DECIDING ON THE MEASURES IMPLEMENTATION FOR RIVERFRONT FLOOD RESILIENCE: ACTOR MAPPING AND NETWORK ANALYSIS

Track: Governance and Policy: Conditions to Increase Civic Engagement in Urban Development

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ABSTRACT

Riverfront redevelopments pose significant challenges in achieving effective flood resilience. The success of riverfront design relies on a strategic combination of measures. Levees, floodwalls, and drainage systems are known as structural measures and help mitigate immediate flood risks, while non-structural approaches, such as land-use planning, policy frameworks, and community engagement, focus on offering long-term, adaptive strategies. Over the past three decades, developments in Hamburg, Germany, have integrated structural and non-structural measures into their flood management strategies. Even though there are exemplary models of effective riverfront design in Germany, there is a lack of research regarding the specific design decisions that contribute to their success. Additionally, the roles and influences of human and non-human actors in shaping flood-resilient designs are insufficiently researched.

This paper investigates the actors involved in the implementation of either structural or non-structural interventions for flood resilience in the riverfront redevelopment in HafenCity in Hamburg. Using actor mapping and visual network analysis, the research identifies key human and non-human actors involved in the process. Furthermore, the mapping examined their influence on decision-making in the redevelopment of the riverfront. Actor mapping and visual network analysis provide valuable insights into the strength and type of relationships that shape the development and implementation of flood resilience strategies. Data planning documents, project documentation, and regulatory frameworks was used to construct an actor-network map.

The analysis points out that HafenCity's flood strategy relies on a three-part core: the City of Hamburg, which sets the rules; HafenCity Hamburg GmbH enforces the rules in every land sale; and the Warft (elevated ground) model that translates law into concrete defence works. This paper provides a comprehensive framework for understanding the interplay of actors that influence the use of structural or non-structural measures for flood resilience in riverfront redevelopment in HafenCity.

Keywords: flood resilience, HafenCity, riverfront redevelopment, urban waterfronts, visual network analysis

INTRODUCTION

In response to sea level rise, fluvial floods and storm surges governments are experimenting with hybrid governance models that mix public regulation, private finance of projects, and involvement of the community (Restemeyer et al., 2018). With the rise of climate-induced risks, such as floods, riverfront redevelopment projects must find the balance between becoming resilient and following their economic and urban development aspirations. This paper investigates how flood resilience measures are conceptualized, negotiated, and implemented in HafenCity redevelopment project in Hamburg. Resilience can be framed in terms of infrastructure or robustness (Ahern, 2011). However, this paper adopts a sociotechnical perspective that understands resilience as an evolving and relational process (Folke, 2006).

Existing research on HafenCity is rich in design narratives and governance mechanisms. This paper fills the gap by mapping the full actor network behind flood-risk protection mechanisms, including all human and non-human actors (such as engineering solutions) and examining how ties evolve from design through operation and maintenance. The research draws on Actor-Network Theory (Latour, 2005; Yaneva & Heaphy, 2012) to trace how decisions about flood protection are shaped by assemblages between human and non-human actors. The HafenCity case is unique for exploring how resilience is embedded both in built forms and institutional decisions, planning, and urban image. This paper contributes to the discussion on urban resilience by focusing on the process of implementing resilience.

HAFENCITY PROJECT

A model for living with the water

The rise of neoliberal urbanism has brought a shift in European flood-risk management from State-centric towards mixed public-private models. Cases like Rotterdam, London, and Copenhagen show that governments sustain their legal authority, but they progressively rely on private resources and expertise for flood management (Klein et al., 2017; Mees et al., 2014; Restemeyer et al., 2018). HafenCity is the largest inner-city development in Europe, which transforms 157 hectares of former port infrastructure into a new urban district on the banks of the River Elbe. HafenCity is one of the precedents of this shift as it requires that developers finance on-parcel protection and develop it.

Site and flood-risk setting

HafenCity occupies the former free-port islands in Hamburg, which are directly exposed to Elbe storm surges that can reach +6 m NN. The 1962 flood still influences local safety culture (Mees et al., 2014). The HafenCity area is exposed to tides as well, so flood resilience was prioritized from the beginning of the project. After the flood in 1962, the city increased its flood protection levels through several dike improvement programs. Today, the LSBG (Roads, Bridges and Waterways Agency) designs the flood protection for a water level rise of +8.3 m NN by 2100. However, the achievement of flood resilience in HafenCity was never understood as purely engineering resilience; socio-ecological resilience is also given significant importance.

