66	159	1,880
99	GE	Georgia	2	0	44	1,244	-	-
49	D	Germany	171	3,310	10,649	39,68	407	5,513
30	GR	Greece	9	0	412	2,356	-	-
36	H	Hungary	12	0	705	8,528	6	444
35	IS	Iceland	14	0	-	-	-	-
35	IRL	Ireland	15	0	180	1,915	-	-
39	I	Italy	105	0	4,085	18,31	-	-
37	LV	Latvia	4	0	67	2,301	-	-
41	FL	Liechtenstein	0	0	3	9	-	-
37	LT	Lithuania	0	0	68	1,970	-	-
35	L	Luxemburg	52	1,917	90	242	1	37
38	MK	Macedonia	35	0	26	736	-	-
35	M	Malta	15	0	-	-	-	-
37	MD	Moldavia	16	0	26	973	-	-
37	MC	Monaco	4	0	2	4	-	-
31	NL	Netherlands	8	0	577	2,643	354	2,518
47	N	Norway	8	0	3,191	4,100	-	-
48	PL	Poland	3	0	1,407	21,91	23	257
35	P	Portugal /	75	0	460	3,119	-	-
40	RO	Romania	53	0	306	9,453	7	1,169
7	RU	Russia	21	0	787	46,64	0	0
42	SK	Slovakia	10	0	1,229	3,741	5	163
38	SLO	Slovenia	7	0	166	1,158	-	-
34	E	Spain / Canary	110	0	1,617	13,73	-	-
46	S	Sweden	1	0	1,162	10,62	-	-
41	CH	Switzerland	21	0	2,117	5,776	10	65

90	TR	Turkey	10	0	118	7,580	-	-
38	UA	Ukraine	7	0	595	19,65	-	-
44	GB	United	110	0	3,913	15,35	-	-
38	YU	Yugoslavia	1	0	259	4,678	2	352
		TOTAL	**1,031**	**5,775**	**44,312**	**323,2**	**1,205**	**14,53**

Transport Services

The Transport Services Database contains timetables, transit times and accessibility for calculating the optimum way of transportation.

Number of services departing from terminals in European countries.

No	Code	Country	Ferry	Railway	Waterway	Sea
355	AL	Albania	2)	0	-	0
374	ARM	Armenia	10	0	-	0
43	A	Austria	0	2,200	131	-
994	AZ	Azerbaydzhan	0	0	-	-
32	B	Belgium	8	1,924	7,612	353
387	BIH	Bosnia and	-	0	-	-
359	BG	Bulgaria	0	0	36	37
375	BY	Byelorussia	0	0	-	0
385	HR	Croatia	177	98	35	12
357	CY	Cyprus	3)	-	-	183
420	CZ	Czechia	0	262	85	-
45	DK	Denmark / Faeroe	859	2,068	-	277
372	EW	Estonia	30	0	-	18
358	FIN	Finland	356	5	-	264
33	F	France	224	710	881	405
995	GE	Georgia	0	0	-	6
49	D	Germany	514	5,194	3,758	711
30	GR	Greece	226	37	-	411
36	H	Hungary	0	324	102	-
354	IS	Iceland	4	-	-	-
353	IRL	Ireland	42	0	-	135
39	I	Italy	444	1,378	-	668
371	LV	Latvia	2	0	-	36

411	FL	Liechtenstein	-	0	-	-
370	LT	Lithuania	7	0	-	3
352	L	Luxemburg	-	3	0	-
389	MK	Macedonia	0	0	-	-
356	M	Malta	2)	-	-	63
373	MD	Moldavia	-	0	-	-
377	MC	Monaco	-	0	-	-
31	NL	Netherlands	4	624	11,873	594
47	N	Norway	647	97	-	390
48	PL	Poland	3	106	0	31
351	P	Portugal / Madeira /	0	46	-	334
40	RO	Romania	0	1	33	38
7	RUS	Russia	0	1	68	56
421	SK	Slovakia	0	43	70	-
386	SLO	Slovenia	0	119	-	24
34	E	Spain / Canary Islands	167	581	-	672
46	S	Sweden	217	2,999	-	293
41	CH	Switzerland	46	373	617	-
90	TR	Turkey	2)	1	-	532
380	UA	Ukraine	0	0	0	51
44	GB	United Kingdom	706	296	-	693
381	YU	Yugoslavia	2)	0	69	1
		TOTAL	**4,693**	**19,490**	**25,370**	**7,459**

9.2 AND Format

The EMOLITE research team used the AND Mapping Format, being an ANSI – string whit a latitude / longitude WGS' 84 projection system. In addition to the proprietary format, EMOLITE support following formats and projections:

Formats: ARC / info (Export, Shape or Generate),
Atlas GIS (BNA; for boundary files only),
MapInfo

String formats: ANSI, ASCII

Projection systems: Latitude/longitude
several cartesian projections

NOTE:
. Boundary files are usually delivered in the BNA format for which a separate format description is available.
. Field separators are commas, they are not used within fields. Strings are in ANSI character set.

An overview of the Node File, Segment File and Intermediate File of the AND Transport Network is given below.

Node File (*. VRT) and unconnected points (*CRD)

Nr	Field	Format	Id	Description
1	ND – ID	N8	NNNNNNNN	Internal AND – ID
2	ND – XLONG	N4.6	NNNN.NNNNNN	Longitude in decimal degrees
3	ND – YLAT	N3.6	NNN.NNNNNN	Latitude in decimal degrees
4	ND – TYPE 2	N3	 0 1 2 3 4 10 11 12 13 14 15 16 17 20 21 22 23 24 25 26 27	Node type Standard node Junction (motor way exit) Intersection (motor way junction) Border note Directional information; only in connection whit type 1 roads. The type for town districts expresses the importance of the item. The following parameters influence the importance; a capital is always type 10 a number of inhabitants. Basic scale as follows; large city > 500,000 medium city > 100,000 small city > 50,000 town > 20,000 village > 5,000 small village > 1,000 tiny village < 1,000 postal code area within city large town district with specific number town district > 100,000 town district > 50,000 town district > 20,000 town district > 5,000 town district > 1,000 town district < 1,000 a town or village is upgraded (one or two types) if it is a national or regional centre. A village type 17 upgraded to 16 if it has an individual postal code. A village (type 16 or 17) is upgraded (one type) if it is of touristic importance. In this way we can guarantee that each level contains a well – balanced number of towns or villages with a more or less equal importance.
			30	Railway station

			36	Car/train terminal (passengers vehicles)
			40	Airport
			41	Large international airport
			42	Medium international airport
			43	Small international airport
			46	Large national airport
			47	Medium national airport
			48	Small national airport
			50	Cluster terminal cargo transport
			51	Terminal road/rail cargo transport
			52	Terminal road/inland waterway cargo transport
			53	Terminal road/sea cargo transport
			54	Terminal road/inland/rail cargo transport
			55	Terminal road/rail/sea cargo transport
			56	Terminal road/inland waterway/sea cargo transport
			57	
			58	Terminal road/rail/inland waterway/sea cargo transport
			59	
			60	Lock (inland waterway)
				Lift for ships (inland waterway)
				Industrial area: area used by companies for industrial or other non – agricultural purposes.
			71	The Government agrees upon this usage. Ferry coding point
5	ND _ NATION	N3	NNN	Nation code (table is available; country . txt)
6	ND _ LEVEL	N3	NNN	Connection level The connection level of a node equals the level of the road on which it is situated (see LINK FILE * SGM)
7	ND _ DELETED	L	1	For backward compability (0)
8	ND _ ZIP	C10	Text	Postal code
9	ND _ NAME	C60	Text	Name
10	ND _ NAME PREFIX	C10	Text	Name prefix, e.g. "la"
11	ND _ NAME SUFFIX	C20	Text	Name suffix, e.g. "bei Wien" or "plage"
12	ND _ NAME COMP	C2	Text	Compass direction (N,S,E,NE etc.) of ND _ NAME
13	ND _ CODE	C18		Unique terminal code comprising of:
			WWW	Country code (list of codes available; ISO – country . txt)
			XXXX	
			YYYY	Town
			NNNN	Terminal name
				Number for exact location
				(e.g. NDL.ROTT.ECDS., 0000, list of codes available; terminal code txt)
				In case of more then 1 terminal in a town the code for a cluster is (list available; terminal – code. Txt):
			WWW	Country code (list of codes available; ISO – country .txt)
			XXXX	
			YYYY	Town
			NNNN	Code for cluster of terminals
				Number for exact location
14	ND _ PROV	N3	NNN	Province code (table is available; prov.txt)
15	ND _ UN _ PROV	L	1	Flag if province code is needed to make ND _ NAME unique

