THE USE OF SIMULATION IN THE SOCIO-ECONOMICAL EVALUATION OF THE MANAGEMENT OF AN INTERMODAL TERMINAL

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ABSTRACT

In this paper we present the application of the PLATFORM simulation tool to the evaluation of alternative management strategies of intermodal terminals. First, the Platform simulation tool is briefly introduced, then it is used in the context of Cost benefit Analysis and Multi Criteria Analysis to assess the impact of alternative investements in terminal management: adoption of computer based management, introduction of new transshipment equipment. These alternatives are compared with the "do-nothing"alternative for the different decision makers involved in the various aspects of intermodal terminal management: the terminal operators, the forwarders, the rail operators, and the policy makers.

INTRODUCTION

In many European countries road only based transport is the dominant mode of transportation, and this causes a series of social problems, road congestions, increase in the average road accident rate, traffic pollution. These problems must be taken into consideration together with the usual cost-related indicators when evaluating the performance of transportation modes. It is therefore auspicable that combined rail-road transport could represent a viable alternative to road-only based transport. The European Community has beed designing policies and recommendations working in this direction, and the PLATFORM project, presented in this paper, represents a research effort to support the socio-economical assessment of the impacts produced by the adoption of different technologies and management policies in intermodal terminals.

Intermodal terminals can be made more attractive for the customers by enhancing their infrastructures, but often the costs associated with these interventions are substantial, and well designed investment plans must be designed. Computer based simulation can provide the decision-makers with the help they need in creating the strategies for development. On the other hand, the renovation of the infrastructures and the adoption of new technologies of the terminals of the 21st century is a process which is undoubtely influenced by the policy making at the international and national level. While terminal operators are mostly interested in an economical evaluation of the impact of the new terminal, the policy maker will be interested in the social aspects and this is the frame of reference where the Platform project positions itself: a common ground where both terminal operators and policy makers can meet, evaluate and discuss their respective viewpoints.

In this paper, we present two major aspects of the Platform project: first we show how we built a general tool for the simulation of a rail-road terminal, then we present the choice and the design of the methodology to be used in the evaluation phase. Finally, we define some simulation scenarios applying the Multi-Criteria Analysis methodology to evaluate the possible management alternatives. Depending on the preferences expressed by intermodal operators through all Europe, the increase in the productivity of one sample terminal will be investigated in two with-project scenarios to be compared with the do-nothing scenario, each one containing the scenarios of the previous levels: present situation; adoption of computer-aided management; adoption of new transhipment equipment.

A SIMULATION TOOL FOR INTERMODAL RAIL/ROAD TERMINALS

One of the aims of the Platform project was the "implementation of a simulation environment for the assessment of impacts produced by the adoption of different technologies and management policies to enhance terminal performances". To achieve this objective, the project needed to encompass all the phases of an intermodal transport of an ITU, a requirement for the comparison of the performance of intermodality against road-only based transport.

An intermodal transport along a rail corridor connecting two terminals can be divided into three legs. The initial leg describes the trip from the origin of the ITU to the first terminal. This leg is usually managed by a forwarding company owning a truck fleet. Trucks pick up and deliver ITUs in the company's user catchment area. The second leg is the transport between the two terminals by train. The railway companies owning the rail network manage this leg. Often, different rail companies cooperate in transnational transports. The third and final leg, the transport from the destination terminal to the ITU destination, is again managed by a forwarding company.

To represent the intermodal transport in all its parts the PLATFORM integrated simulation environment will be composed of three modules: *the road network planning and simulation module*, which plans the management of the forwarders' orders and simulates the traffic of trucks on the road network; *the terminal simulation module*, which simulates the terminal nodes and the change of transport mode, from truck to train and back; *the corridor simulation module*, which simulates the rail network connecting the terminals. These three modules are designed to work in parallel in order to produce results on the performance of the integrated rail-road network. Typically, the road planning and simulation module accepts intermodal transport orders for transport of an ITU from city to city. It then books a place for the ITU on one of the train connecting two intermodal terminals and then schedules truck delivery and pickup of the ITU. The scheduled truck delivers the ITU in the terminal, that is, this information is provided as input to the terminal simulation module. This module takes care of handling the ITU and loading it on the train where it was booked on, then it sends the train to the corresponding terminal. This action is taken care of the corridor simulation module. At the receiving terminal similar actions are preformed: the ITU is unloaded from train and loaded on the pickup truck. The truck is passed back to the road planning and simulation module, which routes it to its final destination.

