1. CONTEXT: THE HEAVY GOODS TRAFFIC ON THE ATLANTIC COAST AND THE NEED OF NEW TRANSPORT SOLUTIONS

1.1 The Pyrenees and Alps road traffic bottleneck

The last 20 years, heavy goods road traffic flow greatly increased across the Pyrenees and the Alps. In 2004, 9.5 millions Heavy Good Vehicles (HGV) ran across the French Pyrenees or Alps. Since 1999, the vehicle number increased by 17 % and the tonnage by 23%. Spain, that benefits this few last years from a better economic growth than most of its European partners, developed its international trade and so its goods traffic across the Pyrenees. Though traffic growth across the Pyrenees decreases, it still remains substantial (28 % between 1999 et 2004).

This huge traffic demand is stressing the capacity of road transportation and has significant impact on the environment. As congestion begins to be particularly worrisome in some border zone, new transport solutions have to be found. The lack of available land and population protest against new roads construction added to road huge cost and funding constraints enhances the development of maritime solutions such as short sea shipping and motorways of the sea.

1.2 Sea motorway advantages

Motorways of the sea appear to be quite attractive solutions to traffic problems. As a frequent and regular service, offering a door-to-door solution to customers, it may substantially contribute to bypass road congestion. This mode isn't land consuming and is environmentally friendly. For the carrier, it can guarantee transit time and avoid delays due to traffic congestion, it is reliable and enable door-to-door solutions. It can be cheaper than road transport.

Considering this, the European Union first promoted motorways of the sea in its September 2001 "White Paper on European Transport Policy for 2010: time to decide" that sets a number of targets to ensure competitiveness and sustainability of mobility in 2010. In the paper short sea shipping and motorways of the sea were to play a key role in reaching these targets. These objectives are again asserted in the mid term review of the paper. Then, since 2003, the EU has granted financial incentives to set up new services through
the Marco Polo programme. And recently, the 2004 revision of the guidelines for the trans-European transport networks (TEN-T) included the development of four sea motorway corridors as one of thirty priority projects that will receive EU funding under TEN-T. The Atlantic and the Mediterranean coasts are among the areas chosen. These two corridors particularly concern France.

Further to the EU decision, Spain and France worked on a sea project on the Atlantic coast to improve transport conditions across the Pyrenees, and a common French and Spanish tender is going to be put out on the end of 2006.

2. WHY USING A COST-BENEFIT ANALYSIS FOR MOTORWAYS OF THE SEA?

2.1 Classical criterions in sea motorway project choice

To make motorways of the sea a success, the EU Commission sets three conditions:

"- First, in order to obtain the necessary concentration of freight flows, choices have to be made concerning ports and intermodal corridors and services.
- Second, all actors in the supply chain have to be committed to these projects.
- Third, motorways of the sea need to feature the best available quality throughout the chain in order to be attractive for users."

And they are two mains criterions in Marco Polo programme when applying for a subsidy:

- the effective modal shift measured in tonne-kilometres;
- the quantitative environmental benefits based on a comparison of the relevant external costs for old "road"-route with the new "modally shifted"-route. The route running through Marco Polo Programme countries are the only one included in the grant calculation.

Concerning the Atlantic coast project currently in study, Spain and France will base their choice on classical economic and financial criterions. But to value long-term environmental effects and to have a global picture of the sea motorway benefits for the community, France also decided to estimate the project collective value, which is quite innovative. This value will be calculated in accordance with a cost-benefit analysis methodology. This methodology is still under construction and first tests on the Toulon-Rome have been carried out to understand which parameters impact the most on the economic return of a motorway of the sea. This paper will discuss these two points.
2.2 Cost-benefit analysis relevance

Cost-benefit analysis aims

Cost-benefit analysis (CBA) takes into account the socio-economic effects of short sea shipping including road congestion, pollution, effect, and road safety. It enables to set up common indicators in order to compare sea projects on homogenous and transparent criterions. The aim of the analysis is to appraise the benefits of motorways of the sea in comparison with road impacts; as a consequence, it only takes into account the environmental and social effects of HGV shifted on a motorway of the sea. If the ship carries other freight they will only be considered in the sea operator financial return. This will give rational elements to enlighten decision makers on sea motorways advantages. Of course to totally inform decisions makers, CBA has to be completed by qualitative analysis on economic development, landscape effect, environmental impact, etc. This part will be included in the French global approach, but it hasn't yet been applied and is beyond the scope of this paper.

