FACTORS OF COMPETITIVENESS OF PASSENGER AIRLINES IN THE CARGO MARKET

Vasco Reis, Instituto Superior Técnico, vreis@civil.ist.utl.pt

Rosário Macário, Instituto Superior Técnico, rosariomacario@civil.ist.utl.pt

ABSTRACT

The emergence of adverse factors, such as: volatility of oil prices, economic recession or imposition of new safety and security measures, have thrown the air transport sector into turmoil in both passenger and freight markets. The negative environment is leading airlines looking for alternative sources of revenues, passenger airlines are no exception and the air cargo market may provide a non-negligible alternative. In average, this market accounts for fifteen percent of passenger airlines. Furthermore, many international routes are only profitable due to the cargo business. However, this market has evolved towards a highly competitive configuration, with passenger airlines revealing considerable difficulties in competing head to head with other players.

Based on the current patterns of demands for freight transport service, the authors defend that intermodality may prove being an adequate strategy for passenger airlines fostering their competitiveness in the air cargo market. The authors then identify two factors that could improve the performance of intermodal transport services and, thus, support passenger airlines' competitiveness.

These factors result from an analysis to the source of performance of intermodal transport services. One of the factors is the fitness of the transport service. The fitness has five basic dimensions, being: physical, logical, liable, financial and relational. Three dimensions have already been fairly achieved by the air transport sector; yet, two – the physical fitness and the relational fitness – are still to be accomplished. Therefore, these two dimensions materialise the potential factor of competitiveness of passenger airlines.

In order to assess the validity of these assumptions an agent based model was developed. This model – so-called AFETAS – simulates an intercontinental freight transport market where intermodal air transport services are required. The results evidence the competitiveness advantage of the fit vis-à-vis the non-fit intermodal transport services.

Keywords: air transport, cargo, fitness, agent based

PASSENGER AIRLINES IN THE AIR CARGO SECTOR

Turmoil in the Skies: drivers and trends of air transport sector

Over the last three decennia, a series of unprecedented forces have thrown the air transport sector into a continuous turmoil. In the adaptation process several trends have been emerging, yet, at the current time. Reis and Macário (2010) review the main drivers and trends shaping the air transport sector. In what concerns the drivers, these authors identified the following ones: Globalisation (Macário et al, 2008), the cyclic and long term growth of the world's economies Boeing, 2008, Zhang and Zhang 2002, Button and Stough, 2000), the international political stability in some regions worldwide, the emergence of new threats such as diseases (e.g: SARS epidemic in Asia in 2002 and 2003, or influenza in Mexico 2009) or terrorism, the growth volatile and upward rise of oil prices (Doganis, 2006, Allaz, 2004), the continuous technological development rendering more capable aircrafts (Rhoades, 2008, Wensween, 2007), and a continuous rise of sustainable concerns and environmental protection (European Commission, 2006).

These drivers have led to the emergence of several trends, such as: progressive liberalisation and deregulation of air transport markets worldwide (Doganis, 2006, Reis, 2005, Sinha, 2001), the long term reduction of yield putting an increasing pressure over companies to find alternative sources of revenue or decrease costs (Boeing, 2008), a cyclical and marginal behaviour of the air transport sector that is raising concerns about airlines capabilities of raising enough return to sustain in the long run (Doganis, 2006, Button, 2003, Button, 1996), a proliferation of agreements and alliances aiming to increase their revenues and market power (Rhoades, 2008, Airline Business, 2008b, Doganis, 2006), a growing level of safety and security measures in the air transport value chain (Jonge, 2008, Shipping Digest, 2008), an increase cooperation with other model, notably in the freight segment with road transport, for replacing short to medium continental legs (Air Cargo World, 2009, Boeing, 2008, Button and Stough, 2000) and in parallel an increase competition from certain modes such as sea on long-haul and road on short to medium-hauls (Boeing, 2008, Airline Business, 2007).

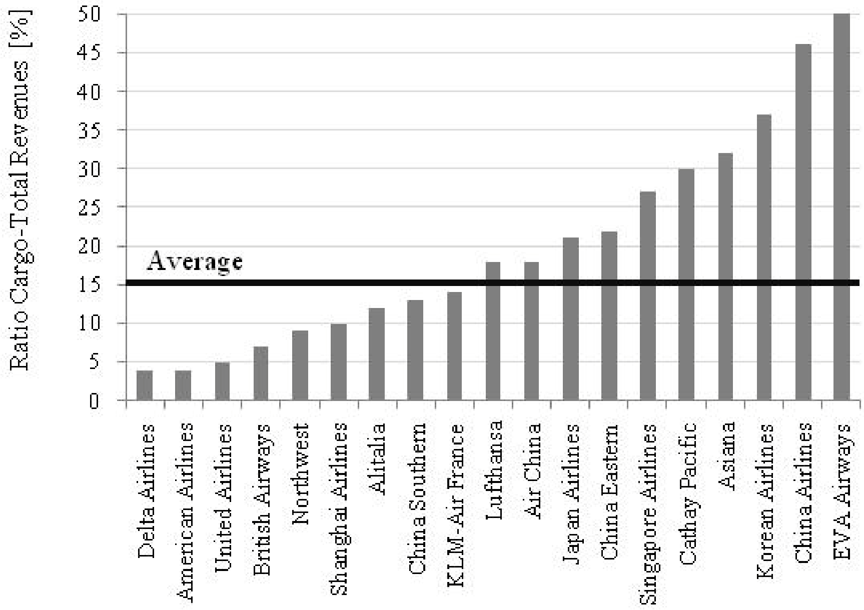
How relevant is air cargo in the air transport companies' business

Passenger airlines are air transport companies that provide both passenger and freight transport services. In 2004, Georg Midunsky, managing director of Cargo Counts[1], pointed out that around 95% of combination companies consider air cargo segment as secondary business (Conway, 2004). Zondag (2006, pp 35) argues that relevance of air cargo business largely depends on how companies' board of administration considers cargo: core, ancillary or dispensable.

Notwithstanding, air cargo business may play a key role on companies' financial performance. Its importance is visible at two levels. Firstly, at route level (or geographical market) level. Profitability in long distance (or intercontinental) transport services is function of air cargo business; as passenger business may not provide enough revenues to generate

[1] Cargo Counts is a Lufthansa subsidiary that manages the capacity of other carriers.

profit. Air cargo business thus plays a key role for sustaining routes and thus market coverage, which is of paramount relevance in a network industry like air transport business (Conway, 2006, Hoppin, 2005). Secondly, at company level. Figure 1 presents the percentage of air cargo business's revenues on some combination companies. The interval is wide and if, indeed, for some companies air cargo business seams positively a marginal activity (as for example Delta Airlines contributing with as low as 4% of total revenues), for many others it should be considered a relevant business contributing with as much as 50% of total revenues. Zondag (2006, pp 37) also points out for 15% the average relevance of cargo business in combination companies.



Source: Serpen and Mirza (2009)

Figure 1 – Cargo revenue as a percent of total revenues, in 2008

Bearing in mind that air transport business is characterised by both a cyclic behaviour and low profit margins (Doganis, 2006, pp 4), even small extra revenues could make the difference between negative or positive results. Thus, air cargo business, albeit its reduced expression, may generate enough revenues (in a negative year) for helping company to breakeven or eventually achieve profits.

In conclusion, owing to the specificities of air transport business, even representing a small share (or at least smaller than average on other industries) air cargo business may be of importance to help companies either achieving positive results or keeping certain geographic destinations.

Challenges facing passenger airlines in the air cargo market

Combination companies face nowadays diverse challenges to the production of profitable air cargo services (Figure 2). These challenges are due to, on the one hand, the specificities of the cargo business in these companies and, on the other hand, the significant transformation air transport sector underwent over the past decades.

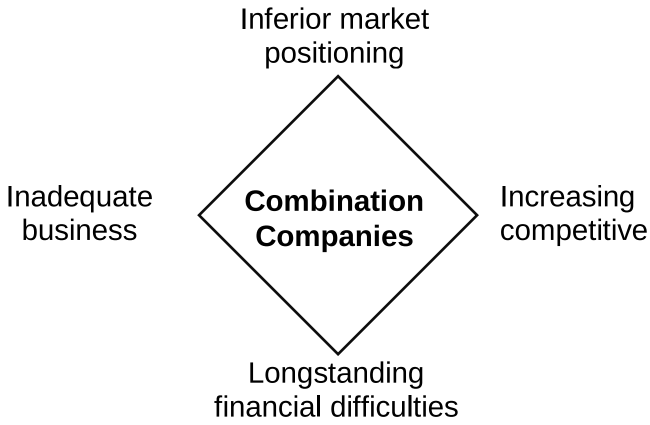


Figure 2 – Challenges facing combination companies

Inferior Market Positioning

In a movement initiated after the World War II, many passenger airlines have progressively focussed on passenger business. Air cargo business became less and less relevant, which was accompanied by a rationalisation of the resources and efforts. Furthermore, costs of cargo related operations increase as the volume decreases (Kadar and Larew, 2003, pp 8), further driving companies to reduce such business. Nowadays, Freight Forwarders continue to be combination companies' main customers and largely control general- freight. Clancy et al (2008, pp 36) estimate that freight forwarders control 85% of the retail sales channel for general freight, and Hellermann (2006, pp 5-6) points out for an interval between 90 to 95%.

Freight forwarder may offer added valued services, upon transport services, being able to increase margins. Thus, competition on freight forwarding market has evolved towards price and quality of services. Conversely, combination companies are relegated to an inferior positioning in the market of mere transport providers. Their scope for offering added valued services is reduced, and thus competition on the air cargo market has evolved centred very much on price (Zondag, 2006, pp 24).

Integrators (such as: FedEx, DHL or TNT) have been ever growing since their emergence around seventies: firstly tackling an underserved market – express freight – and recently moving towards the traditional market – general-freight. Nowadays, they dominate the express freight segment and offer far better transport services (albeit considerably more expensive) than combination companies.

In conclusion, combination companies are stuck in-between Freight Forwarders that control the general-freight market (contact channels with end customers) and Integrators that control express market and provide the highest quality services. A market position which is worsened by the difficult financial situation and lack of know-how.

