A GEOMETRY OF UNCERTAINTY
Cost and time in intermodal freight competition

Patrick Niérat
INRETS-DEST, France

1. INTRODUCTION

What is the best choice to carry a volume of goods between two points? This question has not a single answer. It depends on, among other things, who answers the question, the volume and the nature of the goods, the location of the origin and the destination, the hour, the transportation techniques available.

It is clear that a motor carrier and people living along a road do not agree (the situation in the Alpine valley of Chamonix is an example); but it is less easy to understand that two carriers or two shippers having exactly the same thing to carry may do different choice although they have the same selection criteria. In a cost comparison between all road and intermodal rail-road door to door services, Niérat (1997) shows that one carrier may use intermodal when another may use all road, because the first carrier has enough clients in the terminal market area, because he has a return freight when the other has not.

But cost is not the only one selection criteria. Freight transportation choice relies on other factors: availability, suitability, time, quality of service… Is it possible to take this parameters into account in the theory of market areas?

This paper tries to answer this question with two selection criteria, time and cost. A particular case, intermodal versus all road in France, gives the opportunity to study the roles of each criteria when the choice is possible.

The following presentation will be used. First we present the case study and give a quick summary of the theory of market areas. Second we consider the usual method of generalised cost that appears to be not appropriate, because the transformation of time into money does not take into account the role of time in this field. Then we try two methods. One is inspired by observations inside trucking companies. It shows how the intermodal market area evolves with the required time to deliver goods to the customers (or to collect goods). The other fits with situations where time role is uncertain: we don't know whether time plays in favour or in disfavour of each mode; we build the geographical areas where cost plays a more or less decisive role, It is there that transport competition is the strongest.

2. METHOD

The comparison of intermodal rail-road with all road is of particular interest. These two solutions have a high degree of technical substitutability. They are seen as practical alternatives for general freight, they are able to carry the same goods and the same size of shipment as pointed out by Harper and

Evers (1993). Maritime container inland transportation is the best example of this high substitutability degree.

But intermodal service is not always available. Its competitiveness depends upon high volume long distance traffic, and there is no intermodal supply when those necessary conditions are not achieved. We will limit our comparison to a case where intermodal is a good service in order to compare solutions that are comparable.

2.1 A case study: Paris – Avignon Novatrans service

We selected a specific link between two terminals in France, Avignon and Paris. On this link, intermodal is a very intensive business, with a particularly good service, trains running in less than 10 hours the distance of 680 km. Figure 1 shows the timetable of Novatrans service in may 2002. Novatrans is a French intermodal operator. Its clients are road hauliers, who choose Novatrans rail services between two terminals and organise road pre- and end-haulage or use their trucks for an all road door to door journey. There are four trains from Avignon to Paris, leaving Avignon after 7.00 p.m., and arriving in Paris between 4.00 and 5.30 am the next day. From Paris, there are four night trains and one day train.

From Paris to Avignon				From Avignon to Paris			
Departure	T	Arrival	transit time	Departure	Arrival	T	transit time
14.00	V	22.55	8.55				
18.50	N	4.25	9.35	19.10	4.35	P	9.25
19.45	P	4.10	8.25	19.45	4.00	V	8.15
20.15	P	5.30	9.15	20.05	5.30	N	9.25
20.20	V	4.50	8.30	21.05	5.40	P	8.35

T is the terminal in Paris: Noisy-le-sec, Valenton or Pompadour
Table 1: Novatrans timetable (Source: Novatrans web site, may 2002)

We are not allowed to give the tariffs of Novatrans, but they are said to be “in the market”.

Avignon and Noisy-le-sec are the busiest Novatrans terminals in France, with more than 50,000 transhipments in 2001. In Paris region, Novatrans has its main activity in France with four terminals in Noisy-le-sec, Valenton, Pompadour and Rungis. Rungis is not connected with Avignon.