16	ND _ UN _ CITY	C60	Text	City name to make ND _ NAME unique
17	ND _ UN _ CITY _ PREFIX	C10	Text	Prefix for ND _ UN _ CITY
18	ND _ UN _ CITY _ SUFFIX	C20	Text	Suffix for ND _ UN _ CITY
19	ND _ UN _ CITY _ PROV	N3	NNN	Province code to make ND _ UN _ CITY unique
20	ND _ UN _ CITY _ COMP	C2	Text	Compass direction relative to ND _ UN _ CITY to make ND _ NAME unique
21	ND _ CONURB	C60	Text	Name of conurbation to which suburb or town district belongs
22	ND _ CONURB _ PREFIX	C10	Text	Prefix for ND _ CONURB
23	ND _ CONURB _ SUFFIC	C20	Text	Suffix for ND _ CONURB
24	ND _ CONURB _ UN _ PROV	N3	NNN	Province code to make ND _ CONURB unique
25	ND _ ID _ PERMANENT	N10	NNNNNNNNNN	Permanent node ID, internal AND
26	ND _ DBLINK	C60	TD#NNNNN TD#NNNNN TD#NNNNN	Internal code for connection to services database TD = transport data, "t" is terminal, "c" is cluster, "f" is ferry coding Point, NNNNN is number
27	ND _ OTHER	C60	 Stp = r9999 Stp = i9999 Stp = s9999 Stp = c9999	This field can contain the permanent ID's of points to describe transport routes Points along railways Points along inland railways Points along sea links Points along sea + inland waterways

Link File (*.SGM)

Nr.	Field	Format	Id	Description
1	RD _ ID _ FROM	N8	NNNNNNNNN	ND _ ID of start of link
2	RD _ ID _ TO	N8	NNNNNNNNN	ND _ ID of end of link
3	RD _ LENGTH	N5	NNNN	Road length in hectometres
4	RD _ DIRECTION	N1	 0 1 2	Direction for one – way connections: Both From – to To – from
			1 2 3 4 5 6 7 8 9 10 11 12 21 22	Road type: Motor way Federal highway dual carriage way Federal highway Regional road Local road Other road Ferry (passengers and cargo) Ferry (cargo only) Ferry (train) Sea link Sea link + inland waterway type 21 Sea link + inland waterway type 22 Inland waterway, ships with length > 95m, width > 11.50 m, depth > 2.70 m, height > 6.70m Inland waterway ships with length >95m,

			23	width > 11.50 m, depth > 2.70m, height <6.70m
			24	Inland waterway ships with length > 80m, width >9.50m, depth < 2.50 m, height > 3.95 m
			31	
			32	
			33	
			50	Railway passenger transport
			51	Railway freight transport
			52	Railway passenger and freight transport
			53	Connection between terminal and road
			58	Connection between terminal and sea link
			59	Connection between terminal and inland waterway
				Connection between terminal and railway
				Walking connection between railway stations
				Virtual connection between non – connected networks
6	RD _ NATION	N3	NNN	Nation code
7	RD _ LEVEL	N3		Connection level: The connection level of a road expresses the importance of that road. The general classification is as follows:
			0	All E – roads in Europe (not seamless)
			1	E _ roads and important national roads in such a way that all type 10 to 13 locations are connected.
			2	Scale ~ 1: 2.000.000 All main roads (on maps usually motor ways and red roads) with secondary roads in such a way that all type 10 to 14 locations are connected.
			3	All through roads in such a way that all type 10 to 15 locations are connected. Scale ~1: 750.000
			4	All through and local roads in such a way that all type 10 to 16 and 20 to 26 locations are connected. Every postal code occurs at least once on this level.
			5	All roads Scale > 1: 400.000
8	RD _ DELETED	L	1	For backward compatibility (0)
9	RD _ SLOW	C1		Slow road type
			C	City road
10	RD _ NAME	C60	Text	Road name (not a code)
11	RD _ CODE NAT1	C12	Text	National road code
12	RD _ CODE _ NAT2	C12	Text	National road code
13	RD_ CODE _ NAT3	C12	Text	National road code
14	RD _ CODE _ INT1	C12	Text	International road code
15	RD _ CODE _ INT2	C12	Text	International road code
16	RD _ CODE _ INT3	C12	Text	International road code
17	RD_ TUNNEL	L	1	
18	RD _ TOLL	L	1	
19	RD _ TIME	N5	NNNN	Duration time in minutes (ferries)
20	RD _ FLOOR	N1	N	Road "floor", level of a fly – over (0,1,2…)

21	RD _ TONNAGE	N2	3 28 40	Tonnage (whole metric tonnes), possible entries: Accessible for vehicles of less then 3.5 metric tons Accessible for vehicles of less or equal then 28 metric tons Accessible for vehicle of less or equal then 40 metric tons
22	RD _OTHER	C60	Toll – cargo	Toll for freight vehicles

Intermediate File (*.INT)

Nr.	Field	Format	Id	Description
1	INT – ID – FROM	N6	NNNNNN	ND – ID of start of link
2	INT – ID – TO	N6	NNNNNN	ND – ID of end of link
3	INT – XLONG1	N9	NNNNNNNNN	Longitude in decimal degrees
4	INT – YLAT2	N9	NNNNNNNNN	Latitude in decimal degrees
5	INT – XLONGN	N9	NNNNNNNNN	Longitude in decimal degrees
6	INT – YLAT2	N9	NNNNNNNNN	Latitude in decimal degrees
2N+1	INT – XLONGN	N9	NNNNNNNNN	Longitude in decimal degrees
2N+2	INT – XLONGN	N9	NNNNNNNNN	Latitude in decimal degrees

Overview of Database Links

TRANSPORT RELATED ORGANISATIONS	TERMINAL NETWORK	TRANSPORT SERVICES	TRANSPORT NETWORKS
O- *INDEXNAME*	*T _ ID*	*S _ DPID*	*ND _ DBLINK*
O – OFF NAME	*T _ CODE*	*S _ DPCODE*	*ND _ OTHER*
O – VA	T _ NAME	S _ DPNAME	ND _ ID
O – VAZIP	T _ CLID	S _ DPCLID	ND _ XLONG
O – VATOWN	T _ CLCODE	S _ DPCLODE	ND _ YLAT
O – VANATCODE	T _ CLNAME	S _ DPCLNAME	ND _ TYPE
O – TELO	T _ COUNTRY	S _ COLADDR	ND _ NATION
O – FAXO	T _ TYPE	S _ COLTIME	ND _ LEVEL
O – TELECO	T _ XLON	S _ DPNATCODE	ND _ DELETED
O – EMAILO	T _ YLAT	S _ ARID	ND _ ZIP
O - CONTACTO	T _ VA	S _ ARCODE	ND _ NAME
O – TYPECODE	T _ VAZIP	S _ ARNAME	ND _ NAME _ PREFIX
O – MA	T _ VATOWN	S _ ARCLID	ND _ NAME _ SUFFIX
O – MAZIP	T _ TEL	S _ ARCLCODE	ND _ NAME _ COMP
O – MATOWN	T _ FAX	S _ ARCLNAME	ND _ CODE
O – REM	T _ TELEX	S _ DELADDR	ND _ PROV
	T _ EMAIL	S _ DELTIME	ND _ UN _ PROV
	T _ MA	S _ ARNATCODE	ND _ UN _ CITY
	T _ MAZIP	*S _ OPERATOR*	ND _ UN _ CITY _ PREFIX
	T _ MATOWN	*S _ AGENT*	ND _ UN _ CITY _ SUFFIX
	T _ HOURS	S _ ALLIANCE	ND _ UN _ CITY _ PROV
	T _ OPERATOR		ND _ UN _ CITY _ COMP
	T _ CONTACT	S _ PARTNERS	ND _ CONRUB
	T _ REMGENE	S _ SERVICE	ND _ CONRUB _ PREFIX
	T _ RAILWAY	S _ SLOTSFR	ND _ CONRUB _ SUFFIX
	T _ RAILSER	S _ SLOTSTO	ND _ CONRUB _ UN _ PROV
	T _ FERRY	S _ RESOFREQ	ND _ ID _ PERMANENT
	T _ SEA	S _ FREQ	ND _ KM
	T _ INLAND	S _ DPTIME	ND _ TMC
	T _ OWNER		RD _ ID _ FROM
	T _ ROROAC		RD _ ID _ TO
	T _ TRAILERS		RD _ LENGHT
	T _ TRAILERS		RD _ DIRECTION
	T _ CONT		RD_TYPE
	T _ TANK		RD _ NATION
	T _ SWAP	S _ ARTIME	RD _ LEVEL
	T _ ROLA		

