Architecture of an Information System for an Intermodal Transport Service

Rosário Macário, Vasco Reis

Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
E-mail: rosariomacario@civil.ist.utl.pt

***Abstract*— This paper presents the result of a research project aiming to identify the information requirements of an intermodal transport chain and to design an architecture for an information system. The main results and findings are presented, as well as, the discussion on the potentials benefits of information system for fostering intermodal transportation's performance.**

***Index Terms*—Intermodal transport, Freight, Information System, Track & Trace**

I. Introduction

THIS paper presents the findings of a research project conducted for a major Portuguese-based logistic operator. The company is a road hauler that operates exclusively within Iberia (Portugal and Spain). It offers a wide range of transport and distribution services, namely: door-to-door transport, cross-docking, clients' inventory management or products' labeling or re-packing. The truck fleet is over 2000 vehicles, of which 1300 proprietary and the remaining ones hired or leased on the market. A significant share of the non-proprietary fleet works frequently for the company, so in practical terms they behave as belonging to the company itself both in terms of time availability and capacity.

The company has implemented an Enterprise Resource Planning (ERP) system that manages all business processes, namely: transport orders, human resources, equipments or accounting. Additionally, a track & tracing system has been installed in all proprietary vehicles and in a significant share of the most used non-proprietary vehicles. The system is made of an in-vehicle unit that collects a set of parameters, amongst which the geographical location. This information is periodically sent to the ERP system. After being recorded, the ERP system performs a set of verifications of conformity against initial planning. If some detour is detected warning messages are sent to the operations management people that take the necessary procedures to correct the problem.

Recently the company has decided to prepare its entry into intermodal transportation. Two main reasons have supported this decision. Firstly, rail services are more economically advantageous than road transportation over certain distances and whenever there is enough concentration of flows to justify trains operations [1, 2]. This is the case for the corridor Lisbon (Portugal) and Cataluña (Spain), along which this company has a significant concentration of transport services, particularly between Lisbon and Barcelona (in both ways). In parallel, the effects of the on-going liberalisation process of the European railway market produced the first results as rail operators started offering, for the first time, international services with transit times similar to the road operators. Secondly, the company's administration board understood that the current European Union's development model based upon sustainable development and environmental protection will progressively result in the creation of barriers for road transportation (either through taxation, driving bans or other regulations) and favour the adoption other more sustainable modes of transport, notably rail transportation [3]. As the company had little knowledge on rail transportation it was decided that initiation of rail operations was favourable, before others would take the lead.

There is no consensus about the concept of intermodal transportation [1]. In this way, for this paper we have adopted the definition brought forward by the European Conference of Transport Ministers [4]: "intermodal transportation is the movement of goods (in one and the same loading unit vehicle) by successive modes of transport without handling of the goods themselves when changing modes".

The intermodal services will be between Portugal and Spain (Figure 1). The chain will consist of two modes of transport (road and rail) and three legs (short-feeder road services on both ends and a long rail service in-between Portugal and Spain). The transport services will be entirely hired out to the third transport suppliers. The object of transport is containers. The containers will be dedicated to this transport service. The reasoning for using containers is to increase interoperability amongst modes of transport and speed up transshipment operations. These operations will be conducted by the terminal operator.

A dedicated unit will be created to manage the intermodal transport services. This unit will run almost autonomously from the mother-company. The only connection will be the reception of the transport orders. Whenever a suitable order to be transported via intermodal service is placed, the ERP system sends it to this unit. To be suitable means that, first, the origin and destination are the regions of Lisbon and Cataluña, and second the client's pick up and deliver time windows are compatible with intermodal transport's transit times. The unit will be in charge of hiring road transport services and allocating to the rail service.

The road transport may be hired from either the mother

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company or any other road transport company. The rail services will be provided by a rail operator. Taken into consideration the current rail operations, freight trains will likely run on fixed schedules. Consequently, road services will be coordinated in function of the trains' timetables. The client will not be aware of the transport solution used.

The purpose of having an autonomous unit is to introduce minimum disturbance on the on-going road transportation operations. The administration board prefers to keep apart road and intermodal business, at least, until profitability of intermodal operations is proved and the necessary know how be acquired.

