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Living and Walking in Cities

New challenges for sustainable urban mobility

This Special Issue intended to wonder about the new challenges for sustainable urban mobility, aligning with the European Sustainable & Smart Mobility Strategy. Contributions come from selected papers of the XXVI International Conference "Living and Walking in Cities" and have been collected around two main topics: the relationship between transport systems and pedestrian mobility and the transformative potential of temporary urban changes. Reflections and suggestions elaborated underline a collective great leap forward to reshaping urban mobility paradigms.

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TeMA

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Land Use, Mobility and Environment

Special Issue 3.2024

Living and walking in cities: new challenges for sustainable urban mobility

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Special Issue 3.2024

Living and walking in cities: new challenges for sustainable urban mobility

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Coastal roads atlas. Reshaping daily infrastructures for coastline adaptation

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Abstract

The widespread poor quality that characterizes many cities and urbanization today is often related to the outdoor spaces. These conditions are common situations in many contexts of our country but are intensified where spatial inequality and environmental vulnerability converge. Although declined in different territories these situations have at their center the complex space of the road. The road system not only contributes significantly to climate change but is also the main victim of the consequences related to these changes. The research investigates the role of the roads and parking spaces, interpreted as the main background of our everyday lives, in facilitating socio-ecological transition of most fragile territories. Particular attention is paid to the different vulnerabilities of Italian coastline and to the ways in which adaptation measures can be implemented to mitigate risks.

The initial analyses are focused on developing methods to measure and evaluate the climatic, geophysical, and socio-economic vulnerabilities of coastal roads, which are rendered, through aggregated maps of quantitative and qualitative indicators, in an "Atlas of Coastal Roads". The Atlas is conceived as an operational tool, able to guide stakeholders to develop national and place-specific interpretations.

Keywords

Coastal roads; Public spaces; Socio-ecological transition; Adaptation; Atlas.

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1. Introduction

The widespread poor quality of living that characterizes many cities and urbanization today is often closely linked to what lies outside the domestic space. On the one hand, the lack of common spaces in the neighborhoods, often reduced to mere parking spaces for cars, often overabundant and lacking in overall design and quality, as well as the lack of care and ordinary maintenance of the same. On the other hand, the lack of efficient collective integrated mobility services and other commons, when present, are inaccessible and detached from the surroundings. These are common situations in many Italian contexts, which are intensified where conditions of fragility (social, economic, environmental) are concentrated, and where spatial inequality and environmental vulnerability converge. These conditions are declined in different territories and ways, but often have at their center the complex space of the road: carriageways, pavements, cycle and pedestrian paths, car parks, open spaces, squares, and abandoned-waste spaces (Lanzani et al., 2021).

The research program intends to investigate the street space as the main background of everyday life and as an integral part of a strategic vision for cities and territories. By reinterpreting the road as a "pervasive" (Secchi, 1989) infrastructure that can shape the quality of the environment and living, the research emphasizes its great potential to experiment with an overall socio-ecological transition of the territories.

What new factors can we introduce today about the image of the road, or better, "the vision of man in his 'natural' context: the dark grey parterre, background of action, but also crossing, journey, metaphor of knowledge" and about the asphalt as the "new crust of the earth", fil rouge of the most consistent metropolitan transformations since the late 19th century industrial city evolution (Zardini, 2003)? This is the first research question that will be explored in depth.

The general research question on infrastructure for daily living was referred to the Italian coast, affected by significant anthropogenic pressure and the impacts of climate change. Fragilities and opportunities were analyzed within key buffers, including coastal freeways and urban roads which intersect with various geomorphologic and settlement structures along the sealine.

One of the main goals of the research, described in the second part of the article, is elaborating a trans-scalar Atlas of national Coastal Roads, useful to study the current and future connections between coastal roads and environmental, demographic, socioeconomic factors. It provides both quantitative and qualitative insights, highlighting the critical issues and potential opportunities in different national contexts. The Atlas is conceived as an operational tool, able to guide stakeholders in developing national and place-specific interpretations, orient policies and projects toward a systemic approach, empower sustainable actions, and address future scenarios.

2. Everyday life infrastructure. Interpretations from the past

The invention of the private car in the late 19th century represented the most significant technological change in urban transport since the introduction of the locomotive (Eco, 2012). Its diffusion revolutionized the way we move within the city and the territory, profoundly influencing its conformation. Although the car has played a predominant role in the development of cities throughout its history (Adams, 1970), roads, car parks and their related spaces have been subject to few innovations, which have tended to be technological rather than spatial. In some cities, the footprint of the road and parking network covers more than a third of the land. Surprisingly, this omnipresent network has received minimal attention since the 1950s (Joseph, 2015).

In fact, some famous interpretative efforts in the literature of urban geography and sociology and urban planning and design refer to these two main functions of the street.

