A new approach to sustainable development and decarbonisation of airport and seaport territories trough citizen science – HubCities

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Abstract. The HubCities initiative addresses, in the context of other objectives, is the decarbonization of high-carbon airport and port areas as key hubs of European infrastructure. Ecological, social, and spatial factors are taken into consideration in the project, along with the involvement of the local population. Participatory planning and citizen science play a central role in this process. Therefore it is essential to underscore that citizens take an active role in identifying, planning, and implementing new measures. In this manner the project works towards local transformation via the combination of CO_2 reduction and integration with social justice with aim to reach more sustainable spatial organizations. HubCities as a result acquires valuable experience in the design of climate-neutral, human-scale future cities.

1. Introduction

Decarbonization of energy-demanding infrastructure and industry is one of Europe's greatest challenges in reaching its climate goals (European Commission, 2019; IPCC, 2021). Seaports and airports are especially significant in this context. As gateways to global trade, freight, and transport, they are of high economic importance. At the same time, they also emit massive levels of greenhouse gas emissions, consume numerous resources and they represent areas with a high ecological footprint (Graham and Marvin, 2001). However these places are not autonomous. They are situated in an extensive network that flows together with global supply chains, labor markets, settlement patterns, and mobility systems. Accordingly, in in the process of imagining new climate-neutral futures for airports and seaports, their connection to the surrounding environment must be considered just as much as their embedding within

regional and global contexts. Therefore, the approach requires an integrated framework that goes beyond purely technological reconfiguration, since technical measures alone have proven insufficient to achieve sustainable transformation. For that purpose, this strategy needs an integrated model that is not technologically reconfigured simply, as these measures alone have proved to be inadequate. Therefore, the European research

project ‘HubCities’ intends to establish new visions for the revitalization of these quarters as part of more sustainable urban and regional development. A ‘HubCities’ seeks to be recognised as integral component of a local fabric, shaped by needs, demands and habits by people who work, live and spend their time there (e.g. **Fig. 1**).

Fig 1: From left to right: Spatial organisation of the HubCities (yellow rectangle) around Graz Airport (AT), around the seaport of Koper (SLO), around Trieste Airport and around the seaport of Trieste (IT). Source: Google Maps, Graphic: S.Pansinger

The article introduces the HubCities project strategy. It describes strategic concepts for climate-neutral transformation developed across three European locations: Graz Airport (Graz, Austria), Koper Port (Koper, Slovenia), Trieste Port and Monfalcone Airport (Trieste, Italy). Special attention in the project is given to the local community's participation as active co-creators of transformation. Therefore HubCities places citizen science at its core. Citizen science in HubCities simultaneously offers valuable strategies for a ‘bottom-up’ transformation by integrating every-day knowledge as recognised equally relevant to planning and innovation as technical or scientific expert knowledge. This approach has been granted by the European Commission under the Seal of Excellence 2023 for the HubCities project. This initiative opens a broad spectrum of new possibilities for new infrastructure planning. Instead of further utilizing closed ‘transport machines’ as mono-functional devices, airports and seaports become living spaces that integrate work, recreation, production, mobility, and innovation. By this, previously closed-off areas become open and resilient climate-neutral transformation hubs. Citizen science is central to this transition by providing local communities with room for action, co-decision, and co-design. This helps to elaborate guiding visions for the transformation of these places that are rooted in local experience and need rather than being imposed as external ‘top-down’ solutions.

2. Theoretical framework

2.1 Transformation as a multi-scaler phenomenon

The transformation of seaport and airports into climate-neutral, resilient, and liveable spaces must be understood as a multi-scalar phenomenon. This phenomenon includes technological innovation, spatial and urban transformation, organizational innovation, and social change (Graham & Marvin, 2001). Therefore, this article is based on intellectual logic that combines numerous perspectives: the theory of citizen science, the theory of participatory transformation in planning and the vision for leading the HubCity as a multi-scalar, relational spatial configuration.

2.2 Citizen Science as a participation tool

In contemporary context, citizen science has become a central concept in academic research, spatial planning and governance (Hecker et al., 2018; Bonney et al., 2014). This methodology debates about the involvement of citizens in scientific initiatives – starting from the gathering of data and building research questions and hypotheses through to analysis and application of new concepts. In spatial, environmental, and climate science, this approach provides valuable insights into transdisciplinary research and practice. Citizen science examines how local experiences and knowledge have to be considered equally in order to develop more intelligent, practical, and sustainable have potential to answer to questions of complex spatial challenges . This interactive methodology has a number of advantages for planning: it incorporates realistic everyday knowledge regarding available resources, conflicts, needs, and direction setting on guiding visions. The most crucial is that supports trust building and acceptance of new ideas among the citizens. Despite the fact that supports ownership of one's own world, it enables forms of participation that go beyond information or consultation.