Structural and non-structural measures for flood protection

HafenCity occupies the area outside Hamburg's main dike line. The city rejected a perimeter dike for the area and decided to use the "Warft" approach: In the Sandtorkai/Dalmankai district, every plot and public street is raised to ≥ +7.5 m NN (now +8.3 m NN for new phases (Freie und Hansestadt Hamburg, 2024). The lower quay promenades are floodable (Figures 1, 2, 6, and 7). The new ground surfaces to ≥ +7.5 m NN enable phased, plot-by-plot development without delay (Infrastructure, n.d.). Utilities and evacuation bridges (Figure 3) remain operable when quays, streets, and public spaces are inundated.

Figure 1: Floodable promenades and buildings using waterproof membranes

Figure 2: Flood Gates

Figure 3: Evacuation bridges

Figure 4: In-between public spaces

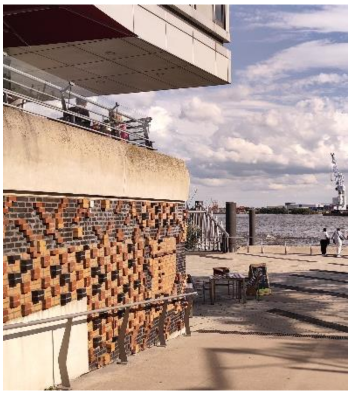

Figure 5: Plinth structures

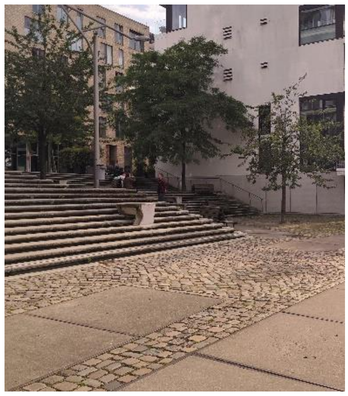

Figure 6: Floodable public spaces

Furthermore, each of the buildings add site-specific defences in form of structural measures. These measures, besides the raised plinths (Figure 5), include escape routes with pre-defined minimum elevation (Figure 5), dry-proof façades (Figure 1), flood gates and water-tight service penetrations (Figure 2) that are sealable. Part of the flood responsibility has been transferred to the private sector as developers were required to build plinths for the buildings at a minimum of 7.50 meters.

Non-structural measures include maintenance and operational plans, flood protection officers per property or building group, yearly testing of closures and technical systems, and notifying the residents of possible storm surges. For this purpose, as inscribed in 2002 Flood Protection Ordinance (Flutschutzverordnung-HafenCity, 2002), each condominium block forms a "collective flood-protection association" (Flutschutzgemeinschaften) which is responsible for annual drills, door maintenance, and closing of the flood gates during events - these tasks are often outsourced to security firms. A real-life test for flood protection came in 2007 when a storm surge overtopped the quay parapet (+5.1 m NN). Minor garage flooding revealed two malfunctioning flood doors. Finally, HafenCity residents are notified of imminent storm surges through printed storm-surge information leaflets and online/app-based warning services (Storm Surge Information for Residents of the HafenCity and the Speicherstadt, 2024).

Flood-Risk Governance Architecture, Legal and Policy Instruments

There are a few legal instruments that organise the HafenCity flood protection process. Its governance is deliberately hierarchical. The decision-making process is publicly led but is privately implemented. Three institutional pillars organise HafenCity's flood governance:

(i) the State Agency for Roads, Bridges and Waterways (Landesbetrieb Straßen, Brücken und Gewässer - LSBG), which oversees city-wide flood defences.

(ii) HafenCity Hamburg GmbH, which coordinates planning and land sales.

(iii) Private investors and developers, which are important after the building completion. They are obliged to form the condominium associations that bear the maintenance duties.

