# NEW INTERACTIVE DECISION GAMES IMPLEMENTED IN DEGA ENVIRONMENT

W. Filipowicz, W. Czuchra, P. Jedrzejowicz

ABSTRACT

Interactive decision games are specifically designed to simulate options and issues of the uncertainty and complexity involved in decision making. Games are used in a PBL (problem based learning) situations, where students are exposed to simulated real-life problems, and learn during the process of solving them. We have already reported (CBLIS'97 and CBLIS'99) on the project involving design and implementation of a computerised environment called DEGA (DEcision GAmes), which can be used to teach and learn problem solving and decision making. The proposed computer environment has been designed as a distributed software system in which users can create, access and play decision games using various available tools and functions. The tools enable, on one hand, to design a simulated model of the decision problem, present it to students, set its initial conditions and suggest format and content of the reports on game results. On the other hand, each participating student is able to view a description of the problem at hand, use available decision-aid software packages to generate and evaluate possible solutions, input final solution, view reports on decisions taken and their results. In this paper we focus on presenting our experiences in using DEGA environment as a tool for developing two selected interactive decision games in the field of transportation and business.

KEYWORDS

Decision support systems, education of OR, software tools for OR

## INTRODUCTION

In this paper we report on the application of management games in the computerised environment called DEGA - (decision games) used to design and play a wide spectrum of various decision games. During CBLIS'97 we presented the purposes and specification of the system [1]. During CBLIS'99 we reported on the finalisation of the preliminary implementation of the project and described the functionality of DEGA [2]. The system was also presented in Joint Proceedings [3,5]. The last paper contains a description of the strategic game we have developed to achieve two goals. The first one was to test the DEGA environment using the game of great complexity and huge number of nodes. The second goal was to create a game, which could be useful in a classroom situation. We have chosen a logistic decision problem and modelled it as a strategic game. The rules of the game follow the description of the logistic game published in [4]. The principles were originally developed by James L. Haskett and next modified at Ohio State University. It has occurred that to take care of the complex situations DEGA requires some extensions and modification. These are briefly presented within the next section of the paper.

The main part of this paper contains a description of the two new management strategic games. The first one is a two-person business investment game and the second is a four-person transportation industry game. Finally we report on the experiences with the application of the game within a project called "Decision processes in the logistics" carried in winter semester as a part of the Logistics Diploma Course at Hochschule Bremerhaven, Germany.

## RECENT MODIFICATIONS IN DEGA

To improve functionality and to extend a range of potential applications we have enriched DEGA with dynamically linked modules and variants. Dynamic-link library (DLL) is an executable module containing code or resources for use by other applications. Conceptually, a DLL is similar to a unit - both provide services in the form of procedures and functions to a program. There are, however, many differences between DLLs and units. Apart from objects' availability - units are statically linked, whereas DLLs are dynamically linked. When a program uses a procedure or function from a unit, a copy of that procedure or function's code is statically linked into the program's executable file. In contrast to a unit, the code in a DLL isn't linked into a program that uses the DLL. Instead, a DLL's code is in a separate file containing binary executable code. The procedure and function calls in the program are dynamically linked to their entry points in the DLLs used by the application. For a module to use a procedure or function in a DLL, the module must import the procedure or function using proper declaration. Imported procedures and functions behave no differently than normal procedures and functions.

The *Variant* type is capable of representing values that change type dynamically. Whereas a variable of any other type is statically bound to that type, a variable of the *Variant* type can assume values of differing types at runtime. The Variant type is most commonly used in situations where the actual type to be operated upon varies or is unknown at compile-time.

Variants have the following characteristics:

- Variants can contain integer values, real values, string values, Boolean values, date-and-time values, and OLE Automation objects. In addition, variants can contain arrays of varying size and dimension with elements of any of these types.
- Variants can be combined with other variants and with integer, real, string, and Boolean values in expressions, and the compiler will automatically generate code that performs the necessary type conversions.

The ability to accommodate different types of data proved to be well suited for parameters' transfer between dynamically linked modules. The only limitation is an order of appearance that is fixed and is to be observed to avoid misinterpretation.

## TWO-PERSON BUSINESS GAME

A player is taking over the company producing a high-tech consumer product of a high unitary value. He has one big competitor and several smaller ones. At the beginning of the game his market share is 40%. His main competitor has identical share. The remaining 20% of the market share is spread evenly among smaller competitors. To control his market share and income level he is expected, at the beginning of each stage of the game, to set the following values:

- budget for marketing and customer relationship management,
- budget for research and development,
- total fund to be distributed among stakeholders in the form of the dividend.

