Chapter 14
A Digital Information Model for Coastal Maintenance and Waterfront Recovery

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Abstract In the context of the global climate crisis and the resulting catastrophic flooding phenomena, the contribution looks at an innovative digital model for the coastal recovery, attentive to the protection of waterfronts and their stakeholders. By intervening in the relationship between transformation and conservation of built environment, it is necessary to establish governance support tools capable of foreseeing emergency scenarios to protect the population. The research looks at the port areas of coastal cities as a contemporary and collective public space in which to test the collaborative digital model proposed for waterfronts recovery and maintenance. The need-based methodological process used the human life protection, exposed to flooding danger, as the input of a design process. Through a survey and modeling phase, the waterfront breaks down into environmental and technological systems, specifying the extent of the failure. The waterfront digitization allows providing the governance with a sensor alert tool that gives the monitoring of the behavior and the state of the waterfront elements' degradation. This information is simplified and given back to the users who both made responsible for the maintenance culture of the places they use and alerted to the possible danger they are exposed. The case is Atrani, where an internal flooding, caused by the estuary overflowing, degenerated in the entire coastal system up to the sea. The results provide a digital model capable of exploring and optimizing the coastal built environment to increase the governance capacity and the waterfront performance.

Keywords Coastal digital regeneration · Maintenance · Port areas · Waterfront recovery · Flooding

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14.1 Introduction

The climate crisis and the consequent catastrophic flooding phenomena drive research to identify an innovative digital model for the recovery of the coastal built environment, attentive to the protection of waterfronts (San-Miguel-Ayanz et al. 2017; Lyddon et al. 2020) and their stakeholders (Costello et al. 2009; Deepak et al. 2020). This need stems from the consideration that 39.3% of the European population resides along the coastal area (Ciampa et al. 2021a), of which 1.4 million people are affected due to flooding phenomena (Raška et al. 2022), suffering approximately 1 billion damages per year (Grillakis et al. 2016; Amponsah et al. 2018; Mannis 2020). Linked to the need is the urgency with which to intervene, as people's exposure to flood events will increase over time (Mediero et al. 2014; Rizzo et al. 2020). The latter is exacerbated by the change in global warming—from level 2.5 to 5.6 over the period 1908–2080 (European Agenda 2020; Rogger et al. 2017)—and the consequent depletion of 0.8% of Europe's gross domestic product (European Commission 2009; Parisi 2021) linked to the vulnerability of coastal systems. These projections push research to intervene in the relationship between use and maintenance of the built environment, trying to establish governance support digital tools capable of foreseeing emergency scenarios to protect the population. The latter is no longer only the receiver of the data but also its co-producer. The community involved as a user of the coast contributes in the digital intervention systems through collaborative information flows (Durugbo et al. 2011; Giurgiu 2021). The user can become a support to digital coastal monitoring and alerting tools through the construction of interaction and interchange networks that offer a new methodology of information flow analysis (Boccaletti et al. 2006).

The latter aims to improve the organizational requirements related to the ability to recognize a waterfront failure, the efficiency to report it, the adaptability to weather monitoring tools and the flexibility to respond promptly to the flood event that might occur (Schultz-Jones 2009; UNRISD 2021). This allows for the possibility of proposing digital models that use information flows from the network of users who, while representing lesser knowledge, can identify themselves as an organized community of "explorers" of their coastal system (White 2008; Biden 2021). The involvement of users becomes a significant requirement within the phases of information flow collection as it improves community collaboration on the one hand and empowers the community for widespread monitoring on the other. In the digital information model, the aggregating factor influences the organizational structure of data processing resulting in more efficient decision-making for expert knowledge (Durugbo et al. 2009; Ciampa et al. 2021b).