Increase Competitive Environment

On the words of Rigas Doganis (2006, pp 12) "the most significant trend during the last 25 years or so has been the gradual liberalisation of international air transport". The United States were the first country to fully deregulate their air transport market. Meanwhile, other countries have been following the lead and liberalising or deregulating their markets. Yet, nowadays liberalisation is still more the exception than the rule. Notwithstanding, where the markets have been open there was the entry of new companies offering innovative services with new strategies. For example, the emergence of the integrators, in the United States, was one only possible due to the liberalisation of the market. As a result, the likely outcome has been a steady increase of the competitive environment, in both passenger and cargo businesses.

In parallel, the other modes of transport: sea transport, in the long distance (intercontinental) and road (and to less extent rail), in the medium distance (continental) have been progressively competing against the air transport. Over the years, these modes of transport have been increasing their levels of reliability (Airline Business, 2007) and, supported on technological developments, reducing transit times. The same has not been paralleled by air transport companies (Airline Business, 2007, Boeing, 2008, pp 7).

Moreover, a progressive slow-down of economic growth (and current economic recession) is leading customers rethinking their transport demands towards low cost modes of transport. Finally, there is a progressive reduction in the rate of creation of high value or mass market products, and a concomitant maturity of the current ones, which is reducing the importance of transit time and increasing the relevance of costs (Clancy et al, 2008, pp 28).

The increase of competitive pressure is visible by the long term downward trends in the cargo and passenger yields (Doganis, 2006, pp 16). Competitive pressure has thus been growing from within and externally the air transport sector.

Longstanding financial difficulties

Air transport business is characterised by marginal profits and cyclic behaviour (Doganis, 2006, pp 4). Moreover, the level of returns is below average return in other industries. Such behaviour is raising concerns on the sustainability of the sector in the long run (in particular, in the capacity of the positive years covering the negative plus generating enough internal capital) (Doganis, 2006, pp 6, Button, 1996, pp 276, Button, 2003, pp 5). Although "no firm conclusions can be drawn" (Button, 2003, pp 13), some authors believe not (Moorman, 2007, Putzger, 2006) and, as evidence, they refer the successive public financings of some companies in the recent past, namely: Air France, Alitalia, Malaysian Airlines or New Zealand Airlines (Doganis, 2006, pp 7-8).

Recalling that passenger business is the core business, it is thus natural companies channel the bulk of financial efforts towards this business and, only in case of availability, favour air cargo business. Moorman (2007) refer the example of Delta Airlines that as part of a cost saving restructuring as almost ended with its cargo division.

In parallel, cargo and passenger yields have been following a long term downward trend. A likely reason for such behaviour is a progressive increase of the competitive environment, which is leading companies to reduce prices. Other reason is the recent contraction of demand that was not accompanied by a decrease of supply (Doganis, 2006, pp 16, Boeing, 2008, pp 53, Hoppin, 2005b). Although yield do not provide whatsoever information about the company's financial health (because it does not incorporate costs), it is hardly questionable that a decreasing yield increases the difficulties in generating revenues and profits.

Additionally, the inherent properties of cargo and passenger businesses in passenger airlines are prone to result in a downward price spiral. The reason lies on the fact that the two businesses partially share the costs of transport; consequently, cross-subsidisation may occur, if one of the businesses supports all (or most) of the costs. The gradual increase of the competitive environment is leading companies to give up revenues (allocating costs to the passenger business) and, consequently, driving prices down (in particular, in those companies that are not able to offer added value services) (Kadar and Larew, 2003, pp 4).

Inadequate Business Model

There are still combination companies faithful to a business model that is no suitable for current market conditions. Often, such business models were developed typically during a period of market regulation when business was done with different rules and competition was restrained. The problem was that, meanwhile, market conditions and demands have greatly changes due to significant changes in both air transport sector and its context, but companies have not adapted accordingly.

Although varying amongst airlines, the traditional business model presents one or more of the factors laid down on the following scheme (Figure 3). These companies prefer to operate stand-alone disregarding the eventual presence and properties of other transport agents. They do not consider that establishing better relationships with other transport companies could generate performance gains in the transport chains. This typically occurs with the companies having lower levels of commitment towards cargo business.

The level of technological development tends to be low (in particular, if compared to the passenger business), with a great emphasis on human labour for the realisation of tasks that could be better and more economically done through technology. A paradigmatic example concerns the revenues management system. Conversely to the passenger business where they are widely used for many years, revenue management systems are only now being implemented (and only by some companies) (Putzger, 2006). Revenue management systems are fundamental for companies to optimise revenues, in particular, to define the minimum levels for prices and avoid downwards price spirals (Kadar and Larew, 2003, pp 4).

The lack of suitable business models precludes the company to offer added value services, control revenues and minimise costs; while the lack of know-how about the cargo business voids any attempt to develop an adequate business model.

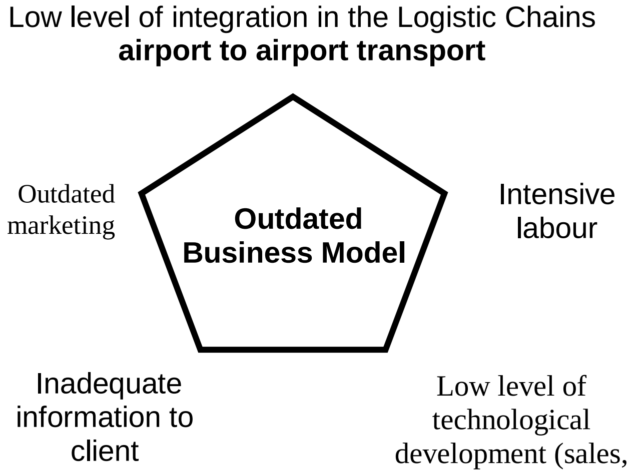


Figure 3 – Traditional business model

Intermodality as a solution for improving passenger airlines' competitive positioning in the air cargo market

The current challenging situation of passenger airline is the outcome of the joint convergence of several factors, such as: the past decision in abandoning cargo in favour passenger business, the liberalisation of the markets, the economic cycles (and, in particular, the downturns), or the evolution in the requirements for transport services. The reduction of cargo business operations led to a loss of know-how and loss of contact with final customers. Moreover, the control of the business moved towards the freight forwarders. Many passenger airlines were relegated to simple transport providers with few to none capacity to offer added value services. In practical terms, such positioning meant they compete on price, which due to the specificities of the cargo business in the passenger airlines is likely to result in a downward trend price spiral.

Yet, the attempt of recovery is not easy. They lag behind their competitors not only have low knowledge about the business as well as have low to none contact with final customers. Moreover, air transport is traditionally a marginal-profit industry. The resources are scarce and, naturally the passenger business is invariantly privileged. The lack of resources make difficult the deployment of resources in the improvement of the cargo business and the very attempt of gaining control of the market (because that would generate retaliation from the main customers – freight forwarders – with the consequently loss of revenues).

On the other hand, the freight transport sector has also greatly evolved over the past years with Globalisation, similar phenomena (such as: European construction) and economic development. Nowadays, the freight transport paradigm is largely based on high-quality, door-to-door transport services. In this new context, passenger airlines, regardless their strategies, will be called to participate and interact with other (door-to-door or point-to-point) transport suppliers in the production of door-to-door transport services. A transport service resulting from the integration of more than one mode of transport is designated as intermodal transport.

passenger airlines may influence and determine the nature of such participation and level of interaction. We may argue that passenger airlines' competitiveness is function of their ability to correctly (and adequately) interact with other transport agents. If such integration is not adequate, losses of performance will occur at the frontiers of interaction. The outcome will be a reduction of the competitiveness of the intermodal transport service, which may lead freight forwarder to opt for other modes of transport, resulting in the decline of the combination company' competitiveness.

Conversely, an adequate interaction will prevent that such losses of performance could occur, which may avoid the freight forwarder to perceive combination companies as either being the weakest links, or as introducing friction in the production of the intermodal transport service; which may positively contribute for their competitiveness.

There are evidences of very successful intermodal air transport services (like for example: Integrators). So, we may expect that a deeper integration would leave to a higher success of the intermodal transport service, which ultimately would push with it all the transport providers (including combination companies). The pursuance of deeper integration may therefore yield positive benefits for the combination companies. The authors this claim that the promotion of intermodality contributes for the achievement of the above mentions objective.

Figure 4 summarises the argument in favour of intermodality: integration fosters the performance and competitiveness of intermodal transport service, which spills into every transport company in the form of better market results, which, in turn, promotes companies to pursue further integration.

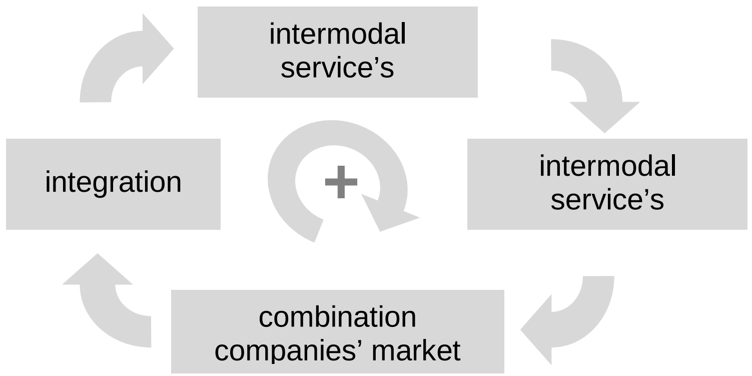


Figure 4 – Virtuous cycle of integration

INTERMODAL TRANSPORT SERVICES

Sources of Performance of an Intermodal Transport Service

In this paper the definitions of multimodal and intermodal transport were draw from the United Nations, being:

- Multimodal Transport is the "carriage of goods by two or more modes of transport" (United Nations, 2001, pp 16);
- Intermodal Transport is the "movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes" (United Nations, 2001, pp 17);

Multimodal transport is a transport service made of a set of independent and non related single-modal transport services. This means that for the point of view of each agent all the others do not exist, which results that each one produces her own transport service regardless the needs, characteristics, etc of the others. Therefore, the overall performance is the result of the simple summation of the various individual transport services.
In an intermodal transport service on the contrary, all agents work together for a common goal: each one is aware of the other, and each transport service is coordinated and tuned with the remaining ones (freight forwarder's role). Such facts generate synergies and benefits for the transport chain, which are added to the performance of each individual transport service, resulting in (leading to) a further increase of the overall performance. A final note for the fact that synergies are created as a result of the presence of another agent: the freight forwarder, whose functions are to organise and manage the various agents, aiming to get the most of each party in favour of the overall performance of the transport service.