Time period

Economic calculation is only significant if applied on a long time period. This period fits road and railway projects whose infrastructures are built for a long time, but is less adapted for sea motorway services that can quickly disappear if they happen to be non profitable. In the Marco Polo Programme, the first three years benefits and costs alone are taken into account for granting the subsidy. However, to really value sea motorway environmental and social benefits it is essential to have a long-term overview. So a 20-year time period analysis will even so be carried out, but a great attention will be paid to the uncertainty of the results.

Discounting

Thanks to the discounting, cost-benefit analysis enable to measure the time value of resources and to compare investment alternatives with different stream of future benefits and costs. The choice of the discount rate is important because it directly conditioned the economic calculation results. For the first tests, the French current discount rate of 4% that allow a good description of long-term effects was used. It may be changed in future study to take the international context into account. To enable comparisons, the entire project will be assessed in constant euros (2000 euros).

Rational assessment tools

Many measures to compare costs and benefits exist in CBA. We will discuss here two of them used in the first tests: the net present value and the internal rate of return.
The Net Present Value (NPV) measures the variation in the collective utility due to a project implementation. It is equal to the difference between the net global benefit and the investment cost discounted on the same base date. It takes into account the surplus for the community this includes users (carriers), State, road and sea operators and neighbours. The NPV is calculated excluding tax. This indicator is used to compare, grade and select independent projects. The selection criterion for a project consists of choosing from those, which have a positive NPV, the one with the maximum net present value.

The Internal Rate of Return (IRR) is the discount rate that makes the NPV equal to zero. It is used to measure the degree of opportunity and also risk associated with the project and enables to compare the different alternatives of a same project. Compared to the discount rate it enables to see if the project provides gains for the community.

So, these two measures will help comparing sea motorway projects and making choices.

3. FRAMING A CBA METHOD FOR SEA MOTORWAYS PROJECTS

A CBA analysis is composed of various steps: defining the actual situation, defining the base case, defining projects scenarios, allocating monetary cost and benefit to the base case and the scenario, testing sensitivities. They will give a robust, transparent and rational picture of the project socio-economic return.

We will only discuss here the specific hypothesis that had to be set up at each stage of the CBA process for appraising sea motorway projects.

3.1 Defining the current situation

The current situation defining entails:
- current road and maritime transport demand and supply in the study area description. The study area includes all the roads whose traffic may be diverted on the new sea motorways but also ports concerned by the sea motorway and their hinterlands;
- environmental context concerning air pollution, noise, greenhouse effect.

3.2 Defining the base case

The economic calculation and the financial calculation are, by definition, differential calculations in which we compare two states of the economy, one without project: the base case and the other with project. Therefore the greatest care must be taken to determine the base case.
The base case is the most probable situation in terms of transportation supply and demand without a project. It includes a global economic and traffic growth hypothesis and network hypotheses.

To start, it was decided to use average French economic forecast to carry out the calculation i.e. a GDP growth of 1.9% and a household consumption growth of 1.6% between 2004-2025. This values will be used to test the methodology, but the aim is then to set economic standards adapted for international projects. Road traffic growth taken into account will be the one nationally spread. Local sea motorway traffic growth hypothesis given by the sea operator will be used in the appraisal if they are well justified.

Concerning the base network, it is rarely the "do nothing" as it entails:
- infrastructure under construction;
- projects of transport master plan in progress;
- any project or operating measure which will most probably be implemented before the studied project and which should not be jeopardised by the studied project;
- and more generally any external element to the project having a marked effect on the project.
It may also include transport infrastructures, which are to be maintained, modified, deferred or abandoned if the project is implemented. For sea motorways, a particular attention must be paid to the concurrence of road-rail or maritime container transport.

Pricing measures, service quality of other mode must also be taken into account in the base case if they have a substantial effect on the traffic of the studied project. In the sea motorways context a vigilant eye must be kept on road rail transport projects that could target the same customers as the sea motorway.