The first is the street as "public space" for people in the city, to observe, or lose oneself (Debord, 1956), a space for meeting. At the beginning of the 1960s, in the United States, the street became a central question in Jane Jacobs' writings for Architectural Forum since 1952 to 1962 (Jacobs, 1958 & 1961). The collaboration between the Massachusetts Institute of Technology (MIT) and Harvard University led to the Joint Center for

Urban Studies series, which will publish some important books dedicated to the street and to the city (Rossi, 2017). Lynch examines the road as a visual experience to investigate the consequences between urban pattern, function and image (Lynch, 1961 & 1964). Serge Chermayeff and Christopher Alexander investigated the relationship between the structure of the city and the influence on its inhabitants (Alexander, Chermayeff, 1964). The anthology *On Streets* collects the results of studies begun in 1970 by a heterogeneous group of researchers examining the semantic, structural, historical and social aspects of the street and interpreting it as public space in the contemporary city, rather than as flow and traffic space (Anderson, 1978). Along the same line of thought are the books *Livable Street* (Appleyard, 1981), and *Life Between Buildings* (Gehl, 1987). The second meaning attributed to the road coming from history is linked to "motion" that is recalled in Lynch's "channels of movement" (Lynch, 1961 & 1964) or in the freeways of "Autopia", where Angelenos spend a large part of their lives, and for this reason, the road system is one of the ecologies of Los Angeles identified by Rayner Banham, who learns to observe the city through the windshield and rear-view mirror of a car: «Just as ancient generations of English intellectuals learned Italian to be able to read Dante in the original, I learned to drive a car to read Los Angeles» (Banham, 1971). In *Learning from Las Vegas*, Robert Venturi offers an effective description of how urban spatial form is determined by the road network and how this influences the access to most places, such as residential buildings, shops and services (Venturi et al., 1977).

To range over other fields of literature and art: "un' autostrada non è solo un' autostrada" is a quote from *Le città invisibili* (Calvino, 1972), which suggests that a highway, is more than just a road for cars, but it's a part of the landscape and it has an impact on the people who use it and vice versa.

Robert Smithson defined the roads as ready-made artwork on a territorial scale, as they are simultaneously works of engineering, architecture, and landscape, which constitute "an artificial geography" (Hobbs, 1982). The distinction between these different interpretations can be described through the "place" and "movement" functions of the street. The same words street and road, which are often used interchangeably, imply different meanings. Etymologically the word "street" derives from the Latin *sterne* (to pave) which denotes a surface that is part of the urban fabric, while the Anglo-Saxon root of "road", implies passages from one place to another, suggesting movement towards a destination (Rykwert, 1986). Thus, a street is often seen as a public space (Kostof, 1993), while a road is more of a functional artery (Maheshwari, 2020).

The "movement" and "place" functions of the street tend to conflict with each other, and it is normal that one imposes itself on the other (London Streetscape Guidance, 2022). This conflict over time has led roads to specialize, generally in favor of the car (Urry, 2004) and according to its urban, suburban speeds.

The gradual specialization of street space into functional transportation infrastructure has displaced its role as the 'housing of the collective' (Benjamin, 1986) and architecture. The new dimension of street space has remarked the caesuras between parts of the city and disqualified all those mediating spaces (parterres and tree-lined strips, ditches and water collection channels, sidewalks, rotundas, parking lots, etc.). What new role can street space take on - its continuity, permanence or transformation with respect to the plots of routes, open space networks and infrastructure - in order to respond to the new environmental emergencies related to mobility, downsizing the auto-centric model?

3. Roads/streets, parking and related open spaces as device to experiment fragile territories' socio-ecological transition

Keeping as fixed points the interpretations on the meaning and role of the street derived from the rereading of some classics of literature (still relevant today), the research seeks to understand what new roles the street, car parks and related spaces can take on in the contemporary world, also in relation to the most recent phenomena affecting society and the environment, such as the pandemic (Gorrini et al., 2021) and extreme climatic events.

3.1 Street as complex ecology

An emerging aspect in recent years that roads, car parks and open spaces must take on is the mitigation of the effects of climate change. The road system not only contributes significantly to climate change but it's also the main victim of the consequences related to these changes (Carraro, 2017). Although the "environmental question" has been strongly posed since the 1960s¹, it is only in recent decades that the need to reduce emissions and the ecological footprint has become more evident through political and economic efforts. The green transition of road transport is the second most important investment areas of the National Recovery and Resilience Plan (PNRR)². Despite in Italy there was a demographic decline between 2011 and 2020 (Istat, resident population, 2011-22) and a constant average family income (Bankitalia, 2011-18), the dominance of the car continues to remain relatively stable over time. Indeed, the motorization rate, in Italy among the highest in Europe, continues to grow (Aci statistical yearbook, 2011-20).

The emergence of new mobility models - such as shared services, electric and/or autonomous vehicles and progress in energy-related infrastructures - has still failed to call this stability into question. Among other things, the real ecological footprint of policies aimed at the development of electric vehicles is not yet clear. While representing a paradigm shift in terms of reducing CO₂ emissions, these models somehow reiterate the extraction of fossil materials (e.g. cobalt) to produce batteries (Carraro et al., 2023).

In recent years, especially in large cities, we are again witnessing a general demand (backed by political will) from citizens to re-appropriate street space for mixed use and mobility (Abdelfattah et al., 2022). A shared street, where there is no formal distinction between spaces dedicated to different transport modes, is never in a state of stability and inherently provides for acceptable levels of conflict.

The implementations of shared streets - starting with the pilot cases in Amsterdam and Vienna³ - up to the many "tactical" experiments of global capitals - embody this conception of the street as a "space of dynamic relations" (Meta, 2014; Bocca, 2024), that derives from networks of interconnected activities, flows and phenomena.

Linking to the concept of "ecology" given by Banham for Los Angeles - to be understood not so much as simple protection of the environment but rather as a product of the interaction of geography, climate, economy, demography, technology and culture - the idea comes forward of the street as a complex ecology. Depending on the context and needs, it can take charge of the management of extreme stormwater, heat waves, air quality and extreme winds, biodiversity continuity, and waste.

