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Risk management of French harbours structures: stakes, current practices and needs – Experience feedback of owners

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Abstract

This paper deals with a national investigation within the GEROM project (Risk Management of maritime and river harbours structures) that aims to analyse the patrimony of French harbours owners, their actual maintenance's practice and associated restraints, but also their needs in risk management and control.

Investigation was prepared with a special care to its use in risk analysis and the results are presented by focusing the analysis on observed levels of heterogeneity.

Keywords: Experience feedback, harbours structures, inquiry, owners, maintenance practice.

1. Introduction

Maintenance of harbour heritage is a major economic and tourist stake. The problem of the owners consists in guaranteeing the ageing structures' operation (wharfs, dry docks, dikes, etc.) with good safety, costs and availability conditions. Moreover the harbour development space is more and more limited in front of increasing environmental constraints.

Today, the maintenance decisions are taken without global vision of the associated risks. That is why they give place to long and difficult exchanges between managers who have various priorities: technical, strategic, financial, etc. Most of the time, maintenance is curative (after not foreseen events) or preventive, with a high cost (anticipation of predictable events) and more rarely, predictive (evolutions prediction). Decisions are generally based on budgetary, operation and safety constraints. Furthermore, structures are operated in more severe service conditions than initially. In these conditions, owners take two major risks: uncontrolled maintenance costs or uncontrolled safety and unavailability costs.

To deal with this problem, the GEROM project (Risk Management of maritime and river structures in harbours) was built within the GIS MRGenCi (Grouping of Scientific Interest "Risk management in Civil Engineering") and lies on a partnership between Oxand company and the Research Institute in Civil and Mechanical engineering of Nantes. The GEROM project takes place from 2006 till 2009. It aims to:

- collect all the elements necessary for the development of an optimized methodology of technical management;
- help owners draw and optimize their decisions concerning the durable management of their structures.

In the first phase, with the support of the CETE de l'Ouest (Engineering centre of the French Ministry of Public Works), a national inquiry was carried out with owners about the technical management of the maritime and river harbours' structures.

This national inquiry's preparation was based on the FMECA method (Failure Mode Effects and Criticality Analysis) *(Peyras et al., 2006, Billard et al., 2006 et 2007, Boéro et al., 2006)* and on maintenance programs (inspection and repairs). Then our objective was to identify and reap information which can be integrated into a risk analysis applied on harbours' structures:

- structures' functions (dikes, locks, graving docks, quays, landing stages, bridges, buildings, roads, etc.), position in the system (**functional analysis**);
- strategic character for the economic, tourist development, national defence, etc., safety of the installations, security of the persons, environmental protection, control of the direct costs (maintenance) and indirect costs (availability, public image) **(consequences, stakes)**;
- constructive techniques, ages, materials, geometry, environment **(factors influencing the frequency of failure modes)**;
- current practice of maintenance (politics and strategies), organization, constraints and capacities to fulfil operations **(maintenance programs)**.

Results are presented by centring the analysis on the observed levels of heterogeneity.

2. Progress of the national inquiry on the harbours heritage management

2.1 Objectives

The inquiry objectives were to:

- facilitate an experience sharing between harbours structures owners and the various actors of this project;
- draw up an overview of the French national patrimony, current maintenance practices (maintenance politics and strategies, experience feedback on the harbours' pathologies, efficiency of technical repair, etc.) and needs in this domain.

2.2 Spatiotemporal perimeter

This inquiry was performed from January 24th to May 12th 2006, and completed in the first quarter 2007.

The geographical perimeter covers a total amount of 7 Autonomous Harbours (AH), 16 National Interest Harbours (NIH) and 3 Military Harbours (MH) located along the French metropolitan coast.

The 532 harbours, already decentralized since 1984, and managed by the General Councils of departments or Municipalities were not integrated because of their large number. However, some of them were interviewed (without inquiry's support) in order to have a global vision.

Further to the recent decentralization of the NIH since January 01st 2007, the status of NIH does not exist any more. In this article, this status was preserved to make the distinction with harbours already decentralized in 1984.

The referees are technical managers of harbours structures, and the following sources were used to contact them: (1) partners of the GEROM project; (2) the maritime structures' club (meetings reports); the AITPE 2005 (Phone book of the French state's engineers); the harbours websites.