Hamburg's Ministry for Urban Development and Environment (BSU) and its agency the LSBG set the safety standards, which are embedded in the 2002 Ordinance (Flutschutzverordnung HafenCity, 2002), check if developers complied to the standards and approve the plans and give building permits at completion stages of building implementation. The LSBG provides technical input on flood levels and minimum implementation standards according to flood levels. First, the 2002 Ordinance codifies minimum plinth height and the duties of the Flood Protection Associations in the maintenance stage of the project. The Local Development plans (Bebauungspläne) for each neighbourhood in HafenCity embed plinth rules in zoning. Finally, the Letters of Intent (Anhandgabe) protocol ensures the building meets the standard.

HafenCity Hamburg GmbH is a completely city-owned developer established in 1997, which coordinates plot sales and ensures designs meet the flood codes using its bargaining power to mediate between the Municipality and the developers. HafenCity Hamburg GmbH works iteratively with each developer. The land sale is executed only after flood-design compliance, aligning market incentives with safety. Flood protection is legally enforced by public authorities, but the operational responsibility (the design, maintenance, and alert systems) is decentralized to property owners. Private property owners are responsible for implementing and financing flood protection measures on their buildings, forming legally mandated Flood Protection Associations. However, there are no direct subsidies or tax rebates to HafenCity property owners – costs for flood protection are viewed as paying for the privilege of waterfront living. While private actors carry the cost and execution of the "Warft" model elevation and the other specific building measures, BSU manages risk communication and emergency planning (Mees et al., 2014).