T_STRANUM	T _ REMMODE	S _ RESOUDURA	RD _ DELETED
T_ STRACAP	T _COGANUM	S _ ITIME	RD _ SLOW
T _ RFSLOTS	T _ COGACAP	S _ FREQDAY	RD _ NAME
T _ REACNUM	T _ MOCRCAP	S _ MODE	RD _ CODE _ NAT1
T _ REACCAP	T _ QUCRNUM	S _ DISTANCE	RD _ CODE _ NAT2
T _ FORKNUM	T _ QUCRCAP	S _ METRTONS	RD _ CODE _ NAT3
T _ FORKCAP	T _ AGVNUM	S _ CONT	RD _ CODE _ INT1
T _ GROUNDEQ	T _ AGVCAP	S _ SWAP	RD _ CODE _ INT2
T _ TRACTORS	T _ YAGANUM	S _ TRAI	RD _ CODE _ INT 3
T _ REMEQUI	T _ YAGACAP	S _ ROROAC	RD _ TUNNEL
	T _ RENTUNI	S _ ROROUN	RD _ TOLL
T _ SECUR	T _ REPAIR	S _ ROLA	RD _ TIME
T _ CUSTOMS	T _ RENTCHA	S _ PPRO250	RD _ FLOOR
T _ BANK	T _ DEPUNIT	S _ PPRO260	RD _ TONNAGE
T _ CATERING	T _ STORAGE	S _ CPRO250	RD _ TOLL _ CARGO
T _ STRIPSTU	T _ DEPCHAS	S _ CPRO260	RD _ OTHER
T _ REFUEL	T _ CLEANING	S _ RAILWAY	INT _ ID _ FROM
T _ ADSERV	T _ TRUCKING	S _ REM	INT _ ID _ TO
T _ REMSERV	T _ REFSERV		INT _ XLONG1
	T _ DANSERV		INT _ YLAT1
			INT _ XLONG2
			INT _ YLAT2
			INT _ XLONGN
			INT _ YLATN

9.3 Transport Network

Ferry Network

Field 13, ND – CODE form above VRT – file contains Ferry information as well as following fields from the SGM – file: 3, RD – LENGHT / 4, RD – DIRECTION / 5 , RD _ TYPE / 10, RD _ NAME / 19, RD _ TIME / 21, RD _ TONNAGE / 22,RD _ OTHER.

Railway Network

Terminals with a rail – connection are described in field 4 of the VRT – file. These are linked to the Railway Network described in field 5, RD – TYPE of the SGM – file.

Inland Waterway Network

Terminals with a river or canal connection are described in field 4 of the VRT – file. These are linked with the inland waterway network described in field 5, RD _ TYPE of the SGM – file.

Sea Network

The Sea Network is described in field 5, RD – TYPE of the SGM – file.

Terminal Network

The VRT file contains 3 fields with terminal information: 4, ND _ TYPE / 9, ND _ NAME and 13, ND – CODE.

Field 13 of the VRT – file is linked to field 1 of the Terminal Network. Field number 1 is the unique ID for terminals and the key field to the other Transport Networks. A complete overview of the Terminal Network Format is given hereafter:

Terminal Network (*. TER)

Nr	Field	Format	Id	Description
1	T _ID	C20	Td#t NNNNN TD#c NNNNN TD#f NNNNN	Internal code for connection to GIS – database TD = transport data, "t" is terminal, "c" is cluster, "f" is ferry coding point, NNNNN Is number
2	T – CODE	C18	 WWW. XXXX. YYYY. NNNN.	Unique code of terminal comprising of: Country code (list of codes available; ISO – country. Txt) Town Terminal name Exact location (e.g. NLD.ROTT.ECDS.0000, list of codes available; terminal – code. Txt)
3	T – NAME	C60	Text	Unique index name of terminal
4	T _ CLID	C20	TD#tNNNNN TD#cNNNNN TD#fNNNNN	Internal code for connection of cluster of terminals to GIS – database TD = transport data, "t" is terminal, "c" is cluster, "f" is ferry coding point, NNNN Is number
5	T – CLCODE	C18	 WWW. XXXX. CLUS. 0000	When there is more than one terminal in a city it is possible to generalise the services of rail, inland waterway and sea to a cluster. This cluster has a unique code Comprising of Country code (list of codes available; ISO – country . txt) Town Code for cluster Code for location (e.g. NLD.ROTT.CLUS.0000 for Rotterdam, lsit of codes and

Nr	Field	Format	Id	Description
				names of clusters available; terminal – code.txt). Note: when there is only one terminal in a city the cluster code is the same as the terminal code.
6	T – CLNAME	C60	Text	Unique index name of a cluster
7	T – COUNTRY	C3	Text	ISO 3 digit country name (list of names available)
8	T – TYPE	N2	50	Cluster (virtual point, representing different terminals in an specific area)
			51	Road / rail
			52	Road / inland waterway
			53	Road / sea
			54	Road / rail / inland waterway
			55	Road / rail/ sea
			56	Road / inland waterway / sea
			57	Road / rail / inland waterway / sea
9	T _ XLON	N4.6	NNNN.NNNNNN	Longitude in degrees with 6 decimals
10	T – YLAT	N3.6	NNN.NNNNNN	Latitude in degrees with 6 decimals
11	T – VA	C60	Text	Visitors address
12	T _ VAZIP	C10	ZIP – code	Visitors address town or village name
13	T_ VATOWN	C60	Text	Mail address
14	T _ MA	C60	Text	
15	T _ MAZIP	C20	ZIP _ code	Mail address ZIP – code / postcode
16	T – MATOWN	C60	Text	Mail address town or village name
17	T – TEL	C20		International telephone number of office for general information, comprising of:
			+	+
			N or NN or NNN	country code
			-	hyphen
			NNNN…N	region code + individual telephone number
18	T – FAX	C20		International fax number for general information, comprising of:
				+
			+	country code
			N or NN or NNN	hyphen
			-	region code + individual telephone number
			NNNN …N	
19	T – TELEX	C20	NNNN …N	International telex number for general information
20	T – MAIL	C60	Text	E – mail number for general information
21	T _ HOURS	C60	Text	Business hours of the terminal
22	T _ OPERATOR	C60	Text	Name of operator(s)
23	T _ CONTACT	C60	Text	Name of external affairs official or operational official
24	T_ REMGENE	C60	Text	Other important information

Information on served modes and loading units

Nr	Field	Format	Id	Description
25	T _ RAILWAY	C60	Text	Names of railway haulage companies with to, from or on the terminal.
26	T _ RAILSER	C60	Text	Names of railway operators with services from this terminal
27	T _ FERRY	C60	Text	Names of ferry operators handlers
28	T _ SEA	C60	Text	Names of sea operators handlers
29	T _ INLAND	C60	Text	Names of inland barge operators handlers
30	T _ OWNER	C60	Text	Name(s) of terminal owner(s)
31	T _ CONT	L	1	Accepts containers
32	T _TANK	L	1	Accepts tankcontainers
33	T _ SWAP	L	1	Accepts swap – bodies
34	T _ TRAILERS	L	1	Accepts semi – trailers
35	T _ ROROAC	L	1	Accepts drive accompanied ro / ro transport of semi – trailers
36	T _ROROUN	L	1	Accepts drive unaccompanied ro / ro transport of semi – trailers

| 37 | T _ROLA | L | 1 | Accepts Rollende Landstrasse |
| 38 | T _ REMMODE | C60 | Text | Other important information |