2.3 Inquiry's process

The inquiry's process is the following:

- look for contacts;
- phone call in order to validate the contacts, introduce the project and the inquiry's process, fix a date of interview;
- send a quick questionnaire by e-mail to present more precisely the various themes which will be approached during the interview and the degree of involvement;
- get back the filled questionnaire and confirm the date of interview after phone relaunching;
- interview during approximately 2 hours (most of the time, meetings were taken two or three weeks after the first phone call).

This process obtained a very good answer level. In fact, of the 23 contacted harbours (AH, NIH, MH), 19 returned the filled questionnaire and were interviewed. That represents approximately 85 % of the targeted owners.

2.4 Themes

The various selected themes correspond to the different stages of the patrimony's management cycle:

- **Know:** which patrimony has to be managed?
- **Organize:** what are the available resources and how must they be structured?
- **Estimate:** what is the performance of the patrimony with regard to its functions and which are the associated risks?
- **Forecast:** how to predict the evolution of risks?
- **Evaluate:** what are the acceptable risks in short and long-term?
- **Define:** what are the actions to control risks?
- **Plan:** which are the actions to do first considering the maintenance constraints (financial, technical and exploitation)?
- **Capitalize:** what information must be capitalized to optimize the patrimony's management cycle?

3. Role and importance of the French harbour system

The French harbour system has an essential role: on the one hand for French business, tourism and industry; and on the other hand for European defence.

3.1 Military harbours

France is, with Great Britain, the only State member of the European Union that owns a navy with world vocation: it should be able to be present on all the seas of the world and to deploy the nuclear deterrence *(Marine Nationale, 2006)*.

Besides, military naval sector (ships construction and maintenance) is an important activity for the balance sheet of France's foreign trade.

In metropolitan France, the main naval bases are: Brest, Cherbourg, Lorient and Toulon.

3.2 Commercial harbours: goods, passengers

Three quarters of the world trade borrow the sea road. Sea transports are in perpetual growth especially since they remain the most economic (between 0.3 and 1.6 % of the final price of the product) and ecological transporting way *(Cluster Maritime Français, 2006).*

France is the 5th commercial world power (5th exporter and 6th importer) in goods value. Two-fifth of the tonnage (40.6 %) and the fifth of the value (20.2 %) of France's foreign trade were forwarded by using a seaport.

Ports and sea transport play an essential role for the imports of vital basic products for economy (oil, ores, coal, fertilizers, foodstuffs), but also for the exchanges of manufactured goods with strong added value. In 2006, French seaports treated approximately 380 million tons of freight: a half of liquid bulk (essentially oil), a quarter of dry bulk (cereal, coal, ores) and a quarter of containerised goods *(DGMT, 2006)*.

A total 564 ports with various activities (goods, passengers, fishing or sailing) are implanted along the French coasts.

Autonomous Harbours treat more than 80 % of sea traffic goods. National Interest Harbours treat the rest and more than 80 % of the passenger's traffic.

Consequently, stakes associated with military and commercial harbours rest on a set of installations for which maintenance is necessary.

4. Functional analysis

The studied system includes all the installations which fulfil the functions relative to ships, or to the operations on the ground (primary activities). The part of the heritage which contributes to the development of secondary activities (industries, tourism, town planning and service, etc.) is also considered. All the installations likely to interact with the primary and secondary activities are presented on *Fig. 1*.

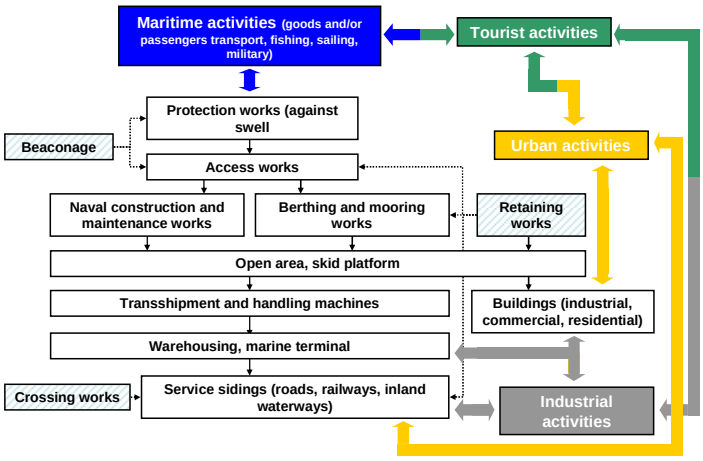

Fig. 1 Activities in interaction with the works composing the harbour system.