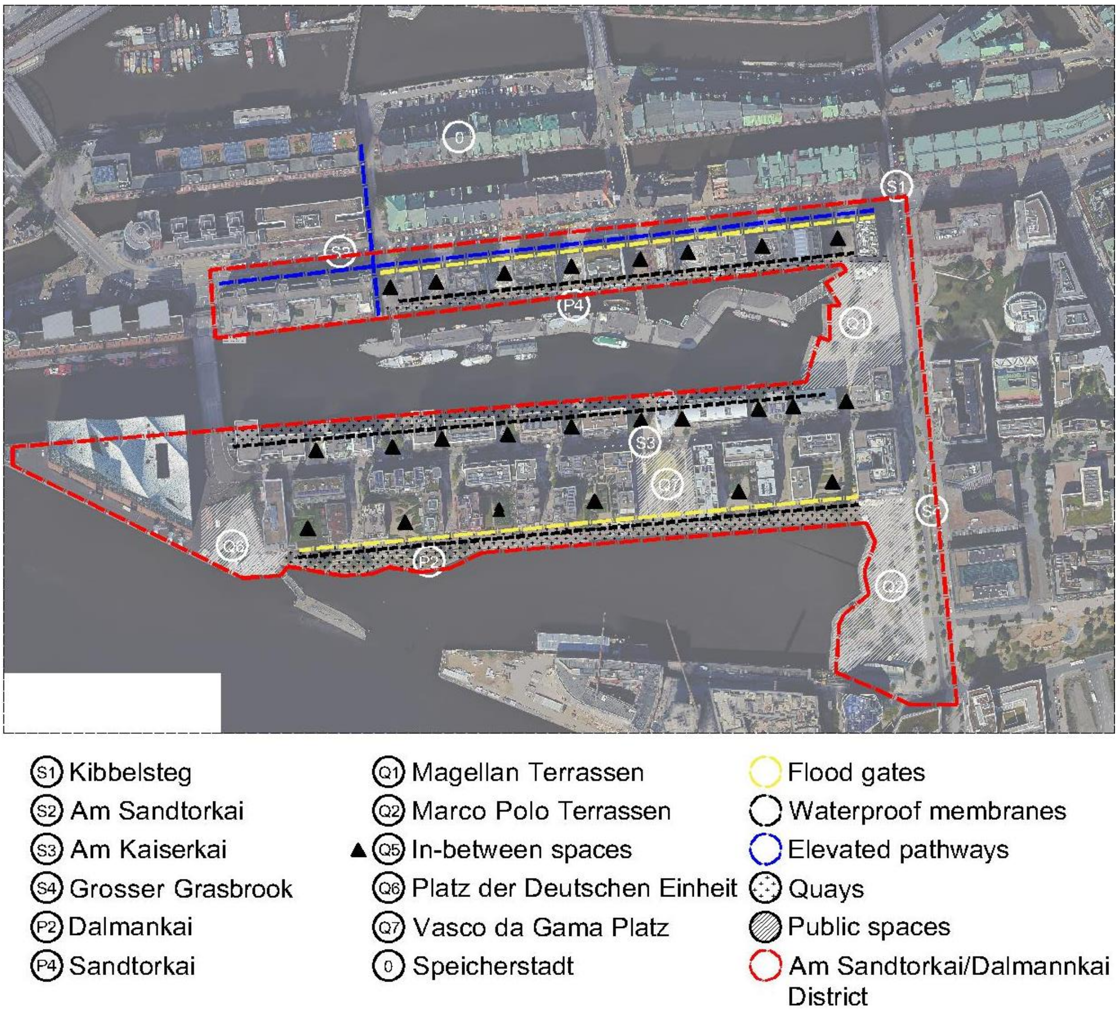

Figure 7: Area being studied. S2, P2, P4 are floodable streets beneath the water level

METHODOLOGY AND THEORETICAL FRAMEWORK

HafenCity was selected as a case study for its prominence, data availability, and advanced project stage: by 2025, roughly two-thirds of its floor area will be complete, which provides insight into both construction and maintenance phases. Data was collected through review of the project website, planning documents, policy reports, scientific literature, and design guidelines. At the explorative stage of the research experts from ASTOC and KCAP were interviewed to gain knowledge on the process of urban planning and how it involved flood protection. The focus of the research was the Am Sandtorkai / Dalmankai District (Figure 7).

This research applies a qualitative, Actor-Network Theory (ANT) informed methodological approach. The first step of the research was actor mapping to identify important institutional, technical, material, and environmental actors (Latour, 2005) through processes of negotiation and translation. This method reveals resilience not as a static goal, but as a situated, socio-material outcome of continuous reconfiguration (Latour, 2005; Yaneva and Heaphy, 2012). The second step was to trace the networks and see how their relationships shaped decision-making.

Each mention of interaction relevant to flood-risk management generated an edge linking a source actor to a target actor. The coded edge types are regulation, authority, resource-flow, partnership, conflict, and expertise. The process mapping covers the period from the project's start year to the present and is drawn synchronically—that is, not all actants (nodes) appear or are active at the same time. Around 62 nodes (public bodies, private developers/owners, legal instruments, infrastructural elements, civic groups, and non-human/environmental actants) were coded and are represented on the map. The Multi Gravity ForceAtlas2 algorithm was used to generate the network (Figure 8). The node size is determined by its betweenness value.

ACTOR–NETWORK ANALYSIS

The network map immediately points to three dominant actants or actant groups: the City of Hamburg + HafenCity Hamburg GmbH, the non-human "Warft Model", and the Flood Protection Ordinance. The density of links radiating from them towards other actants illustrates that they sit on most of the shortest paths across the network. This makes them very important mediators, or even translators between policy, capital, and concrete flood-protection measures (structural or non-structural). HafenCity Hamburg GmbH connects outwards to developers, engineers, residents, and legal instruments. This illustrates its role as a node that every other actor must pass through when moving between the public-law arena and the implementation of projects. The Warft Model, although it is a non-human actor, operates as an "obligatory passage point" (OPP) in Latour's sense. This shows that every technical component - plinth structures, flood doors, sump pumps - relies on this elevated-ground concept, which in turn links up to modelled water levels and the 2002 Ordinance (Flutschutzverordnung HafenCity 2002). The 2002 Ordinance's high betweenness value shows how the legal text itself channels regulatory authority toward plot-level developers.