Despite many advantages, the inclusiveness of citizen science faces several limitations. The application of citizen science differs by region, citizens knowledge and socioeconomic background. Citizens with limited access to technology, language barriers or less participation awareness can be unintentionally excluded. The adoption of citizen science, as before mentioned, is also strongly dependent on social and spatial context. Participation opportunities are more likely to be available in urban areas, while rural or marginalized groups may face infrastructural or logistical barriers. There is also a real risk that citizen science would be used as an instrument to legitimize already made decisions, instead of truly empowering people to shape outcomes. When participatory processes are introduced at the late stage of planning or without open backchannel feedback loops, they are likely to be deployed as tools for persuasion, not co-creation. Behind this, the theoretical framing of citizen science often assumes that participation automatically leads to empowerment and equality. The assumption can reproduce

existing hierarchies and exclusions without active attention to power relations, however digital platforms can both enable and restrict participation. They enhance communication and transparency but can simultaneously reinforce inequalities based on digital literacy, access to devices, or language barriers.

2.3 Participatory planning as a transformational guiding principle

Citizen science must be grounded in a participatory planning approach in order that 'everyday knowledge' can be actualized and make a useful contribution toward the strategic action involved in the transformation of port and airport sites (Forester, 1999; Healey, 2006). Participation accordingly goes beyond the dissemination of information, this implies that has to be addressed as an equal component of a discourse where diverse perspectives are negotiated. Under these circumstances, the negotiating space, the 'agora' of public argument, offers a stage for expressing technical requirements, economic interests, and social visions (Habermas, 1996).

As a result, citizen participation in planning in the HubCities initiative required the incorporation of the following key aspects:

1. Early Involvement. Citizens, firms, public authorities, and civil society are engaged on board into planning processes from the beginning.
2. Open Communication. Framework conditions, guiding objectives, limits, and scenarios are readily provided.
3. Co-Creation. Guiding visions, scenarios, and concepts are co-created rather than imposed 'top-down.'
4. Negotiation. Contrasting ideas are negotiated, compromise solutions are designed, and strategic decisions are made by discussion.

2.4 HubCites as a theory of multi-scalar structure

This theoretical approach is grounded on the conceptual structure of the HubCities, which identifies the port and airport space as a multi-scalar, relational, and functional system. The hubs are usually presented as mono-functional 'transport node' or a closed spaces that are disconnected from its context. Rather than presenting in this way, this hubs need to be understood as local, regional, European, and occasionally global network of spaces, that shape or are shaped by the spatial systems to which they belong. With aim to develop deeper understanding these multi-scalar relations, this article conceptualizes hubs as relational nodes.

For instance:

1. The Port of Trieste is a local labor market, a European supply chain, and an international logistics network.

2. The Airport of Monfalcone plays a key role in local tourism, international connectivity, and the European strategy for transport decarbonization.
3. The Port of Koper acts as a gateway to Central Europe.
4. The Graz Airport is equally important for its surrounding region and for international connections.

While the multi-scalar framework demonstrates how hubs operate ad different spatial and functional scales, an STS perspective extends this view by questioning the technical processes behind these relations. It invites everyone to look beyond spatial scales of interactions between technology, society and power that align with operation these infrastructures. In this context, the multi-scalar shape of HubCities is not only spatial phenomenon but also technological construct, expression of broader institutional decisions, economic agendas and scientific compromises. HubCities can be also understood as an attempt to open ‘black box’ of technological neutrality while threating airports and seaport as socio-technical arenas where decisions about design, energy use and spatial development are shaped by citizens who live or work in this environment. With this perspective, HubCities project situates decarbonization not as optimisation process but as negotiation between different actors, values and scales that define what ‘sustainability’ actually is in practice.

2.5 Summary

The theoretical framework outlined before provides the foundation for developing transformational strategies at airport and port locations. Participation, citizen science, and the conceptual model of the HubCities collectively constitute the theoretical foundation for:

- understanding and coordinating multi-scalar interrelation;
- connection of experiential, daily and expert knowledge into planning process;
- develop climate-neutral transformational visions out of local participation;
- fostering innovations and test new ideas under real conditions;
- and reimagining current places into ‘living nodes’ for sustainable and resilient transformation.

This long term holistic strategy supports the process of decarbonisation (e.g. **Fig. 2**).