The role of the system can be assured only if all the functional domains are successful. For example, for a commercial harbour:

- the ship must be able to fasten quickly and easily to its berthing and mooring's structure. For it, the ship is often constrained to cross diverse docks, sluice and locks before arriving alongside the quay;
- the goods must be able to be quickly transhipped or, if necessary, stored for a more or less long time in the port with the aim of its forwarding, all of it with the lowest cost;
- finally, goods have to pass in transit through the port to the crossings with the outside transport networks by ground transportation (roads, railroads) and\or ways of inner navigation.

5. Quantitative patrimonial analysis

5.1 Typological analysis

The distribution, in linear kilometres, of the constructive techniques used for the berthing and mooring's structures is presented on *Fig. 2*.

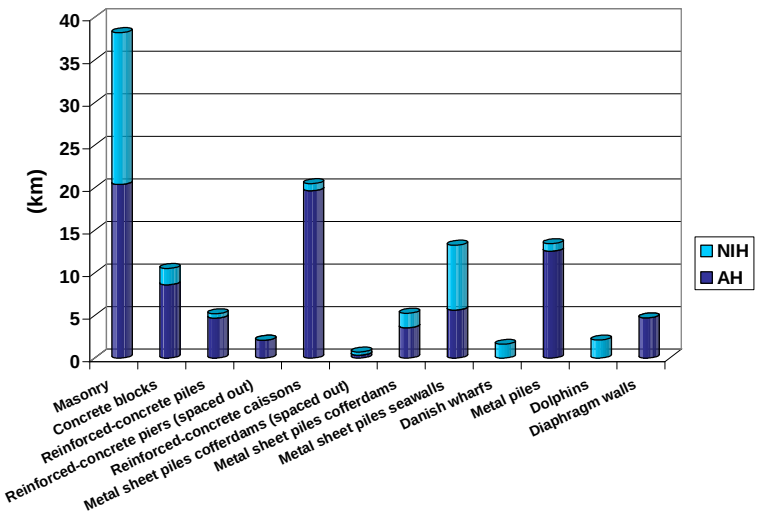

Fig. 2 Distribution of constructive techniques of berthing and mooring structures.

They are classified from right to left in order of chronological appearance. After the six first ones, techniques coexist.

The great majority of the structures is in masonry, then come reinforced-concrete caissons, wharf piles, metal sheet piles seawalls and concrete blocks. This figure illustrates the inventiveness of engineers confronted with the maritime structures challenges, but it places the owners in front of a delicate management with regard to the principles of mechanical functioning and multiple failures.
A part of the answer is in the monitoring of structures and the instrumentation of the more recent ones (Schoefs *et al.*, 2004, Yanez-Godoy *et al.*, 2006a and 2007), especially to re-evaluate their reliability (Yanez-Godoy *et al.*, 2006b). This double level of heterogeneity (concept and material) is one of the bolts that the GEROM project wishes to raise.

5.2 Age analysis

The harbour's ages for the three types of owner are presented on *Fig. 3*. Even if the main part of the structures was built more than 25 years ago, the owners don't have equivalent patrimonies: (i) the NIH manage a patrimony for the main part previous to the twentieth century (essentially in masonry), (ii) MH have a patrimony essentially bound to the reconstruction period after the war and thus previous to 1955, (iii) AH have a patrimony built for the main part between 1955 and 1980. This can be explained by a more recent status and a growth strongly bound to the economic development.