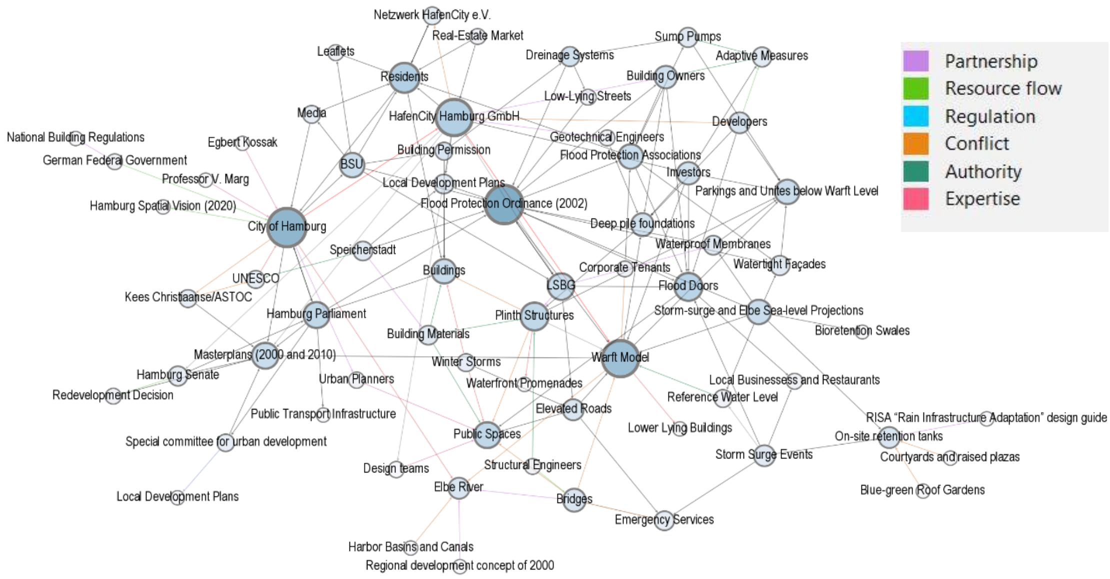

Figure 8: Actor-network map of flood management in HafenCity

There is a second ring of influential but slightly less central nodes visible on the network. The LSBG acts as a mediator between engineering knowledge and power. It is connected through purple edges (which represent partnership) to nodes that are of a technical nature, while green edges (representing regulation) link it back to the City of Hamburg. This illustrates LSBG's dual mandate as an expert and supervisor. Two non-human actants: buildings and public spaces, betweenness indicates how many individual measures and actors are routed through these physical domains.

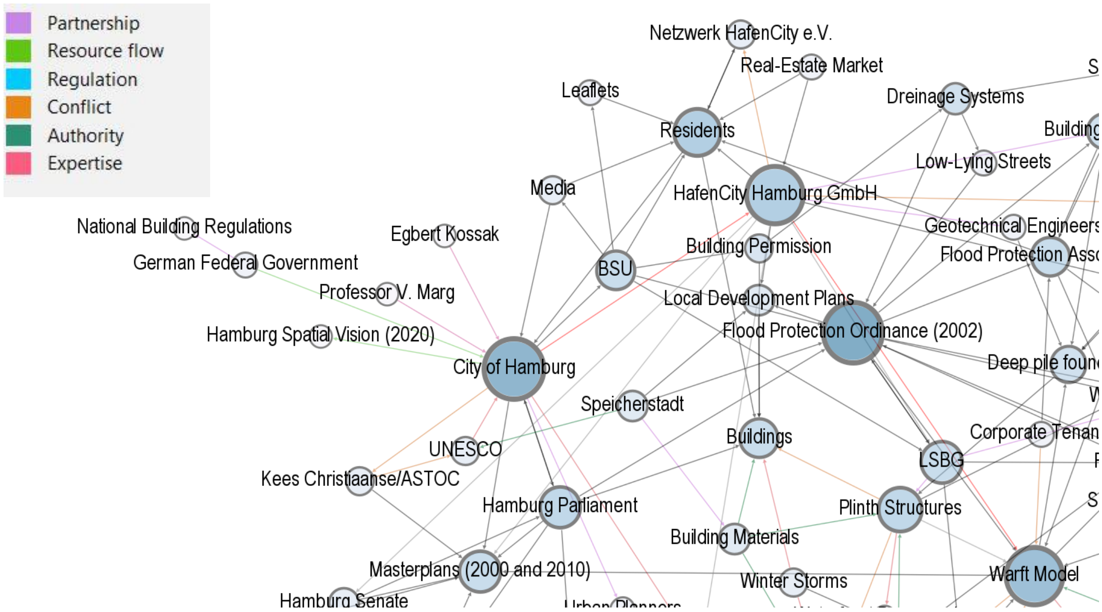

Figure 9: Fragment of the actor-network map showing the policy cluster

Beyond the core actors, the network map shows three modular clusters. At the upper-right, there is a policy cluster (Figure 9) that includes the Masterplan, local development plans (Bebauungspläne), the Hamburg Parliament, and the Hamburg Senate. This cluster is dominated by authority edges, which illustrates the formal planning hierarchy. Around the Warft Model node (Figure 10) sits a densely wired implementation cluster of structural defense elements and specialist contractors. There is also a third, more fragile civic cluster—Residents, "Netzwerk HafenCity" e.V., Flood Protection Associations, that connects to the core of the network almost exclusively via HafenCity Hamburg GmbH and LSBG. This represents the limited number of direct pathways through which citizens can influence flood-protection decisions.