Expanding these interpretations, the street also becomes a space of decompression, "urban emptiness" (Trancik, 1986; Secchi, 1986). Bernardo Secchi speaks of soil design also in terms of "thickness"⁴, topography, while Gilles Clément provides the image of the "third landscape" (Clément, 2005) that arises at the edge of the roads as a corridor of biodiversity, and other landscape architects speak of "intermediate landscapes" (Desvigne, 2009), of ground depaving and reclamation, of green infrastructures.

On the one hand, we pursue the despecialization of the streets in the urban neighborhood networks (which are redesigned as woonerfs, with resilient floodable spaces, vegetation, spaces of shared mobility and continuity between services and neighborhoods) associated with strategies to strengthen public transport and

¹ Consider the thoughts of Ivan Ilich and the discussions on "political ecology" that inspired environmental movements in the years to come.

² In Italy the energetic transition and the sustainable mobility is the first most important investment area of PNRR. t

³ A practical application of shared streets occurred in 1970 in Delft, where a group of residents transformed their neighborhood streets into "woonerven" - shared streets where the space for car movement was converted into shared public space. In Austria more recently, shared streets have become part of the "traffic code" through the introduction of the *Begegnungszone* or "encounter zone". Today, this type of space is experienced in many capitals around the globe and is codified in numerous street design manuals.

⁴ A large part of the streets' role is invisible in the contemporary city. The streets facilitate the space-time compression of urbanity by transporting people, goods, water, energy, waste and information in spaces that are all in all limited or underground (Graham & Marvin, 2001).

sharing mobility. On the other, greater specialization of broader road networks and metropolitan corridors, is required.

3.2 Street as equity space

But what happens if we move outside the street grids of dense metropolitan neighborhoods, if we change scale or context?

The experimentation of these sustainability measures on road space - shared roads, resilient public spaces, fifteen-minute cities, "tactical" roads and schools' streets - and the implementation of integrated mobility models⁵, has taken place almost exclusively in large cities, which have a consolidated public transport network and greater investment power. These strategies have favored large cities, increasing the gap between metropolitan areas and other territories (Coppola et al., 2021). In recent years, a substantial part of European funds has been dedicated in Italy also to the most isolated areas, "the Strategy for Internal Areas" and mountains regions.

But, in the constellation of ordinary landscapes of small and medium-sized cities, in the territories of dispersion or informality or in those with low intensity of accessibility - which represent the majority in Italy (Lanzani, 2022) - the only possibility of mobility in reasonable times, compared to the daily needs of family, study and work, remains the private car. This phenomenon exacerbates an already known problem of disconnection and inequity in the accessibility (Ghigi & Nadini, 2022) potential of those marginal territories that can hardly be experienced with a sustainable and convenient way of moving.

According to Rudofsky (1969) the roads is not only a surface, part of an urban texture characterized by an extended area lined with buildings on either side but it's a volume (Rykwert, 1926), it is inseparable from its environment (Rudofsky, 1969), if in an urban context, a *continuum* with the ground floors of the buildings.

The same road, therefore, becomes a powerful connecting device between urban or environmental segments, starting from its distributive property. In ordinary urban contexts, often affected by scattered phenomena of abandonment, disuse, depopulation or regeneration opportunity, the street can be the bearer of vitality and greater widespread urban quality. Similarly, the road, within the non-urbanized open space, can take on the role of a biodiversity corridor and bridge between the fragmented parts. At different scales, the road is a device for balancing resources, from north to south and between large cities, intermediate and isolated territories.

3.3 Street as multiscale and multidisciplinary space

The third interpretation, transversal to the first two points, is related in fact to a necessary up and down scaling the transport and environmental scenarios, policies, master plan and projects from the global to the regional-local scale (or vice versa). It's the daily and incremental transformation of ordinary and small-scale public spaces that must contend with the global impacts of climate change and human activities. To implement integrated and systemic projects in specific places, it is necessary to understand the nature of their transversal relationships in a broader context.

The management of emergencies and disasters that have hit the Italian peninsula in the past has generated a series of political choices, for the restoration and recovery of the affected places, which are not very well adapted to the specificities of the territories, since they were taken, in most cases, very quickly. Also, the management of the approximately four hundred million euros allocated to the Italian territory in recent years⁶,

⁵ Which are based on the scale of mobility flows and urban dimensions.

⁶ See Projects and reforms for the ecological transition MIT (2021).

coming both from the PNRR post pandemic emergency⁷ and from previous agreements with Europe, is no less complex (Pasqui, 2021)⁸.

Again, the timeframe for project implementation by public authorities is tight and the involved parties are seldom not equipped with trained skills. If it is partly understandable to act hastily and disconnected from the territories in emergency conditions⁹, it is not so with respect to the myriad of ordinary maintenance, redevelopment and prevention activities carried out cyclically and extensively throughout our territory, but which remain chronically far from a perspective of medium and long-term planning, system planning, and monitoring.

In this perspective, the research wants to highlight also the role of the road as an artefact of an interscalar and multidisciplinary nature that could be able to bring into coherence with each other the multiplicity of sectoral tools that concern public open spaces, mobility and collective services spaces, and the disused, such as Urban Plans, Urban Traffic and Sustainable Mobility Plans, Green and Services Plans, and Implementation and Detailed Plans-the various projects and actions. The implementation of a multi-scalar and multi-disciplinary Atlas, which investigates the everyday life space of the road in relation to the environmental and socio-economic phenomena of some specific contexts and described in the following paragraphs, aims to orient policies and projects towards systemic knowledge and actions, making superordinate policies less generic, but also to systematise or define a set of good practices to achieve concrete and replicable results, also with a bottom-up approach (Richiedei & Pezzagno, 2022). The theme of the road again offers itself as an emblematic space for a significant and pervasive opportunity for systemic investigation.