All three types of expenditures are covered from the reserve fund available at the beginning of each stage. This fund, at the end of each stage is increased (respectively decreased) by the amount of net profit (respectively net loss) from the previous stage. Players reserve fund at the beginning of the play is worth 60 million EURO. His stakeholders do not allow arranging for any outside financing. For his information the company's results during the previous 3 stages are given and shown in Table 1 and Table 2.

| Variable | Stage 0 - 3 | Stage 0 – 2 | Stage 0 - 1 |
|---|---|---|---|
| Market share | 50 % | 45 % | 40 % |
| Marketing budget | € 20 M | € 15 M | € 25 M |
| R&D budget | € 10 M | € 20 M | € 15 M |
| Total dividend paid | € 15 M | € 15 M | € 10 M |
| Reserve fund at the beginning of stage | € 50 M | € 55 M | € 50 M |
| Company value | € 16 M | € 17 M | € 20 M |
| Stock exchange index | 111 | 120 | 135 |

Table 1. First Company Data.

| Variable | Stage 0 - 3 | Stage 0 – 2 | Stage 0 - 1 |
|---|---|---|---|
| Market share | 20 % | 25 % | 40 % |
| Marketing budget | € 10 M | € 20 M | € 20 M |
| R&D budget | € 20 M | € 0 M | € 0 M |
| Total dividend paid | € 0 M | € 0 M | € 5 M |
| Reserve fund at the beginning of stage | € 30 M | € 20 M | € 25 M |
| Company value | € 10 M | € 12 M | € 18 M |
| Stock exchange index | 111 | 120 | 135 |

Table 2. Second Company Data.

Each player has the full knowledge of historical data from his/her own company and is presented with information on history of the market share, total dividend paid, and company value of the other company only.

<u>Information given to players at subsequent stages</u>

After both players have made their decisions as to the value of decision variables the results of the stage are given. Each player gets information on market share of the own company and its main competitor, value of both companies as determined by the stock exchange, value of the stock exchange index and the value of the reserve fund of its own company.

Calculations

*1. Stock exchange (SE) index*. Stock exchange index is growing at the rate of 10% per stage plus an adjustment factor, which is a uniformly distributed and randomly generated integer from the interval [-5,5]

*2. Market share*. Market share of each company at stage *x* depends on three factors namely: marketing budgets of each main competitor and the research & development budget set at stage *x*-1. Investing in R&D may bring you an increase in your market share the following stage. Undercutting the marketing budget (compared to competitor) can bring the player an immediate decrease in his market share. However expenditures on marketing do have a diminishing returns to scale.

*3. Reserve fund*. A reserve fund at the end of the current stage is calculated as a sum of the remaining funds from the previous stage plus profit generated at present stage. The profit, in turn, is calculated from the market share at the rate of: 1% of market share = 1,2 mln. EURO * (current SE index/previous SE index).

*4. Company value***.** Company value depends on past performance with respect to market share and dividend as well as on a stock exchange index. Formula for calculating company value follows:

> *Company value* = ((Sum of reserve funds from the last three stages)*2 + (Sum of dividend paid during the last three stages)*4)* (current SE index/previous SE index)

The influence diagram of this game is shown in Fig.1.

TRANSPORT GAME

The decision problem modelled in this game reflects a competitive environment in cargo transportation. To make the problem realistic enough and not bother with different price, law, and tax regulations in this extraordinarily international industry we have limited the environment to a given transportation market of a selected country. The activities of up to 4 players who act as the managers of the transportation companies take place within the territory of Germany. There is some randomly generated demand on transportation services, (called transportation orders) that should be satisfied by the transportation companies. The transport of goods causes costs to carriers but on the other hand brings income from clients. The goal of the player, who is a manager of the firm, is to maximise the surplus of incomes over costs in a given period of time.

Transportation industry

We have chosen 47 cities within German territory. These cities are regarded as origins and/or destinations of goods to be transported. They are depicted in Figure 2. For the sake of simplicity we assume that

- a single voyage means transportation of one particular cargo type or commodity,
- there are no combined tours with many destinations,
- the distance matrix is a symmetric one.