The following picture (Figure 5) depicts the performance of multimodal and intermodal transport services. The vertical axis represents the performance (measure in some unit). It is considered a transport service with three dual systems[2]: M1, M2 and M3.
Let us first assume a set of dual systems involved in a multimodal transport service. By definition the overall performance is the summation of each individual transport service performance (left bar in Figure 5). If those same agents are now involved in an intermodal transport service, the overall performance will be higher due to the synergies created by the freight forwarder. Let us now assume that each dual system is being used at the maximum of its performance, yielding the maximum possible overall performance of the transport service. Let us call this performance the theoretical performance (right bar in Figure 5). This theoretical performance determines the maximum performance attainable for that specific set of dual systems, by definition no more performance could be obtain.
Yet, the world is not perfect and some sort of frictions may occur amongst the dual systems' profiles. Therefore, the maximum performance achievable in the real world is inferior to the theoretical performance. Let us call this performance as the real world performance (second right bar in Figure 5). A gap occurs between the theoretical performance and the real world performance (Gap 1 in Figure 5). This is the so-called Fitness Gap, which corresponds to the level of friction. The real world performance is therefore the maximum performance attainable by a non-fit intermodal transport service.

[2] Dual system is a set compound by the transport agent and the mode of transport. If the same transport agent operates more than one mode of transport, than she forms several dual systems (one for each different mode of transport)

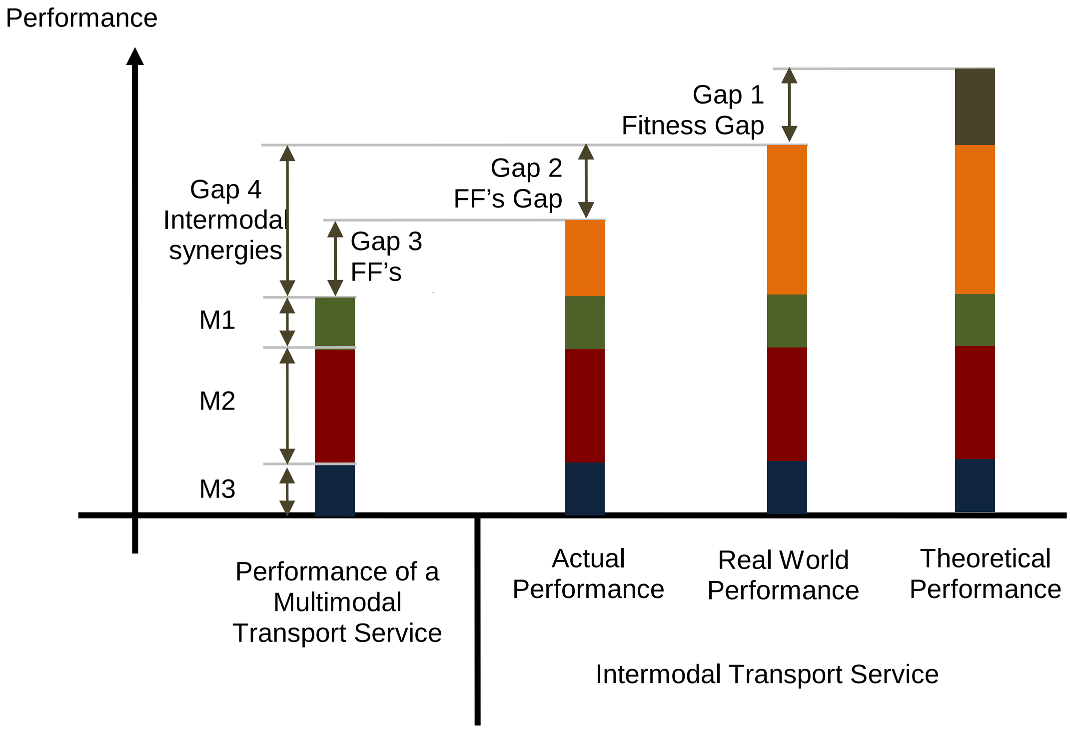


Figure 5 – Depicting the performance of intermodal transport services

To obtain the real world performance, the agents and modes have to be assembled, managed and deployed by the freight forwarder in the best way; otherwise the performance really achieved is inferior. Given that the freight forwarders are not all equally skilled, different ones will certainly get different performances, from the same set of agents and modes. So, the performance really achieved by a set of agents and modes, depends ultimately on the capabilities of the freight forwarder in charge of the transport service. Let us calls the performance really achieved by the intermodal transport service as actual performance. The actual performance lies between the performance of a multimodal transport service and the real world transport service (second left bar in Figure 5). The actual performance is higher than the performance of a multimodal transport service because there will be always some synergies created by the presence of the freight forwarder, adding to the individual performance of the dual systems; and it is lower or equal than the real world performance because this performance is the maximum attainable by a transport chain.
A second gap occurs between the real world performance and the actual performance. This is the so-called Freight Forwarder's Gap (Gap 2 in Figure 5) and corresponds to the inability of the freight forwarder in extracting the most from the dual systems and, ultimately, the transport service.
A third gap is also identifiable between the actual performance and the performance of the multimodal transport service. This is the so-called Freight Forwarder's synergies (Gap 3 in Figure 5) and corresponds to the added valued brought by the freight forwarder.
A final gap can be identified and corresponds to the difference between the real world performance and the performance of the multimodal transport service. This is the so-called Intermodal synergies (Gap 4 in Figure 5) and corresponds to the full potential of intermodality

over multimodality (that may not be entirely explored due to the incapacity of the freight forwarder).

From this reasoning, it can be concluded that the performance of an intermodal transport service is function of three factors, being:

- Performance of the dual system: transport agent – mode of transport;
- Freight forwarder's capabilities of managing;
- Fitness gap;

Concept of Fitness and Friction

Fitness is a concept that represents the match of the profiles of two successive dual systems in a transport chain.
Recalling that along an intermodal transport chain, four types of flows may be identified, being: physical flow, informational flow, liable flow and financial flow. Fitness occurs when there are flawless flows; or by other words, when there are no losses of performance at the contact points of a pair of agents. Any other situation reflects a non-fitness situation and occurs when there is some sort of losses at the contact line between the pair of agents.
Fitness thus designates a specific state, which is the perfect match between the modal profiles or the flawless movement of the flows. Thus, a lack of fitness denotes the non-existence of a perfect match between the modal profiles or the existence of flaws in the movement of the flows. However, it does not allow to infer on the level of dissimilarity between model profiles or the amount or flaw in the movement of the flows.
The quantification of this 'dissimilarity' calls for a different approach. The solution found was to introduce a new concept to designate the losses of performance at the fringe of interaction between transport agents (that yields an intermodal transport chain being non-fit). The term proposed herein is the *friction*. Friction denotes the existence of losses of performance at the fringe of contact between two dual systems. It results from the existence of repulsion (factors) amongst the same variables of the two profiles. Such repulsion hinders the correct passage of the flows. Therefore, if there is (are) attraction (factors) between the variables, then they are correctly aligned and the flow moves smoothly between dual systems, leading to no friction whatsoever and the agents are fit.

Factors of Competitiveness of the Passenger Airlines in the Cargo Market

From the analysis on the previous section, we may conclude that, other factors being equal, a decrease of the fitness gap (or friction level) would result in an improvement of the intermodal transport service's performance, which, ultimately, would lead to an improvement of air transport agents' competitiveness (Figure 4). The rational of this paper is based on this assumption which results that the factors of competitiveness of passenger airlines are actions taken to reduce the fitness gap with other dual systems (transport agents and modes of transport).

The authors have identified that the fitness of an intermodal air transport service has two main dimensions, being: ***Physical Fitness*** and ***Relational Fitness***[3]. These two dimensions of fitness correspond to the factors that passenger airlines may deploy to improve their competitiveness in the air cargo market.

Physical Fitness

The physical dimension of fitness is achieved for a flawless physical flow. Physical friction concerns the flaws or resistances that occur during the process of transfer (transhipment) of freight. Thus, physical fitness is related to the physical interoperability of the modes of transport.

The physical fitness is function of three factors, being: level of containerisation, modes of transport and handling equipment. The first factor is related with the level of containerisation of the goods. The transport of goods inside (or onto) a container (or pallet) promotes the physical interoperability and, thus, the fitness. The second factor is related with the type of modes of transport. The level of interoperability differs between pairs of modes (for example: the level of interoperability between a ship and truck is higher than a ship and an aircraft). The third factor is related with the type of handling equipment. The utilisation of non-adequate equipment for handling the goods or the containers may introduce considerable friction in the transfer process.

Relational Fitness

The relational dimension of fitness embraces those intangible factors with influence in the production of intermodal transport services. Two sources of relational fitness were identified: one, concerns the agents' commitment to intermodality; two, concerns the knowledge and trust amongst each agent's employees.

The first source of fitness refers to changes of adaptation amongst agents that could lead to improvements in the performance of the intermodal transport service. This may happen at multiple levels and with different intensities, for example: coordination of schedules, establishment of commercial agreements, alignment of processes, investing in interoperable equipment, etc.

This source of fitness is directly related with transport agent's strategy towards intermodality. Because if there is strategic interest in intermodality, than actions at all levels of decisions (strategic, tactical and operational) may be taken to improve the relational friction; if, on the other hand, the transport agent has no strategic interest in intermodality than there could hardly be improvements in the relational fitness because no action will be taken.

The second source of fitness is related with the nature of the relationships amongst employees. The production of an intermodal transport chain entails some sort of contact between employees of the agents. Although in theoretical terms the nature of their interactions is irrelevant for the production of transport services, in practical terms the informal networks play an important role in the production of transport service.

[3] Other three dimensions have been identified, namely: Logical Fitness, Liable Fitness and Financial Fitness, yet these have already been fairly solved by the air transport sector. The interested reader is referred to Reis (2010).