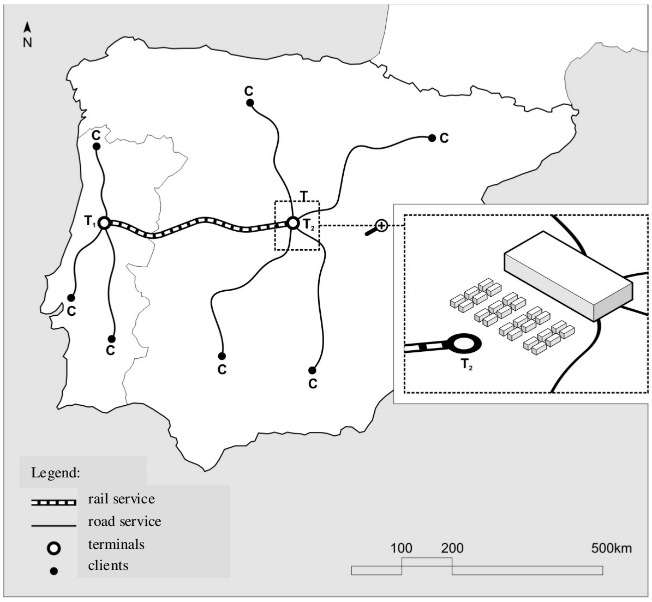


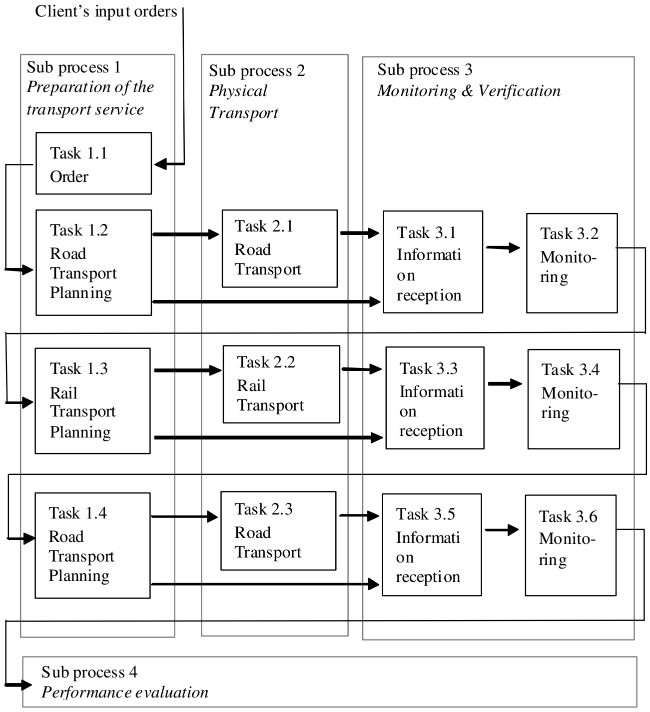
Fig. 1. Intermodal transport services between Portugal and Spain.

The need for monitoring and controlling the transport services raised some concerns as the transport suppliers do not have either any or compatible track & tracing systems. Installing compatible track & trace systems in the transport suppliers is out of question due to high costs, so it was decided to install on board units (OBU) on the containers with geo-processing built-in capabilities. Since the company had little to none experience on intermodal transportation, it decided to launch a research project to, firstly, understand the information requirements and, secondly, design the architecture for an information system for managing and monitoring the intermodal transportation services.

II. The Methodology

A. Process of an Intermodal Transport Chain

The project began by an analysis to the process of the intermodal transport service.



Process analysis is the most suitable technique for depicting and understanding the web of tasks and relationships undertake to produce some product. A process can be understood as a set of interrelated, coordinated and sequential tasks whose purpose is to produce a determined output or outputs from a given input or inputs. Such act of transformation consumes a certain amount of resources: man power, equipment or materials [5]. Other authors and organisation bodies have put forth other definitions for process. For example, Sharp and McDermott [6] defined process as "a collection of interrelated works tasks, initiated in response to an event that achieves a specific result for the customer of the process"; while Davenport [7] considered process as "a structured, measured set of activities designed to produce a specific output for a particular customer or market" and as "a specific order of work activities across time and place, with a beginning, an end, and clearly identified business and outputs: a structure for action"; and Pall [8] referred to a process as being "the logical organization of people, materials, energy, equipment and information into work activities designed to produce a required end result (product or service)". Recently, the ISO 9001:2000 standard defined process as a set of interrelated activities that transform inputs into outputs.