The distances given and the assumed average working speed of lorries guarantee that the maximum duration of a voyage does not exceed two days. After a cargo is delivered to a destination the respective lorry stays there and waits for the next order. If the order will be assigned to a given lorry this has to move to the origin of the next tour and if this differs from the waiting place the covered distance increase length of the voyage. If the transport finishes sometime during a day, the next transportation can not start before the next day.

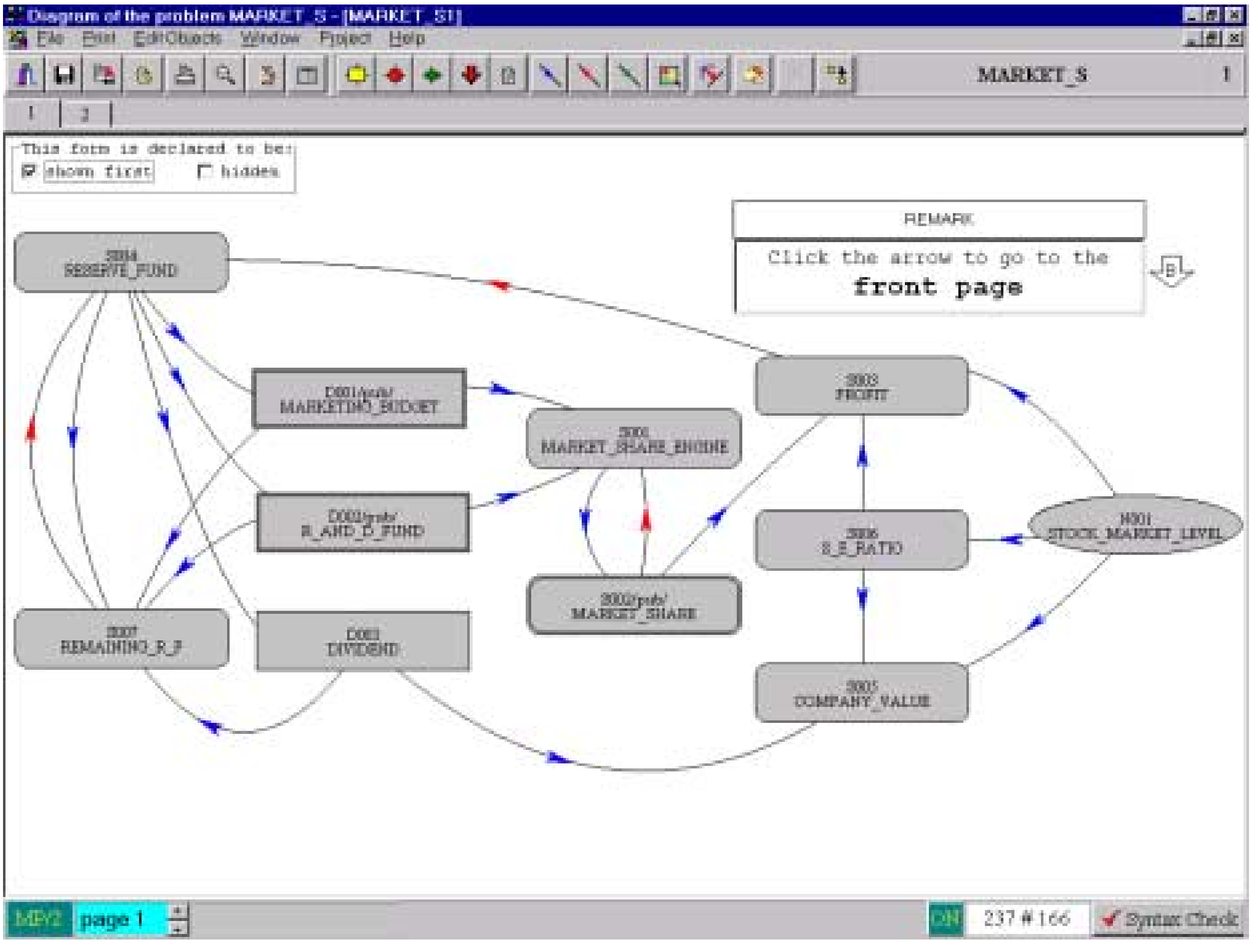


Fig. 1. Influence Diagram of Business Game.

The decision cycle in the game covers one day. There are no holidays – each calendar day is a workday.