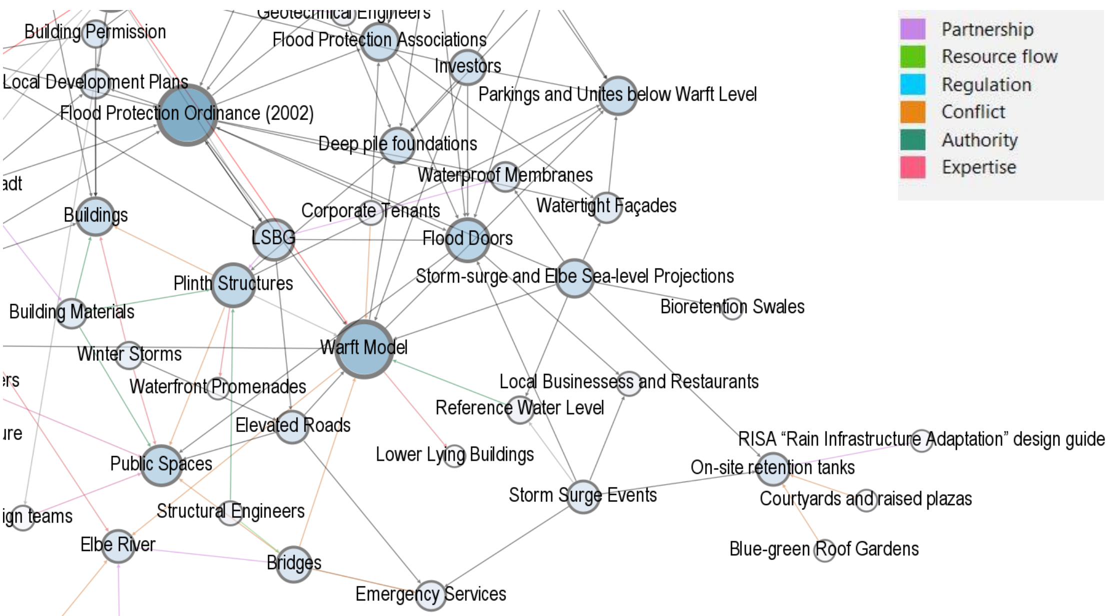

Figure 10: Fragment of the actor-network map showing the structural flood protection nodes

In the actor-network, the structural flood-defence measures form a belt wrapped around the Warft Model and the Buildings nodes. Plinth Structures, Deep-Pile Foundations, Watertight Façade, Flood Gates, Underground Parking, Sump Pumps, Drainage Systems and the small satellite of On-site Retention Tanks/Bioretention Swales all radiate from, or sit one step away from, the Warft Model node and occupy the inner-periphery (Figure 10) they are closer to the part of the cluster of the policy cluster and the Warft model than the civic cluster or the outlying planning documents. That shows that these measures are functionally central but relationally dependent as they rely on the Warft Model node to reach the rest of the network. The Flood Gates bridge two clusters, they connect to the technical belt and, also, to Flood Protection Associations, which shows how certain structural devices also depend on civic action for operation. Finally, Retention Tanks and Bioretention Swales nodes sit further out on the right side of the network, tied to the Warft and Elbe River and Climate-Change influenced water reference level that shows their dual identity as both engineering and ecological measures.

Discussion

The actor–network map of HafenCity's flood governance shows a tri-centric arrangement in which the political authority (Senate and the City of Hamburg), the development mediator (HafenCity Hamburg GmbH), and the material structural measures (Warft Model) form the backbone of the actor-network. Unlike the conventional public-private relationships described in much of the neoliberal-urbanism literature, decision-making in the case of HafenCity must go through an obligatory passage point that is neither purely institutional nor purely technical: raising every parcel to a prescribed level higher than the reference flood risk water level.

