

# EVALUATION AND MONITORING OF THE LIVORNO'S FOSSI SYSTEM

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**Abstract** – The ditches and canals of Livorno, also called Fossi, are the most characterized elements the city, not only from a historical point of view, but also and above all from an urban landscape characterization point of view. Currently the canals are used as moorings for boats and along the circuit there are many nautical circles; but the use as a waterway, or as a functional element of the city, is made difficult by some solutions not fully in line with optimal safety standards. The importance of the Livorno's Fossi system is fundamental because they are a place of aggregation before circulation. Despite this relevance for the city and its inhabitants, the state of conservation and maintenance is not adequate for use.

*Central theme and hypothesis* - Due to the overlapping of skills not yet resolved, fragmented information and data exist regarding the real extent of the pleasure craft, the status of the canals, the provision of services and general safety. On the stimulus of the Tuscany Region, the Northern Tyrrhenian Sea AdSP has started the first monitoring of the pleasure craft in the Livorno's Fossi system with an assessment of possible future scenarios. The hypothesis is to succeed, through a multi-criteria assessment of scenarios, to support and quantify the displacement of vessels that negatively affect safety, accessibility and the landscape of Livorno's Fossi system elsewhere.

*Methodology* - This work started with the analysis of the Livorno's Fossi system. The aim is to explore tools and scenarios useful for the re-functioning and safety of the ditches. In the first phase, an aerophoto monitoring of the Fossi system will allow to pull out the counting and characterization of the boats, as well as the mapping of the concessions. The results are then collected maps, trying to objectify and explain the qualitative and quantitative setting system, called Scenario 0. This scenario highlights the weaknesses of the current system. Starting from scenario 0, the navigation safety parameters contained in the PIANC guidelines, scenario 1, will be applied first; a further scenario will instead follow the landscape and cultural criteria, freeing the most significant historical-identity areas from the boats, scenario 2; finally a hybrid scenario between the last two, scenario 3. All the scenarios will be assessed according to environmental, landscape, socio-economic and navigation safety indicators.

*Expected outcomes* - Thanks to the quantification and punctual evaluation of the monitoring, being able to have a plan of displacements useful for the planning of a new landing place for pleasure boats that negatively affect the Livorno's Fossi system.

## **A brief historical introduction**

The system of ditches and canals of Livorno is closely linked to the history and growth of the city. Livorno was geographically located at the southern part of a large lagoon, now entirely filled, which stretched from Massaciuccoli to the reliefs of Montenero. Thanks to its strategic position, the area was home to the Porto Pisano, one of the main ports in the Mediterranean. Over the centuries, the Port was fortified with the construction of numerous towers that determined its typical appearance. In the central centuries of the Middle Ages, the progressive burial of the Porto Pisano determined the rise of the reality of Livorno. In 1300 a real fortress was built by Pisa connecting the pre-existing towers through a quadrilateral structure. The new fortress then took the name of “Quadratura dei Pisani” and formed the nucleus of the current Fortezza Vecchia.

The rise of the Medici family, who obtained stable and legitimate control of the complete region in 1530, greatly influenced the development of the city of Livorno as a new strategic landing place for Florence. In 1519 Antonio da Sangallo designed the fortress incorporating the Quadratura dei Pisani. In 1522 work was started on the moat that would isolate the new construction, demolishing part of the medieval residential fabric. The construction of the new fortress was functional both to the new military requirements and to the protection of the seaport and it represented the first step of an urban planning strongly desired by the political leadership. The act of foundation of the new city dates to the year 1537. Cosimo I proposed to strengthen the Livorno port as a centre of storage and exchange between Mediterranean and the ports of Northern Europe.

Bernardo Buontalenti was commissioned to design the new city. The design envisaged a pentagonal city wall extending for five kilometres, connected to a large system of ditches for its protection and communicating with the sea. Buontalenti's project underwent profound rethinking and transformations in its implementation because it had not declined in detail all the aspects related to the needs of the emerging merchant class. The design of the city border determined by the bastions was influenced by the economic crisis, which overwhelmed the Grand Duchy of Tuscany at the end of the 16th century and in the first decades of the 17th, and by the Grand Duke's decision to build a second fortification on the mainland side, the Fortezza Nuova, designed at the same time as the reorganization of the arrival area of the Navicelli Canal. The Navicelli Canal connected the port of Livorno with the cities of Pisa and Florence. The completion of the Canal, together with the approval in 1566 of the new customs regulations, are some of the actions taken to relaunch the landing as an international seaport. The new customs rules and the strengthening of the warehouse port changed the relationship between the city and the sea. The flourishing economy of maritime trade and the changing defensive needs of the city led to the creation of two urban increases at the expense of the original Fortezza Nuova that led to a new configuration of the urban quadrant of the northeast, with a very strong port commercial connotation. In the first decades of the 17th century the urbanization of the filling land between the sea and the Navicelli canal took place. The district built here took the name Venezia Nuova because of