4. Coastal territories as priority field of investigation

The relationship between infrastructure, climate change and coastal territory can be regarded as one of the most important architectural themes for our peninsula. In the transition zones between inland areas and the sea, the interaction between anthropic and climatic pressures leads to conflicts in the balance between economic development, securing and environmental sustainability (De Meulder, 2017).

Based on global, European and national scenarios, some main phenomena emerge that may induce relevant impacts for Mediterranean coastal areas (IPCC, 2022)¹⁰. In recent years, the European population living in coastal areas has more than doubled, and the same trend has occurred in Italy.

In Italy there are 644 coastal municipalities¹¹. Almost 17 million people reside in these municipalities - just under 30% of the Italian population, to which the seasonal inhabitants should be added - which are distributed over about 43 thousand square km, just over 14% of the national territory (Mirto, 2022). Approximately one quarter of the surface area within the three hundred meters from the coastline, protected by Galasso Law, no. 431 of 1985¹², is urbanized. More than half of this territory is occupied by sprawl settlements (66%). The remaining part is made up as follows: dense settlements (21%), bathing facilities (7%), and infrastructure works (6%). The alteration of the shoreline stands at 8%: 62% with shore defensive structures, 38% with port and similar structures (Formato, 2019; Munafò, 2022).

⁷ Which amount to 222.1 billion euros.

⁸ Structural Funds for development and cohesion 2021-27; REACT EU funds.

⁹ Perhaps, as Fabian and Bertin argue (Fabian & Bertin, 2021) the rhetoric of emergency has tended to hide the very character of the Italian territory, which by its very nature is fragile, unstable and, for the most part, very difficult to inhabit. It is necessary to assume the extreme fragility of our country as a given and ordinary condition.

¹⁰ The Mediterranean basin is defined as a climate change "hotspot", the most affected by rising temperatures in the world (Le Cozannet, 2022).

¹¹ We refer to those municipalities that directly touch the shoreline (reference boundaries ISTAT 2022).

¹² The Law introduced protection of landscape and environmental heritage. Through the editing of the "Piano Paesistico" each Italian Region imposes non-buildability constraints in some vulnerable and valuable landscapes (mountains, coasts and rivers, Ramsar zones). In our case, within 300 meters from the seashore. All the areas identified by Galasso are subject to state jurisdiction.

In 2021, almost 43% of the sandy coastline is occupied by bathing establishments, with considerable differences between regions. Moreover, when considering maritime state concessions¹³, a 17% increase can be observed at national level over the last three years. Liguria and the Adriatic coast are much more congested, with 70% of sandy shores not freely accessible (Mirto, 2022).

Fragmentation has generated a progressive reduction of natural environments and an increase in their isolation. The result is a reduction in the resilience of habitats, which over time has affected the quality and value of the landscape (Nifosì, 2022), both natural and man-made¹⁴.

Having dissipated the pre-existing territorial resources - landscape, environment, healthy air, which originally attracted inhabitants, vacationers, and tourists - and having consumed the "positional value", in many coastal settlements we are observing phases of decline and abandonment (Goula et al., 2012), even during the summer season. Residents and holidaymakers have preferred other or more attractive destinations. The result has been a gradual decrease in the number of visitors, the lack of care and maintenance of commons, and finally the diffused abandonment of public and private space (Nifosì & De Angelis, 2023). Roads, car parks, and services, losing their role, are underused. Much of the existing building stock, in excess compared to demand, has depreciated in value and now is not worth the taxes and maintenance costs necessary for its preservation (Formato, 2022). To these specific areas we turn our investigation and project attention.

4.1 Coastal Road Atlas. Methodology and first measurements

The methodology for the Atlas elaboration relates some coastal roads spatial dataset indicators with other demographic, socioeconomic and environmental indicators (Gargiulo et al., 2020). The quantitative aspects, represent in a series of national maps the aggregated indicators; the qualitative ones, through a bottom-up analysis on the case studies, looks closely at the morphologies of the roads, the land uses, the specific conditions. This methodology makes it possible to frame the national coastal system by aggregating phenomena that are often studied and viewed independently, to identify their interdependencies, and finally to assess the transformative and adaptive potential of the coastal everyday life infrastructures to contrast territorial fragility, abandonment and marginalisation phenomena.

The data collected and analysed from various national research institutes and public administrations are at the municipal scale and are represented in the Atlas, both at the national and at the local scale within certain focuses.¹⁵ The following table shows the main sources used to produce the maps.

The roads, in linear geometry, were taken from the *Openstreetmaps* database, while the road surfaces come from the databases of some territorial authorities (municipalities, provinces and regions).

The density of coastal roads is expressed in km (graph) at the national scale and in sq.m. (surface area) at the local scale and analysed within some significant buffers: 300 m from the coast (Galasso Law, environmental protection constraint of the coastal strip), 1 km from the coast or within the municipal boundaries (Istat, 2022). For the definition of the "high coast" (which will have to mitigate the risk of landslides) and "lower coastline" (which will have to measure the sea level rise) on a national scale, the surface area below (or above) 20 metres asl was obtained from the INGV high-definition DTM (10 metres), re-processed as a contour line in vector format.

To elaborate some focuses among the "lower coastline" the density of coastal roads (expressed in surface) was cross-referenced with the scenario of ground level rise >1m and ground acclivity <5 degrees.

¹³ The Ministry of Infrastructure and Sustainable Mobility, through the Maritime State Property Information System (S.I.D), has updated data on state property concessions after 3 years. The new data has been processed till May 2021.