Most of the traffic is between Avignon and Pompadour, with full trains running between these terminals. The Noisy train links Marseille and Avignon with Paris and Lille. The train of Valenton is shared between three operators.

2.2 The theory of market areas

To compare the two solutions, we will take the perspective of the haulier, and try to define which is the best one for him. Niérat (1997) uses the market areas theory to compare costs. Figure 1 shows the construction of the intermodal market area, defined as the loci around terminal T where intermodal door to door transport is cheaper than an all road transport.

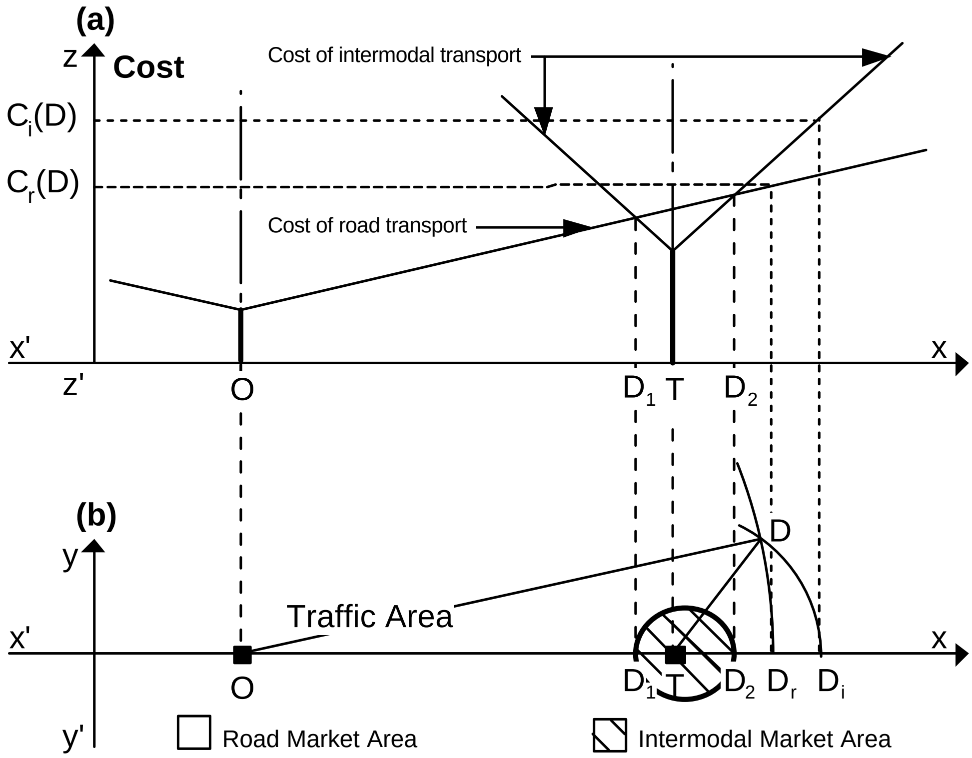

Figure 1: Construction of the intermodal market area (Niérat, 1997)

In figure 1(b), intermodal as well as road may be used to carry out a shipment between the origin O and destination D. All road is a direct way. Intermodal from O to D is a three steps journey: the first step is road from O to a departure terminal (Avignon in our example); the second step is rail from departure terminal to arrival terminal T (Paris), and then road from T to D.

In the cost dimension [figure 1(a)], road cost has a fixed part and a variable part, proportional to the Euclidean distance from O to D. For intermodal, it’s important to see that here intermodal cost has also a fixed part and a variable part, but the variable part is proportional to the distance from T to D, and not from O to D. The fixed part includes all the costs to go from O to T (pre-haulage, rail, transhipments…).

The spatial theory builds the market area of the terminal T. Its size and shape are relative not only to freight characteristics (tonnage, distance, nature), but also to the decision maker characteristics (level of imbalance in its long distance traffic, efficiency of its pre- and end haulage…).

How time (and other parameters) can be introduced in this comparison? How do evolve the market areas?