In the full version of the paper, we present the software component of the PLATFORM project dedicated to terminal and corridor simulation. Here, we remind that the PLATFORM terminal simulator has been developed in MODSIM III (CACI, 1996), a commercially available object-oriented and process-oriented simulation language. The adoption of the object-oriented paradigm allowed to design and implement software components corresponding to their real-world counterparts and with a similar behaviour. The terminal components modelled in the terminal simulator are:

– the *road gate*, where trucks enter and leave the terminal;
– the *rail gate*, where trains enter and leave the terminal. The rail gate is connected to the *shunting area*, outside the terminal, where the rail network operator shunts trains before they enter the terminal. The rail gate is also connected to the *rail tracks* inside the terminal;
– the *platforms*, each composed by a set of rail tracks and by a *buffer area*. The buffer area is a temporary storage area for ITUs that are waiting to be loaded/unloaded to and from trains entering the platform. Each platform is served by a set of *gantry cranes*, spanning the platform length and serving the set of rail tracks and the buffer area;
– the *storage area*, a longer term (usually 24 hours) area to park ITUs. The *front lifters*, serve the storage area, they serve trucks directed to the storage area picking up the ITUs and storing them in the storage area.

These components are implemented in the simulation code as *classes*, using the object-oriented programming language provided by MODSIM III. The modeller can easily assemble a rail/road terminal model creating instances of these classes. Moreover, since the Platform simulation model reads from a database the structure of the terminal model and creates the instances of the model components, the modeller does not need to write code to create different terminal instances. This allows the Platform simulation module to be quite generic and to be able to model a variety of different terminal layouts and equipment.

PLATFORM EVALUATION METHODOLOGY

The PLATFORM evaluation methodology is applied to the outputs supplied by the simulation of different scenarios of development in intermodal terminals. It can be regarded as a before-after appraisal with a particular mixed timing: it is applied to the choice among alternative scenarios of development, typical situation for the ex-ante procedures, but it is also based on simulation outputs considered as measurements, which is typical of the ex-post procedures (MAESTRO, 2000).

The evaluation of a project on the entire intermodal transport chain involves various actors and makes it difficult a global appraisal. Therefore, this kind of projects is usually evaluated choosing the point of view of only one actor: the methodologies developed under APAS (APAS, 1996; EURET, 1994) for nodal centres for goods, for example, were focused on the nodal centres of the intermodal freight transport chain and, even if all the different actors were considered, the evaluation was determined only from the terminal managers point of view. Since the PLATFORM simulation environment reproduces the entire chain, the different scenarios can include technological and managerial innovations in every chain leg. Therefore every actor in the chain can use PLATFORM to evaluate different interventions:

shippers, terminal operators, forwarders, rail operators, and policy makers.

Shippers will not directly use PLATFORM, but the optimisation of the intermodal chain in terms of performances and costs, derived by the application of the results of PLATFORM, should convince them to send larger amounts of freight via intermodal transport.

Terminal managers, forwarders and rail operators are commercial operators and have the main goal of increasing their profits while minimising costs: the best evaluation technique for their exigencies is the Cost Benefit Analysis (CBA). On the contrary policy makers are mainly concerned with community welfare and other non monetary impacts, therefore the most adapt technique is the Multi Criteria Analysis (MCA).

Terminal operators may use PLATFORM to analyse the impacts produced by almost every terminal enhancement: new equipment, storage areas and rail tracks, additional personnel as well as innovative management procedures and telematics technologies. Their goal is to improve the productivity of the terminal, which means to increase the total number of ITUs handled and trains arrivals/departures. This implies to reduce the unit costs for handling ITUs, to reduce the total travel time, to improve the quality of the service.

Forwarders may use PLATFORM to investigate how to enlarge their market share and increase the level of the service they provides. Their main goals are to lower the costs of handling ITUs and to optimise the use of resources on the road legs.

Rail operators may use PLATFORM to decide if more train paths might be given to a terminal. Their main goals are to supply a better level of service (in terms of travel time reduction and punctuality), to increase the productivity of rolling stock and personnel, to increase safety levels by reducing the number of manoeuvres per train, to assess whether is there enough time to serve new trains in the terminal. Least but not last, policy makers may use PLATFORM to analyse projects regarding intermodal transport terminals. They are mainly interested in reducing the costs of transport (comprising accident costs), the external effects of heavy vehicles on the road network, the energy consumption, the intrusion of terminals in the territory (reduction of space usage).