### 3.3 Defining project scenarios

When defining the project scenarios, one must detail the new transport supply. The sea motorway description must contain information about service frequency, capacity, transit time, loading and discharging time, and some ship characteristics as energy consumption.

Concerning traffic demand, it is important to know where the HGV shifted on motorways of the sea come from and run to. A distinction must be made between accompanied and unaccompanied transport. The maritime operator must precise if he already has transport contracts with partners, and who these partners are. This data among others will enable to compare traffic risk on different project.
3.4 Allocating monetary costs and benefits to the base case and the scenario

Costs

Costs associated with construction, operating, and maintenance activities of each alternative being compared are identified and monetised. They are summarized in the table here below.

<table>
<thead>
<tr>
<th>Building costs</th>
<th>Cost of a new shipbuilding, port developments, railway or inland waterway connections developments, road development.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance and operating costs</td>
<td>Vessel costs (fuel, insurance, crew costs, etc.), road infrastructure operating costs.</td>
</tr>
<tr>
<td>Port costs</td>
<td>Handling costs, port taxes, charges for specific services such as water, storage, pilots, towage, etc.</td>
</tr>
</tbody>
</table>

Table 1 Costs definition

Benefits

The net benefits of a project during the year $t$ is calculated as follow:

$$a_t = \Delta T_t + \Delta X_t + \Delta M_t + \Delta R_t + \Delta Env_t + \Delta S_t + \Delta C_t - \Delta P_t$$

With
- $\Delta T$: the carrier benefits composed of transit time gains, avoided road costs, avoided toll, and sea motorway fares (-$\Delta M$);
- $\Delta X$: the state benefits composed of road taxes variations (transfers from carriers to state);
- $\Delta M$: sea motorway fares (transfers from carrier to maritime operator);
- $\Delta R$: road operator revenue variation (transfer from carrier to road operator);
- $\Delta Env$: air pollution, noise and greenhouse effect value;
- $\Delta C$: congestion gains;
- $\Delta S$: safety gains;
- $\Delta P_t$: project port, operating and maintenance costs.

Monetary values

To calculate this net benefit value, monetary values have to be assigned. For the first tests, it was decided to use the French national monetary values for transport infrastructure described in Table 2.

When no French standard values were available, in particular for sea motorway transport, hypotheses were made. It was so considered that motorways of the sea have only marginal noise, safety and air pollution impact that can be neglected. Noise avoided because of HGV shifting from road to sea is also considered marginal and not taken
into account. These hypotheses are in line with Marco Polo and IWW Infra recommendations.

Concerning time value, it was supposed that time value of an HGV on a ship with its driver was the same as the time value of an HGV on road. For HGV on a ship without driver, it was considered that the time value of the HGV during the loading and discharging and the sea transit time was of 15 €. This includes saved driver costs and organisation additional costs.

<table>
<thead>
<tr>
<th></th>
<th>2000 value in 2000 euros</th>
<th>Growth hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGV operating costs</td>
<td>0.13 € / HGVxkm</td>
<td></td>
</tr>
<tr>
<td>HGV fuel costs</td>
<td>0.26 € / HGVxkm</td>
<td></td>
</tr>
<tr>
<td>Time value for HGV on road</td>
<td>38.4 € / h</td>
<td>The shipper time value increase as 2/3 of the GDP.</td>
</tr>
<tr>
<td></td>
<td>carrier operating value : 31.4 € / h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>shipper time value : 7 € / h</td>
<td></td>
</tr>
<tr>
<td>Time value for HGV with driver on sea</td>
<td>38.4 € / h including :</td>
<td>The shipper time value increase as 2/3 of the GDP.</td>
</tr>
<tr>
<td></td>
<td>carrier operating value : 31.4 € / h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>shipper time value : 7 € / h</td>
<td></td>
</tr>
<tr>
<td>Time value for HGV without driver on sea</td>
<td>15 € / h</td>
<td></td>
</tr>
<tr>
<td>Road pollution</td>
<td>0.006 / HGVxkm (country)</td>
<td>2000-2020: - 4.9 %</td>
</tr>
<tr>
<td></td>
<td>0.099 / HGVxkm (urban area with average density)</td>
<td>From 2020: + 1.6 %</td>
</tr>
<tr>
<td></td>
<td>0.28 / HGVxkm (urban area with high density)</td>
<td></td>
</tr>
<tr>
<td>Greenhouse effect</td>
<td>100 € / carbon tonne</td>
<td>From 2010: + 3 %</td>
</tr>
<tr>
<td>Road safety</td>
<td>0.018 € / HGVxkm</td>
<td>From 2000: + 1.6 %</td>
</tr>
<tr>
<td>Road congestion</td>
<td>0.34 € / HGVxkm for congested 2x3 lanes motorway</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 French standard monetary values