Information on terminal equipment

Nr	Field	Format	Id	Description
39	T _ COGANUM	N2	NN	Number of container gantries ship – to – shore)
40	T _ COGACAP	N4.1	NNNN.N	Maximum lifting capacity of container gantries in metric tons
41	T _ MOCRNUM	N2	NN	Number of mobile cranes
42	T _ MOCRCAP	N4.1	NNNN.N	Maximum lifting capacity of mobile cranes in metric tons
43	T _ QUCRNUM	N2	NN	Number of quay cranes
44	T _ AGVNUM	N4.1	NNNN.N	Maximum lifting capacity of quay cranes in metric tons
45	T _ AGVCAP	N2	NN	Number of AGV's
46	T _ YAGANUM	N4.1	NNNN.N	Maximum lifting capacity AGV's in metric tons
47	T _ YAGACAP	N2	NN	Number of yard gantries
48	T _YAGANUM	N4.1	NNNN.N	Maximum lifting capacity of yard gantries in metric tons
49	T _ STRANUM	N2	NN	Number of straddle carriers
50	T – STRACAP	N4.1	NNNN.N	Maximum lifting capacity of straddle carriers in metric tons
51	T _ REACNUM	N2	NN	Number of reach stackers
52	T _ REACCAP	N4.1	NNNN.N	Maximum lifting capacity of reach stackers in metric tons
53	T _ FORKNUM	N2	NN	Number of forklift trucks
54	T _ FORKCAP	N4.1	NNNN.N	Maximum lifting capacity of forklift trucks in metric trucks
55	T _ GROUNDEQ	C60	Text	Number of and measurements of yard chassis and trailers
56	T _ RFSLOTS	N3	NNN	Number of reefer slots
57	T _ TRACTORS	N2	NN	Number of yard tractors
58	T _ REMEQUI	C60	Text	Other important information concerning equipment (e.g. voltage on reefer sots, specification of other terminal equipment)

Information on additional services on or near the terminal

Nr	Field	Format	Id	Description
59	T _ SECUR	L	1	Security
60	T _ CUSTOMS	L	1	Customs
61	T _ BANK	L	1	Bank
62	T _ CATERING	L	1	Catering
63	T _ STRIPTSU	L	1	Stripping and stuffing of containers
64	T _ RENTUNI	L	1	Rental of loading units
65	T _ REPAIR	L	1	Repair of loading units
66	T _ RENTCHA	L	1	Rental of chassis
67	T _ DEPUNIT	L	1	Depot of units
68	T _ STORAGE	L	1	Storage of units

69	T _ DEPCHAS	L	1	Depot of chassis
70	T _ CLEANING	L	1	Cleaning of loading units
71	T _ TRUCKING	L	1	Trucking
72	T _ REFSERV	L	1	Reefer services
73	T _ DANSERV	L	1	Dangerous cargo services
74	T _ REFUEL	L	1	Refuelling services
75	T _ ADSERV	L	1	Administrative services
76	T _ REMSERV	C60	text	Other important information concerning services of the terminal

Transport services

The Ferry services can be linked to the Ferry Network via the terminal code S_DPID in field 1. Railway Services, Inland waterway Services and Sea Services and Sea Services files can be lined to the Terminal Network via the terminal code S_DPCODE in field 2. The services files contain information connected to the terminals of departure.

Services File (*.Ser)

Nr	Field	Format	Id	Description
1	S _ DPID	C20	TD#tNNNN	Internal code for connection to GIS – database
			TD#fNNNN	TD = transport data, "t" = ferry coding point,
				NNNNNN = number
				Note: this field is the key field to link to the Transport networks
2	S _ DPCODE	C18		Unique code of terminal services which a certain service departs,
				Comprising of:
			WWW.	Country code (list of codes available; ISO – country. txt)
				Town
			XXXX..	Terminal name
			YYYY.	Exact location (e.g. NLD.ROTT.ECDS.0000, list of
			NNNN	codes: terminal – code.txt)
3	S _ DPNAME	C60	text	Geographical name of location (terminal) form which service departs
				(e.g. Rotterdam – ECT Delta / Sea – Land Terminal)
4	S _ DPCLID	C20	TD#tNNNN	Internal code for connection to GIS – database
			TD#cNNNN	TD = transport data, "t" = terminal, "f" = ferry coding point, "c"

			ldc-TD#fNNNN	= cluster, NNNNNN = number
5	S _ DPCLCODE	C18		When there is more than one terminal in a city it is possible to group the rail, inland waterway and sea services into a cluster. This cluster of departure has a code comprising of:
			WWW.	Country code (list of codes available; ISO – country.txt.)
				Town
			XXXX.	Code for cluster
			CLUS.	Code for location
			0000	(e.g. NLD.ROTT.CLUS.0000 ofr Rotterdam , list of codes and names of cluster available; terminal – code.txt.).
				note: when there is only one terminal in a city the cluster code is the same as the terminal code.
6	S _ DPCLNAME	C60	Text	Unique index name of a cluster of departure
7	S_ COLADDR	C60	Text	For later use: collection address if location is ot the same as S _ DPNAME (field 3)
8	S _ COLTIME	C5	Time	Ultimate time stated between 00:00 and 23.59 hours at which cargo must have arrived at collection address for further transportation by "Service" (local time)
9	S _ DPNATCODE	C3	text	ISO – country code in three digits, country of departure (e.g. Germany = DUE, list of codes available; ISO – country. txt)
10	S _ ARID	C20	TD#tNNNN	Internal code for connection GIS – database.
			TD#fNNNN	TD = transport data, "t" = terminal, "f" ferry coding point, NNNNNN = number
11	S _ ARCODE	C18		Unique code of terminal of arrival, comprising of:
			WWW.	Country code (list of codes available; ISO – country.txt)
			XXXX.	Town
			YYYY.	Terminal name
			NNNN	Exact location
				(e.g. NLD.ROTT.ECDS.0000, list of codes: terminal – code.txt)
12	S _ ARNAME	C60	text	Geographical name of location (terminal) at which service arrives (e.g. Rotterdam – ECT Delta / Sea – Land Terminal)
13	S _ ARCLID	C20	TD#TNNN	Internal code for connection GIS – database
			TD#cNNN	TD = transport data, "t" = terminal, "c" = cluster. "f" = ferry
			TD#fNNN	Coding point, NNNNNN = number
14	S _ ARCLCODE	C18		Unique cluster code of arrival comprising of:
			WWW.	Country code (list of codes available; ISO – country.txt)

				Town
			XXXX.	Code for cluster
			CLUS. 0000	Code for location (e.g. NLD.ROTT.CLUS.0000 for Rotterdam, list of codes and names of cluster available; terminal- code.txt).
				Note: when there is only one terminal in a city the cluster code is the same as the terminal code.
15	S _ ARCLNAME	C60	text	Geographical name of cluster (terminal) at which service arrives
16	S _ DELADDR	C60	Text	For later use: collection address if location is not the same as S _ ARNAME (field 12)
17	S _ DELTIME	C5	time	Ultimate time stated between 00:00 and 23:59 hours at which cargo can be taken after arrival at destination terminal (local time)
18	S _ ARNATCODE	C3	Text	ISO – country code in three digits, country of arrival (e.g. Germany = DUE, list of codes available; ISO country.txt)
19	S _ OPERATOR	C60	text	Name operator (e.g. P&O Nedloyd, Ukrainian), file with names and descriptions of operators see &2.3
20	S _ AGENT	C60	text	Representative office in / near location of departure or arrival, file with names and descriptions of agents see&2.3
21	S _ ALLIANCE	C60	text	Name alliance (e.g. Global Alliance, ASA, Penta)
22	S _ PARTNERS	C60		Name of co-operative operator within alliance or service
23	S _ SERVICE	C60		Particular name for service between a number of locations either;: routing of regions (e.g. Mediterranean / US west Coast,or given name (e.g. China Express, WECON)
24	S _ SLOTSFR	C60		Name of colleague operator from which space is taken
25	S _ SLOTSTO	C60		Name of colleague operator to whom space is granted
26	S _ REOFREQ	C60		Relevant time – units: months, weeks, days, day, hour
72	S _ FREQ	C10		Amount of departure within time units of field 26
28	S _ DPTIME	C18		Moment of departure, stated between 00:00 and 23:59 hours (local time)
29	S _ ARTIME	C5		Moment arrival, stated between 00:00 hours and 23:59 hours (local time)
30	S _ RESODURA	C5		Relevant time units: minutes, days, hours
31	S _ TTIME	N2		Duration of specific transport form A to B, stated in time units of field 30
32	S _ FREQDAY	C10		1 = Monday, 2 = Tuesday, 3 = Wednesday, 4 = Thursday, 5 = Friday, 6 = Saturday, 7 = Sunday
33	S _ MODE	C2		Transportation category:

				F	F = ferry (freight, cars and passengers)
				FC	FC = Cars passengers only
				FP	FP = Passengers only
				FF	FF = Freight (and some passengers) only
				I	I = inland
				R	R = rail
				S	S = sea
34	S _ DISTANCE	N5		NNNNN	Distance between location of S_DIPCODE and location of S_ARCODE stated in km's as given by an operator or calculator along the network of the relevant mode.
35	S _ METRONS	N3		NNN.N	Number of metric tons that can be transported
36	S _ PPRO250	N2		NN	Height in cm to be added with 330 centimetres for admission of semi – trailers in rail transport, width semi – trailers > 2.6 m
37	S _ PPRO260	N3		NNN	Height in cm for administration of semi – trailers in rail transport, width semi – trailers > 2.6 cm.
38	S _ CPRO250	N2		NN	Height in cm to be added with 245 centimetres for admission of swap – bodies and containrs in rail transport, width swap – body container > 2.5 cm.
39	S _ CPRO260	N3		NNN	Height in cm for admission of swap – bodies and containers in rail transport, width swap – body container > 2.6. cm.
40	S _ RAILWAYS	C60		Text	Involved railways during transportation from A to B
41	S _ CONT	L		1	Container
42	S _ SWAP	L		1	Swap – body
43	S _ TRAI	L		1	Semi – trailer
44	S _ ROROAC	L		1	Driver accompanied transport
45	S _ ROROUN	L		1	Driver unaccompanied transport
46	S _ ROLA	L		1	Rollende Landstrasse (Rolling highway)
47	S _ REM	C60		text	Information about ferries

Transport Organisations

The addresses of Transport related Organisations can be incorporated in the Terminal Network via Field 22, T – OPERATOR and in the Transport Services file via field 19, S _ OPERATOR AND FIELD 20; S – AGENT.

Organisation File (*Org).

No	Field	Format	Id	Description
1	O_INDEXNAME	C60	Text	Index name of organisation, this is key field to field "T – OPERATOR" in terminal file (*TER), fields "S _ OPERATOR" and "S _ AGENT" in services file (*.SER)
2	O _ OFF _ NAME	C60	Text	Official name or organisation
3	O _ VA	C60	Text	Visitors address
4	O _ VAZIP	C20	ZIP – code	Visitors address, ZIP – code / Post Code
5	O _ VATOWN	C60	Text	Visitors address, town or village name
6	O _ VANATCODE	C3	Text	ISO 3 digit abbreviation of country name (list of names available)
7	O _ TELO	C20	+ N or NN or NNN - NNNN…N	International telephone number for general information, Comprising of: + country code hyphen region code + individual telephone number
8	O _ FAXO	C20	+ N or NN or NNN - NNNN…N	International fax number for general information, comprising of: + country code hyphen region code + individual telephone number
9	O _ EMAILO	C60	Text	E – mail number for general information
10	O _ CONTACTO	C60	Text	Name of external affairs official or operational official
11	O _ TELEX	C20	NNNN…N	International telex number for general information
12	O _ TYPECODEO	N3	1 2 3 4 5 6 7	Type of organisation: Agent / groupage / nvocc Barge operator Ferry operator Forwarder Groupage / nvocc Network operator Road hauliers

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|					
				8	Rail operator
				9	Railway company
				10	Ship operator
				11	Shipping agent
				12	Terminal operator
					Nvocc: non vessel ocean common carrier: party who undertakes to carry goods issues in his own name a Bill of cargo, without having the availability of any own means of transport (taken from having the availability of any own means of transport (taken from operators).
13	O _ MA	C60		Text	Mail address
14	O _ MAZIP	C20		ZIP – code	Mail address, ZIP – code / Post code
15	O _ MATOWN	C60		Text	Mail address; town or village name
16	O _ MANATCODE	C3		Text	ISO 3 digit abbreviation of country name (list of names available)
17	O _ REM	C60		Text	Remarks, other important information

10 Annex 3: additional technical information

10.1 *The approach used to develop the project*

The problem domain was studied using the standard UML (Unified Modeling Language) approach. First we identified actors and use cases, then built the use case diagram (see figure 24).

Figure 24. Use case model
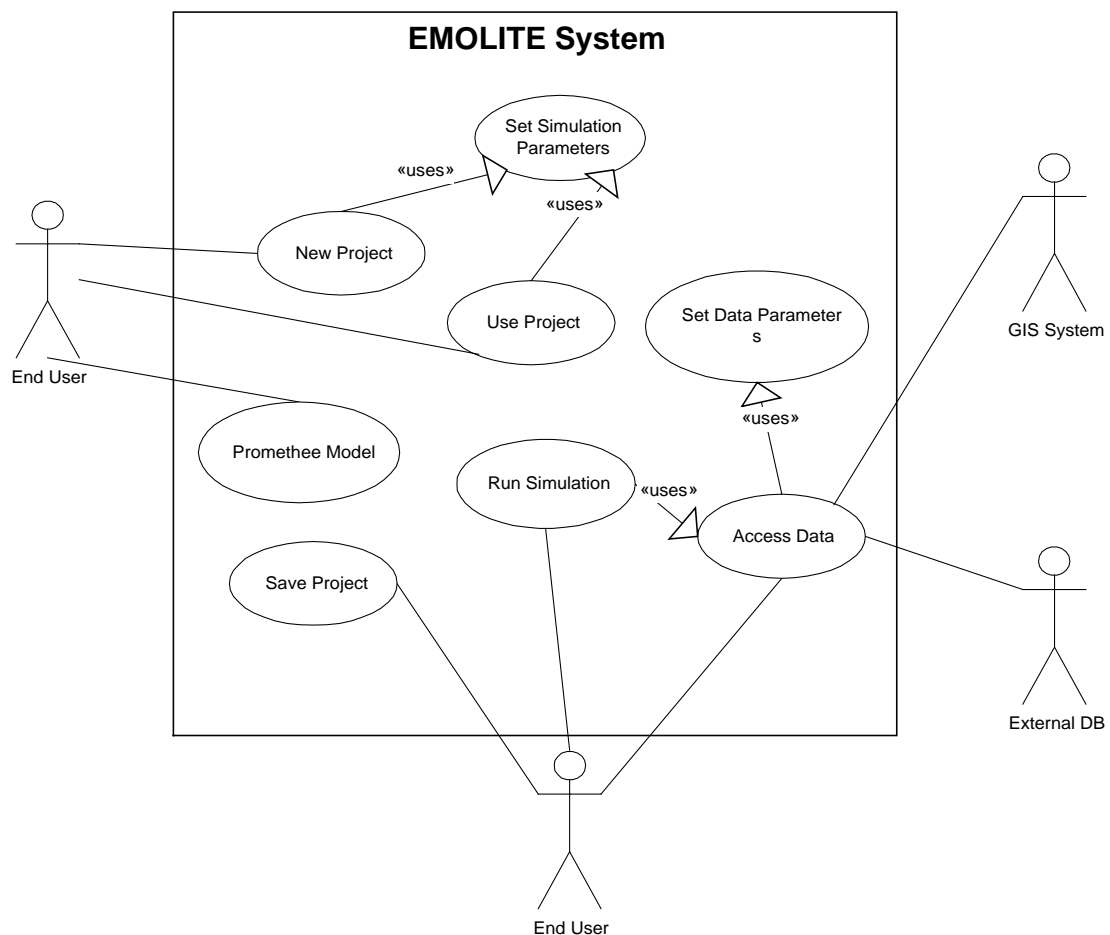
The use case model shows the system boundaries, demonstrates how actors communicate with use cases and relates use cases between each other.