EVALUATION OF SCENARIOS

PLATFORM defined three scenarios to evaluate possible enhancements of an intermodal terminal according to the preferences expressed by intermodal operators throughout Europe: present situation (do-nothing scenario); adoption of computer-aided management; adoption of new transhipment equipment.

The succession of the scenarios, in the order they are reported, corresponds to increasing levels of investments.

Despite PLATFORM simulator is able to simulate terminal layout changes, in none of the three scenarios structural changes have been evaluated. This is because the intermodal operators interviewed saw the structural changes of the terminal as the very last chance to increase terminal productivity.

Present state

The do-nothing scenario is the term of comparison for the evaluation. The simulation of this scenario allowed to calibrate and validate the simulation tool. Input data (e.g. train timetable, trucks arrival time at the road-gate) have been supplied by CEMAT, a technical partner in the PLATFORM project, for one week of operations.

The time spent by trucks queueing at the road gate varies between the observed minimum technical time of 8 minutes and a maximum of 54 minutes. It can be observed (figure 1) that the difference between two different peaks is approximately 12 hours, corresponding to the morning peak at about 9.00h and the evening period at 20.00h. The peak flows are higher at the end of the week.

The average time spent in queue at the road gate to enter the terminal is about 15 minutes, which is 7 percent less than the observed average time (16 minutes). The minimum technical time of 8 minutes is reached in 30% of the cases. The average time of 16 minutes is not exceeded in 70 percent of the cases, while 90 percent of the trucks spend less than half an hour.

Trucks spend an average time of 22 minutes in the terminal for the internal movement and the transhipment of the ITUs. The equipment operates an average of 1.7 movements per ITU, which means that about 30 percent of the ITUs are directly moved from the train to the truck or vice versa.

The residence time of the ITUs in the terminal is very close to the real one. The overall average residence time amounts to 13 hours and in 90 percent of the cases this time is lower than 48 hours. For the ITUs delivered by train, the average residence time is 17 hours, in 90 percent of the cases it is lower than 43 hours, while the maximum simulated amounts to 75 hours. The average residence time of the ITUs delivered by truck is 10 hours, in 90 percent of the cases the residence time is lower than 24 hours and the simulated maximum is 60 hours.

Each train, considering that on each platform more trains are handled in parallel, occupies in the average the track about 4 hours for the loading or the unloading operations.

Finally the buffer areas along the rail tracks are used on average for 31 percent of their capacity. The storage area remains substantially unused.

These results show that for our evaluation purposes the Terminal Simulation model can be judged a valid

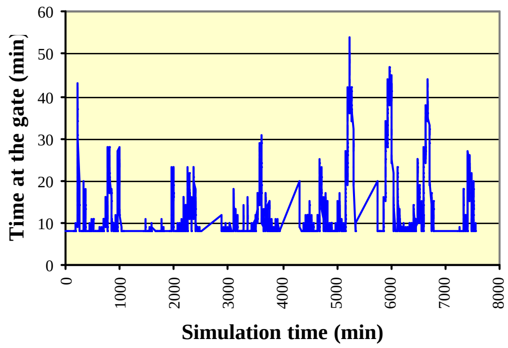

Figure 1. Time spent at the road gate during the simulation

representation of the Quadrante Europa Terminal operated by CEMAT in Verona.

Adoption of computer aided management

This scenario is characterised by two interventions:

- *automated road gate*, in which the effects of a 50 percent decrease in the time taken at the road gate has been assumed as the consequence of a full automation of the gate operations;
- *traffic planning*, in which the effects of traffic planning have been added, as a consequence of the adoption of integrated telecommunication technologies among the forwarding agencies, the trucks and the terminal. This effect was represented in the simulation by truck arrivals synchronised with the train arrivals and departures.

The adopted CBAs have four steps: definition of the do-nothing and with project scenarios, identification and evaluation of costs and benefits, choice of the evaluation criteria, and decision[1].

In a CBA the with-project situation is be compared with the do-nothing situation. The do-nothing and the with-project scenarios are both analysed with the present market situation, without forecasting changes (since the time horizon is less than one year).