4. EXPERIMENTAL IMPLEMENTATION OF THE METHOD ON THE TOULON CIVITAVECCHIA MOTORWAY OF THE SEA

To have a general survey of what can be expected for a motorway of the sea and to identify problems in the methodology implementation, a first test has been carried out on the Toulon Rome (Civitavecchia) sea motorway that was launched in 2005 by Grimaldi Louis Dreyfus (GLD). This line capacity reaches 160 trailers, 150 cars and 400 cabin passengers. It makes three rotations a week. Before the sea motorway implementation, a deal was concluded with the logistic group GEFCO to carry PSA new cars from France to Italy. Readers are warned that this test is experimental and based on many hypotheses so the results are not validated. The aim of this was to provide a global view of parameters influencing sea motorway CBA and to understand
how they impact on the results. This isn't a robust appraisal of the Toulon-Rome motorway of the sea.

4.1 Hypotheses

Test scope

The test is about the gain provided by the shift from road to sea of HGV shipped on the GLD line. The economic and social benefits of shipping passengers and PSA new cars aren't taken into account but their financial contribution through fare is included in the calculation of the operator benefits. The time calculation is of 20 years beginning in 2005. The base year is 2004, the monetary value used are those described in paragraph 3. They are calculated in 2000 euros.

Transport network

As no data about the complete origin-destination of HGV shipping on the motorway of the sea were available at the time of the test, it was supposed that before the implementation of the sea service, all the HGV were running on the French A8 and the Italian E80 motorways from the La Barque interchange to the "North Civitavecchia" exit slip road. So their "old" road route was of 775 km long. This set up the base network. (This is a rough estimate because the HGV base route is much longer than that, but the benefit and cost allocated to the route up and down this point would cancel each other out in the differential calculation between the base case and the project scenario.)

The project scenario network is composed of the sea route between Toulon-Bregaillon port and Civitavecchia port and of the initial freight collection and final distribution road routes between the La Barque interchange and the Toulon port and between the "North Civitavecchia" exit slip road and Civitavecchia port. This initial freight collection and final distribution road routes are 74 km long.

4.2 Traffic

GLD traffic forecasts between 2005 and 2008 are used for the appraisal.

After 2008, it is supposed that the shipped HGV traffic increases as the road traffic across the Alps in Vintimille i.e 2.8% per year from 2008 to 2017 and 2.5% from 2018 to 2025. These figures are those of the Lyon-Turin railway project forecasts. The real traffic data were not available.

The passenger numbers is supposed to increase by 2% per year.

The PSA new cars traffic deal with the logistic group GEFCO is supposed to remain of 30000 vehicles per year after 2008.
These traffic growths may be questionable but they are only hypotheses to carry out the test.

4.3 Sea motorway operator costs and benefits

GLD ports, maintenance and operating costs forecasts as fret and passengers port taxes forecasts between 2005 and 2008 are included in the appraisal. They increase between 2008 and 2025 according to the operator growth hypothesis from 2005 and 2008. GLD costs forecasts data used in this appraisal can't be published in detail.

Sea motorway fares are those given by GLD calculated in 2000 euros, in Table 3.