10.2 Fuzzy an crisp approach

Attributes represent a common property of a collection of alternatives pertaining to a class. Objects are elements of attributes that can be crisp or fuzzy and, if fuzzy, discrete or continuous. Fuzzy attributes and respective linguistic labels are associated with a specified universe of discourse, which defines the problem space. For example, height and weight are attributes of John, Peter, Philip etc.

There are two types of attributes in EMOLITE, notably "crisp" and "fuzzy". For instance sex is a crisp attribute, which can take discrete values female or male. A fuzzy attribute is for instance height which could take values on universe [0, 2.5] meters and be divided into linguistic fuzzy subsets short, average and tall. Fuzzy attributes are linguistic variables {Zadeh, 1983}; {Zadeh, 1987}, where the values (here designated fuzzy objects) are linguistic rather than numerical.

In more formal terms, a linguistic variable X is characterised by a quadruple (X, T(X), U, F) where:

X is the name of the attribute, e.g. height;

T(X) is a collection of the fuzzy objects e.g. T(X) = {short, average, tall};

U is the universe of discourse e.g. U = {0, 0.4, ... ,2.5 meters};

F is a semantic rule which associates each fuzzy object x of T(X) with a possibility or probability distribution F(x) in U, depicting the degree of each value of U belonging to the fuzzy object x, expressed as $\mu_X(u) \to [0, 1]$, e.g. $\mu_{short}(1.4) = 0.7$.

The rationale for using linguistic variables is that it is quite difficult to classify quantitatively, alternatives in a fuzzy multiple attribute problem. The attributes are used both as features to describe properties and as criteria for alternatives which, themselves, are the elements (objects) of classes. As an illustration, it is quite difficult to say an exact height for a person, as for example 1.8m, while to say it is tall is more "common sense" knowledge. Note that linguistic variables are an efficient way to express ambiguous concepts and an integrate part of approximate reasoning {Zadeh, 1979} {Baldwin, 1979}.

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Examples of each possible type of attributes are:

- attribute fuzzy continuous unions (bad, average, good)
- attribute fuzzy continuous gate-cost (low, medium, high)
- attribute fuzzy continuous price (low, medium, expensive)
- attribute fuzzy discrete social-status {'A', 'B', 'C', 'D'}

Formally, the mathematical trapezoidal and triangular distribution for continuous fuzzy sets, independently of the range distributions, are:

$$\text{Triangular } (x:\alpha,\sigma,\beta) \begin{cases} = 0 & \text{for } \beta \le x \le \alpha \\ = \dfrac{x-\alpha}{\alpha} & \text{for } \alpha \le x \le \sigma \\ = \dfrac{\beta-x}{\alpha} & \text{for } \sigma \le x \le \beta \\ = 1 & \text{for } x = \sigma \end{cases}$$

where parameters $c_1 = \dfrac{\alpha+\sigma}{2}$ and $c_2 = \dfrac{\alpha+\beta}{2}$ are cross-over points.

$$\text{Trapezoidal } (x:\alpha,\rho,\sigma,\beta) \begin{cases} = 0 & \text{for } \beta \le x \le \alpha \\ = 1 & \text{for } \rho \le x \le \sigma \\ = \dfrac{x-\alpha}{\alpha} & \text{for } \alpha \le x \le \rho \\ = \dfrac{\beta-x}{\alpha} & \text{for } \rho \le x \le \beta \end{cases}$$

Where parameters $c_1 = \dfrac{\beta-\sigma}{2}$ and $c_2 = \dfrac{\rho-\alpha}{2}$ are simetric cross-over points,

and $(\beta-\sigma)=(\sigma-\rho)=(\rho-\alpha)$ on interval $[\alpha,\beta]$.

Note: When $\rho = \sigma$ the distribution is triangular.

Specifically, the algorithms for the automatic calculation of triangular or trapezoidal distributions "by attribute" range, using middle point values (MPV) are:

- Triangles MPV   = (upper lim. - lower lim.) / (No. objects + 1)

- Trapezium MPV = (upper lim. - lower lim.) / (2 * No. objects +1)

- Cross-over point   = MPV/2

Then, using the middle point value (MPV) the fuzzy sets are:

- Triangles   [lower lim: 0 , lower lim+MPV: 1 , upper lim: 0]

- Trapeziums {lower lim: 0, lower lim.+MPV:1, lower lim+ (2*MPV):1 upper lim:0]

- The cross over point, cp = MPV/2, of the previous distribution (n-1) to determine the beginning of the next distribution object (n) is used for the automatic calculation of all objects of an attribute possibility distributions (for the option "by attribute").

Triangle n [upper lim(n-1) - cp : 0 (upper lim(n-1) - cp) +MPV: 1 (upper lim(n-1)- cp) +2*MPV] for all objects except first.

Example 1. Consider the object, cheap, within the interval (0 - 7000), then:

triangular MPV = 7000 - 0 /1+1 => so the fuzzy set built by the system would be: (cheap [0:0 3500:1 7000:0])

trapezium MPV = 7000 - 0 /2*1 +1 => so the fuzzy set built by the system would be: (cheap [0:0, 2333:1, 4666:1, 7000:0])

Example 2. Now consider that moderate is the next overlapping object of attribute price, then:

cp = 3500/2 -> 1750, so (moderate [5250 : 0 8750 :1 12250 :0]).

Briefly, to define the overlapping indentation for the sequenced objects, cross-over points were used, as the starting point for the next object of the attribute. This corresponds to using the alpha-cut 0.25 of the outside leg, of the object distribution

for the next object, considering that the attribute objects list is in increasing sequence. Illustrating, let attribute A = {object1, object2, ..., object $_n$}, where object$_n$(xi) - object$_{n-1}$(xi) _ 0 and (cross-over $_{n-1}$)/2 = x1 for object$_n$(x1).

Both triangular and trapezoidal distributions could have open or closed intervals for their limiting objects, the extreme linguistic variables of the fuzzy set (attribute). The meaning of open intervals is that all values situated to the left and right respectively of the object limits, will maintain the same membership value, μ(x), as the last value of that object. Closed intervals means that the limiting objects are completely defined by the space (range) provided when inserted. The respective graphical representations are shown in figure 25.

Figure 25: Graphical Distributions
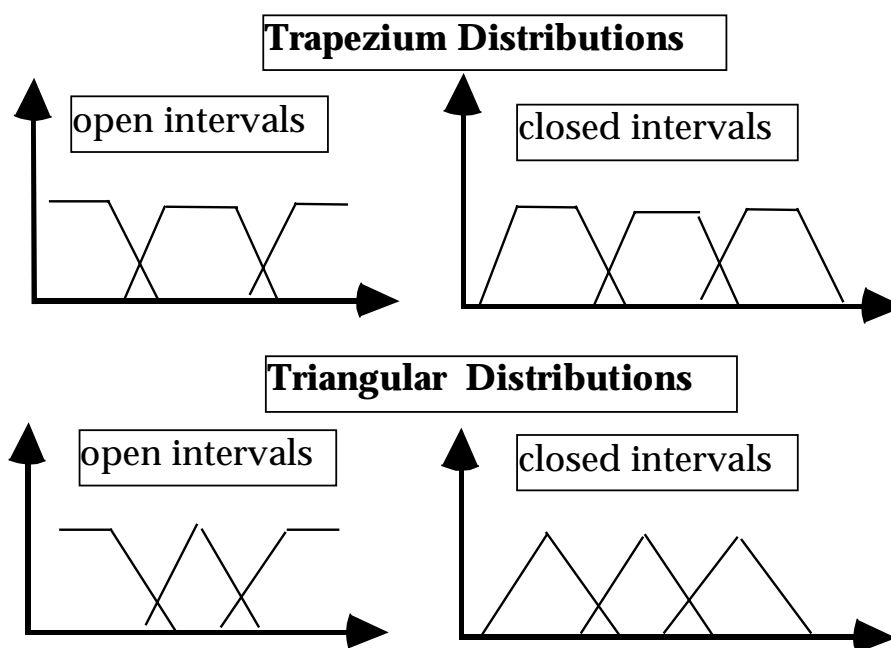
The second type of fuzzy attributes, the discrete objects, have a much smaller range of options since they are single point values and not distributions. Since the objects are discrete it is irrelevant to have possibility distributions. Therefore the expert will

(1) insert the memberships for each object (component) and (2) generalise, if the objects are numeric and integers.