Precise quantification of the investment and maintenance costs of a computer-aided management system has not been performed because a detailed technical specification of the system was necessary and this is not the scope of PLATFORM project. Furthermore, with respect to the other terminal, road and rail equipment a computer system has a negligible cost. The benefits induced are represented by expense reduction, such as those related to crane movements (energy consumption, maintenance costs, personnel time, asphalt consumption), and future possible modal shift from road-only transport induced by the increased level of service provided.

The evaluation criteria adopted in PLATFORM is the Net Present Value because is the one giving an index of the investment profitability.

The adoption of such a system is practically free and produces the main benefit of reducing the crane operations number and service time, the direct transhipment increases to 69% and the number of movement per ITU managed decreases to 1.3 (see fourth column of table 4.1) from 1.7.

The evaluation of this scenario is therefore extremely positive for **terminal managers**. The NPV is directly obtained by the reduced personnel, maintenance and operational costs. Future expectations are also possible since adopting such a system the terminal, even with the same transhipment equipment, has a higher capacity and better performances.

The cost-benefit analysis from the **railway operator**'s point of view is even easier. No investments at all are required and no direct benefits are visible. The NPV for rail operators is zero.A traffic growth that without efforts of any kind will produce benefits for railways can be expected.

Even if the NPV must be positive to make a scenario acceptable to an evaluator, in this particular case no decision making is required to railways, and no drawbacks at all are foreseeable. The rail operator have not to decide if adopt or not the system but can be sure that if the other actors will decide in that sense he will have a return.

This evaluation demonstrated that **forwarders** are the actors that would have the highest benefits adopting such a system.Most forwarders' operational costs are directly dependent on the number of kilometres travelled. At the moment nearly half of the trips are non-productive; the adoption of such a system will reduce the number of non-productive journeys to one third.

Furthermore the time lost in the terminal for loading/unloading is decreased from 22 to 14 minutes per ITU, with a gain also in terms of time. The NPV is in this case given by the reduction of operational costs, and it is positive.

The multicriteria method chosen for evaluating the **policy-makers'** point of view on the simulated scenario is the conjunctive method. MCA produces a yes or no answer to whether a project is to be approved or not. To be approved a scenario must give positive answers to five criteria:

1. non-negative NPV in terminals CBA;
2. non-negative NPV in railways CBA;
3. non-negative NPV in forwarders CBA;

[1] A CBA should need two more steps: discounting and sensitivity analysis. Since the time horizon of the scenario is less than one year discounting is not necessary and sensitivity analysis is mainly necessary to assess if the possessiveness of the CBA is due to the discount rate chosen. In this case are both unnecessary

4. overall reduction of the kilometres travelled on the road;
5. overall reduction of number of crane movements, which means lower energy consumption and higher safety.

As already seen, the three CBAs have non-negative NPV; the kilometres travelled on the road by trucks operating the road leg of the intermodal chain decreased and considering a possible modal shift even the road-only can have a reduction of kilometres travelled; the number of crane movements is reduced of around 25 %.

All the criteria give positive answers, then the scenario can be positively evaluated.

Adoption of new transhipment equipment

The third scenario is represented in the PLATFORM project by the adoption of faster transhipment equipment. In the simulations the fast transhipment is obtained increasing the hourly performance of cranes and lifters.The only new parameter with respect to the previous scenario is: *fast transhipment*, in which the performances of the cranes and lifters used in the terminal has been increased by 20 percent;

A full evaluation of this scenario has not been performed, because none of the investigated fast transhipment technologies are yet on the market; no installation or maintenance costs are available either.

Anyway, the functionality of the fast transhipment has been shown in terms of performances of the terminal.Three different configurations have been simulated and compared with the *present state* (table 1):

1. *fast transhipment*, in which the capacity of the cranes and lifters used in the terminal has been increased by 20 percent;
2. *automated road gate*, in which the effects of a 50 percent decrease in the time taken at the road gate has been added, as a consequence of a full automation of the gate operations;
3. *traffic planning*, in which the effects of traffic planning have been added, as a consequence of the adoption of integrated telecommunication technologies among the forwarding agencies, the trucks and the terminal.