There are 4 transport companies in the industry: A-Trans, B-Trans, C-Trans and D-Trans. Each of them owns a lorry fleet of 10 vehicles of the same type and structure. There are:

- 4 lorries for transporting light, high cube, voluminous cargo (LHV),
- 2 lorries for transporting heavy but rather small units (HS),
- 4 lorries for transporting refrigerated cargo (R).

The details of the lorries' features are given in Table 3.

A lorry can cover the distance of 600 km each day and is driven by one driver. The resting time, maintenance time and loading/unloading operations are indirectly included in the mean velocity. Each vehicle is ready for disposal at any time – there are no delays whatsoever due to weather, technical problems nor to traffic jams and road accidents.


Fig. 2. Transport Origins and Destinations.

| **Lorry type** | **LHV** | **HS** | **R** |
|---|---|---|---|
| Fix costs per day [DM] | 850 | 1050 | 1250 |
| Variable costs per km [DM] | 1,50 | 1,80 | 2,00 |
| Maximum volume to carried [$m^3$] | 100 | 40 | 60 |
| Maximum payload [t] | 4 | 23 | 20 |

Table 3. Types of Lorries.

The variable costs are to be considered also for empty travel. This is especially valid for the travel to the city where the cargo is to be collected. This must be taken into account when calculating the prices and the dates for the tenders (quotations).

There are three types of goods and commodities:

- LHV category (specific weight - 40 $kg/m^3$ ); e.g. insulation materials, wall papers, refrigerators, sweets, spirits, wood,
- HS category (specific weight - 575 $kg/m^3$ ); e.g. cement, lead plates, steel bars, bricks,
- R category (specific weight - 333 $kg/m^3$ ); e.g. fruit, vegetables, milk products, chocolates, meat.

The following rules must be observed:

- R-category of cargo can be carried only by R-lorries,

- HS-category of cargo can be carried by HS- and/or R-lorries,
- Each lorry can carry LHV-category of cargo.

40 transport orders are randomly generated in every cycle of the game. Each order contains the following data

- origin,
- destination,
- cargo type,
- insurance premium,
- deadline for shipment,
- maximum price.

The maximum price is unknown to the player and cannot be exceeded in the tender. In this way a case is excluded in which for one unattractive order the only tender with an extraordinarily high price will be accepted since there are no other tenders.

Players' activities

At the beginning of the game each player chooses precisely one out of four transport companies. Next he/she must decide about the company's location in one of the cities. This choice is of importance only in the first cycle of the game since thus the distance to the first city for loading cargo can be optimised. The lorries do not have to return to the company's location after cargo delivery – they stay at the city of their last cargo destination.

In each cycle the generated transport orders should be executed. The player can use all the lorries that are available at the time or will be available within a certain time horizon, which is suitable to collect the cargo at the right time. Each company can prepare its tenders for all or for some chosen orders.

The following data should be included in the tender:

- type of the lorry,
- priority of this particular tender,
- freight,
- day for collection of cargo at the origin.

*Type of the lorry*
When making this decision the player must consider whether the chosen lorry is free and is suitable to carry a given type of cargo. The payload of the vehicle must not be exceeded.

*Priority of the tender*
In each cycle there are 40 transport orders generated – i.e. 30 orders more than the number of lorries of one company. That is why the player must decide about the priority of tenders. The lower the priority of the tender the more this tender is to be preferred. It means that if the player assigns the priority of 1 to 10 tenders all his vehicles are free at the latest date and if other players have not given a better tender (i.e. at a lower price), these 10 tenders will be accepted. Apart from the 10 tenders with priority of 1 there should be prepared at most 10 tenders with priority of 2, 10 tenders with priority of 3 and 10 tenders with priority of 4. It is possible that not all lorries are free in a given cycle. This results in the fact that the number of accepted tenders can be smaller than 40.

*Freight*
The price of a given transport should be calculated as the sum of transport costs, insurance premium and profit. The player should consider variable costs (depending on the distance of the voyage) and fixed costs (determined per one day of vehicle exploitation) when calculating the overall transport costs. The insurance premium differs with the type of cargo. The profit in the tender is calculated automatically by the system as a percentage value of the overall costs. The player determines this ratio for all tenders in one cycle.