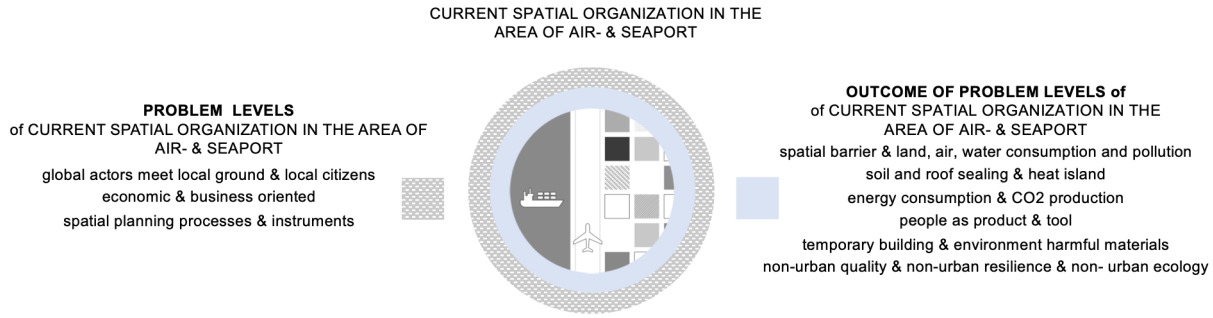

Fig 2: Current problem level in the field of airport and seaport areas. Graphic: S.Pansinger

3. Methodological Approach

The methodological approach adopted in this research project is integrative, transdisciplinary in nature that employs both qualitative and quantitative research methods with aim to determine the complex spatial, social, and cultural processes of port and airport spaces. The biggest aim is that transformation of such spaces is interpreted by considering the infrastructural, societal, and cultural drivers comprehensively.

The methodological framework is grounded of three main pillars:

1. Field survey and case studies in Graz, Koper, and Trieste cities
2. Participatory approaches and citizen science
3. Comparative analysis and transfer potential identification

3.1 Case studies based on field research

The empirical ground is based on qualitative case studies performed in the three selected cities: Graz (Austria), Koper (Slovenia), and Trieste (Italy). The cities are exemplary representations of varied urban and historic environments and thus are worthy of a comparative analysis of airport and port territories. The case studies are theorized as paradigmatic cases intended to identify commonalities and local differences.

The airport in the south of Graz, approximately 9 km from the city center, largely in the town of Abtissendorf in the town of Feldkirchen and partly in the cadastral town of Thalerhof in the town of Kalsdorf. Spatial embedding of the Graz airport in the wider

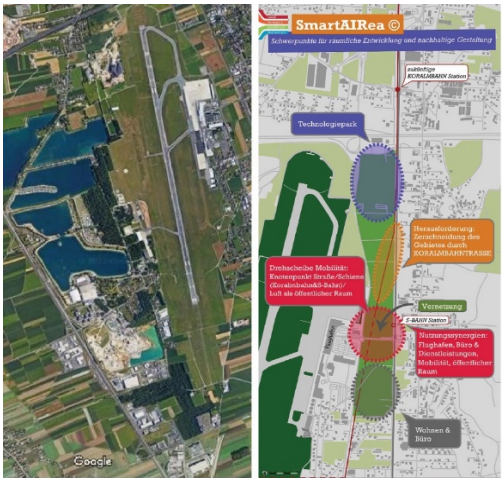

Fig 3: Current spatial organisation around Graz and smartAirea - www.smartairea.eu. One of the results shows that a polycentric development or the activation of the individual spatial areas of the airport environment offer the possibility of securing the spatial quality of the airport environment and thus at the same time the airport location in the urban-rural dimension. The challenges lie in a responsible process design that takes into account not only ecological, economic and social aspects, but also design and spatial aspects. Source: Sanela Pansinger, SmartAirea, GoogleMap

spatial context of housing, quarters, towns, region, and country is determinant for its overall beneficial contribution to spatial and urban development. Previously isolated regions around the airport are proposed to be integrated through manifold activities (life and work, transport and communication, food and entertainment). Graz Airport is designed to be a central node for international connectivity and an element of the city and region's mobility network. The link from Graz main station to the airport is especially highlighted as an axis of innovation, economy, and mobility. Alongside former railway lines, greenways, cycling routes, and footpaths have been developed to link the new quarter with the city center and surrounding residential areas. Industrial heritage is preserved and reinterpreted as part of new urban typologies. An area once exclusively logistical has become revitalized as a dynamic, multifunctional community with strong local identity potential (e.g. **Fig. 3**). Qualitative research methods were applied to the case study: in-depth interviews with local stakeholders from municipal administration, business community, and civil society, complemented by participatory on-site observations. Interviews focused on expectations, usage patterns, and perceived potential of the airport surroundings.