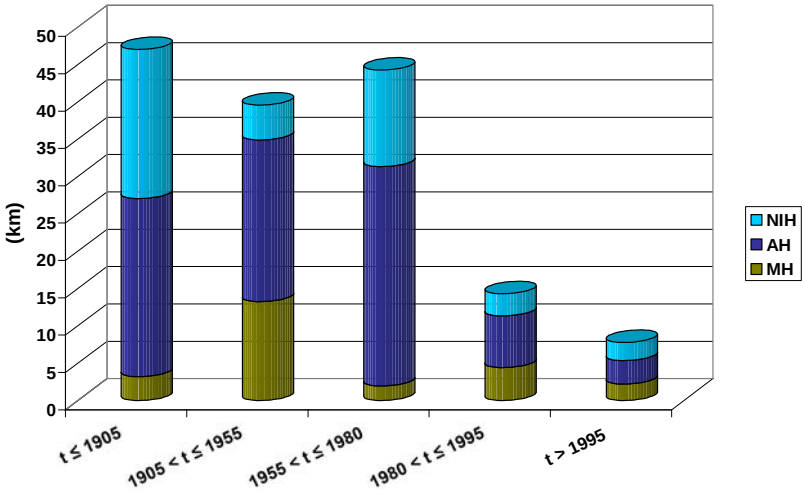

Fig. 3 Age distribution of constructive techniques of berthing and mooring structures.

These results can be easily compared with the data of investments in harbour facilities published in March 1994 by the Economic Observatory of Transport Statistics: in constant francs 1980, this investment is approximately 1400 million francs from 1957 till 1970, it increases strongly until 1975 with on average 2500, exceeding even 3000 in 1975 and becomes established till the end of the 80s at the level of 700 million francs. (1 euro is equal to 6.55957 francs).

5.3 Economic analysis

Upon 205 km were analyzed during the inquiry, 64 % (130 km) are managed by AH, 24 % (50 km) by NIH and 12 % (25 km) by MH.

Through the ratio of million tons of raw goods by linear kilometre (Mt / km), the inquiry supplied interesting data: a third of the NIH treats a very weak tonnage under 100 t / km, another third, a tonnage of the order of 0.5 Mt / km, and remains a 1 Mt / km tonnage; the AH has a ratio exceeding 2 Mt / km with on average 3 Mt / km.

A NIH has a very particular profile due to the Transmanche traffic fluidity and dynamism and reaches 6 Mt / km. The economic patrimonial analysis needs specific studies in every harbour and it is not discussed here.

6. Maintenance practices

6.1 Current practices

The quantitative patrimonial analysis displays a heterogeneous and ageing harbour patrimony. The most recent part of this last one is essential for the local, national and European economic development.

To keep an acceptable level of performance, the owners have to program and to carry out various maintenance actions. The respect of the established program depends on operation constraints, technical and financial constraints associated with the harbour structures and with their technical management.

The operation constraints mainly concern the structures which can't be temporarily stopped, even if an activity transfer is possible on another structure. It is generally the case of locks, mobile bridges, specialized berthing and mooring structures (oil, containers, etc.). In these conditions, the definition of a preventive intervention must be established through dialogue with all the users. Given the difficulties which it implies (partial interventions, between operations of load and\or unloading) the maintenance of these structures is frequently postponed, generating an increase of risks.

In marine environment (swell, tides, climatic hazards, physical and chemical actions of the sea water), maintenance of structures requires specific means (underwater works, works in the tide, materials in the sea). These technical constraints, coupled with the length of the structures and operation constraints, increase the maintenance actions costs.

At the same time, the maintenance strategies drawn up by the owners are largely piloted by the financial constraints: budgets and limited workforce. The AH has a budget for maintenance more important than NIH, which seems to be logical in relation to the ratios "million tons of raw goods by linear kilometre (Mt / km) ". On the contrary, workforce dedicated to the harbour maintenance is less important in the AH (3.5 persons fulltime equivalent) than in the NIH (8.5 persons on average: except staff allocated to the mobile structures). The staff of the AH organize the surveillance (detailed inspections) and the project management during the repairing projects whereas surveillance and maintenance actions are given to private enterprises. The NIH have a tendency to carry out a maximum number of actions in state control: surveillance of the visible parts, light maintenance and in certain cases major repairs on locks and mobile bridges for example. In front of the strategic importance of these structures for the naval and/or urban transport, the owners benefit from additional means. They must then be more responsive at the maintenance level. It explains the existence of differences between NIH which do not contain mobile works and NIH which do.

Budgets, limited workforce and high costs of maintenance actions, consolidate the fact that owners need simple and successful patrimonial management tools to optimize the maintenance. They also need global indicators to offer a vision of risks control to the decision-makers. This vision can be used to adjust or not the budget.