*Cargo collection day*
The latest day for collecting the cargo at the city of origin of the transport is determined for each transport order. If this date cannot be met such a tender will not be accepted despite the price and priority given to it.

There are four cases in which the lorry will stay at the city of the last destination

- The player has calculated for the transport a price which is below real transport costs
- The other players have quoted lower prices
- The latest date for collection can not be met
- The maximum price is exceeded

Player should manage his lorries (i.e. transport company) so that it brings profit. The number of idle days for a lorry should be minimized. That is why he/she should pay great attention to the above conditions.

<u>Rules of assigning orders to the lorries</u>

Immediately after issue of tenders by all players the orders will be assigned to tenders (and transport companies which have quoted them). Each order will be assigned to not more than one transport company (it can happen that some orders will not be allocated since some lorries could be busy at the time or there are no suitable lorries available to carry a given particular cargo. The algorithmic order assignment is done due to the following rules:

1. The transport order $T_x$ is assigned to the company $C_x$ if (these are AND-conditions)
    - the company $C_x$ has less than 10 assigned orders,
    - the transport order $T_x$ is signed by company $C_x$ with the highest (1) priority,
    - there is no delay in collection of the cargo at the city of origin,
    - the price is lower than the maximum acceptable price,
    - the lorry is suitable to carry the cargo and the payload is not exceeded,
    - the price in the tender is lower than the competitors' prices.
2. The priority 1 has not be given to the transport order $T_x$ by any company; then the company $C_x$ will be found satisfying the following (also AND-conditions)
    - the company $C_x$ has less than 10 assigned orders,
    - the transport order $T_x$ is signed by company $C_x$ with the priority of 2,
    - there is no delay in collection of the cargo at the city of origin,
    - the price is lower than the maximum acceptable price,
    - the lorry is suitable to carry the cargo and the payload is not exceeded,
    - the price in the tender is lower than the competitors' prices.

The same to be continued correspondingly for priorities 3 and 4.

Players' goal

While defining this transport game in the DEGA-environment at its initial stage a number of cycles must be determined (e.g. 10). The goal is to gain the maximum profit during this period. The player with the maximum profit at the end wins the game.

Model of the transport management game in DEGA

The transportation industry was modelled within the DEGA environment on 8 pages. These are:

1. Starting page,
2. Menu page,
3. Distance matrix page,
4. Cost report page,
5. Orders page,
6. Lorries report page,
7. Company profit report page,
8. Auxiliary page for calculation (it is hidden for the players).

Since the generating of transport order and their assignment to companies are very complex procedures we call some DLL procedures from extra *.DLL-file to calculate them. Two exemplary parts of the model are shown at Figure 3 and Figure 4.