14.2 Stakeholders Role into a Digital Information Model

Human participation within digital information models is based on the sense of "responsibility" and "empowerment" of users toward the built environment through the same tool: in the first case, it refers to the individual willingness to perform actions of indirect care of the used space through signaling actions that they can actively perform. In the second case, reference is made to the educational training that induces the user to move away and get to safety when they are warned in case of imminent natural danger of the space used (Mohseni et al. 2013; Sun and Ye 2021). This mechanism is based on the prosumer perspective (Izvercianu et al. 2014), which marks the evolution from user to prosumer. Whereby, the citizen is no longer the one who simply uses the places but becomes a producer of the quality of the space contributing with own co-creative actions as a guarantor of vigilance (Boeri et al. 2016; Xin et al. 2022). This perspective determines a multilevel knowledge system at different scales that combines expert knowledge with local knowledge in a multi-sectoral view. The model proposed generates both digital and connective infrastructure (Fusco Girard 2014; Malekloo et al. 2021) because of it involves stakeholders attributing them a monitoring role in place they are located (Viola, 2016; Perez et al. 2019). This allows the stakeholders to point out, in the observation area indicated to them, certain vulnerable units as a field in which to identify and recognize elements to be reported (Caterina 2013; Na et al. 2021). This mechanism allows the community, a holder of common knowledge, to have an active monitoring role with innovative digital tools (Kong et al. 2018). They can report through a mobile application managed by the public administration, which records failures and abnormal performance found by users. In this way, municipality can to intervene in real time through the expert knowledge service offered by competent technicians (Perez and Tah 2021). The feedback that stakeholders identify comes back to them as a capacity to enhance the resilience of the environment and their increasing education about danger (German et al. 2012; Luckey et al. 2021). The stakeholder identifies signs of inefficiency in the space they use by contributing to the reliability of natural hazard warning data (Huang et al. 2016; Hou et al. 2021). The interpretation of the mismatch between the state of the space in efficient performance and that in degraded state serves to intervene on the functional loss. It lets public administration to mitigate the impacts that such degradation would have on the community and the settlement system. In this way, the digital information becomes the built environment vulnerability data linked to the performance decay of the technical element or component affected by the failure (UNI 99100/1993).

14.3 Methods and Materials

The methodology is based on the exigency performance approach (Pinto and Talamo 2015), i.e., meeting primary needs—the protection of human life related to vulnerable and flood-prone users—as input to a transferable digital model (Bosone and Ciampa

2021). This tool experiments and enhances the participation of communities in the maintenance and alerting processes of the port areas used, indirectly contributing to the protection of their lives and the performance efficiency of their built environment in case of catastrophic events (Ciervo et al. 2012). Through a graphical survey and modeling phase, it is possible to break down the waterfront into environmental and technological systems, specifying the extent of disruption. The digitization of the waterfront allows providing governance with a sensor alert tool that provides monitoring of the behavior and degradation status of the waterfront elements.

This information is simplified and feedback to users who are empowered about the culture of place knowledge they use and alerted to the possible danger they are exposed to. The experimental case is the waterfront of Atrani (Fig. 14.1), on the Amalfi Coast in Italy, where a case of flash flood of the Dragone river in 2010 invaded areas from the inner settlement system down to the sea.

The flooding phenomena were linked to both natural causes (low pressure and convective thunderstorm systems resulting in a cumulative daily rainfall of 129.2 mm–19.4 mm/h) and anthropogenic causes (the artificial diversion of the river below the urban area through an underground channel to the sea). The channeled flow generated an overpressure that progressively led to the breaking of the channel slab cover, modifying the flow on the road downstream. In the absence of hydrometric and environmental data, the acquisition of information about the process took place only through the documented testimony of the local population who, with the support of amateur videos, collaborated in the development of identifying the loss of performance of the built environment elements (Fig. 14.2).

Fig. 14.1 Atrani waterfront, 2022. *Photo* Francesca Ciampa

Fig. 14.2 Atrani flooded port area, 2022. *Photo* Francesca Ciampa

The methodology offers a scientific advancement in digital maintenance tools because it identifies in the involvement of coastal built environment users the possibility to enhance the information flows by the collaborative tool proposed. The user involvement indicates in the processes of monitoring the loss of coastal system functionality while preventing the human and urban safeguard. The advancement is to induce community empowerment toward the waterfront by employing indirect monitoring and care actions for the built environment. This methodology improves and simplifies the acquisition of digital data by returning a model of shared information capable of interacting with users in both direct and feedback forms. The methodology uses the privileged user point of view to optimize data collection methods with respect to coastal technical elements monitored by inspection over time. The methodology merges the decision makers view with stakeholders one in order to optimize the data collection, both monitoring the inspection elements over time. The methodology innovates the prefiguration of new models of management, evacuation and sustainable maintenance of the coastal environment both through alerting technologies and through the assessment of the efficiency parameters and waterfront livability quality. This allows the cooperation of different figures, respecting the specific and/or general knowledge and competences, related to each other for the effectiveness and the safe control of the usability of the coastal area.