The actual importance of this kind of networks emerges in atypical circumstances. For example, in a special situations, such as: incomplete information, delays, special requirements, etc., employees of an agent may resort to the employees of the other agents. If they know each other they will be more willing to help than in case of not knowing. Additionally, the need for double checking or additional verifications may not be necessary if employees trust each other (and, know the employees of other company are reliable), which may lead to reductions of time. This source of fitness also exhibits latent behaviour because it only emergences in particular situations.
Thus, relational friction emerges when there is either lack of commitment towards intermodality, or tensions or suspicions amongst the agents' employees. The relational friction may be strong enough to dictate the failure of intermodal transport services.

SIMULATION MODEL - AFETAS

In order to assess the influence of integration on the performance of an intermodal transport service an Agent Based Model (ABM) has been developed. ABM is a conceptual mindset more than a technique or tool. ABM follows a bottom up approach to understanding real world systems; in this sense, it describes a system by looking to its constitutive parts (Bonabeau, 2002, pp 7280). It is therefore a micro-simulation conceptual tool for the study of real word system that re-creates, in virtual environment, their essential properties and behaviours. This tool considers a system is made of a set of entities – agents – that interact amongst themselves and with an environment that supports their very existence. The concept of agent is the most relevant in ABM. An agent is an autonomous, behavioural and social entity. The system's overall properties and behaviours result from the agents' behaviours and dynamical interactions, which in turn are the consequence of agents either pursing to their own goals or reacting to some external stimuli.
ABM approach can be used for exploring a wide range of real world systems and, indeed, over the past decades it has been gaining popularity in many domains of research. As a result, ABM is nowadays applied to a large variety of problems and domains, such as: transportation and traffic systems (Davidsson et al, 2005), animal societies (van der Vaart and Verbrugge, 2008, Grefenstette, 1992), physiological systems (Jager, 2000), social systems (Conte et al, 1998), organisations (Clippinger III, 1999), economic systems (Tesfatsion and Judd, 2006), ecological systems (Janssen and Ostrom, 2006), physical systems or robotic systems (Reis, 2003), archaeological reconstruction (Brantingham, 2003), biology (Vodovotz et al, 2009), patterns of diffusion (Helbing, 2000) or political sciences (Axelrod, 1997). Applications range from simple academic exercises up to large scale commercial solutions (Castle and Crooks, 2006, pp 41). ABM is primarily used to make analysis and to less extend to make predictions and verifications (Davidsson et al, 2007).

Basic description of ABM components: agents, interactions and environment

An agent based model is made of three basic components, namely: agents, interactions and environment (Figure 6). Of these basic constituents, agents are undoubtedly the most relevant and “the primary focus” (North and Macal, 2007, pp 88) of ABM; and those who receive more attention and efforts during the modelling process.

There is no single universally accepted definition of agent on the literature (Wooldridge, 2006, pp 15, Truszkowski, 2006, pp 5, Dannegger,). In this paper the following definition of agent was adopted: an agent is an independent entity, with precise boundaries, that exhibits autonomous behaviour and with both sensorial and communicational capabilitiesAn agent’s behaviour can also be the reaction for a need for accomplishing one or more goal or goals.

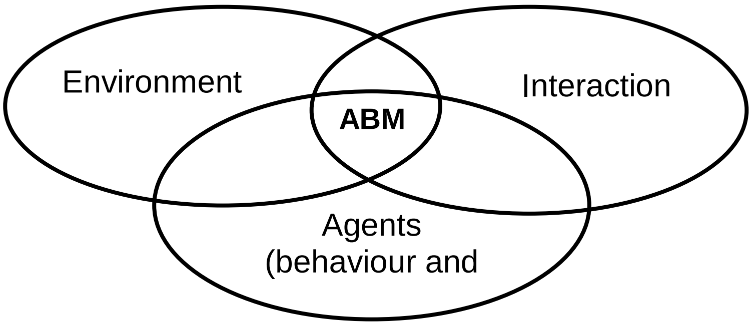


Figure 5.6 – ABM’s basic components

The next component of an agent based model refers to the interactions. Interaction refers to an agent’s ability to exchange information with other specific agent. It is a temporary linkage between a pair of agents, through which information flows in one direction. An interaction is temporary because it is only established during the strictly necessary period of time. It is unidirectional because it flows from the sender towards the receiver, and it ceases existence here. In this sense, a conversation can be understood as an ordered sequence of interactions amongst agents (where interactions are established back and forth amongst the pair of agents). Agents may establish in simultaneous more than one interaction with the same or different agents.

The final component of an agent based model is the environment. The environment consists in all the properties exterior to the agents. An agent is able to capture information from the environment concerning either properties or other agents. The environment also provides support to the interactions amongst agents. At a given moment, the specific value and nature of the properties along with the arrangement of agents configure the environment’s state.

An environment is built to recreate properties similar to those found on real world conditions, such as: time dimension (for example: second, hour, day, or year), geographical dimension and eventual barriers to the agents’ movement or interactions (for example: rivers or lakes; or walls, stairs, or elevators), limit values (for example: vehicle’s maximum speed, or weight and volumes always non-negative values) (Russell and Norvig, 2003).

Model Architecture

A simulation model has been designed for assessing the influence of the factors of competitiveness This model is hereinafter designated by Air Freight Transport Market Simulator (AFETAS). AFETAS is a generic tool for micro level simulation of freight transport markets. As already mentioned, ABM was the method of modelling used to build AFETAS. The implementation of AFETAS was done through the commercial software: AnyLogic[4].

Figure 6.1 presents the conceptual structure of AFETAS's freight transport market. On this market, Customers generate the demand for freight transport services. Freight Forwarders organise and manage their transport services. The freight transport services are provided by multiple Freight Transport Companies. Freight Transport Companies convey cargo either between origin and terminal (door-to-airport) or terminal and destination (airport-to-door); or between the terminals (airport-to-airport). Each transport company use one mode of transport to provide its own services.

Competition takes place at two levels: firstly, between freight forwarders when competing for customers' transport services; and secondly, between transport agents when competing for freight forwarders' transport services. Freight forwarders compete based on price, transit time and customer's perception, while transport agents compete based on price, transit time and freight forwarder's perception. Transport companies are not fully nor equally reliable, therefore failure (either in terms of delay or damage) is inevitable. Penalties are associated with failure that, ultimately, result in loss of competitiveness, for both transport agent and freight forwarder (that has chosen that transport agent). Additionally, every freight forwarder and transport agent adopts a specific price strategies aiming to leverage their competitiveness position (which are function of inner properties, external pressures and agreements between them).

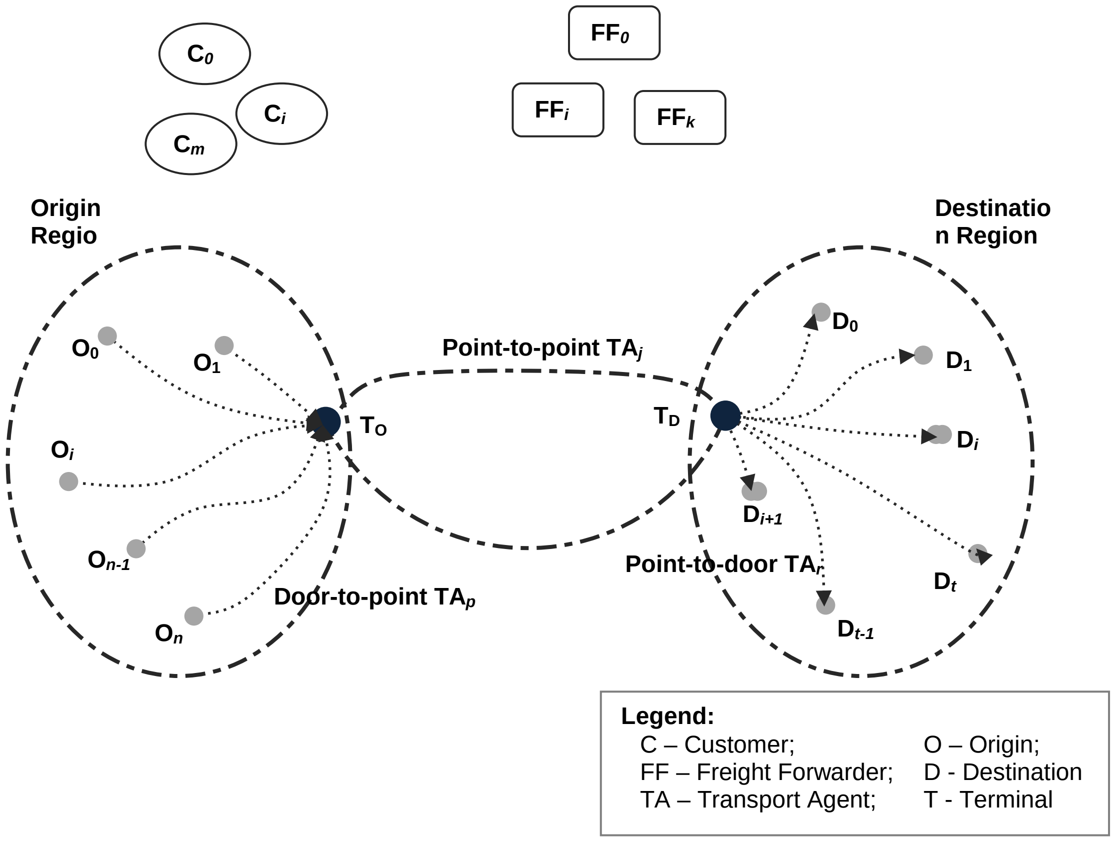


Figure 7 – AFETAS' virtual freight transport market

[4] More information on AnyLogic website: www.xjtek.com (31st January 2010).

Owing to space restrictions only a brief description of AFETAS is presented in this paper. The interested reader is referred to Reis (2010).

Environment

In what concerns the geographical-related dimension, AFETAS recreates a market geography that proportionate air transport services (Figure 7). The market is represented by two separated regions: *Origin Region* and *Destination Region*. Each region has a set of facilities (Origin Region: O_0 to O_n, and Destination Region: D_0 to D_t, $n, t \in N$), and one *Terminal* (Origin Region: T_O, and Destination Region: T_D). Facilities are places of either origin or destination of freight. Terminals correspond to the airport, where cargo is transferred between modes of transport (land and air transport modes). AFETAS considers there is enough cargo flow to support air transport links.
Freight transport services occur in one direction from the origin region to the destination region. In what concerns the agent's mobility, there is no actual movement of agents. The transport of freight is simulated using time-based referential: calculated with an average speed and the distance between points, plus a stochastic variable (to incorporate factors causing delays or earlier arrivals). Freight is considered to have volume, weight and a certain level of fragility. The level of fragility influences the likelihood of damage, the higher the level of fragility, the higher the probability of damage. Air freight rates are given on basis of Equivalent Weight (EW), which is computed as follows: $EW = \max(weight, volume/6)$.