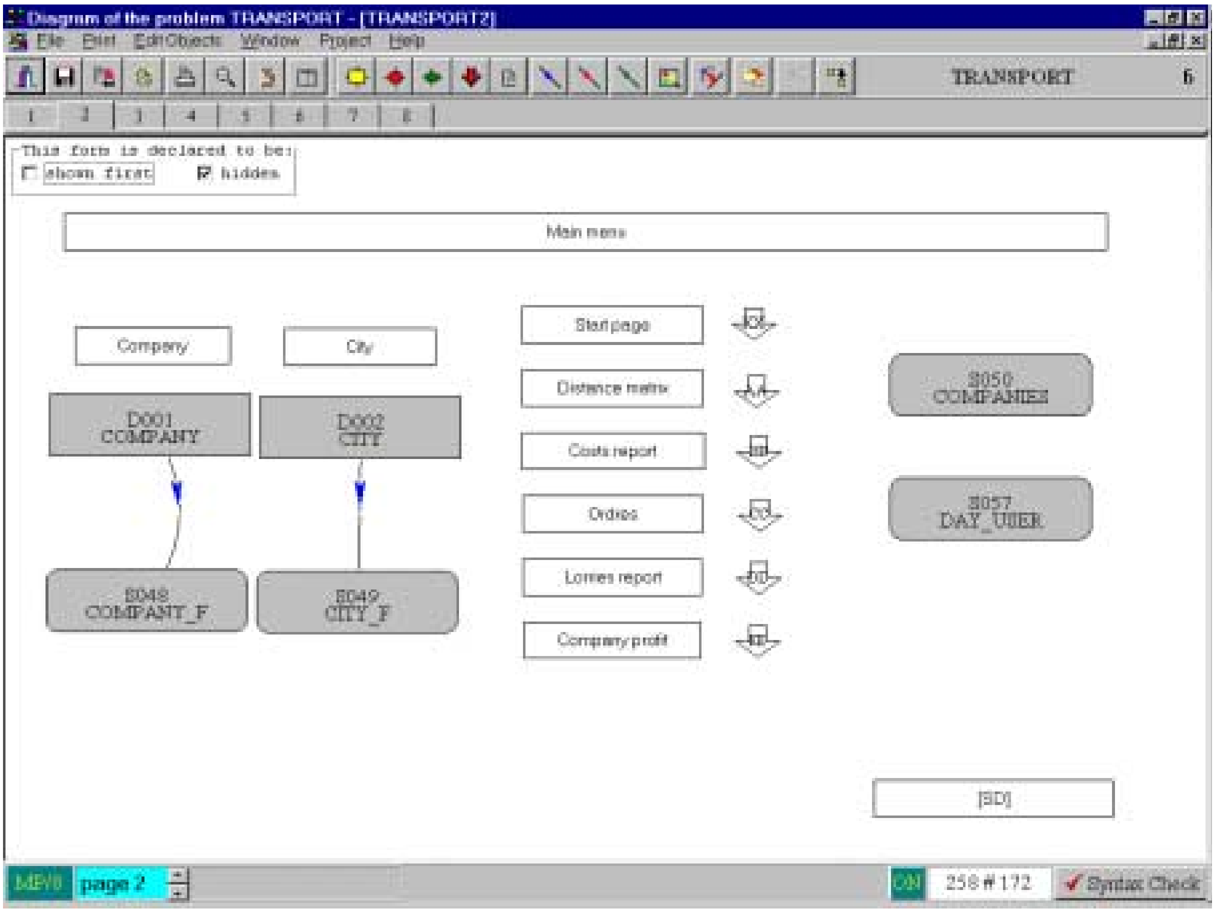


Fig. 3. Menu Page of the TRANSPORT Game.