<table>
<thead>
<tr>
<th>Toulon Civitavecchia forecasted fares</th>
<th>2005 euros</th>
<th>2000 euros</th>
</tr>
</thead>
<tbody>
<tr>
<td>passengers</td>
<td>80 €</td>
<td>74 €</td>
</tr>
<tr>
<td>accompanied trailers</td>
<td>450 €</td>
<td>385 €</td>
</tr>
<tr>
<td>unaccompanied trailers</td>
<td>279 €</td>
<td>257 €</td>
</tr>
<tr>
<td>PSA new cars</td>
<td>67 €</td>
<td>62 €</td>
</tr>
</tbody>
</table>

Table 3 Motorway of the sea fares

The French government subsidy of 1M€ alone was integrated in the analysis. At the time of the tests, the amount of Marco Polo subsidy wasn't decided.

4.4 Transit time gains

The base transit time by road between La Barque and the "North Civitavecchia " exit slip road is about 10h50 hours excluded legal break time. These reach 12h30 hours (11h + 2x45 mn), so the total base transit time is of 23h20. The French legal break times were taken into account. Organisations where several drivers drive the HGV to save break times were not envisaged.

The sea transit time is of 14h30. 4h are added for the loading and discharging time and 1,1h is also added for the initial freight collection and final distribution road route. So the project scenario time is of 19,5h.

Time is valued as indicated in paragraph 3.

4.5 Avoided toll

The French A8 and part of the Italian E80 motorway are tolled motorways. The average fare for the base route is 118 € and for the freight collection and distribution route of the project scenario 18 €.

4.6 Congestion mitigation

The French standard value for assessing HGV impact on congested 2x3 lanes motorways is applied on 100 km. It entails the HGV impact on the A8 congestion mitigation between La Barque and Nice and an increase in the
congestion on the freight collection and distribution road route between Toulon port and La Barque. Congestion is supposed to stay constant between 2005 and 2025 regarding the projects planned in the Alps area to shift trucks from road.

4.7 Air pollution

It is assumed that the "old" road route and the project scenario road route always cross urban area with medium density since they are almost always coast roads.

4.8 Sensitivity analysis

As lots of uncertainty remains in the hypotheses chosen to achieve the test, sensitivity analysis have been carried out on the following parameters:
- traffic;
- transit time monetary value;
- pollution;
- congestion;
- GLD costs.

5. RESULTS

With the above hypotheses the CBA shows that the motorway of the sea that takes HGV from road provides gain for all the community. Between 2005 and 2025 the NPV is about 32 M€ with a 4% discount rate and the IRR about 23 %.

<table>
<thead>
<tr>
<th>State</th>
<th>- 51 M€ (but they are transfers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road operators</td>
<td>- 34 M€</td>
</tr>
<tr>
<td>Maritime operator</td>
<td>29 M€</td>
</tr>
<tr>
<td>Carrier</td>
<td>62 M€</td>
</tr>
<tr>
<td>Externalities</td>
<td>28 M€</td>
</tr>
<tr>
<td>Total: Net present value</td>
<td>32 M€</td>
</tr>
</tbody>
</table>

Table 4 CBA results

Externality gains are important: about 28 €. They are mainly composed of pollution and congestion gains. Greenhouse gains are negative: the ship emits more carbon than HGV on roads, even when the on ship HGV number reaches the ship capacity. These results must be put into perspective with the fact that cars and passengers on the ship aren't taken into account in this appraisal.

The results sensitivity to externalities is substantial as shown in the Tables 5 and 6. It indicates that externalities monetary value for the community has a great influence on CBA.
Air Pollution

<table>
<thead>
<tr>
<th></th>
<th>Considering country value</th>
<th>Considering urban area with medium density value</th>
<th>Considering urban area with high density value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externalities</td>
<td>13 M€</td>
<td>28 M€</td>
<td>57 M€</td>
</tr>
<tr>
<td>NPV</td>
<td>18 M€</td>
<td>32 M€</td>
<td>61 M€</td>
</tr>
<tr>
<td>IRR</td>
<td>11%</td>
<td>23%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Table 5 Air pollution value sensitivity

<table>
<thead>
<tr>
<th></th>
<th>Congestion 50 km long</th>
<th>Congestion 100 km long</th>
<th>Congestion 200 km long</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externalities</td>
<td>20 M€</td>
<td>28 M€</td>
<td>43 M€</td>
</tr>
<tr>
<td>NPV</td>
<td>25 M€</td>
<td>32 M€</td>
<td>48 M€</td>
</tr>
<tr>
<td>IRR</td>
<td>18%</td>
<td>23%</td>
<td>37%</td>
</tr>
</tbody>
</table>

Table 6 Congestion length sensitivity

For the carrier, fuel and time saving contribute the more to the benefits. Compared to externalities, the monetary value of time saving has a limited effect on the results.