The network also shows the power of legal artefacts like the 2002 Ordinance, which is an active actant that shapes the flow of money, authority, and technical details in the area. The 2002 Ordinance is second only to the Municipality and HafenCity Hamburg GmbH in its betweenness value. Because the ordinance codifies the Warft height and obliges developers to form Flood Protection Associations, it connects through both authority and partnership, edges into the "structural" ring of nodes (plinths, sump pumps, and flood doors) which include both structural and non-structural measures for flood protection. The law thus behaves as a mediator. By contrast, the technical nodes exhibit low mediating power, but collectively they constitute the material backbone of the flood-risk strategy. In ANT terms, they are "inscriptions" of safety. The structural measures are dependent actants whose connectivity and their capacity to protect collapse if the Warft Model node is removed. The system's engineering resilience is therefore represented by a single-point-of-failure risk - the Warft concept is the obligatory passage point that activates each structural element. This means that, should future sea-level scenarios demand a further plinth upgrade, the Warft concept - and the ordinance behind it - must be reopened, which will create a moment of potential contestation. Finally, the position of other structural measures' nodes, like on-site retention tanks, bioretention swales, shows they remain peripheral to the flood-safety strategy.

Developers bear the entire expense of building the plinth structures on their plots and building-level defences and emerge as a second strategic pillar. This market mechanism that frees municipal budgets is accepted as the "price of admission" to a waterfront location. The ANT map also exposes the downside of the distribution - the civic actors and small businesses connect to the core almost exclusively via HafenCity Hamburg GmbH. The scarcity of direct links from civic actors into the regulatory core makes visible the lack of participatory input in HafenCity's flood-risk management. This shows its top-down character in the planning phase and the important mediator, HafenCity Hamburg GmbH. The ANT map also points out the debate on public–private partnerships. Although the private sector finances and operates most structural measures, the City of Hamburg retains agenda-setting power through the 2002 Ordinance and through its complete ownership of HafenCity Hamburg GmbH. This hybrid allows rapid decision cycles. If HafenCity Hamburg GmbH were ever dissolved, the number of paths between clusters would lengthen, which would reduce the adaptive speed of the whole flood protection system.

There are possible ways to include participation and civic engagement in the process of flood management. A co-production inside tendering is one possibility. This means actively involving residents or civic groups before the formal submission of a project proposal from the developer. It could be co-designing parts of the project and sharing power and knowledge early inside the competitive tendering process itself. Furthermore, HafenCity already rewards 'inclusive building design' (Interreg Europe, 2023). Therefore, a possible model of increasing participation could be projects to get higher scores if they include citizens in early stages of project design and include design features that support accessibility, mixed-use, social cohesion, etc.

CONCLUSION

HafenCity's flood strategy relies on a tight, three-part core. This arrangement delivers clear duties while shifting all construction and maintenance costs to private developers who profit from the waterfront location. Governance and funding of the project are highly centralised: if either the 2002 Ordinance or HafenCity GmbH dissolved, the actor-network would lose its main bridge between public authority and technical structural measures for flood protection. Civic actors remain peripheral, and are consulted mainly after decisions are made, and green-blue engineering solutions that are supposed to mitigate storm surges play a secondary role in the flood protection.

While it is effective now, the network's lack of participation from civil society may constrain future adaptation cycles. Resident participation mechanisms can be implemented before the eastern phases reach the implementation phase and before plinth heights require another upgrade because of sea level rise. This would strengthen social acceptance and long-term adaptive capacity of the HafenCity area redevelopment. Furthermore, green–blue infrastructure integration would diversify structural measures for flood resilience and would distribute responsibility beyond the Warft monoculture. To stay relevant as the sea levels rise, Hamburg should embed periodic reviews of the flood code and weave ecological measures more tightly into the formal flood protection system.

Finally, HafenCity's network shows high technical robustness, but its social robustness is dependant on a narrow corridor – the HafenCity Hamburg GmbH and limited civic voice. Future research should test whether more polycentric governance could achieve comparable robustness without sacrificing inclusivity of the residents in earlier stages of projects' implementation.

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