14.4 Results and Discussion

The results provide a digital model capable of exploring and optimizing the coastal built environment in order to increase the governance capacity and overall performance of the waterfront. By discrediting the coastal built environment through classes of environmental and technological units, it has been possible to simplify the reading of the complex port area using analogy by image. This brought the community closer to knowing their built environment despite not having technical knowledge. In order to allow stakeholders to identify the classes of technical elements, it was necessary to guide the user to the signaling, directing and simplifying of the input data, and thus, giving the possibility of categorization through a univocal association. To this end, the image that the user could provide needed textual accompaniment to be selected based on pre-set definitions agreed with the expert knowledge. Acting on the individual performance dysfunction of the coastal margin or its urban surroundings allows for a flexible information organization construction. An artificial intelligence algorithm that analyzes the photograph and labels it based on data training establishes the association between the picture taken and the list of accompanying technical commentary. The latter acts by evaluating both whole image classification and object detection. The signaling of a fault, through digital application tools of the public administration (decision-makers), can affect the functional loss of relations with other potentially damaging parts. This decomposition therefore intervenes on an interscalar logic that allows monitoring, in an indirect way, including the intermediate levels through the mitigation of the damaged relations. The complex system of the port area identifies the waterfront as an observation site whose sensitive unit is represented precisely by the subset of technical elements that influence the classes and the close relationships with the built environment. The class of vertical elements refers, for example, to the waterfront embankments; the class of horizontal elements refers to the surface of the pier; the class of installations refers to the technological solutions for mitigating and raising the water level. The class of furnishings refers to those coastal soil modeling solutions that trap excess waves in emergencies, and instead, in normal conditions, act as recreational equipment or street furniture. The alert system provided by the users (stakeholders) flows into the support of alert situations, which are then evaluated by the technical operator in order to define the need and priority of possible inspection methods. These professionals return the data to the alarm operator who communicates to the public administration (decision-makers) both the possibility of intervening to realign a loss of performance and to evacuate the area in case of the simultaneous occurrence of a flooding event (unmanageable due to the absence of functional safety). The contribution identifies the involvement of different actors, with specific reference to stakeholders, in the digital monitoring tools which include four benefits of coastal performance efficiency: adaptation, perception, coordination and reciprocity. Proposed model has the adaption capacity to merge the tangible flexibility, linked to the physical transformations of coastal environment; and the intangible one, linked to the community use modalities of the waterfront. Adaptation expresses the need to use digital tools that involve and, at the same time, empower stakeholders to their built heritage. The model perception aspect concerns the intuitive ability to monitor the built environment, transforming users knowledge into a tool to support technical knowledge. Perception expresses the possibility of binding the built environment to an image/state of the built environment that monitors its performance whenever it is out of line with perception. The model concerns a reciprocity aspect based on the simultaneous ability to protect both people by protecting the built environment of the coastal system they use. Coordination as the ability to translate qualitative data into technical and scientific data. Coordination as collective sharing for the pursuit of the common good. Reciprocity expresses the ability to return performance so that the connections and balances between the single functional loss and the system with the realignment which it communicates. The model proposed represents a collaborative digital tool for coastal recovery and maintenance. (Fig. 14.3).