3. ABOUT TIME

To take many factors into account, the economist usually transforms time (and other parameters) into money, adds it (them) to transport cost and gets a generalized cost (GC_s) given by:

(1) $GC_s = C_s + VOT \cdot t_s$

where C_s is the carrier cost (truck, driver…), VOT the value of time and t_s, the duration of the trip for the solution s.

To use the generalised cost instead of the transport cost in the market areas theory, a value of time and a function of the travel time for each solution must be defined.

The two steps are difficult. We will only mention the problem for the value of time, for which a debate exists about its level. But we will not deepen it. We will focus on the second question, that of travel time.

3.1 Selection of a value of time

The first step is to select a value of time. There are several ways. One way uses the carrier value of time. Wynter (1995) presents results from a stated preference survey in France; the aim is to measure the tradeoff points between tolled fast autoroute and free road. The mean value of time is € 79 per hour and per truck, and it increases with distance. Another way is the shipper value of time. Jiang et Calzada (1998) use the French shipper survey and get a mean value of € 4.42 per hour and per tonne. A third way is based on commodity interest costs as used by Konings and Ludema (2000) to study the competitiveness of river-sea transport between United Kingdom and Germany. A fourth way is administrative value of time (used by French government for infrastructure evaluation) which is said to be € 0.45 per tonne and per hour both for road and rail-road transport (Boiteux, Baumstarck, 2001). A fifth way is to use a parameter in order to test the sensitivity to the value of time level.

As one can see, this selection is not easy, it needs an in depth analysis of the different methods and of the necessary assumptions to calculate a value of time. It may be necessary to get a special survey as that of Wynter for the particular case of truck versus intermodal.

But, whatever the selected value of time, it is multiplied by the travel time to get an additional cost, then added to transport cost. This method is useful when there are strong differences in time or cost between the transport solutions. For example between Hong Kong and New-York, maritime intermodal transportation may go westbound via Suez canal or eastbound via Panama canal, or through US west ports and a landbridge, according to the cargo value (Bascombe, 1998), the fastest eastbound way via US west ports (18 days) being the cheapest for high value goods, the slowest westbound way (28 days) being as cheap for low value goods as the route via Panama.

But in our case study, time difference appears to be small. It may be a couple of hours, it may be few minutes… Next section studies rail-road and road transit time.

3.2 Best transit time and frequency

In the case of Avignon-Paris, rail-road and road have similar travel times. For road, a journey of 700 km may be done in 11 hours, with respect to European drivers rules, including the rest times. Intermodal door to door travel time is made up of rail travel time (table 1), waiting time at terminals (all swap bodies are not transhipped as soon as they arrive in the terminals) and pre- and end-haulage travel time.

So, if we just look at road and rail transit times, we have the situation described by figure 2 for trains leaving Avignon to Pompadour at 19.00 and 21.00. We see that whatever the hour of departure from the origin, the lorry may be at the destination about 11.00 or 12.30 hours later (according to congestion…). Rail terminal to terminal transit time is between 8.35 and 31.30 hours, and more for door to door rail-road transit time which must take into account pre- and end-haulage.