Figure 2 presents a very simple scheme (due to space restrictions) of the process of an intermodal transport chain. It consists in four main sub-processes: preparation of the service, physical transport, monitoring and verification and performance evaluation. The arrows mean information flow.

Sub process 1 refers to all tasks (like determination of the time windows of pick up and deliver) carried out before the transport services occur. Sub process 2 consists in the transport of the goods from origin to destination. Sub process 3 gathers all tasks involving in verifying if the transport services are being performed within scheduled. Finally, Sub process 4 occurs after the transport being conducted and involved all tasks related with performance evaluation. The following table (Table I) describes the information flows in each task of the process.

Process analysis makes clear the information flows that occur along in intermodal transport chain. Upon this information it is possible to identify the type and timing of information necessary to gather from the field.

TABLE I
DESCRIPTION OF PROCESS TASKS

Task	DESCRIPTION
1.1	Receives information from the client and builds the schedule of intermodal transport service, particularly: location and windows times for pick up and deliver of road transport services. Rail services have fixed schedules.
1.2	Sends information for the road transport suppliers
1.3	Sends information for the rail transport suppliers
1.4	Sends information for the road transport suppliers
2.1	Loading container at origin, transport to the terminal, unloading container
2.2	Loading container, transport in between terminals, unloading container
2.3	Loading container, transport to destination, unloading container
3.1 3.3 3.5	Periodic reception of the information from OBU
3.2 3.4 3.6	Verification of field information against planning

B. Information requirements of an intermodal transport chain

Due to space restrictions only the information requirements concerning Sub process 2 will be presented. This Sub process is the most important one because it is when goods are being effectively conveyed. Table II summarizes the information requirements, along with the timing for the information transmittal.

This is the information the OBU is required to transmit to the in-house system so that the intermodal transport system could be monitored and controlled. Consequently, after installed regardless the transport supplier, the company will be in position of adequately monitoring and controlling the intermodal transport service.

C. Information System Design

With the information fully identified, it was necessary to proceed with the design of the information system for the intermodal transport service.

The current freight transport paradigm is based on high quality door-to-door transport services; and for continental distances, the competition is fierce mainly from road transportation. Several factors contribute for this situation, like for example: the excellence of the European road infrastructure, the ability of trucks offering door to door transport services or the traditional very high reliability of road transport suppliers. On the other hand, intermodality suffers from some problems, like for example: the low speed of freight trains across Europe, the lack of suitable road rail junction points or the time loss at terminals [9].

TABLE II
INFORMATION REQUIREMENTS

Task	Trigger	Details
2.1	Loading container on truck (at containers' terminal)	- Identification number of container; - Identification of the vehicle; - Identification of the driver; - Date and Hour.
	Beginning of the road journey	- Date and Hour.
	Every one-tenth minutes of the total time journey (with a minimum interval of one hour and a maximum of five)	- Date and Hour; - Geographic coordinates;
	Arrival at client's premises	- Date and Hour.
	Opening of the container doors	- Date and Hour.
	Closing of the container doors	- Date and Hour.
	Beginning of the road journey	- Date and Hour.
	Every one tenth minutes of the total journey time length (with a minimum interval of one hour and a maximum of five)	- Date and Hour; - Geographic coordinates;
	Arrival at terminal	- Date and Hour.
	Unloading container from truck	- Date and Hour.
2.2	Loading container on train	- Date and Hour.
	Beginning of the rail journey	- Date and Hour.
	Every one-tenth minutes of the total time journey (with a minimum interval of one hour and a maximum of five)	- Date and Hour; - Geographic coordinates;
	Arrival at terminal	- Date and Hour.
	Unloading container from train	- Date and Hour.
2.3	Loading container on truck at terminal	- Date and Hour.
	Beginning of the road journey	- Date and Hour.
	Every one-tenth minutes of the total time journey (with a minimum interval of one hour and a maximum of five)	- Date and Hour; - Geographic coordinates;
	Arrival at client's premises	- Date and Hour.
	Opening of the container doors	- Date and Hour.
	Closing of the container doors	- Date and Hour.
	Beginning of the road journey	- Date and Hour.
	Every one-tenth minutes of the total time journey (with a minimum interval of one hour and a maximum of five)	- Date and Hour; - Geographic coordinates;
	Arrival at containers' terminal	- Date and Hour.
	Unloading container from the truck	- Date and Hour.