Agents

The following agents have been developed in AFETAS for simulating the freight transport agents:

- Customer: places orders on the market;
- Freight Forwarder: assembles and manages freight transport services on behalf of customers;
- Freight Transport Companies:
  - Air Transport Company: conveys the cargo, there are three types of agents (considering the origin and destination points).
  - Land Transport Company: provides land transport services between origin and airport (door-to-terminal) or airport to destination (terminal-to-door);

Additional proto-agents have been considered. These are entities with simple internal structures, that perform simple tasks and do not exhibiting all features of an agent. Instead they embody part of the agent's properties mentioned earlier on this dissertation (Figure 5.5). These entities are:

- Terminal Handling Company: provides transhipment services, between land and air transport;
- Vehicle (aircraft, truck or multi-modal vehicle): conveys one or more orders between two points.

Interactions

Interactions are an integral element of any agent based model. An interaction is the vector whereby an agent receives from (inbound flow) or sends to (outbound flow) the environment or other agents any kind of object (either material or immaterial). It simulate the real world's social, professional or other relationships among people or organisations (the agents), or between these and society or markets (the environment). AFETAS simulates a freight transport market where the various freight transport agents interact (compete, cooperate or negotiate) on intermodal or single agent transport services aiming to win the customer's confidence. In this context, different kinds of interactions may occur, which are intrinsically linked to the type of flows that exist along an intermodal transport service. The presentation of AFETAS's interactions will be done independently for each one of these flows. This is for both simplicity and clarity purposes, as it provides a simpler and direct comparison with real world.

On an intermodal transport service there are four main types of flows:

- Physical: corresponding the transfer of the goods between freight transport agents (unidirectional from origin to destination);
- Informational: corresponding to the exchange of information between freight transport agents;
- Legal: corresponding to a freight transport agent's liability for carrying freight;
- Financial: corresponding to the payments (or indemnities) for providing the transport service.

Decision Making Process Engine

The decision making process is emulated through a Fuzzy Logic Inference Mechanism (FLIM) based on fuzzy sets theory and fuzzy control (Zadeh, 1975, 1965). FLIM considers two modal choice factors (price and transit time), which can have different impact in the decision making process.

Fuzzy sets theory and fuzzy control have proved being particularly suitable to handle the subtleties and lack of precision of human language, as well as the prominent qualitative nature and complexity of human decisions; firstly, it allows the direct usage of human language, overcoming the need of a translation into quantitative values; and secondly, it is able to translate into mathematical formulation the qualitative nature or complexity of human language. Such properties have opened the door for the mathematical manipulation and computation of eminently qualitative domains where exact quantification was so far difficult or impossible, such as human thinking or reasoning. Over time, fuzzy logic controllers used to emulate human reasoning and decision making processes have been developed (Jang, 1993, pp 665). An explanation of the decision making process is provided in Annex I.

EMPIRICAL SIMULATION ASSESSMENT

Recalling that an intermodal transport service has three sources of performance (Figure 5); than we may conclude that the unequivocal assessment of the influence of fitness in the performance would require the isolation of this source of performance. In this paper, the authors used AFETAS to find evidences about influence of fitness in the performance of the intermodal transport service. The utilisation of AFETAS consisted in changing the level of friction of in one dimension of fitness, ceteris paribus, and measuring the change in the level of performance. The measurement of the change implied the consideration of two situations:

- A base case that served as benchmark for measuring the default level of performance;
- A fitness case where only one source of friction was changed.

Since the only difference between the base case and the fitness case was the change in the level of friction (and in one dimension); than any eventual change in the level of performance could be unequivocally ascribed to the influence of that dimension of fitness.
The variable used to measure the level of performance of the intermodal transport services was the: *market share*. An intermodal transport service's market share is defined as the ratio between the total quantity of freight transported by the transport service over the total quantity of freight transported in the market. The rationale is that an intermodal transport service with higher performance than the others, it is more competitive than the others and it will transport more consignments than the others, which ultimately will be translated in higher market share.

Design of the Experiments

Three types of factors were taken into consideration in the design of the experiments, being: nature of customers, amount of transport agents and customers, and the number of fitness dimensions.
In what concerns the nature of customers, three types were considered, being:

- Time sensitive customer – emulates customers that give higher importance to time than price;
- Neutral customer – emulates customers that give similar importance to price and time;
- Price sensitive customer – emulates customers that give higher importance to price than time.

Three types of markets were taken into consideration (Table 1). In Markets Type 1 and 2, every transport agent is invited and all possible combinations are taken into consideration during modal choice process. In Market Type 3, only the top five agents (on each leg) are invited (number in brackets, last row Table 1). This means that in Market Type 3 there are 4000 possible intermodal transport chain combinations, but each freight forwarder will only evaluate 125 possible combinations.

Table 1 – Quantity of transport agents and customers

Market Type	Transport Agents				Customers
	Land Base Origin Leg	Air Leg	Land Base Origin Leg	Freight Forwarders	
1	1	2	1	1	1
2	2	4	5	3	10
3	20 (5)	10 (5)	20 (5)	5	20

As explained, air transport sector has already fairly eliminated the sources of friction along some of the dimensions of fitness. Thus, the dimensions of fitness to be assessed are: physical and relational. This defined the necessity of conducting four cases, being:

- Base case;
- Physical fitness case;
- Relational fitness case (schedule coordination);
- Relational fitness case (price coordination);

In the *base case* no dimension of fitness is evaluated. Its presence is meant for enabling the ceteris paribus situation, since all other cases are variants of this one. In other word, the results of the base case are the benchmark against which the (eventual) influence will be assessed. In this case, all of the agents and proto-agents are considered to be identical.

Physical Fitness

The physical dimension of fitness concerns the movement of goods along an intermodal transport chain, which the authors considered being related with the transport agents' interoperability of equipment, such as: utilisation of same type of containers, forklifts, packing equipments, etc.). In these conditions, goods are considered to be transportable within containers from origin to destination. Two benefits accruing from interoperability are:

- Reduction of the airport transhipment times because cargo does not requires, being unloaded from (or loaded into) from land based vehicle, sorted and loaded into (or unloaded from) containers. It is considered that transhipment time is reduced to a fixed value of 2 hours (the minimum amount of time for processing the bureaucratic procedures and handling operations of containers).
- Reduction of the handling operator's level of damage because cargo is protected all through the journey within containers and it is not subjected to any handling procedures at airports. It was considered that level damage in this condition was half than average handling operator's level of damage.

Schedule Coordination

The assessment of the influence of factor schedule coordination was done by considering that one or more air and destination land based transport agents align their schedules, while the remaining transport agents have non-coordinated schedules. In this situation, the origin land based transport agents have no influence since they operate non-fixed schedules and can automatically coordinate the schedules.

The market in AFETAS was defined as follows. The air and destination land based transport agents with coordinated schedules were defined so that, in ideal conditions, as soon as cargo is available at airport of destination (importation procedures) the land based leg starts. Thus, the waiting time at airport of destination is zero. Certainly, that in case of any delay of the air leg, the land based transport service is lost, and cargo is kept on ground (the same would not occur if case of some gap between transport services).

Price Coordination

Price coordination factor is one of two factors (the other one is the schedule coordination factor and it was discussed in the previous chapter) of the relational dimension of fitness. Price coordination occurs when a set of transport agents (of the various legs) decide to abdicate of part of their profits, when producing an intermodal transport service. The assessment of the influence of the factor price coordination, for purposes of validation of the theory, was done by considering that one or more transport agents agree on reducing their

prices (by the same amount) when working together (otherwise, there is no discount). The amount of discount was of five percent. This value was considered equal to all agents, and it was set at this level because air transport companies tend to operate with small profit margins and they hardly could afford higher rates of discount.
The market in AFETAS was defined as follows. One or more sets of three agents (one from each leg) were flagged as having a price agreement; while all the other transport agents were flagged as not having price agreement. Thus, when the freight forwarder is computing the price, if the three agents have the same flag, than there is a discount of 5%; otherwise there is no discount.

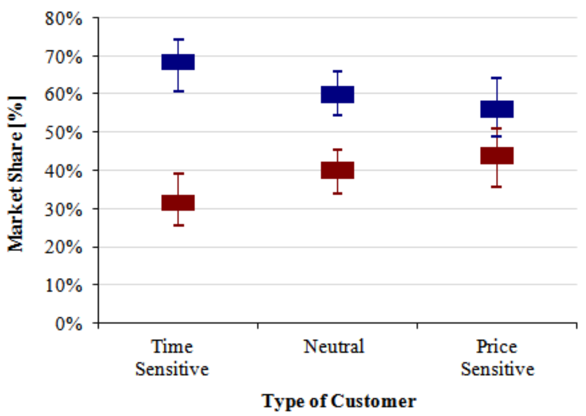
AFETAS, as a dynamical model, takes into consideration the dimension of time. Such feature implies the need to define a time span for the simulation runs. A time span of five years was considered enough for the model to reach a dynamical equilibrium. After an initial period of some oscillation, the values of market share tend to stabilise and either converge to a value or oscillate with a defined period. Every experiment was reran either 1000 (in case of Market type 1 and 2) or 250 (in case of Market Type 3) times.
The next table summarises (Table 2) the various cases considered.