its construction, on piling foundations, were probably called Venetian workers. At the end of the same century, the new urban district experienced a further important growth, through the demilitarisation and transformation of part of the imposing Fortezza Nuova. In this way, valuable spaces were made available to merchants because of their location closely connected to the port by canals. With the urbanization of Venezia Nuova, Livorno took on the appearance of a city on the water, with canals, bridges, ports of call and cellars on the level of the ditches, projecting the port area into the city: in short, the fully merchant city was born, in which the sea penetrated deeply into the hinterland through the network of canals.

In the 1830s the expansion of the city beyond the fortified walls accelerated rapidly, with an increase in the number of residents in the eastern part of the settlement. To reunite the old city with the new one, the bastions were demolished and the Fosso Reale was rectified. A large bridge was built on the Fosso Reale, called 'Voltone', which served as a link between the Medici city and the Lorena expansion. The commercial role of the ditches became more and more marginalized throughout the 20th century, as the role of waterway disappeared due to the effects of the modernization of the logistics linked to the port activities. It was only in the second half of the 20th century, with the development of the pleasure boating sector and popular sports activities, that ditches found a new role, such as venues and facilities for nautical sports, sports fishing clubs or art workshops.

## Central theme and hypothesis

Fossi and canals of Livorno are the element that most characterizes the city. Not only from the historical point of view, but especially for the urban landscape characterization. Currently Fossi are used as mooring for boats; along the circuit there are numerous nautical clubs. The use of the ditches as a waterway, or as a functional element of the city, is made difficult by some solutions and *de facto* uses not fully in line with optimal safety standards. The aim of this work is to explore tools and scenarios useful for the re-functionalisation and safety of the ditches. The reconnaissance has been stimulated by the Region of Tuscany and by the requests for the updating of the Conscious Framework of the Masterplan of Ports.

In a first phase a simple reconnaissance of the Fossi system was carried out, through the counting and characterization of the boats, as well as the mapping of the concessions. The analysis was based on the mapping of the vessels moored along the perimeter of the ditches, canals and docks of the marina, also taking into account the concession areas. The map of concessions was provided by AdSP for the year 2019 in .shp format. Further cartographic bases used were the three orthophotos relating to the years 2010, 2013 and 2016, available on the Geoscopio portal of the Region of Tuscany. The vessels were then counted and categorised within the various concessions. The analysis stimulated the search for an analytical method for the reorganization of the system. To collect data in a consistent and functional way, it was decided to divide the circuit into 17 stretches and to draw up a datasheet for each one. To divide the Fossi's path, bridges were used as boundaries instead of concessions limits, so the division was clearer and more intuitive. In the paper, for the sake of brevity, only the images and analyses of stretch 16 are reported. Stretch 16 is circumscribed between Via Augusto Novelli and Piazza Cavour.



Figure 1 - Ortophoto stretch 16, between Via Augusto Novelli and Piazza Cavour.

## Methodology

The first step for the realization of a scientific method to study the distribution of boats along the Fossi circuit was to analyze the size of the canals. Evaluating the size of the Fossi sections seemed to be an impossible mission without an *ad hoc* survey campaign. By studying the functions of QGIS instead, it was possible to evaluate the size of the section.



Figure 2 - Sections along stretch 16.

First, the ctr (regional certified map) was used in shapefile (.shp) format and ditches' axis was drawn to create the sections. On the axis, a step of 5 meters was established in order to identify the remarkable points where to draw the sections. Then, thanks to a function that allows to calculate the minimum distance (perpendicular) between two lines, the distances between the axis and the edge of the ditch were calculated, thus obtaining the measurement for each remarkable point identified. The scanning of the 5 meters was then simplified and rationalized. The width of the ditch is therefore considered to be estimated: since it does not derive from a measured survey, but being based on certified cartographic data, it can be considered true and with a tolerance of less than decimeters.