¹⁴ In addition, the coastal zone planning framework in Italy is also characterized by the fragmentation of responsibilities (state, regional and local) for coastal zone management.

¹⁵ ISTAT borders were used for the socio-demographic analyses and the final representation, while OSM borders were used for the road density indexes elaboration.

A table with several indicators - and their sources - used in the mapping process is shown below (Tab.1).

	Year	Unit of measure	Source	Territorial extension
Indicators				
<i>Resident population</i>	2005-2022	Inhabitants (Trend evaluation)	ISTAT	Municipalities
<i>Average purchase and sale value</i>	2005-2022	Euros per sqm (Trend evaluation)	OMI Database, Agenzia dell'Entrate	Municipalities, OMI zones
<i>Share of inhabited dwellings</i>	2019	% of dwellings	ISTAT	Municipalities
Spatial datasets				
<i>Terrain elevation</i>	2022	Meters above sea level	DEM of Italy with a 10 meters cell size from INGV	Coastal areas
<i>Roads</i>	2023	Km	OpenStreetMap	Coastal areas
<i>Landslide risk degree</i>	2020-2021	Low-medium-high	ISPRA	Italy
<i>Hydraulic hazard degree</i>	2020	Low-medium-high	ISPRA	Italy

Tab.1 Sources used to produce maps

The following maps from the Atlas are an example of the application of the introduced methodology. The first image (Fig.1a) relates the density of roads within the 1000 m buffer to the percentage of unoccupied houses in coastal municipalities. Territories that are more fragile than others in terms of underutilization (or capacity for re-use) are highlighted. On the other hand, the map on the right (Fig.1b) shows the change in the average real estate value trend in the littoral municipalities (the devaluation and revaluation of real estate assets), taken from the database of the Agenzia delle Entrate's real estate market observatory. Coastal roads are interpreted as a potential space connecting segments and scattered artefacts affected by strong phenomena of disuse or seasonality, and therefore, as a potential for redevelopment of waterfronts through interventions aimed at the quality of public space and the environment.

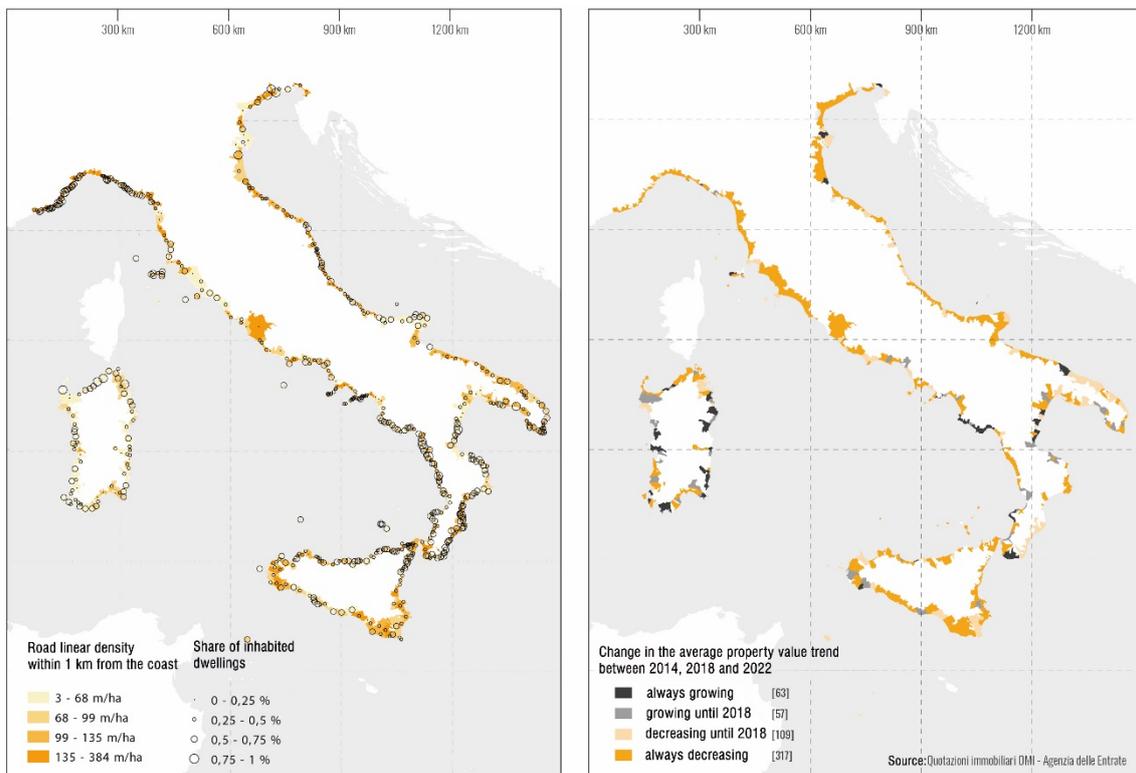


Fig.1 a) Unoccupied houses in coastal municipalities and coastal road density (left); b) Change in the average property value trend between 2014, 2018 and 2022 (right)