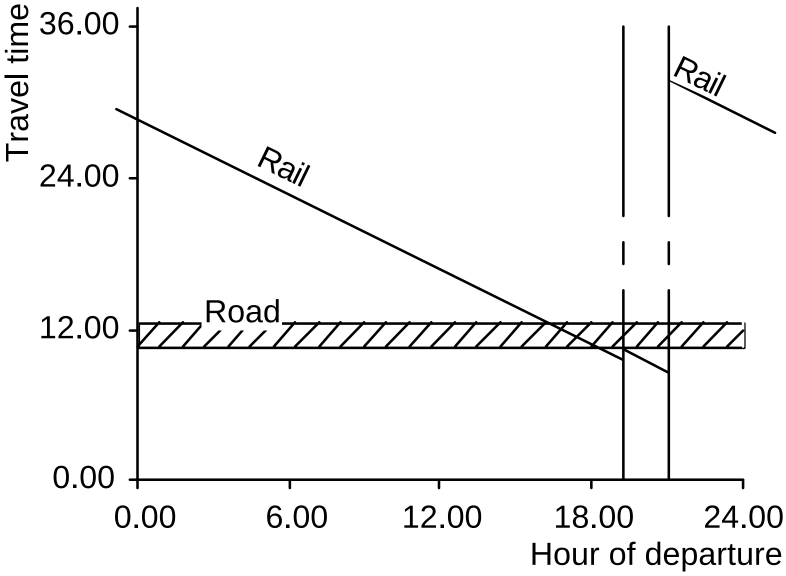

Figure 2: Travel time, according to the departure hour

The first conclusion that may be drawn from this figure is that rail-road seems to be worse than road, except for some loads sent late in the afternoon from the origin, between 17.00 and before 21.00. Of course, the departure hour depends of the travel time of pre-haulage and also of end-haulage.

The second conclusion is that the last train (21.00) is the most risky. The most urgent goods may be interested with it. For exemple parcel carriers are interested to keep their trucks loading as late as possible at their consolidation platform. Trucks tend to leave the platform at the latest hour, and it may happen that the swap body is a few minutes late for transhipment in the terminal. Next train is next day at 19.00. It’s a consequence of low frequency or bad over day distribution. Here, the four trains to Paris are leaving Avignon between 19.00 and 21.00. Trains could start each 6 hours, reducing the gap of a missing train. But today, Novatrans is not able to get another traffic distribution over the day (too low traffic volume during the day, bad schedule because of passenger priority, and Novatrans will remove its day train from Paris in september…). Another aspect of the risk of the last train is due to service quality. Parcel carriers (and they are not alone) are interested in being early at their consolidation platform near the destination. They are very sensitive to delayed trains, to punctuality.

The third conclusion is that from some shipper location, Novatrans is a good service when the shipment leaves at a good hour, but it is a bad service for other hours. It strengthens one of the market area conclusions, that there is no general rule, that transport modal choice must be studied case by case.

Then, when we look at transit times, we can’t see any general rule. If one rule must be choosen, it would be that most often, time doesn’t play in favor to intermodal.

The figure 2 is built for a journey of about 700 km. The same arguments could be used for longer distances. Intermodal as well as road travel times would be greater. For road, it would be possible to distinguish one driver case from shuttles where several drivers are used to get a quick road service (Germain et Niérat, 1989)… It would not lead to different conclusions.

3.3 Travel time

The time in the previous section is the fastest one. Some shippers are looking for speed, and will choose one or the other solution according to the time of departure at the origin.

Nevertheless most shippers or carriers are not concerned by speed, but by the ability to be at destination the next morning. Then, when the two solutions have this ability, the travel times are about the same. And then the added parts in the generalised costs do not change anything in the cost comparison. It means that the market areas are about the same.

It is the case in this comparison. Both intermodal and road are able to deliver next morning in Paris region a good sent from the south of France.

In this case, generalized cost (with time and transport components) does not change the results. It is not here a worthwhile method.

4. THE OPERATING TIME

If the generalised cost method does not appear suitable in this case, that does not mean however that time does not play any role. Two methods are investigated.

The first method is inspired by observations inside a trucking company that make use of rail-road transport (Niérat, 1990). It shows how the intermodal market area evolves with the required time to deliver goods to the customers (or to collect goods). It leads to a spatial share of the market.

One week spent at the carrier premises near the haulage operator (the man who dispatch work among drivers) made it possible to gather precise information on the real conditions of operating in the company and, in particular, on the role of time in pre- and end haulage. Intermodal market area of this company was built, with its precise operating performances.

Time is obviously a significant factor. To deliver a customer occupies sometimes the whole day of a driver. To go to a customer far away from the terminal takes time; unloading a swap body can last a long time (fragile goods, nof handling equipment at customer, queue). Up to what point does the duration of the operation deteriorate the profitability of intermodal?