Table 2 – Experiments for theory validation

Factor	Properties
Nature of customers	• Time sensitive; • Neutral; • Price sensitive.
Amount of transport agents and customers	• Market Type 1: 1 -2 - 1 - 1 - 1; • Market Type 2: 3 -4 - 5 - 3- 10; • Market Type 3: 20(5) -10(5) - 20(5) - 5- 20;
Dimensions of fitness	• Physical fitness; • Price coordination; • Schedule coordination;

RESULTS

Physical Fitness Case



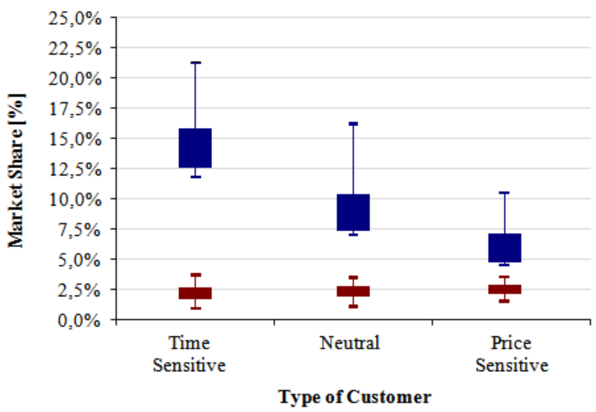


Figure 8 – Market share of fitness chain versus other chains in Market Type 1

Figure 9 – Market share of fitness chain versus other chains in Market Type 2

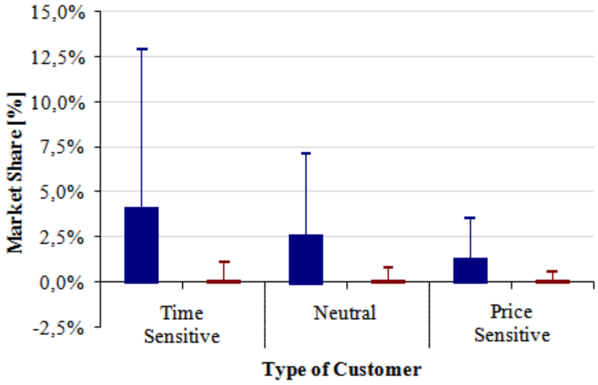
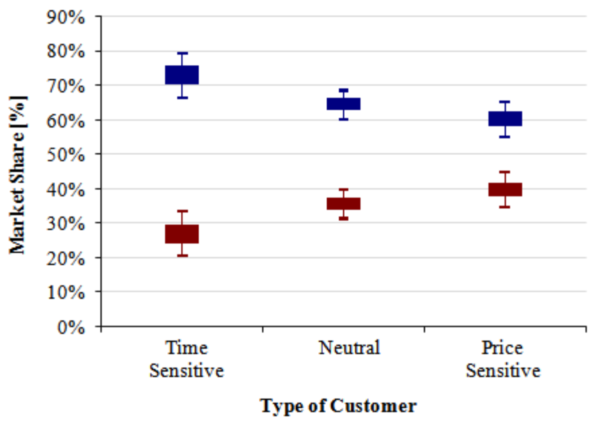


Figure 10 – Market share of fitness chain versus other chains in Market Type 3

The results evidence the existence of benefits accruing from the physical dimension of fitness. The evidences are stronger on the Market Type 1 and for all types of customers. In what concerns Market Type 2, the evidences are also strong in both time sensitive and neutral customers. In price sensitive customers the evidence is less strong, but still visible. Finally, in what concerns Market Type 3, the evidences are weaker, since there is no clear gap between fitness chains and the others. Yet, the authors believe that that advantage is likely to exist, however due to the specificities of the market they were somehow diluted (which would require further research). In this type of market not all chains are necessarily evaluated in all decision making process and, even, in every run. Thus, a null value does not entail a transport chain is not competitive, but simply that it could have never been evaluated ending up with zero market share.

Relational Fitness Case: Schedule Coordination



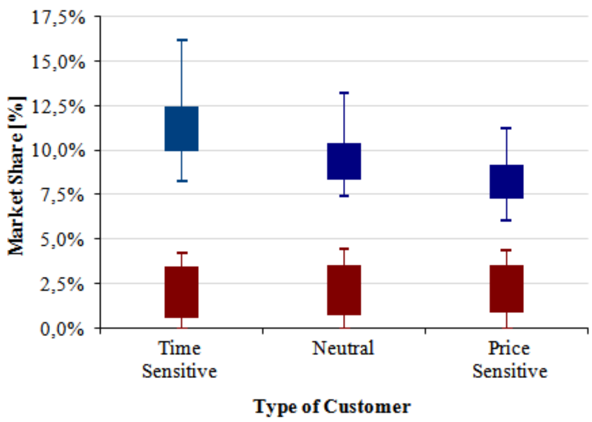


Figure 11 – Market share of fitness chain versus other chains in Market Type 1

Figure 12 – Market share of fitness chain versus other chains in Market Type 2

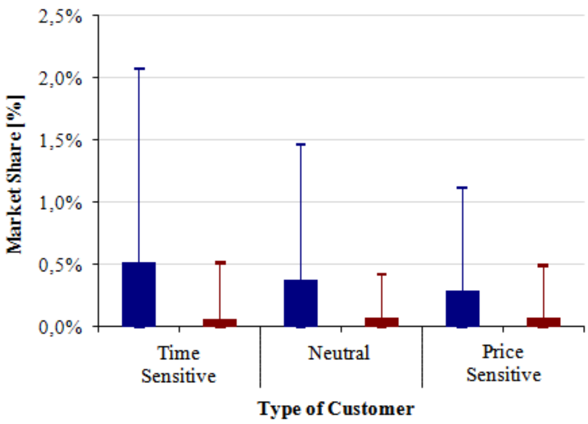


Figure 13 – Market share of fitness chain versus other chains in Market Type 3

The results evidence the existence of benefits accruing from the relational dimension of fitness (factor: schedule coordination). The evidences are stronger in the Market Type 1 and Market Type 2 for all types of customers. In what concerns Market Type 3, the performance of fitness chains is considerably larger than the others, in terms of both average and maximum attainable market share as in terms. However, the authors acknowledge that stating that fitness generates added value is disputable. Therefore, no sharp evidence was found about the advantages of fitness in Market Type 3.

The behaviour of the markets in this dimension of fitness is similar to that found for the physical dimension of fitness, which is consistent with the fact of both dimensions of fitness having a temporal factor[5]. However, it should not be forgotten that, firstly, the physical dimension of fitness also influences the intermodal transport chain's level of damage and, secondly, the quantity of fitness chains is different in both cases; therefore, no direct comparisons are possible to be made.

Relational Fitness Case: Price Coordination

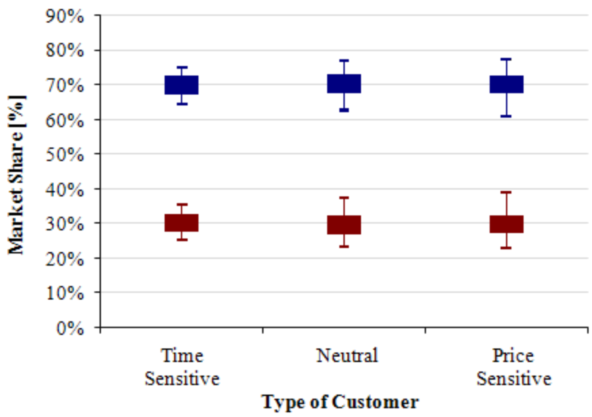


Figure 14 – Market share of fitness chain versus other chains in Market Type 1

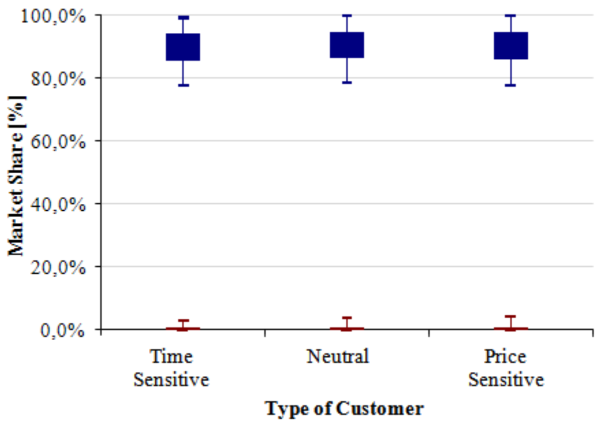


Figure 15 – Market share of fitness chain versus other chains in Market Type 2

[5] The temporal gain in the current dimension is in average of 6 hours. The temporal gain the physical dimension of fitness is in average of 1 hour.

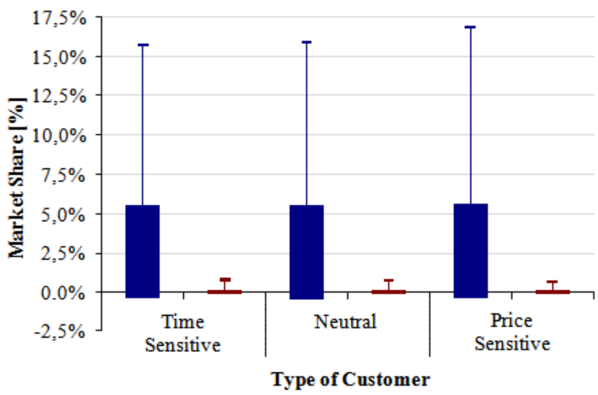


Figure 16 – Market share of fitness chain versus other chains in Market Type 3

Fitness chains present in both Market Type 1 and Market Type 2 a clear advantage in relation to the other chains. The market share gap is around 40 % and 90%, respectively, in all types of customers. The minor differences amongst customers may be ascribed to the random effects on the model. The results in Market Type 3 are in line with the previous results, although a higher dispersion is visible. Such result may evidence the higher random nature of this market vis-à-vis the other types of market. The results obtained for this type of market reveal that the non-fitness chains have a market share of around zero and a maximum of around 0.7%; and that the fitness chains have a market share around 2.5% with a maximum of around 16%. The difference of results is clear that, notwithstanding not being possible to claim that null values represent no evaluation, the author is convinced of the advantage of the fitness chains over the others.
Of the various dimensions of fitness, the price coordination factor of the relational dimension of fitness is the one where the advantages are more evident and sharp. In Market Type 1 and Market Type 2 there is little room for doubts about the importance of this factor; while for Market Type 3 the results are not so clear; however, the difference between fitness chains and the others is considerably higher, which leads the author to state that the advantage is present.

Summing up, in two of the markets, Market Type 1 and Market Type 2, the results evidence a clear advantage of the fitness chains vis-à-vis the non-fitness chains; whereas, in Market Type 3, the results fail in clearly demonstrating the advantage of the fitness chains. Nonetheless, the existent (weak) evidences seem to support the validity of the author's claim that the dimensions of fitness are potential factors of competitiveness.