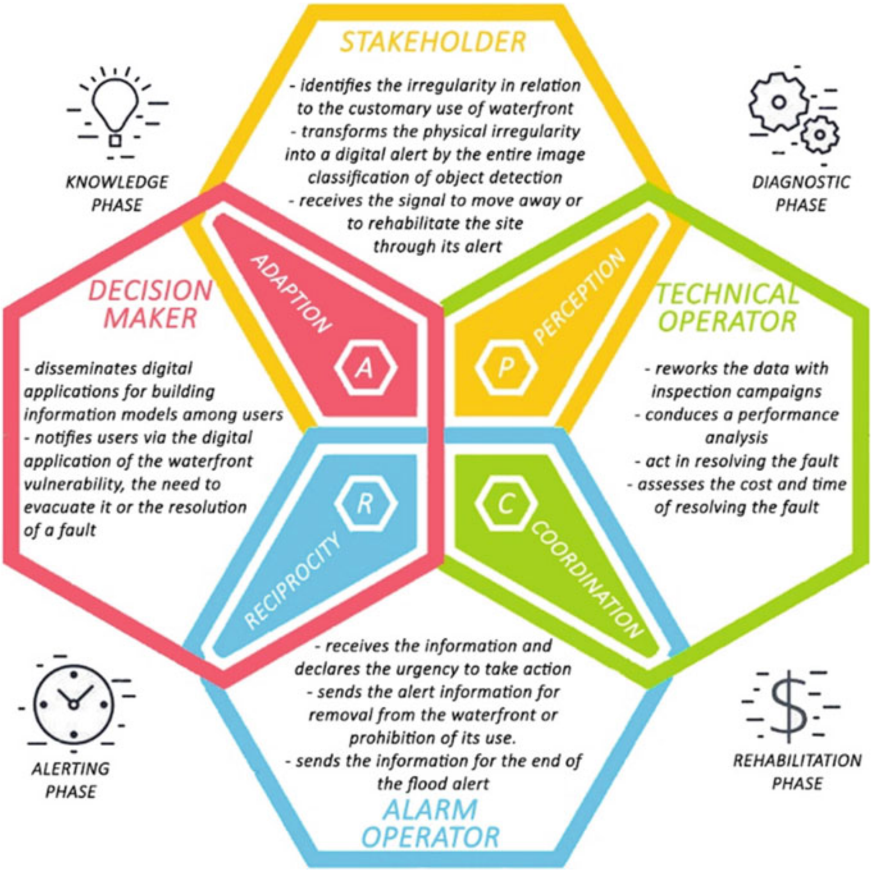

Fig. 14.3 Shared digital information model

14.5 Conclusions

The digital coordination of waterfront recovery and coastal maintenance actions finds application in urban activities assisted by the contemporary technological context. The diffusion of digital systems and devices makes it possible to improve the performance of the built environment and to monitor the performance of activities in aggregated multi-actor forms. The maintenance of settlement quality, while respecting the safety, usability and well-being of its users, is also based on the ability to recognize, in a shared way, the loss of functionality of the coast constituent elements. Waterfronts, which have accommodated settlement processes for generations by adapting to community spaces, find in digital information models tools to mitigate and prepare for the consequences of climate change and to respond effectively to community needs.

The proposed model opens the research toward a type of service in which the stakeholder becomes an active part in the effectiveness of the digital action through interfaces with a simplified communication language in a network of user communities.

The model represents functionalities designed for the protection of human life and active monitoring for coastal recovery activities. The model offers the possibility of integrating information necessary for the management and appropriate operation of the waterfront and its expected performance. The model, accessible remotely and interactable or independently updatable, allows stakeholders and administrations to interact to form different information systems. The model of shared digital information opens toward the possibility of connecting the performance alignment of the coastal built environment with applications and services, generating a complex process characterized by a capillary integration of connectivity at different scales of action, replicable in a built environment with similar vulnerabilities. The shared digital information model explores the use of models that integrate a centralized component and backend systems. It makes them available as service interfaces, using a system that interconnects the elements of the coastal built environment with a network of stakeholders. The latter can transmit information or coordinate an alert and retrieval process reducing dependencies between them. This type of model offers greater flexibility and speed in the coordination of recovery actions, identifying in a timely and circumscribed manner space the elements on which to intervene. This, on the one hand, represents an extensibility and scalability of the model's functionalities, and on the other, it reduces costs through greater agility of action, developed by the efficiency dictated by the shared need. The shared digital information model could be further advanced by generating standardized communication protocols to which the community could be educated, resulting in a higher level of interaction, and scaling back inconveniences or transmission errors. This would allow the model to offer ever greater reliability both as a stakeholders involved responsibility and in terms of the process effectiveness. In this way, the shared digital information model acts in the built environment, realigning performance with new needs, receiving stakeholder requests by transferring them as intervention requirements and inducing appropriate response transformations.

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