10.3 Three-tier architecture

Although the EMOLITE prototype was planned to be a standalone application, it has been designed following the general guidelines of three-tier applications. In some cases, a pragmatic approach took the place of pure formal aspects in a three-tier architecture. Overall, we feel that we achieved a good compromise. In what follows, we provide a top-level description of both logical and physical views of the EMOLITE system.
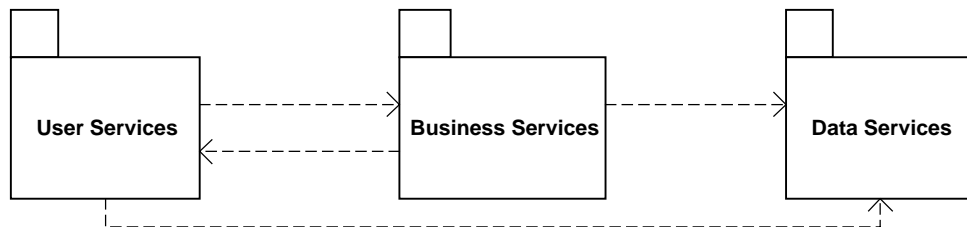

The User Services is composed of:
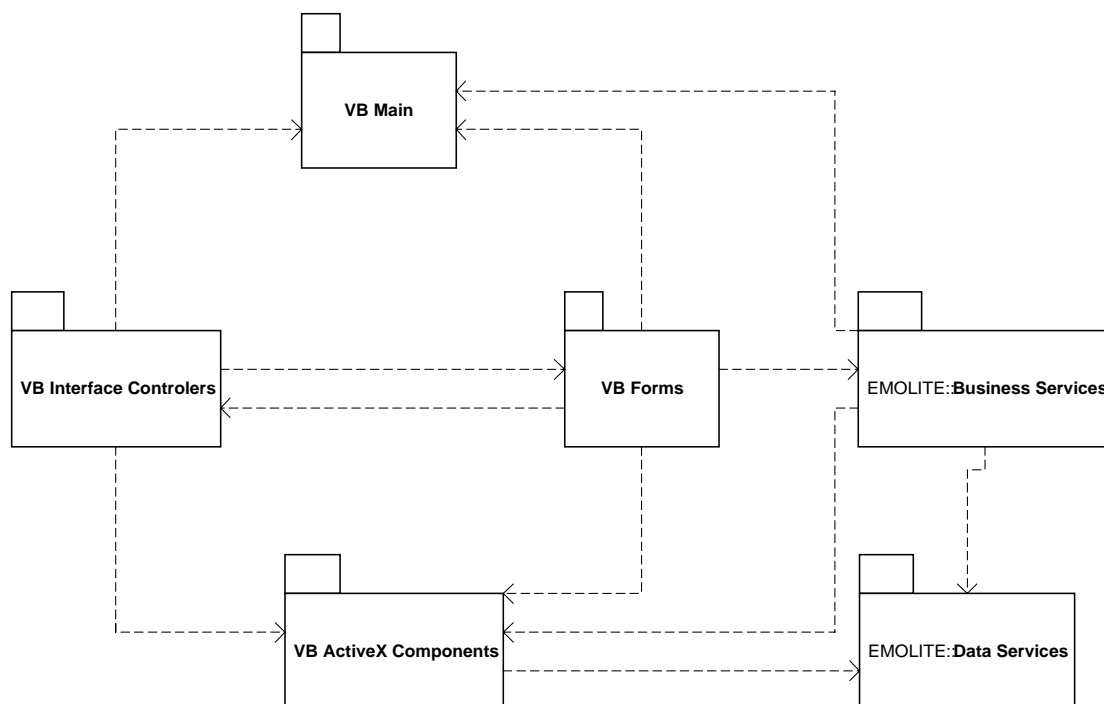
The VB Main is composed of:

modApp	modDecls

modUtils	modRegistry

modWin32

modMain
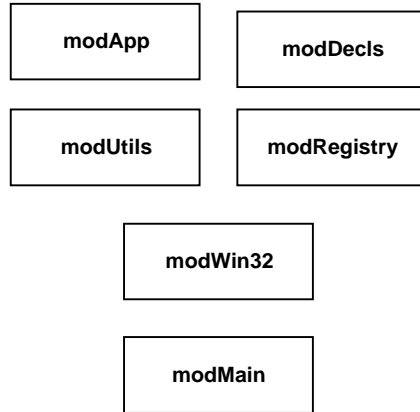
The VB Interface Controlers is composed of:

frmMDIBrowser	frmPreview

frmWizardDB	frmWizardPSI
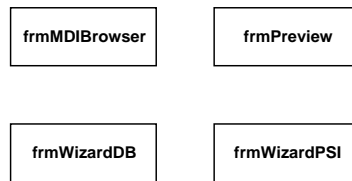
The VB Forms is composed of:

frmMain

frmSplash	frmMDIOpen	frmProperties
frmMsgBox	frmLog	frmProgress

frmGraph	frmPSI	frmEDITCterminal
frmMap	frmFuzzySet	frmEDITPterminal
frmReportFull	frmCostCriteria	frmEDITCountry
frmReportSumary	frmFlexibilityCriteria	frmEDITConnect
	frmReliabilityCriteria	
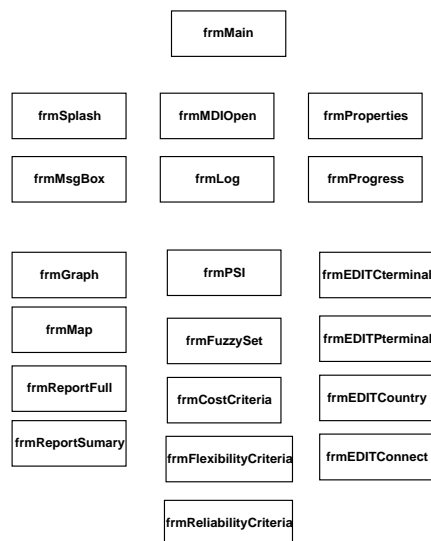
The VB ActiveX Components is composed of:

ComCtl32	**DBList32**	**RichTX32**
ComDlg32	**TDBG5**	**MSChart**
Crystl32	**Threed32**	**DAO**
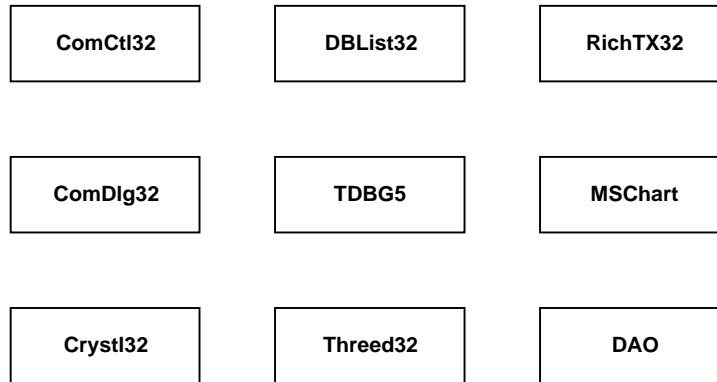
The Business services is composed of:

User Services:**VB ActiveX Components**	**VB Classes**	EMOLITE:**Data Services**
User Services:**VB Main**	**VB Modules**	
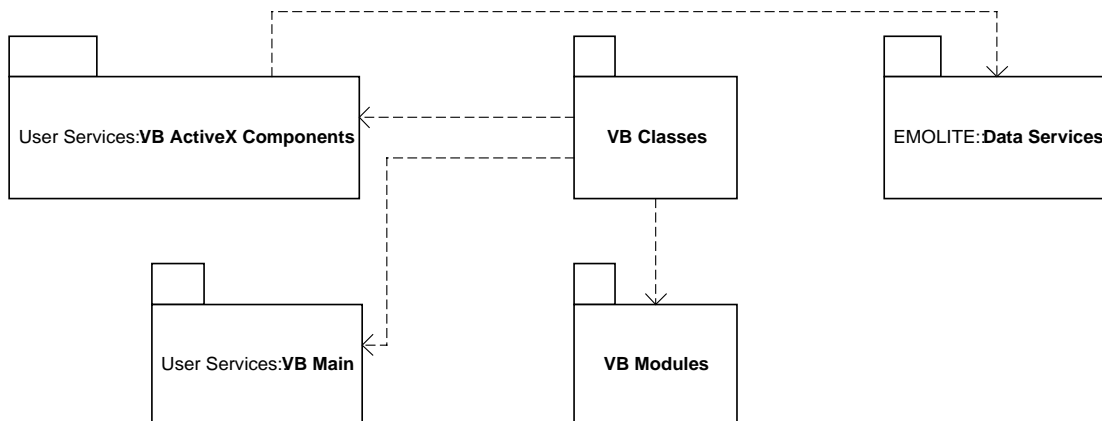
The VB Classes is composed of:

modSimulation
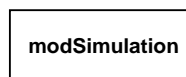
The Data services is composed of:
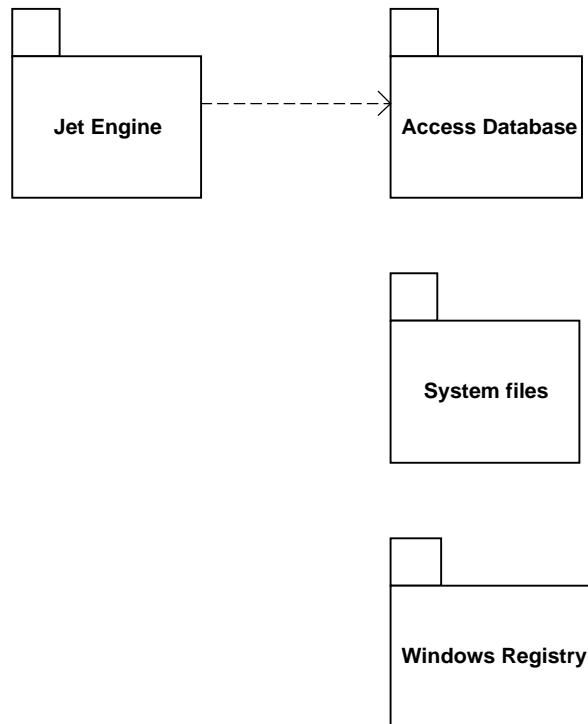
Jet Engine	- - - →	**Access Database**

System files

Windows Registry

11 Annex 4: Short presentation of EMOLITE results and potential

database

result → potential

Internal database
- geographical
- logistics
- socio-economic
- societal
- infrastructure

External database
- freight terminals
- freight related information
- terminal interconnectivity

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interface
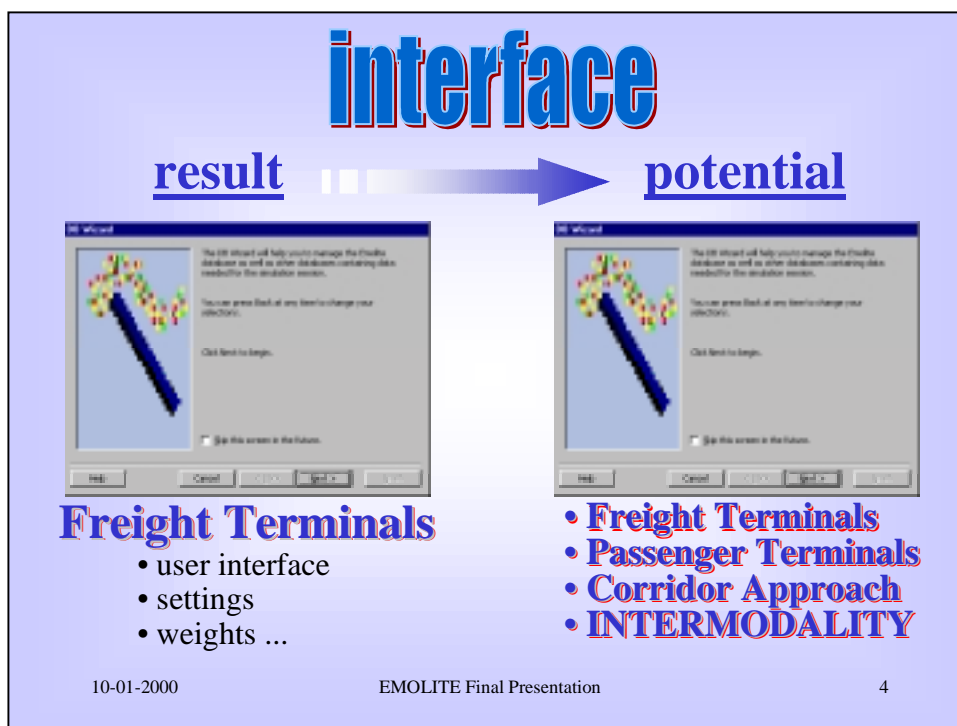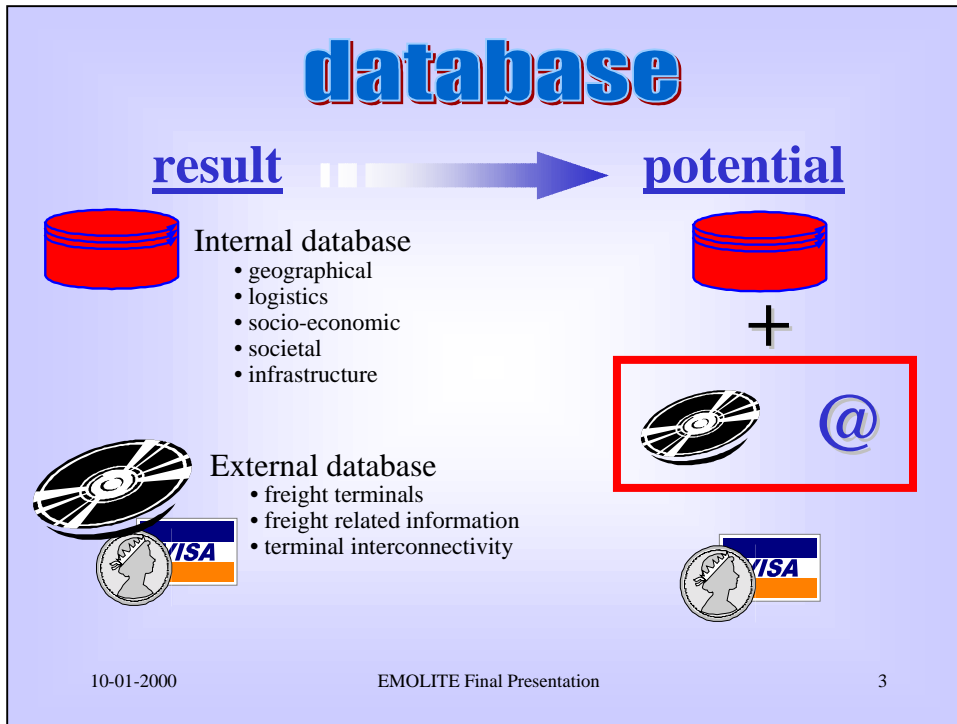
result → potential

Freight Terminals
- user interface
- settings
- weights ...

- **Freight Terminals**
- **Passenger Terminals**
- **Corridor Approach**
- **INTERMODALITY**

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