Table 1 - Estimated width of each section along stretch 16.

Section	Estimated width (m)
1	24,4
2	24,4
3	24,3
4	24,3
5	24,3
6	24,2
7	25,2
8	26,2
9	27,1
10	28,1
11	29,0
12	28,9
13	28,9
14	28,9
15	28,8
16	28,8
17	28,9
18	31,1
19	31,1
20	31,0
21	31,0
22	31,0
23	30,9
24	30,9
25	21,9
26	21,9
27	21,9
28	22,0
29	22,0
30	19,1
31	16,0
32	14,1
33	12,5
34	12,5
35	12,4

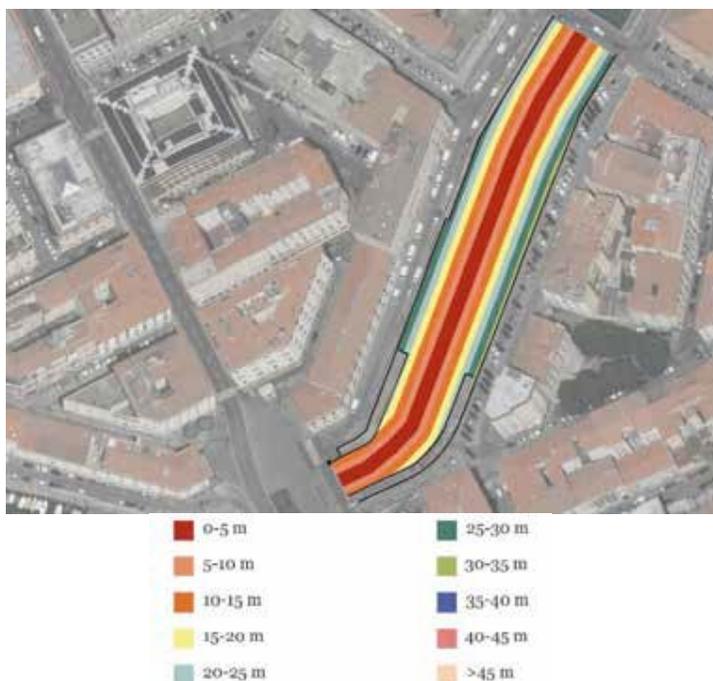


Figure 3 - Graphic analysis stretch 16 - the colour bands identify the distance from the hypothetical centre of the ditch.

In addition to a numerical analysis, a graphic analysis of the size has also been carried out. The axis of the ditch was used as a basis for creating coloured buffers that identify the increasing distance from the centre of the ditch. The central strip is 5 m wide and the adjacent strips each add 5 m to the central strip. A graphical analysis of this kind makes it possible to understand, at a glance, the size of the stretch and, in front of the complete map, to have an immediate picture of the homogeneous sections and the navigability of the circuit.

The data on the counting of the vessels through the orthophotos were compared with those declared by the nautical circles present along the ditch circuit. The circles were analysed based on data provided by the State Property Office in the form of shapefiles and data relating to the 2018 concessions. This comparison between state property data and the census was necessary because, even to an occasional observer, it is evident that the situation along the ditches is in some points regulated more by practice than by the concessions: there are numerous boats moored outside the water surface under concession, which are therefore not present in the state property data. However, it is precisely these situations of irregularities that must be documented to reorganize the circuit.

The Fossi system for Livorno is of fundamental importance: not only for the historical memory, but because, as can be seen from the analysis of the clubs, they are a place of aggregation and circulation. Despite this importance for the city and its inhabitants, state of conservation and maintenance is not adequate for use.



Figure 4 - Graphic analysis of the entire circuit and identification of stretches.

The analysis described in this paper can be a first instrument of knowledge and deepening of the situation and the basis for a redesign and upgrading of the whole system. The section analysis in the different stretches of the Fossi system shows that the width is homogeneous in some areas, but uneven when considering the whole circuit. In particular, the Venezia Nuova has a very narrow section with numerous curves, especially in stretches 7 and 8, while the Fosso Reale in the southern part has more linear and wider sections. The stretch of Fosso surrounding the Fortezza Nuova has two different halves: one sized like the ones in Venezia Nuova, being its extension, while the other one is wide more than 50 m. Despite these differences, the whole route is uniformly occupied by the circles and their concessions. The concessions concern the state property water: each club has an assigned area and declares how many boats are moored there. As regards the census of the boats present along the circuit, as already described in the introduction to the method, the data provided by the circles have been cross-referenced with the data from the 2016 ortho-photo-based census. Since the concession was based on the size of the water surface and not on the number of berths, it was decided to verify the consistency between the two sources. The comparison shows that there is a greater number of boats present along the circuit than the authorized one.