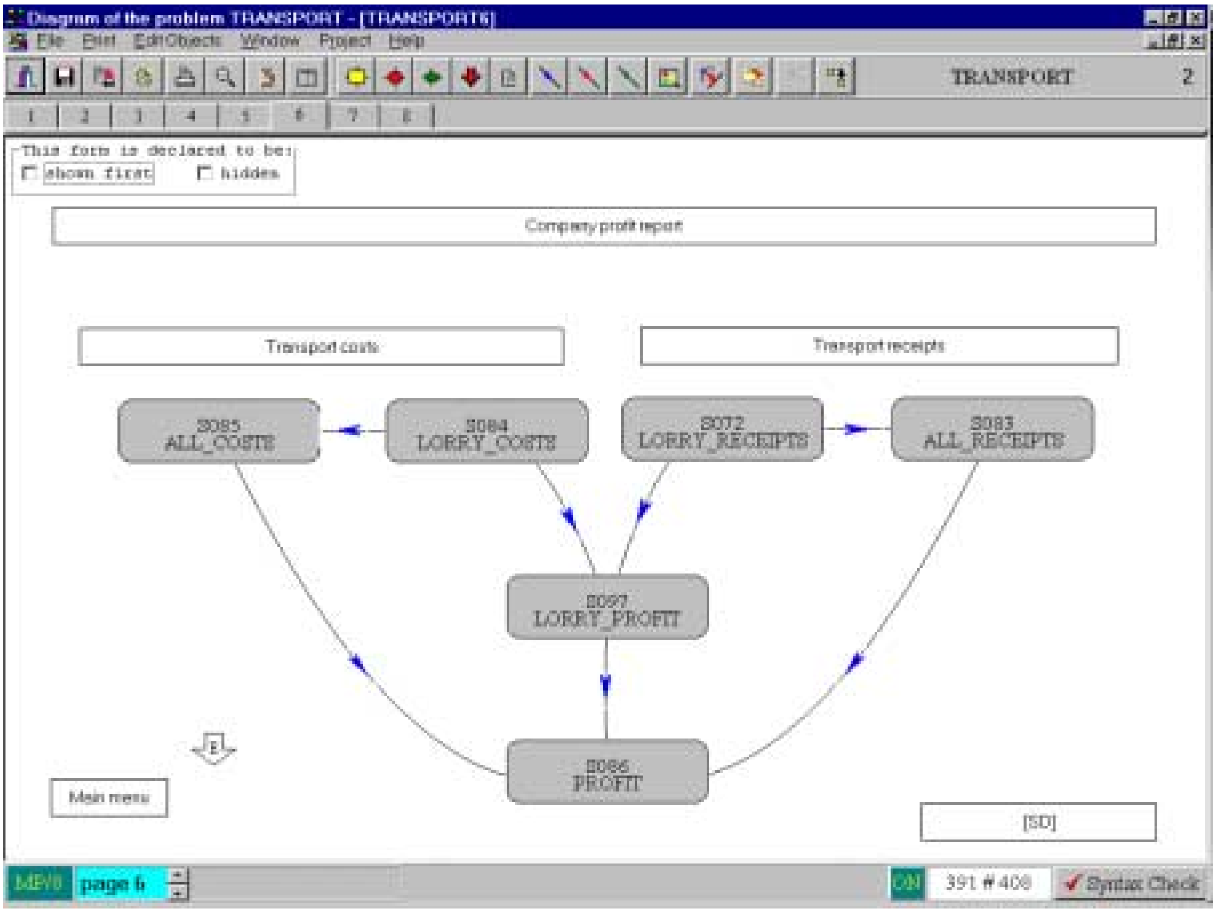


Fig. 4. Costs Report Page of the TRANSPORT Game.

FINAL REMARKS

The DEGA environment reported and discussed at previous CBLIS conferences [1,2] has been further developed and improved. Variant parameters used with dynamically linked modules have dramatically increased the functionality of the system. This enables modelling of a wide variety of problems covering different fields. Two example applications presented in this paper are related respectively to managerial decision making and transportation. The discussed examples are being used for educational purposes. Feedback from the students brings new ideas that remain to be implemented in the near future. This will result in enrichment of the available library of models creating opportunity for selecting those best suited for different situations and problem areas.

The logistic game is already used in the project "Decision techniques in logistics" within the Transportation Engineering / Logistics Diploma Course at Hochschule Bremerhaven with the students of 7$^{th}$ semester. The DEGA environment as well as the game itself is found an interesting and even enjoyable tool. Students are able to gain some feeling and experience making decisions in situations in which many conflicting factors influence company performance. The presented transportation game will be used in the classroom environmrnt during the first half of 2001 and at the time of the presentation of this paper at the conference we will be able to report on its appreciation by students.

REFERENCES


1. Barbucha D., Czuchra W., Filipowicz W., Jedrzejowicz P.: *Design of the Intgerated Environment to Model and Plan Managemnet Decison Games,* Proceedings of the Conference Computer Based Learning in Science, Leicester 1997, ed. G.M. Chapman.
2. Barbucha D., Czuchra W., Filipowicz W., Jedrzejowicz P.: *DEGA Environment as a Tool for Developing an Interactive Decision Games in theField of Logistics*, Proceedings of the Conference Computer Based Learning in Science, Leicester 1999, ed. G.M. Chapman.
3. Barbucha D., Czuchra W., Filipowicz W., Jedrzejowicz P.: *Design of the Integrated Environment to Model and Plan Management Decision Games*, Joint Proceedings, 1999
4. Beier F.J., Rutkowski K.: *Logistyka*, Szkola Glowna Handlowa, Warszawa, 1995
5. Czuchra W., Detert M., Feldhusen J., Sekula M.: *Modelling of Logistic Game in DEGA Environment*, Joint Proceedings, 2000.



Wlodzimierz Filipowicz
Chair of Computer Science and Computer Networks
Faculty of Navigation Engineering
Gdynia Maritime Academy
ul. Morska 83, 81-225 Gdynia, Poland
tel.: +48 58 621 70 41, fax: +48 58 620 14 67
e-mail: *wlofil@wsm.gdynia.pl*

Waldemar Czuchra
Transport Engineering and Logistics Faculty
Hochschule Bremerhaven
An der Karlstadt 8, 27568 Bremerhaven, Germany
e-mail*: wczuchra@hs-bremerhaven.de*

Piotr Jedrzejowicz
Chair of Information Systems
Faculty of Business Administration
Gdynia Maritime Academy
ul. Morska 83, 81-225 Gdynia, Poland
tel.: +48 58 621 70 41, fax: +48 58 620 14 67
e-mail: *pj@wsm.gdynia.pl*