The company carries out an estimate of the profitability of an operation by evaluating its duration. We will translate its reasoning by using the market areas theory.

In pre- or end-haulage, each operation (loading or unloading a swap body) is charged a cost according to its duration and to its distance. The day of a driver is broken up into four vacations, representing each one a quarter of day. The cost of an operation is then estimated on the basis of 1, 2, 3 or 4 vacations.

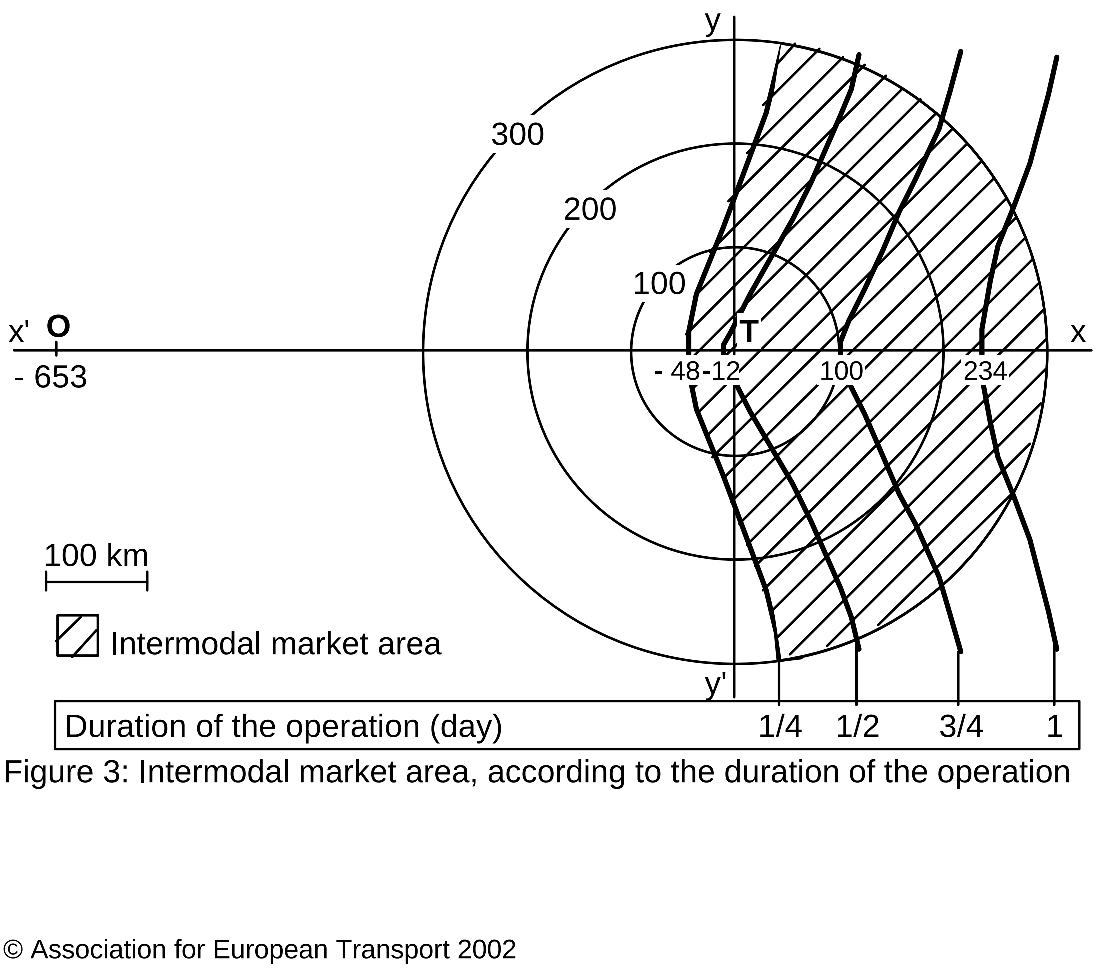

Figure 3: Intermodal market area, according to the duration of the operation

Figure 3 shows the market area of the company, built according to its own situation for a virtual origin O. It is arbitrarily limited to 300 km, distance which appears to be the maximum a truck can serve in a one day round trip.