ABACUS	CHARACTERISTICS	IDEOGRAMMATIC SCHEME
berth 1	berth dimension 2,5x7 m	
berth 2	berth dimension 3,0x8,5 m	
berth 3	berth dimension 3,5x10 m	
berth 4	berth dimension 4,0x11,5 m	
berth 5	berth dimension 4,5x13,0 m	
red	non-compliant situation	
yellow	to be evaluated	
green	compliant situation	
o	no berth	
1a	berth only by one side, lateral	
1b	berth only by one side, longitudinal	
2a	berth by both sides, only lateral	
2b	berth by both sides, only longitudinal	
c	berth by both sides, mixed	

Figure 5 - Abacus of navigability.

With a view to upgrading and redesigning the system, this analysis focused on defining how many vessels to be relocated. AdSP MTS has produced a technical-economic feasibility study on a new landing place for social boating in the Bellana area of the Port of Livorno. The new dock will cover the stretch of coast between the Morosini dock, the Scoglio della Regina and the Nazario Sauro marina. The new dock will respond to specific needs of the territory, including the need to create a new infrastructure for "minor" boating, which currently crowds the Fossi. The relocation of the boats is not only possible, therefore, but a special space is already provided.

## Expected outcomes

In order to arrive at a scientific definition of the number of boats to be relocated, also compatible with the urban plans, the requirements of Annex A "Discipline" of the Masterplan "The network of Tuscan ports" have been taken into consideration. Regarding canals, it is specified that they should normally be sized according to the following criteria:

- at least 1.3 times the length of the largest berth accessed from the channel with lateral mooring devices (briccole, finger or cat-way, mini-finger)
- at least 1.7 times the length of the largest berth accessed from the channel with longitudinal mooring devices (mooring post with drapes or slopes or similar).

Segment 16		Average segment width (m)					
Berth typology	Berth dimension	No	16 (1.3)	16 (1.3)	16 (1.7)	16 (1.7)	No (vertical berths) / 16 (1.3)

Figure 6 - Result analysis stretch 16.

To guide the correct design, the Discipline defines the size of the berths with reference to the maximum size of the moored boat. The dimensions considered relevant for the analysis are reported in Figure 6, as they include the boats present along the circuit. For each stretch the average section has been taken into consideration, the types of berths present, and the size of the boats moored have been identified, thus defining the Scenario 0 of the current state.

To determine Scenarios 1 and 2, the data related to the mean section has been crossed with the data related to the minimum project section prescribed by the masterplan. To do this, the minimum channel widths were calculated based on the moored vessel. When entering these data in a matrix, when the minimum design size is smaller than the average channel width, the box is green (situation compliant with the masterplan); when the minimum design size is larger than the average channel width, the box is red (situation non-compliant with the masterplan). When the two numbers are too similar, the box is yellow: this is because, being the average and not absolute section of the stretch, the compliance with the masterplan must be verified. The project sections have been calculated both by type of moored boat and by type of berth: this is because it is the type of berth that determines the coefficient to size the channel, to be multiplied by the length of the berth. As regards the calculation of the section for one-sided approaches, the Annex is clear and specifies the coefficients. From the width of the ditch has been subtracted the size of the gangway, since gangways are always internal along the ditches, floating or suspended, reducing the useful section. For double berths, the useful width of the section was the total width from which were subtracted the widths of the gangways and of the berth on the other side. In the case of mixed berths, the minimum project canal width was calculated considering the longitudinal berth coefficient (1.7) with a lateral berth on the other side.

Within the matrix are also identified with an "X" the boats present along the stretch of ditch and how they are moored. In this way it is immediately possible to verify the suitability of the state of affairs with the requirements: when the X is in a green box, the situation conforms to the Masterplan; when it is in a red box, the situation does not conform to the Masterplan and those boats must be relocated.