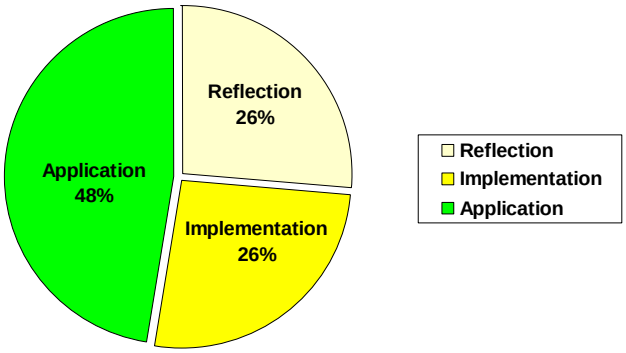

Fig. 4 Progress state of owners in terms of asset management methodology.

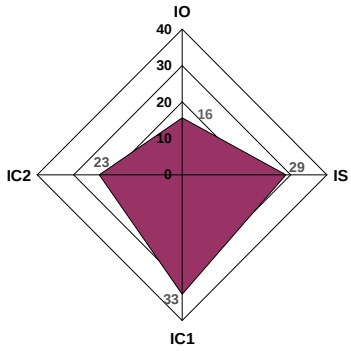

Fig. 5 Weights allocated to the various impacts by technical managers during national inquiry.

During the national inquiry, various methodologies of asset management were identified. Technical managers are in different stages. This result is illustrated on the *Fig. 4,* where three levels were defined: "Reflection"; "Implementation"; "Application".

A quarter of the respondents (MH, AH, NIH) are reflecting on the best methodology adapted to the harbour structures, while another quarter is implementing it.

In both cases, they are dealing with formalized methodologies which are based on a risks approach or on notation systems (coupling the structure's state (estimated after inspection campaigns) with their strategic importance in the studied system).

The remaining half already applies a methodology of management: 50 % used formalized methodologies and 50 % used non formalized methodologies because they consider that the number of structures and the linear kilometres are not sufficient to look for more advanced decision-making tools.

6.2 Expectations and needs in risk management and control

After describing the current practices of harbour structures asset management in the previous section, the reasons which motivate the owners to develop their own practices are highlight. This evolution is translated by the expression of needs in terms of means (workforce and budgets), but also in terms of asset management methodologies.

During the national inquiry, the technical managers have to choose among several reasons of evolution associated with the following categories:

- Security impacts **IS** (safety of the people, environment).
- Direct and indirect economic impacts **IC1** (port dues, operating loss, patrimony valuation, competitiveness preservation, brand image).
- Budgetary impacts **IC2** (maintenance costs).
- Organizational impacts **IO** (crisis situation, know-how transmission).

Weighting factors allocated to the various impacts by technical managers are presented on *Fig. 5*. They can be injected in a multicriteria evaluation, such as the one developed within the French National research Project RERAU (for Renewal of Non Man Entry Sewer System – in French - Réhabilitation des Réseaux d'Assainissement Urbains), in order to define the patrimony performance with regard to the owner's expectations (*Breysse et al., 2007)*.

The multicriteria evaluation can combine the *i* dimensions of the performance (Roy and Bouyssou, 1993). One can thus define the Index of Technical Performance ITp (t) as a combination of all the Performance Index PI_i (ranging in the [0, 1] interval):

$$ITp\,(t) = ITp_0 * \left[1 - \frac{\sum_i w_i * PI_i}{\sum_i w_i} \right] \qquad (1)$$

where ITp_0 is the cost of new construction and where w_i is a weighting factor chosen by the manager, who wants to give more importance to some dimensions than to others (for instance, Security Impacts (IS) rather than Organizational Impacts (IO)). In Equation (1), the ITp(t) value decreases from ITp_0 to 0 while PI increases from 0 to 1.

7. Conclusions

This article presents the national inquiry results of maritime and river harbours structures technical management led in 2006-2007. Results show a big heterogeneity between the structures in age and in constructive technique. Technical managers do not have the same patrimony, this last one depends mainly on the harbour status (MH, AH, NIH).

Besides, to process this inquiry with the aim of a risk analysis, ratios of million tons of raw goods by linear kilometre of berthing and mooring structures are established. Other important information is that owners begin to use formalized asset management methods.

8. Acknowledgements

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