When the operation is done in less than a quarter of a day, the market area is very large. On the left of the terminal (on the x'x axis), the company can serve clients located up to 48 km of the terminal. On the right, the market area has no limit, exept the distance a truck may serve during a quarter of a day (a round trip). When the operation takes more time, the border shifts towards the left, and the market area narrows. When the operation is one day long, the market area is limited to location more than 234 km from the terminal and up to 300 km.

A first conclusion is that the longer the operation, the narrower the intermodal market area. A second conclusion is that when road intermodal haulage is too time consuming, intermodal only concerns clients far from the terminal and in the opposite direction from the origin.

But the case of this company is not generalyzable. This company has been using intermodal for a long time, and has choosen its clients according to intermodal constraints. It only shows how time plays a role in this case.

5. THE PLACE OF TIME

The observation of this company shows another facet of time. In real time dispatching, time looks like uneasy constraints: (a) shippers give hour of rendez-vous (for loading or unloading) but do not respect them, it means that the dispatcher doesn't know the idle time at shippers, it may be what was said, it may be not; (b) because of congestion, the dispatcher doens't know how long will be the driving time between two clients; (c) during the day, shippers modify their commands. They add sendings, they remove others. The dispatcher must adjust his means with the evolutions; (d) the working day stops with the train departure. The train departure hour is a dead line. If the swap body arrives after the train has gone away, the dispatcher fails his work, and may lose his clients.

This time has no measure. But it actually plays a role in modal choice. And it is difficult to say what is this role. Is it possible to introduce this uncertainty in the theory?

The theory of market areas shares space in fields clearly allotted to each of the two studied solutions. The cost is the only parameter which determines this partition. Inside a zone, one of the two transport solutions is cheaper than its competitor. This zone is called its market area. On the border between the zones, the two solutions have the same cost. In this construction, the carrier adopts the cheapest solution. Thus, its choice is guided by the cost and the sharing corresponds to what the theory defines.

In fact however, choices are not so clear. If it is certain that the choice is favorable to the cheapest solution when the cost difference is large enough, it is also sure that other considerations are taken into account when the costs are not very different. Thus, according to whether the cost difference is more or less large, the cost is more or less important to define the space sharing. As it is done, the theory of market areas does not take into account this uncertainty: the only places for which the choice is unspecified are located on the border between the market areas.

Fuzzy set theory developed by Zadeh (1965) seemed to integrate this idea. Based on the fact that the belongness relationship is not always reduced to two possibilities (belongs or does not belong), Zadeh developed a theory where an element can belong "more or less" to a unit, to have "more or less" a property. Geographical and transportation works already integrate this theory (Leung, 1987, Teodorovic, 1999). But we don't make use of it, because it needs more precise informations than we really get, whith the replacement of the two-valued set-membership function with a real-valued function (membership is treated as a probability, or as a degree of truthfulness).

Our objective is more modest: we only wish to show that for some places our assumptions do not allow us to conclude. Fuzzy set theory inspired our reflexion, but we choose another way.

We will observe a simple rule: when the cost difference (relative or absolute) between the solutions of transport is higher than a given level, the least expensive solution is adopted; otherwise, the choise is uncertain.

Then for a given level, this rule allows to use again the market areas theory to build three boundaries. The first boundarie is the set of places for which the cost of the two solutions is the same. For the others, the cost difference is equal to the given level, and one solution is least costly than the other. These boundaries share the space in four areas.