The quality of a transport service depends upon the client's criteria, but nonetheless it is possible to identify a core of attributes that tend to be systematically highly valuated [10]:

--*Cost of the transport service* - total out-of-pocket costs of the various transport suppliers and any other agent;

--*Transit time* - total elapsed time from pick up to delivery;

--*Flexibility* - adaptation capacity to unforeseen situations;

--*Reliability* - capacity of delivering goods within scheduled;

--*Visibility* - capacity of knowing where goods are at a given moment .

The information system is supposed to support and foster the intermodal transport service's competitiveness. In other words, this system will act as a lubricant to the transport service. As a result, the basic functions identified for the information system are presented in the following figure (Figure 3).

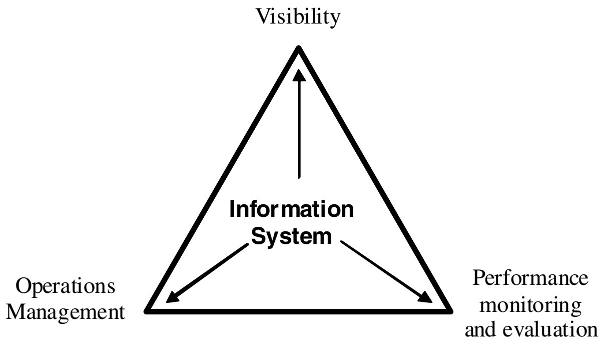


Fig. 3. Functionalities of the information system

Visibility function creates a bridge between the real world, on which physical transport actually occurs, and a virtual world on which information flows. Through this functionality the physical flow is transformed in information flows which enable the processing of all verifications and operations. This function is dependent upon the adequate communication between the OBU and the in-house software. The operations management function refers to the optimization of resources and agents involved in the transport operations. Finally, the performance monitoring and evaluation function assesses the performance level of the process and agents, promoting the continuous increase of performance.

After the identification of the basic functions the information system should have to perform, it was possible to design its architecture (Figure 4). The information systems is composed by seven basic modules, which one performing a specific task. All the previously identified functions (Figure 3) are covered by this architecture plus an additional fourth function had to be added to cover some practical functionalities. The modules are:

--*Context* - function visibility;

--*Transport service planning* - function visibility;

--*Performance evaluation* - function performance monitoring and evaluation;

--*Track & trace* - functions visibility, operations management and performance monitoring and evaluation transport service planning;

--*D*atabase - information system backup functions;

--*Clients and other agents' interface e*- information system backup functions;

--*Hardware monitoring* - information system backup functions.