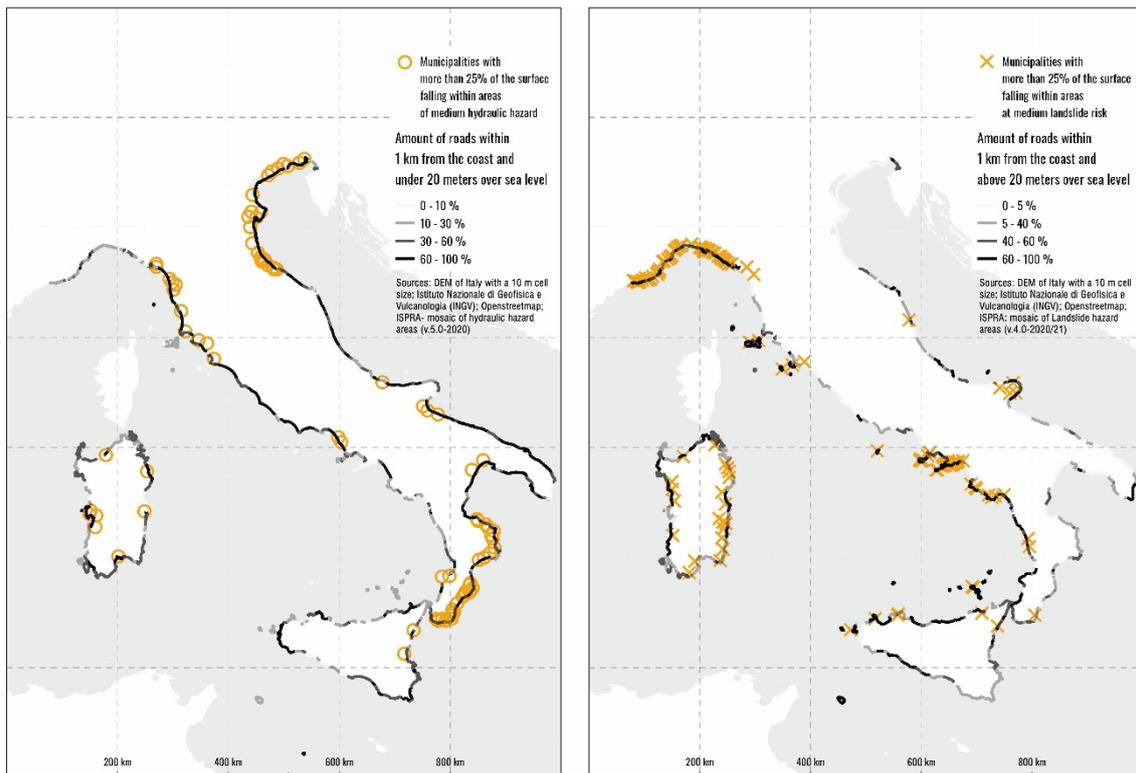


Fig.2 a) Roads density within 1 km from the coast, below 20 masl and hydraulic hazard; b) Roads density within 1 km from the coast above 20 masl and landslide hazard

Several criteria were used and superimposed to construct the next two maps (Fig.2a-2b). In the map on the left, the density of roads within 1 km from the coast and below 20 m above sea level is related to the hydraulic hazard (coastal municipalities that have more than ¼ of the area of the municipal territory classified by the PAI as at hydraulic risk). In the map on the right, the same spatial data are related to landslide risk (coastal municipalities that have more than ¼ of the surface area of the municipal territory classified by the PAI as at landslide risk).

4.2 Lazio region case study

As a relevant case for a more detailed exploration of a "lower coastline" we have chosen the region of Lazio, and in particular the territorial transect between the municipalities of Sabaudia and Sperlonga.

In Fig.3 the percentage of land use within 300 m and 1 km from the coast is estimated and depicted. The area of coastal roads (infrastructures in the legend) is placed in relation to the soil materials distinguished in densely urbanized areas, urbanized areas, green areas and urban equipment, agricultural areas, greenhouses, areas with wooded and shrub vegetation, riparian and coastal areas. A detailed land use analysis allows us to imagine a balance between impermeable and draining surfaces for water management risk mitigation.

The rise of the sea along the Italian coast is estimated by 2100 to be between 0.94 and 1.035 meters (conservative model) and between 1.31 meters and 1.45 meters (on a less conservative basis). The projections are given by the IPCC and ENEA. To these values we have to add the so-called storm surge, i.e. the coexistence of low pressure, waves and wind, which varies from area to area (Bondesan et al., 1995), which in particular conditions causes a rise in sea level with respect to the coastline of about 1 meter.

In the Fig.4, the road area (expressed in square meters) within 300 meters from the coast with ground acclivity < 5°, is superimposed on three different sea level rise scenarios (1,2,3 meters) and on the PAI medium hydrogeological risk band. Within this transect, in addition to the area of exposed road infrastructure, the resident population at risk is also estimated.