Figure 4 is built with a set of assumptions for which there is a market area for intermodal transport (it doesn't exist in all the cases) for the Novatrans service between Avignon and Paris. The productivity of haulage around the terminal is defined with the two parameters used by Niérat (1997) with three operations per day and per truck and 50% of empty hauls. It's a usual case. We set the cost difference to 5%, that is a solution is choosen when it is 5% less costly than the other. The space is shared in four areas: the external zone (white) is that of the road transport, the interior zone (black) is that of intermodal. Between the two, appears an intermediate zone (hatched) for which the choice is "uncertain". This zone itself is shared into two (by the direction of the hatchings), to distinguish the solution which profits from an advantage in cost, road for external hatched surface, intermodal for interior hatched surface.

This formulation is very instructive. It reveals a zone where the choice is uncertain, when the cost difference is not large enough to be significant. The level of 5% was selected for the demonstration, but it does not have more significance. One will retain the principle rather than the numerical values.

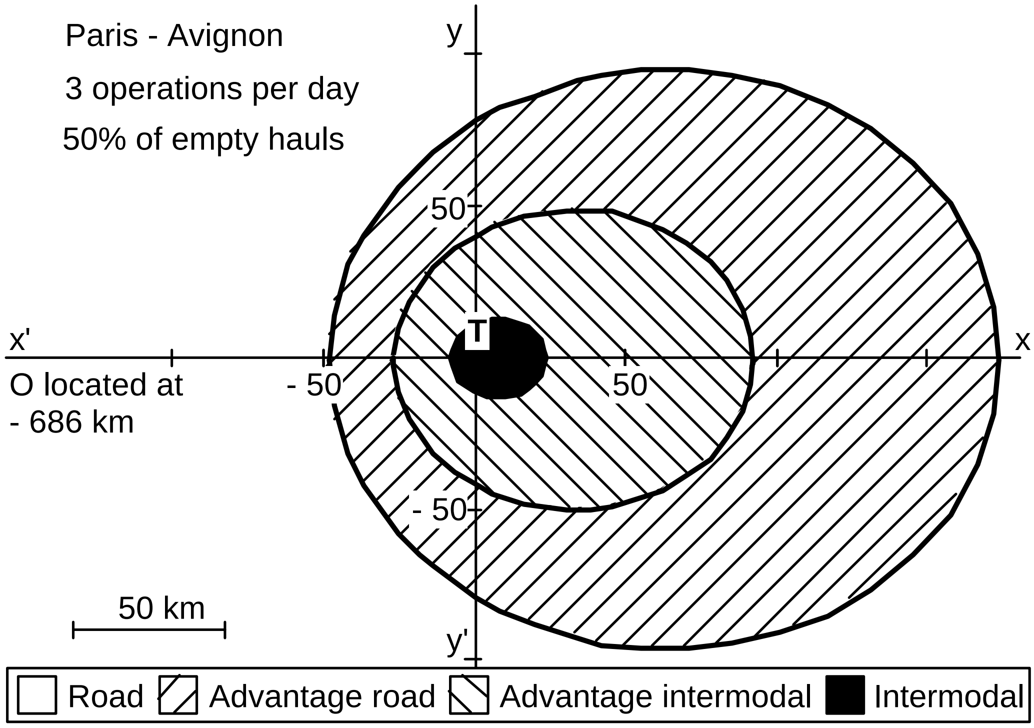

Figure 4: Uncertain choice places

First of all, it appears that uncertain surface is a large zone, and that it has a geometry. Its width varies according to direction. It is minimal in the direction of the origin (when end-haulage goes towards O); on the figure, it is close to 40 km. It is maximum in the prolongation of the railway link and reached here 150 km.

The uncertain zone knows significant variations of surface, according to the "ingredients of profitability", parameters we identified earlier. Without taking them again one by one, it is however necessary to insist on this point because the surface for which the choice is favourable to rail-road (black area) can disappear completely. It is what would occur in particular if we had retained to build figure 4 two operations per day for end-haulage instead of three or if we had considered that the carrier did not profit from any discount from Novatrans. In certain cases, the uncertain zone can completely disappear, when the cost of intermodal transport is too high compared to that of the road transport. This is the situation when the railway distance is too short.