Scenario 1 provides for a 1.20 m wide quay or walkway that meets PIANC accessibility standards; Scenario 2 provides for a 0.80 m wide quay or walkway, considering a possible derogation from the 1.20 m standard given the historicity of the site. Scenario 3 differs in that it only considers boats located near the scalandrone. Scalandrone is a typical access to the Fossi, identified by a large masonry chute that allows you to pass from road level to water level. With a view to upgrading the system, these accesses should be restored and made safe. Therefore, boats now moored in front of scalandrone, preventing access to the water, were counted in order to arrange for their relocation. Figure 6 shows an extract from the comparative table, where section status and boats to be relocated are highlighted.

## **Conclusion**

It is possible to sum up the method in a flux diagram, showed in figure 7. This method is replicable and usable in all similar situations. The use of QGIS tools has saved a lot of time and resources. Comparing the analyses with Annex A prescriptions also makes them suitable compared to planning tools. Developing different scenarios has shown that, despite several assumptions, the number of boats to be moved is still of note.

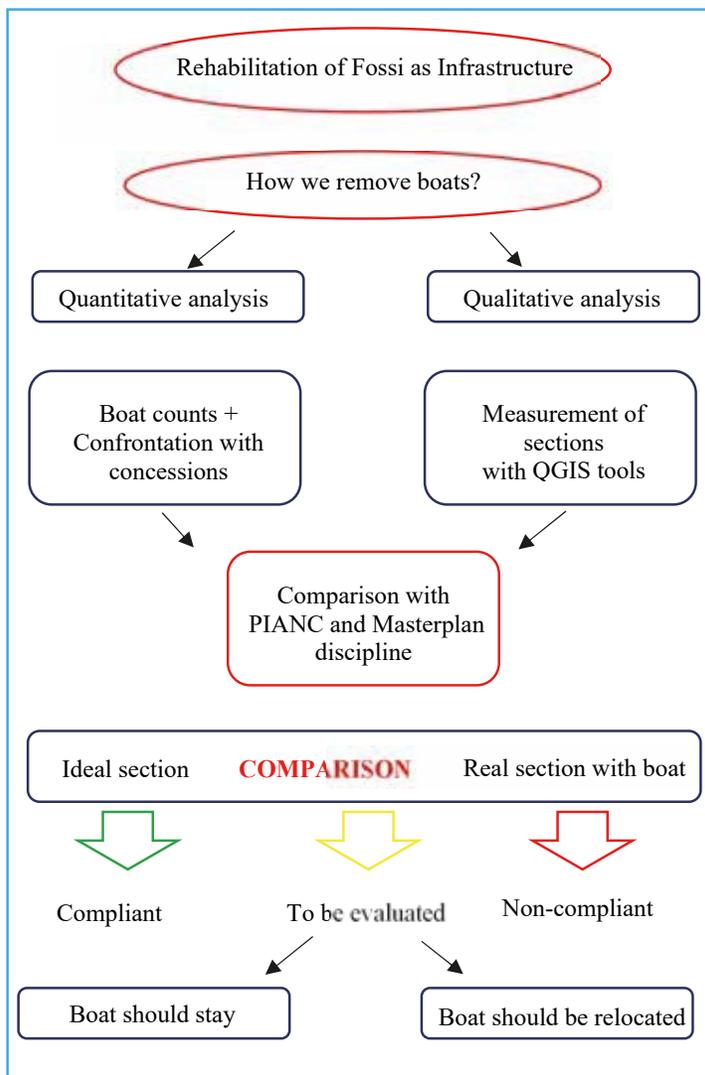


Figure 7 - Flux diagram.

In fact, the scenarios developed involve the overall displacement of a fair number of boats, about 45 % of the total. This means that now the situation is completely inconsistent with the regulations and the Fossi circuit is inadequate, in terms of size, to accommodate so many moored boats. Safety is not assessed since navigation safety plans are drawn up by other competent bodies (Harbour Master's Office).

However, possible solutions to such a situation have already been identified. As explained above, the new dock in the Bellana area would quickly solve the main problem of too large number of vessels. As far as nautical standards are concerned, however, the specific nature of the Fossi must be considered. Although it can be considered a port area for pleasure boating, the historicity of the site must necessarily be accounted for. As a cultural heritage site, it could be subject to derogations allowing it to be used without necessarily following the standards of the Masterplan. A redevelopment of the system, lightened by the cumbersome presence of many boats and transformed perhaps into a waterway and not just a parking lot, could return to Livorno and its citizens an important part of the city today undervalued.

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