The adoption of only new transhipment equipment has no influence on the characteristics of the entering truck flow. However, it affects the overall duration of the permanence of the trucks in the terminal: the operations internal to the infrastructure require an average of 16 minutes. Aggregating the queue at the road gate and internal operations, the reduction in time amounts to 17 percent of the present state.

The adoption of telematics for the road gate can provide an additional advantage to the forwarders. Faster transhipment technologies and halving the minimum technical time translate in the simulation in a lowering of the time needed to enter the terminal to 6 minutes, while the time spent internally to the terminal is again about 16 minutes. The overall decrease in time, 37 percent of the present state, is greater than in the previous case. An appropriate distribution of the trucks flow in time can reduce the time they spend in delivering/picking up the ITUs by 46 percent. This decrease is less than expected, but it must be considered that the number of productive journeys has increased. The share of this kind of journey increases from less than 10 percent in the present state to more than 20 percent in the traffic planning scenario. If the train timetable is adapted to better fit the truck service, this share can increase further.

In the fast transhipment scenario, the share of direct transhipments drops to 20 percent, in this way increasing the number of movements of cranes and lifters. The same result is given by the simulation of the automated road gate scenario. The absence of co-ordination between trucks and terminal increase the resources consumption.

This problem is solved in the traffic planning scenario: the share of direct transhipments increases to 70 percent, while the crane movements per ITU decrease drastically to 1.3.

The fast transhipment scenario and the automated road gate scenario show a residence time of the ITUs in the terminal somewhat less than in the present case, but the difference is negligible. The very significant change occurs in the traffic planning scenario, in which the average residence time is almost 70 percent lower, due to the higher number of rendezvous between trucks and trains.

As a consequence the average occupancy of the buffer areas has a slight increase from 31 in the present state to 32 percent in the fast transhipment and automated road gate scenarios. The traffic planning scenario shows a decrease in the average occupancy to 12 percent. The maximum occupancy rate rises from about 80 to 100 percent.

The storage area too presents a different use in the final scenario: while in the present state and in the first two scenarios it is substantially unused, an average occupancy of 40 percent and a maximum of 90 percent is simulated in the final scenario.

In the average the storage spaces available in the terminal are used at a lower level, but with peak periods when they are used almost at capacity.

In the present state, each train occupies the track for loading or unloading purposes about 3.8 hours, considering that more trains are handled in parallel. In the fast transhipment and in the automated road gate scenarios this time decreases to 3.5 hours, which is about 10 percent lower. In the traffic planning scenario the decrease amounts to 30 percent, since the average time needed to load or unload a train decreases to 2.7 hours.

These results demonstrate that the use of new transhipment technologies and telematics for the management of the road gate cannot modify substantially the situation of the terminal without the aid of telecommunication technologies for the management of the road traffic.

Table 1. Comparison of simulation scenarios

	Present	*Fast*	*Automated*	*Traffic*
Trucks				
Average time at the road gate (min)	15	15	6	7
Average time in the terminal (min)	22	16	16	14
Cranes				
Average movements per ITU	1.7	1.8	1.8	1.3
Direct transhipments (percent)	27	19	19	69
ITUs				
Average residence time in the terminal (h)	12.6	12.4	12.3	4.0
Buffer areas				
Average occupancy rate (percent)	31	32	32	12
Maximum occupancy rate (percent)	78	79	79	100
Storage areas				
Average occupancy rate (percent)	0	0	0	38
Maximum occupancy rate (percent)	0	0	0	90
Trains				
Average loading or unloading time (h)	3.8	3.5	3.5	2.7

CONCLUSIONS

In this paper we presented some of the results of the EC-sponsored PLATFORM project. First, we introduced the PLATFORM simulation tool, a software for modelling and simulation of intermodal rail-road terminals, which can simulate both a stand-alone terminal and a network of interconnected terminals. Then, we showed how the PLATFORM simulation tool can be used to assess the impact of proposed changes in the terminal structure and management. The impact assessment is performed by means of Cost Benefit Analysis and of Multi Criteria Analysis, according to the value system of the interested party. In particular, terminal managers, forwarders, and rail operators are interested in CBA, while policy makers prefer to use MCA. The results show how the adoption of computer aided terminal management can improve the terminal performances at a reduced cost, while the adoption of new transhipment equipment can provide even greater margins for improvement but at a higher cost and only when coupled with appropriate computer-aided management, both inside the terminal and on the road, to synchronize the import and export ITU flows with the terminal internal state.

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