Which lessons can be drawn from this presentation?

The uncertain zone gathers the places for which the cost difference is not sufficient to determine the modal split. It is there and only there that the other characteristics of transport may play a role. We assumed that these characteristics were not determining to hold the first role in the choice. But here, because first role is erased when the costs have about the same level, they occupy the front of the scene.

Here, competition is time oriented. The transportation choice relies on time (duration of the course, times of departure and arrival), quality of service, reliability, punctuality… It is difficult to say which solution best suits these characteristics. It may be the place of subjective since each decision maker has his own vision, function of his experiment, his need and his initial reaction. Everywhere else, competition is cost oriented.

According to this more or less subjective appreciation, a solution is said to be the best when the cost difference does not seem an obstacle. Then, for those who will judge the intermodal solution best adapted, the intermodal market area will include the uncertain zone; contrary, for those who will consider that road solution is better, the road market area will extend on all the uncertain zone.

If intermodal is favoured when cost difference is acceptable, road transport preserves an area since its territory surrounds that of intermodal transport.

But, if road transport is favoured when cost difference is acceptable, intermodal market area is strongly reduced. This reduction is a significant handicap because it limits possibilities of loading. This remark is to compare with the conclusions on the effect the length of the railway link on the size of the intermodal market area: the handicap will be a function of the density of industrial environment; it is stronger as industrial environment is not dense.

6. CONCLUSION

In competition between all road and intermodal freight transportation, it is important to know where and in which conditions each solution looks its best. Many factors play a role in modal choice. But the study of a particular case where solutions are available and presents a high degree of substitutability allows to only take into account cost and time.

In this comparison, we assume that cost plays the first role and time the second one. Then, the theory of market areas was used to build the field of each transport solution. It defines areas where competition is cost oriented and areas where competition is time oriented, when cost difference is small. The interest of this method is to show that cost and time do not play the same role, but that there are places where each one is determining.

This method may integrate other factors. The idea is to rank the factors. Some are first ranked, others second ranked… Then the method builds a geometry of uncertainty, and define the loci where first ranked factors are similar: it is the place where differences in second ranked factors may be decisive.

REFERENCES

Bascombe, A. (1998) Shipping it east, *Containerisation International*, June, 62-63.

Boiteux, M. et Baumstark, L. (2001) *Transports : choix des investissements et coût des nuisances*, La documentation française, Paris.

Germain, C. et Niérat, P. (1989) *Traction routière en longue distance : les navettes, une organisation particulière*, Rapport Inrets n°91, Inrets, Arcueil.

Harper, D.V. and Evers, P.T. (1993) Competitive Issues in Intermodal Railroad-Truck Service, *Transportation Journal,* **32** (3) 31-45.

Jiang, F. et Calzada, C. (1998) Modélisation de la valeur du temps des chargeurs, *Notes de synthèse du SES,* 119 5-10.

Konings, R. and Ludema, M. (2000) The competitiveness of the river-sea transport system: market perspectives on the United Kingdom-Germany corridor, *Journal of transport geography,* **8** (3) 221-228.

Leung, Y. (1987) On the Imprecision of Boundaries, *Geographical Analysis*, **19** (2) 125-151.

Niérat, P. (1990) *Transport combiné : organisation des dessertes terminales*, Rapport Inrets n°110, Inrets, Arcueil.

Niérat, P. (1997) Market area of rail-truck terminals: pertinence of the spatial theory, *Transportation Research***,** **31A** (2) 109-127.

Teodorovic, D. (1999) Fuzzy logic systems for transportation engineering: the state of the art, *Transportation Research,* **33A** (5) 337-364.

Wynter, L.M. (1995) The value of time of freight transport in France: estimation of continuously distributed values from a stated preference survey, *International journal of transport economics,* **22** (2) 151-165.

Zadeh, L.A. (1965) Fuzzy sets, *Information and Control*, **8**, 338-355.