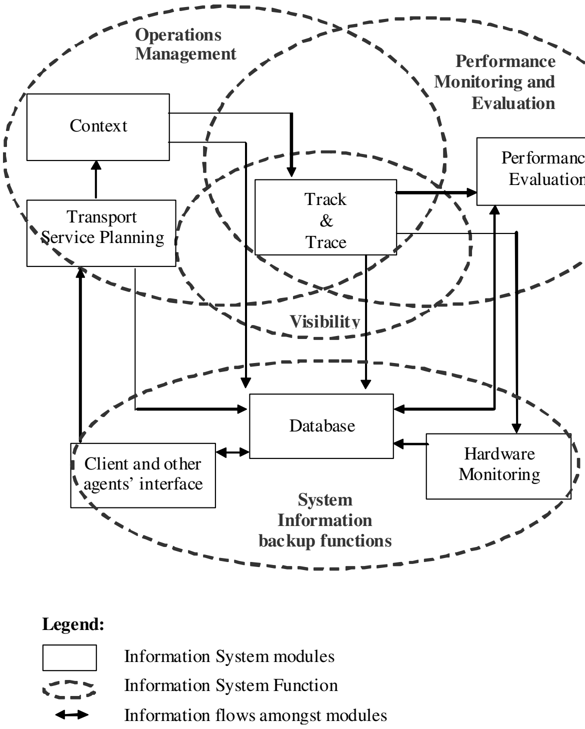


Fig. 4. Information system architecture

The *transport service planning module* has the key function of preparing the transport service, namely: identify the container, prepare the schedule for the road transport services and identify suitable transport suppliers, and identify the train. Additionally, these tasks have to done in a way of optimizing the existent resources in order to maximize profits and reduce costs. This module uses the information received from the client. Subsequently, the information should be sent to the various agents and for the database and context module.

The *context module* receives the information from the previous module and prepares the spatial and temporal windows the transport suppliers will have to fulfill in order to deliver on schedule. The information is again sent to the database module and for the track & trace module.

The *track & trace module* is the core module of the information system. This module runs throughout the entire physical transport service, continuously receiving the information of the actual transport service (OBU) and comparing it against the planned schedule (prepared by the previous module). If any detour is detected warning messages are sent so that the necessary actions could be taken.

The *hardware monitor*ing module is responsible for monitoring and detecting any flaw in the hardware, particularly in the OBUs. The OBU are powered through batteries with a limited life, being necessary to replaced them periodically.

This module identified whenever a battery need to be replaced. Additionally, any other mal function should also be reported.

The *module of performance* evaluation enters into action after the physical transport has occurred. Its function is to assess the performance and productivity achieved by the transport service; in particular, to evaluate the detours in relation to the initial schedule.

The *database module* gathers in a coherent way all information concerning the transport service, namely: origin, destination; date and hour of pick up, modal transfer and delivery; transit time; number of containers; loading and unloading times; weight of the goods; any change to the initial order, transport suppliers; performance and productivity; financial details.

Finally, the *client and other agents' interface module* is responsible for all communications between transport suppliers, clients and the company itself. The interface should provide a friendly and easy way of communication and allow any last minute manual change.

III. Discussion

Over the past few decades, Globalization and other economic dynamics have put the logistics system under several structural changes. The main trends being: the restructuring of logistic processes, the realignment of supply chains, the rescheduling of product flows, and changes in transport management and product design [9, 10]. New supply chain techniques as *lean production* or *just in time* have emerged and been implemented worldwide. Transportation has become a key factor on supply chain's competitiveness, and consequently, new demands have been imposed over transport suppliers (recall chapter II.C above).

At the same time, the transport sector has seen a move towards the concentration of transport in distribution hubs and therefore the development of hub and spoke systems, linked through transhipment, has been achieved. Along the years these trends fostered the growth of road transport volume (offering door to door mobility and high flexibility of solutions) threatening the sustainability of economic and social systems through the level of externalities produced.

The production of intermodal transportation is considerable far more complex than single modal transport solution, particularly road transportation (recall chapter II.C above). A main issue being the difficulty of aligning and coordinating a group of different transport suppliers. A solution for overcoming this potential barrier is by introducing transparency and visibility to all the transport process. Transparency will make easier for each transport supplier to understand its role and mission. Visibility will enable the manager of the transport service to control and evaluate the process. In this way, any detour to the scheduled may be quickly detected, and corrective actions may be taken.

The information system introduced visibility and provides the tools for managing the transport. Consequently, an adequate information system is of paramount importance in the success of intermodal transportation.

IV. Conclusions

A major Portuguese logistic operator is planning initiating intermodal transport operations but lacked the knowledge on the information requirements necessary to effectively monitoring, controlling and managing the transport services. Additionally, it was asked to develop the information system underlying the transport operations.

This paper presents the methodology and achievements of a research project conducted on behalf of a major Portuguese logistic operator. The intermodal transport service was considered has being a process, which enabled the understanding and identification of all information flows.

The architecture of the information system was developed upon the identification of the care competencies it has to fulfill.

The project has fulfilled all of its initial requirements, being expected now the development and implementation in the field, when the operations start.

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