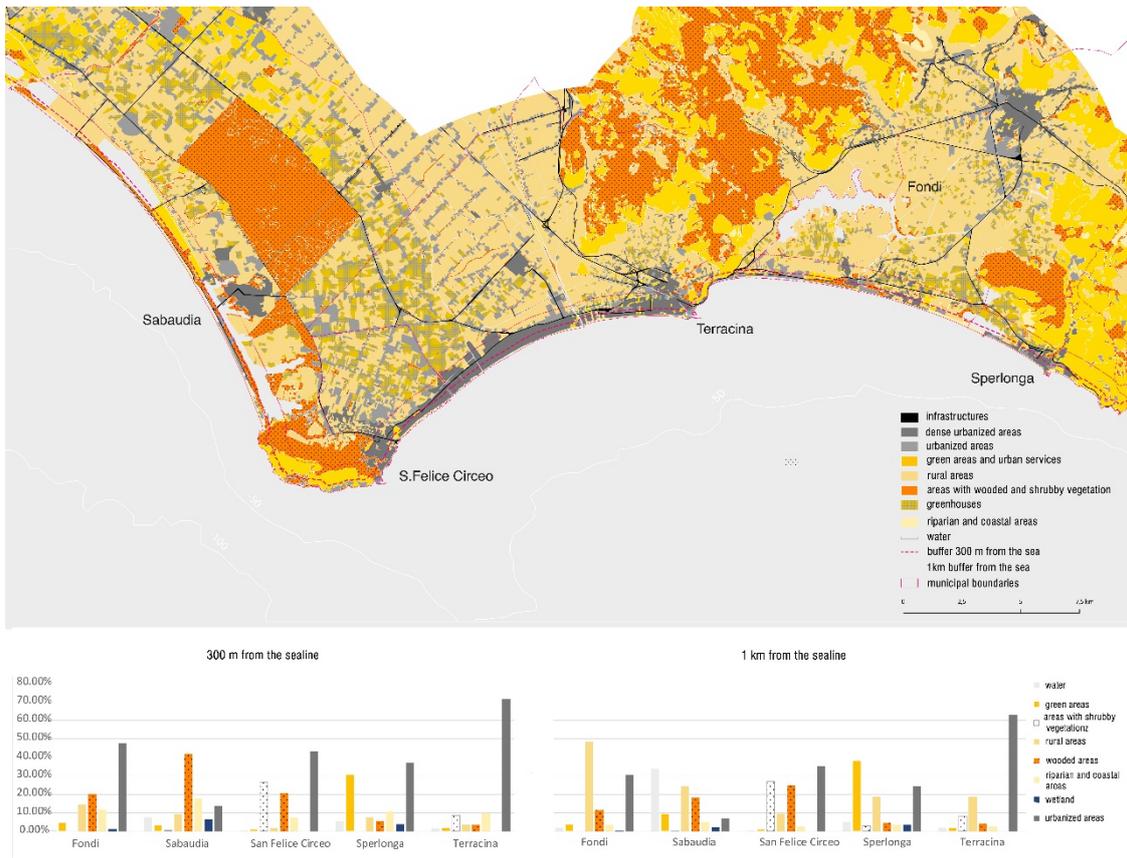


Fig.3 Percentage of land use within 300 m and 1 km from the coast between Sabaudia and Sperlonga

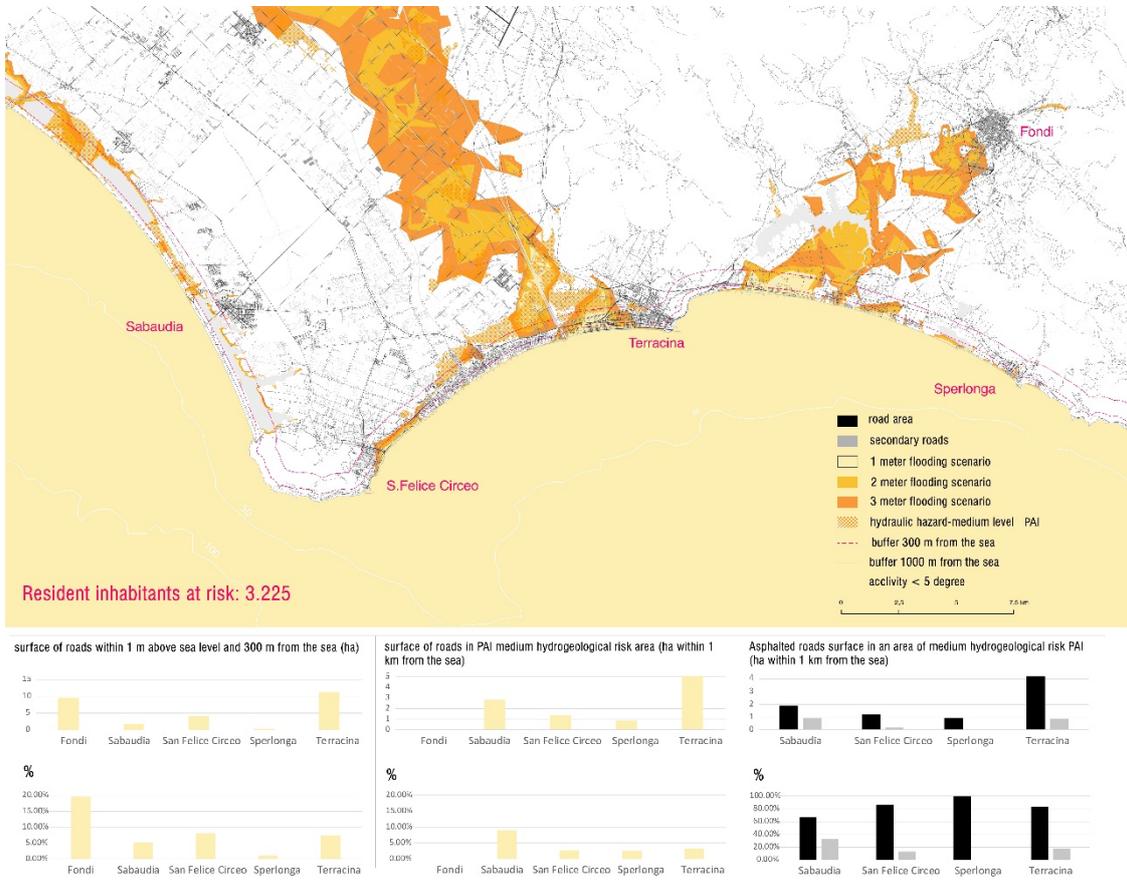


Fig.4 Circeo peninsula Focus. Road area within the medium hydraulic hazard and sea level rise scenarios related to the inhabitants (3,225 inh.)