CONCLUSIONS

This paper was motivated, firstly, by the difficult positioning of passenger airlines in the air cargo market and, secondly, by the potential importance of air cargo business on their sustainability and competitiveness. The main challenges impacting passenger airlines are: steady increase of the competitive environment, inferior market positioning, longstanding financial difficulties and outdated business models. Furthermore, the subordination of cargo business to passenger business introduces additional particularities, namely, driving prices towards marginal costs. Yet, real word data evidences the relevance of cargo business in combination companies' total business, contributing with as much as fifty percent although market average is around the fifteen percent.

Hence, there is a need of passenger airlines find alternative ways to increase their competitiveness in the air cargo market. The improvement of the level of integration between combination companies and other transport agents was the envisaged solution for attaining that objective. The current paradigm of demand is largely grounded in high quality and door-to-door transport services and, two, the air transport mode offers point to point transport services; then, it is expectable that they will eventually be called to integrate with other modes of transport (in the production of door-to-door intermodal transport services). If such integration is not correctly processed, than losses of performance may occur. Consequently, improvement of the integration may lead to a reduction of the losses of performance, thus, contribute to the improvement of the performance of the intermodal transport service and, ultimately, contribute for competitiveness of combination companies.

The paper starts with an analysis to the sources of the performance of intermodal transport services, to conclude that there are three main sources of performance being: dual systems' own performance, freight forwarders' capabilities of managing and fitness gap.

The fitness of an intermodal transport service develops along five dimensions, being: physical fitness, logical fitness, liable fitness, financial fitness and relational fitness. Three of these five dimensions have already been fairly achieved by the air transport industry, being: logical fitness, liable fitness and financial fitness. It remains however to be solved the physical and the relational dimensions of fitness.

An agent based model - called AFETAS - was developed to assess the influence of these dimensions on the competitiveness of passenger airlines in the air cargo market. The model simulates an intercontinental freight transport market where intermodal air transport services are required. AFETAS simulates the competition between fitness chains and non-fitness chains. A set of independent experiments were ran. Each experiment concerned one dimensions of fitness, being: physical fitness and relational fitness (in this case two situations were considered: schedule coordination and price coordination). The results evidenced a higher competitiveness of fitness chains vis-à-vis the others. We may therefore conclude that passenger airlines pursuing deeper integration along these dimensions of fitness may expect achieving higher performance and, thus, saw an increase on the competitiveness levels.

Concluding, both the physical dimension of fitness and the relational dimension of fitness are factors of competitiveness of passenger airlines in the air cargo market.

BIBLIOGRAPHY

Air Cargo World (2009) "Back burner for cargo emissions?", published in February

Airline Business (2007) "Sea change", Vol 23, Issue 11

Airline Business (2008) "Alliance stress relevance", Vol 24, Issue 11

Allaz, C. (2004) "The history of air cargo and airmail from the 18th century", Christopher Foyle Publishing, London (United Kingdom), ISBN: 1902579828

Asariotis, R. (1999) "The need for an integrated intermodal transport liability Regime", Transport Quarterly, Vol 53, Issue 2, pp 45-55

Axelrod, R. (1997) "The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration", Princeton University Press, Princeton (United States), ISBN: 0691015678
Boeing (2008a) "World air cargo forecast 2008-2009: Power Point Slides", Boeing Commercial Airplanes, Seatle (United States)
Bonabeau, E. (2002) "Agent-based modelling: methods and techniques for simulating human systems", PNAS, Vol 99, Issue 3, pp 7280-7287,
Brantingham, J. (2003) "A Neutral Model of Stone Raw Material Procurement", American Antiquity, Vol 68, Issu 3, pp 487-509
Button, K. (1996) "Liberalising European Aviation: Is There an Empty Core Problem?Liberalising European Aviation: Is There an Empty Core Problem?", Journal of Transport Economics and Policy, Vol 30, Issue 3, pp 275-291
Button, K. (2003) "Does the theory of the 'core' explain why airlines fail to cover their long-run costs of capital?", Journal of Air Transport Management, Vol 9, pp 5-14
Castle, C.; Crooks, A. (2006) "Principles and concepts of agent based modelling for developing geospatial simulations", University College of London, Working paper series – paper 110, ISSN: 14671298
Clancy, B.; Hoppin, D. (2000) "Post crisis management", Air cargo World
Clancy, B.; Hoppin, D.; Moses, J.; Westphal, J. (2008) "End of an era?", American Shipper, August 2008, pp 33-47
Conte, R.; Gilbert, N.; Sichman, J. (1998) "MAS and social simulation: A suitable commitment", in "Lecture Notes in Artificial Intelligence, Vol. 1534 - Multi-Agent Systems and Agent-Based Simulation" Ed. Jaime Sichman, Rosaria Conte and Nigel Gilbert, Springer Verlag, Berlin (Germany), pp 1-9, ISBN: 978-3540654766
Conway, P. (2004) "Diverging paths", Airline Business, Vol 20, Issue 11
Conway, P. (2006) "Does cargo count?", Airline Business, Vol 22, Issue 11, pp 36-41
Dannegger, C.; Dorer, K. (2004) "Living agents", in "Evolution of supply chain management: symbiosis of adaptive value networks and ICT", Ed. Yoo Chang, Harris Maktsoris, Howard Richard, Kluwer Academic Publisher, Boston (United States), ISBN: 1402078129, DOI: 10.1007/b110025
Davidsson, P.; Henesey, L.; Ramsted, L.; Törnquist, J.; Wernstedt, F. (2005) "An analysis of agent-based approaches to transport logistics", Transportation Research Part C, Vol 13, pp 255-271
Davidsson, P.; Holmgren, J.; Kyhlbäck, H.; Mengistu, D.; Persson, M. (2007) "Applications of Multi Agent Based Simulation", Multi-Agent-Based Simulation VII, Lecture Notes in Computer Science, Springer Verlag, Vol. 4442, pp 15-27
Doganis, R. (2006) "The airline business", Routledge, Oxon (United Kingdom, ISBN: 0415346150
European Commission (2006) "COM(2006) 314 - Keep Europe moving - Sustainable mobility for our continent - Mid-term review of the European Commission's 2001 Transport White paper", Link: http://ec.europa.eu/transport/ strategies/2006_keep_europe_moving_en.htm (22 May 2009)
Grefenstette, J. (1992) "The evolution of strategies for multi-agent environment", Adaptive Behavior, Vol 1, Issue 1, pp 65-90
Helbing, D.; Farkas, I.; Vicsek, T. (2000) "Simulating dynamical features of escape panis", Nature, Vol 407, September 2000, pp 487-490
Hellermann, R. (2006) "Capacity options for revenue management: theory and applications in the air cargo industry", Springer, Berlin (Germany), ISBN: 978-3540344193, DOI: 10.1007/3-540-34420-9
Hoppin, D. (2005b) "Cargo counts", Airline Business, Vol 21, Issue 9
IATA (2009a) "Cargo Plummets 22.6% in December", IATA Press Release n.º 4, 29th January 2009
IATA (2009b) "Cargo Accounts Settlement Systems – CASS", IATA website, Link: http://www.iata.org/ps/financial_services/cass/index.htm (10th August 2009)

Jager, W. (2000) “Modelling consumer behaviour”, Doctoral Thesis, Groningen University, The Netherlands.
Janssen, M.; Ostrom, E. (2006) “Empirically Based, Agent-based models”, Ecology and Society, Vol 11, Issue 2, pp: 37-49
Jonge, J. (2008) “No break in the storm”, Air Cargo World, December 2008
Kadar, M.; Larew, J. (2003) “Securing the future of air cargo”, Oliver Wyman, pp 1-9, Link: www.oliverwyman.com/de/pdf.../MOTL-SecuringFutureAirCargo.pdf (1st September 2009)
Macário, R.; Reis, V.; Filipe, L. (2008) “ELOFRET - Elements for the optimization of intermodal chains in freight transport”, Centre for Urban and Regional Systems, Instituto Superior Técnico, Technical Univeristy of Lisbon, Portugal, Project funded by the Portuguese National Science Foundation (POCTI/TRA/60585/2004)
Macário, R.; Reis, V. (2010) “Strategies of passenger airlines on air cargo market”, submitted to Transportation Journal on Air Transport Marketing
Moorman, R. (2007) “Rejuvenating cargo”, Air Cargo World, May 2007
North, M.; Macal, C. (2007) “Managing Business Complexity”, Oxford University Press Inc., New York (United States), ISBN: 978-0195172119
Putzger, I. (2006) “Can cargo yield profits?”, Air Cargo World, June 2006
Reis, L. (2003) “Coordination in Multi-Agent Systems: Applications in University Management and Robotic Soccer”, Doctoral Thesis, Faculty of Engineering of University of Oporto
Reis, V. (2005) “The performance of the European liberalisation process – an evaluation of the scheduled air transportation market”, MSc Thesis, Faculty of Engineering of Oporto University (Portugal)
Reis, V. (2010) “Development of Cargo Business in Combination Airlines”, PhD Thesis, Instituto Superior Técnico, Lisbon (forthcoming)
Russel, S.; Norvig, P. (2003) “Artificial intelligence –a modern approach, 2nd edition”, Prentice Hall, Upper Saddle River (United States), ISBN: 0130803022
Serpen, E.; Mirza, A. (2009) “The world economy and air cargo business”, presented at 7th Annual Cargo Aircraft & Operations Conference, Brussels (Belgium), April 1-2 2009
Shipping Digest (2008) “Air cargo industry group says security should not hinder trade”, issued on 22nd December 2008
Sinha, D. (2001) “Deregulation and liberalisation of the airline industry”, Ashgate, Hampshire (United Kingdom), ISBN: 1840148357
Tesfatsion, L.; Judd, K. (2006) “Handbook of Computational Economics, Volume 2: Agent-Based Computational Economics”, Elsevier, Amsterdam (The Netherlands), ISBN: 978-0444512536
Walter Truszkowski, Springer-Verlag London Limited, London (United Kingdom), ISBN: 1852339470
United Nations (2001) “Terminology on combined transport”, Geneva (Switzerland), Link: http://www.unece.org/trans/wp24/documents/term.pdf (accessed on 22 May 2009)
Van der Leeuw, S. (2004) “Why Model?”, Cybernetics & Systems, Vol 35, Issue 2-3, pp 117-128, DOI: 0.1080/01969720490426803
Vodovotz, Y.; Constantine, G.; Rubin, J.; Csete, M.; Voit, E.; An, G. (2009) “Mechanistic simulations of inflammation: Current state and future prospects”, Mathematical Biosciences, Vol 217, Issue 1, pp 1-10
Wensveen, J. (2007) “Air transportation: a management perspective”, Ashgate, Hampshire (United Kingdom), ISBN: 978-0754671718
Wooldridge, M. (2006) “An introduction to multi agent systems”, John Wiley & Sons Ltd., Chichester (United Kindgom), ISBN: 978-0471496915x
Zadeh, L. (1965) “Fuzzy Sets”, Information and Control, Vol 8, pp 338 - 353.
Zadeh, L. (1975) “Calculus of fuzzy restrictions”, in “Fuzzy Sets and their applications to cognitive and decision processes”, Editors Lofti Zadeh, King-Sun Fu, Kokichi Tanaka, Masamichi Shimura, Academic Press Inc., New York (United States), ISBN: 0127752609
Zhang, A.; Zhang, Y. (2002) “Issues on liberalisation of air cargo services in international aviation”, Journal of Air Transport Management, Vol 8, pp 275-287