<table>
<thead>
<tr>
<th>Time gains</th>
<th>With a value of time of 12€/h for unaccompanied trailers</th>
<th>With a value of time of 15€/h for unaccompanied trailers</th>
<th>With a value of time of 38€/h for unaccompanied trailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Benefits</td>
<td>64 M€</td>
<td>62 M€</td>
<td>50 M€</td>
</tr>
<tr>
<td>NPV</td>
<td>34 M€</td>
<td>32 M€</td>
<td>21 M€</td>
</tr>
<tr>
<td>IRR</td>
<td>25%</td>
<td>23%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Table 7 Unaccompanied HGV value of time sensitivity

As fuel price impacts on both carrier and maritime operator costs, its increase or decrease has little influence on the results.

With the above hypotheses of traffic and costs, the motorway of the sea is profitable for the maritime operator in 2010 or so (depending of the amount of Marco Polo subsidy). Table 8 shows that the operator benefits are greatly dependent upon costs (port, maintenance and operating costs).
Table 8 Costs sensitivity

<table>
<thead>
<tr>
<th>Costs</th>
<th>-20%</th>
<th>Medium costs hypothesis</th>
<th>+20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maritime operator</td>
<td>69 M€</td>
<td>29 M€</td>
<td>- 11 €</td>
</tr>
<tr>
<td>NPV</td>
<td>73 M€</td>
<td>32 M€</td>
<td>- 7 €</td>
</tr>
<tr>
<td>IRR</td>
<td>109%</td>
<td>23%</td>
<td></td>
</tr>
</tbody>
</table>

With 20% added traffic, the motorway of the sea becomes profitable for the maritime operator in 2008. Benefits of this traffic increase aren't linear because of the need to charter another ship. If the charter of a new ship provides a 30% traffic increase on the ship, then the NPV is about 38 M€, but if this charter provides no traffic increase the NPV is about 23 M€. If the maritime operator decides not to charter another ship its gains are more important.

Table 9 Sensitivity to a 20% traffic increase

<table>
<thead>
<tr>
<th>+ 20 %Traffic impact</th>
<th>With one ship</th>
<th>With two ships and no particular increase</th>
<th>With two ships and a 30 % traffic increase due to service frequency improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maritime operator</td>
<td>61 M€</td>
<td>36 M€</td>
<td>50 M€</td>
</tr>
<tr>
<td>Externalities</td>
<td>38 M€</td>
<td>17 M€</td>
<td>21 M€</td>
</tr>
<tr>
<td>NPV</td>
<td>70 M€</td>
<td>23 M€</td>
<td>38 M€</td>
</tr>
</tbody>
</table>

With 20% less traffic, the sea motorway has a negative NPV of –7 M€, externality gains are about 18 M€ and the maritime operator loses 7 M€ between 2005 and 2025. So traffic is a very sensitive parameter.

6. CONCLUSION

In a context of congested roads across the Pyrenees or the Alps, the motorway of the sea seems to be a sustainable solution. First CBA test tends to show that its effect on the environment can be significantly positive. However, a great attention must be paid to sea motorway impact on the greenhouse effect: indeed if traffic on the ship is not sufficient, it can emit more carbon than trucks on road, because ship motors don't have car motors emission qualities.

Regarding this CBA experimental calculation, motorways of the sea appraisal seems to be more sensitive than classical road appraisal through CBA. Externalities particularly influence the NPV value, but costs and traffics are also very important parameters.
This test confirms that sea motorway impacts are of long term and urges to recommend CBA approach to have a full picture of the project effects. But it also stresses the importance of risk analysis of the main parameters i.e. costs, traffics and externality value that can have a huge impact on the sea motorway economic returns.

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