In the composite image we see at the top the analysis of the entire transect, and at the bottom a focus on Terracina. The central table summarizes: the quantities (in hectares and percentage) of roads at risk of flooding, within the 1 m sea level rise scenario, falling within 300 meters and 1 km from the coast; the quantity of roads falling within the PAI medium risk band and within 1 km from the coast. Finally, paved roads (urban, provincial and state) and minor roads (dirt roads and paths) falling within 1 km from the coast are distinguished and quantified. Here too, it is interesting to measure the degree of waterproofing of road soils to possibly devise strategies for de-paving or protecting white roads, replacing the road surface with more draining materials, and introducing rain garden systems starting from the redesign of the road section.

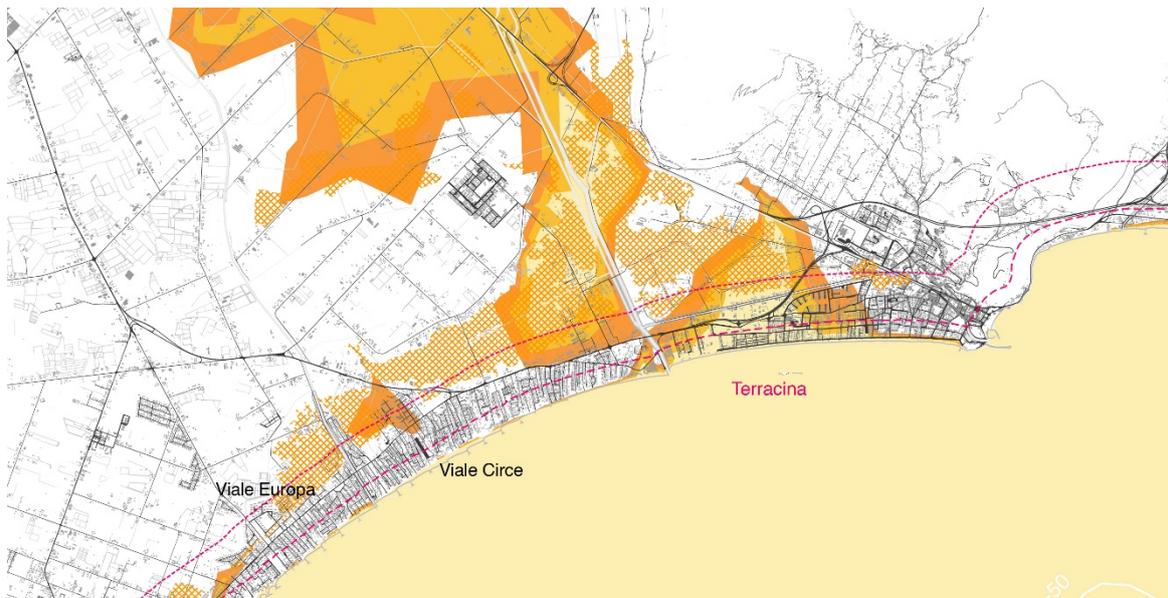


Fig.5 Terracina focus (2,636 inh.)



Fig.6 Morphological readings and bottom-up mapping of Terracina's coastal roads

5. Conclusion

The study analyses the effects of the ongoing socioeconomic and climatic changes in Italian coastal territories through the lens of road space and aims to implement a multi-scalar atlas aimed to make the multiplicity of

sectoral tools and projects working on everyday public spaces coherent with each other, in response to ongoing changes. The concentration of population and economic activities along the coast has been based, and is still based, on infrastructures that depend mainly on road transport (Rocchi et al., 2023). Lines, grids, combs of coastal roads have rigidified the coastline, reducing its natural thickness that governed its hydraulic regulation. Damage caused by climate change is expected to increase significantly over the century. In particular, the intensification of flooding for low-lying coasts and landslides for high coasts, will cause an increase in the number of people and commons exposed to risk. By integrating social-climate resilience into the planning (Burden, 2013; Carra, 2022), design and ordinary maintenance practice of coastal roads, risks for infrastructure and communities can be reduced and long-term adaptation processes can be fostered. The measures that can be pursued are of different types (Al, 2018) and find their way not only into road areas but also into the appurtenant spaces that are available or will be made available. Actions can be taken, for example, through:

- a planned setback;
- a planned selective demolitions actions associated with forms of compensation/equalization for private actors involved;
- the reclassification of some coastal roads, rethinking them with pedestrian and bicycle priority (Tira, 2005), building new relationships between the coast, the network of services and underused assets;
- the implementation of existing ecosystems through the conservation or restoration of coastal habitats and biodiversity, strengthening the natural framework of the remaining coastal territory;
- dynamic coastal management that may include the restoration or creation of natural buffer zones (beach nourishment, dune stabilization, wetlands, shrublands or wooded areas that can absorb wave energy and provide natural protection against storm surges, reducing the vulnerability of coastal roads;
- the introduction of green infrastructure within coastal roads for water and temperature management (rain gardens, permeable pavements and biofiltration systems). Starting from the more detailed observations of the case studies, the experimentation of these measures on the coastal roads in the most vulnerable parts of the territory will proceed towards two declinations: 1) measures for the highways (SP, SS) where it will be urgent to rethink the problematic relationship between living spaces, services and crossing car traffic; 2) the network of secondary urban roads, which can be reconsidered as waterfronts, with limited traffic, greener and bluer.

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Image Sources

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