Zondag, W-J. (2006) “Competing for air cargo – a qualitative analysis of competitive rivalry in the air cargo industry”, Master Thesis, Free University of Amsterdam, Amsterdam (The Netherlands), Link: http://www.tiaca.org/images/TIACA/PDF/Competing%20for%20Air%20Cargo.pdf (5th September 2009)

ANNEX I

This Annex provides further explanation about the Decision Making Process Engine implemented in AFETAS.

The decision making process engine is divided into three phase:

- Fuzzy Logic Inference Mechanism (Figure A1):
    - *Fuzzification* – conversion of real world variables (normally denominated as crisp variables) into fuzzy input variables based;
    - *Fuzzy inference* – computation of fuzzy output variable (or variables);
- Identification of the transport solution winner;

Fuzzy Logic Inference Mechanism

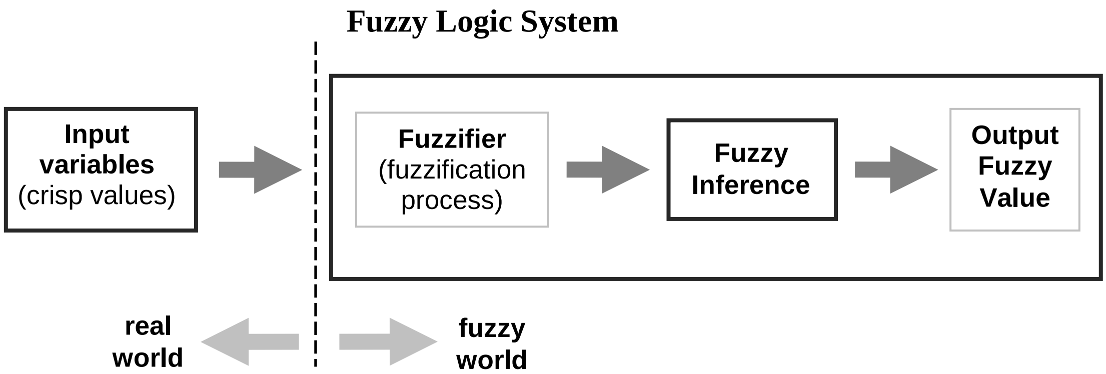


Figure A1 – Fuzzy Logic system

In what concerns the *fuzzy inference step*, the process consists in computing the final output fuzzy value for every option. Thu, for every option *i*, the final output fuzzy value is computed as follows:

$$\mu_i(x) = Weight_{Time} * \mu_{Time} + Weight_{Price} * \mu_{Price}$$

i = 0, 1, …, n

n being the total number of options.

In what concerns the *fuzzification* step. Figure A2 sketches the shape of the membership functions for the input variables, the specific valuation depend on the mode of transport they refer (road, air, sea or train). The output variable ranges between zero (0) and one (1). Zero denotes a bad option; while one denotes maximum values and thus an excellent option.

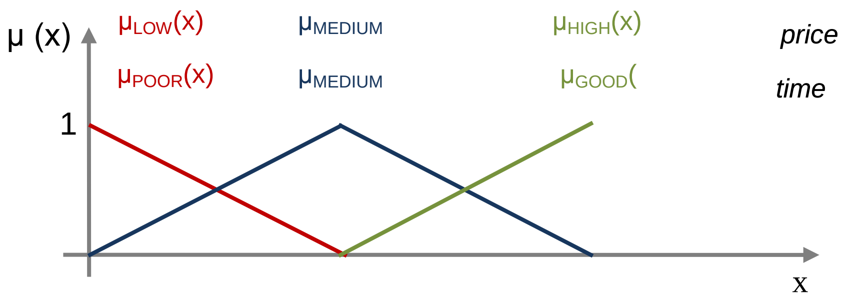


Figure A2 – Fuzzy membership functions for input variables

The computation of the membership functions for the variable Price is computed as follows:

$$\mu_{Low}(x) = \begin{cases} 1 - \dfrac{x}{P_{Med} - P_{Min}}, x \in [P_{Min}, P_{Med}] \\ 0, x \in [P_{Med}, P_{Max}] \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} \dfrac{x}{P_{Med} - P_{Min}}, x \in [P_{Min}, P_{Med}] \\ 1 - \dfrac{x}{P_{Max} - P_{Med}}, x \in [P_{Med}, P_{Max}] \end{cases}$$

$$\mu_{High}(x) = \begin{cases} 0, x \in [P_{Min}, P_{Med}] \\ \dfrac{x}{P_{Max} - P_{Med}}, x \in [P_{Med}, P_{Max}] \end{cases}$$

With,

$P_{Min} = Min\ (P_i), i = 0,1, \ldots n,$

$P_{Max} = Max\ (P_i), i = 0,1, \ldots n,$

$P_{Med} = 0.5 * (P_{Min} + P_{Max})$

P being the price of the option;

n being the number of possible options (transport chains, in case of freight forwarder's decision making process, or number of bids, in case of customer's decision making); process.

The computation of the membership functions for the variable Time is computed as follows:

$$\mu_{Poor}(x) = \begin{cases} 1 - \dfrac{x}{TT_{Med} - TT_{Min}}, x \in [TT_{Min}, TT_{Med}] \\ 0, x \in [TT_{Med}, TT_{Max}] \end{cases}$$

$$\mu_{Medium}(x) = \begin{cases} \dfrac{x}{TT_{Med} - TT_{Min}}, x \in [TT_{Min}, TT_{Med}] \\ 1 - \dfrac{x}{TT_{Max} - TT_{Med}}, x \in [TT_{Med}, TT_{Max}] \end{cases}$$

$$\mu_{Good}(x) = \begin{cases} 0, x \in [TT_{Min}, TT_{Med}] \\ \dfrac{x}{TT_{Max} - TT_{Med}}, x \in [TT_{Med}, TT_{Max}] \end{cases}$$

With,

$TT_{Min} = Min\ (TT_i), i = 0,1, \ldots n,$

$TT_{Max} = Max\ (TT_i), i = 0,1, \ldots n,$

$TT_{Med} = 0.5 * (TT_{Min} + TT_{Max})$

TT being the transit time of the option;

n being the number of possible options (transport chains, in case of freight forwarder's decision making process, or number of bids, in case of customer's decision making); process.

In what concerns the *fuzzy inference step*, the process consists in computing the final output fuzzy value for every option. Thu, for every option *i*, the final output fuzzy value is computed as follows:

$$\mu_i(x) = Weight_{Time} * \mu_{Time} + Weight_{Price} * \mu_{Price}$$

i = 0, 1, …, n

n being the total number of options.

In what concerns the *fuzzy inference step*, the process consists in computing the final output fuzzy value for every option. Thu, for every option i, the final output fuzzy value is computed as follows:

μ_i (x)= 〚Weight〛_Time* μ_Time+ 〚Weight〛_Price* μ_Price

i = 0, 1, …, n

n being the total number of options.

Identification of the transport solution winner

The final step of the decision making process consists in determining the actual winner option. This step is conducted outside the fuzzy engine.

AFETAS determines the winner randomly, based on the propensity of each final output fuzzy value. The reason for utilising a random process instead a deterministic one is based on the fact human judgement not being strictly rational (and thus far entirely known). In case of a deterministic situation, the option with higher output fuzzy value should be the chosen one.

However, it is expectable that a human decision maker does not always chooses the highest ranked option Firstly, let us consider a case where more than one option have similar output fuzzy values. In case of a deterministic situation, the choice would always be for the higher, even the difference being very low. Yet, a human decision-maker could consider then as being practically identical and, therefore, choosing one or another in similar ways. Secondly, because for some reason, the decision market may decide for a low valued option (either because she believes on those transport agents, or because she is (in same way) offended with the people working on the high ranked options), instead the highest ranked option. Certainly, this may occur only sporadically, but it is nevertheless possible to happen.

The procedure built in AFETAS is explained below, and consist in three steps.

Step one consists in determining the propensity of each option, in relation to the set of option. The propensity is determined as follows:

$$Propensity_i = \frac{Final\ Output\ Fuzzy\ Value_i}{\sum_{j=0}^{n} Final\ Output\ Fuzzy\ Value_j}$$

Step two consists in forming a vector of propensities. Each position is calculated as the sum of the propensities of the previous positions, thus, the first position is equal to the propensity of option 0, the second position is equal to the sum of the propensity of option 0 and option 1, and so on and so forth.

$$List\ of\ Propenities = \{\ Propensity_0, \ldots, \sum_{k=0}^{i} Propensity_k, \ldots, 1\}$$

Step three consists in drawing a random number, *r*, with uniform distribution, between 0 and 1. And finally step four consists in determining the winner option. The winner option is the one that fulfils the following condition:

$$Option\ i\ is\ winner\ if\ \sum_{k=0}^{i} Propensity_k \leq r$$

This procedure ensures, firstly, the random nature of the decision making process, which is inherent to every human decision. Secondly, it provides similar probability of choice to options with similar output fuzzy values, likewise real world. And, thirdly, it provides probability of even options with low output fuzzy values to be chosen, although with low probability, again similarly to real world.