The Port of Koper, as the country's primary seaport and an interior inland transshipment center, is complemented strategically by the nearby Portorož Airport, enhancing regional connectivity and tourist accessibility. The use of the ‘axis-node model’ encourages more integration of the port and historic city center with enhanced passenger as well as freight transport through a newly formed corridor. The airport is a complementary transportation node that complements the international connectivity and maritime economy of Koper. The functional and physical proximity of the airport and port generates synergies in logistics, tourism, and innovation activities. As part of redevelopment city’s port efforts, numerous locations have been opened up to the public, such as promenades, parks, and restaurants, turning parts of the industrial landscape into a lively and accessible city zone. Meanwhile, formerly abandoned port buildings have been reconfigured to accommodate new and innovative uses, such as co-work, innovation hubs, and cultural facilities, thereby rendering the port itself a pulsating center of economic activity as much as urban

renewal. During the time the Port of Koper has evolved from a mono-functional economic space to a multifunctional space that brings together tradition, culture, and innovation. The positioning of Portorož Airport also helps this move forward by enhancing regional and global connectivity and bringing new economic dynamism into the master plan of the region (e.g. **Fig. 4**).

Fig 4: Professional guidelines for the Master Plan for the port of Koper, project team and source: Ažman, Venturi, Bercic et. al.

Being an economically significant port city, Koper provided a given environment under which the methodological focus was on the integration of participatory data collection and spatial analysis. Spatial trends of the port and its connection to adjacent neighborhoods were systematically mapped, with particular focus on transport corridors, green infrastructure, and accessibility. At the same time, focus groups were conducted with representatives of urban planning, ports authorities, and environmental NGOs to identify key planning questions, specifically ecological sustainability concerns and social inclusion concerns. The synthesis of spatial analysis findings and stakeholder deliberations enabled a better grasp of spatial interconnection and identified areas where optimization is possible within the port-city context.

As a former Habsburg port on the Adriatic, Trieste is noted for its high-density and multi-strand architectural and cultural tradition. The location of port, railroad, and airport facilities at their union produces a twin transport and economic node that is still framing urban and regional development. Trieste was a major city as a leading and prosperous port city in the 19th century, but its importance waned in the 20th century to make it one of the remaining port cities of the northern Adriatic (Ažman Momirski, 2021). As a result of increasing global competition within port logistics, Trieste has been continuously making efforts towards modernization and restyling. The city's Port Master Plan has been revised 24 times since 1957, the last time in 2010. The Free Port of Trieste is now divided into five diversified areas: three for commercial purposes (old free zone, new free zone, and timber terminal) and two for industrial purposes (mineral oils free zone and zaule channel free zone). The port follows the coastline, sea to city, but is spatially starved

through a shortage of storage and cargo space. Historically, large areas of valuable urban land have been used for port purposes (see Figure 10), excluding other possibilities for the city. In order to overcome these obstacles and unleash new urban opportunities, numerous strategic interventions have occurred. The central railway station has been reconverted into a multifunctional transport hub, fulfilling local, regional, and international mobility needs as well as business, educational, and gastronomic needs. Simultaneously, the newly built 'activity corridor' functionally and physically connects the port with the former old city center, enhancing the permeability of the city and enabling new uses that combine industry, heritage, and public life. Trieste Airport is central to this infrastructure chain by supporting maritime transport and reinforcing the city's status as a regionally significant and internationally connected node (e.g. **Fig. 5**). The city has further pursued a policy of cultural conservation and adaptive reuse. Previous port structures i.e., customs houses and warehouses have been reutilized as galleries, studios, and co-workspaces, thoughtfully conserving the cultural nature of the city while fulfilling modern urban functions. Cumulatively, Trieste's port, railroad, and airport complex is an officially designated urban and regional node. The planned convergence of old and new functions in old structures constitutes a hybrid spatial texture, one that intertwines through cultural heritage, economic innovation, and urban quality of life. Thus, Trieste is a model instance of sustainable and adaptive urban rehabilitation in the context of global change. The methodological approach employed in Trieste reflects the city's unique cultural and infrastructural legacy. Walk-throughs and systematic surveys were conducted in order to intercept both the continuity and the discontinuity of port–city development. In addition, ethnographic method, as participant observation at cultural events and interviews with residents and tourism industry and cultural arena actors were employed. This two-pronged approach allowed for a penetrating view of how the reshaping of infrastructure shapes local narratives, identities, and urban routine.

Fig 5: Spatial Organisation of the seaport of Trieste, and spatial organisation around the airport Ronchi in Trieste. Source: GoogleMaps

3.2 Participatory methods and citizen science

One of the central components of the strategy is the involvement of the local public and stakeholders interested in participatory formats. This is achieved through workshops, co-design events, and web-based platforms where the users are able to contribute their knowledge, needs, and visions. The purpose is to make planning processes more democratic, transparent, and user-oriented. One of the most important pieces of digital infrastructure supporting this strategy is the multilingual online platform HubCities (https://www.hubcities.net/), which has four language versions (e.g. **Fig. 6**). HubCities is an open-source platform that combines citizen participation, data visualization, and collaborative planning into a single digital platform. On the platform, it is possible to upload one's own observations or propose the development of urban and infrastructural spaces. The platform is already operational in all three case studies and facilitates the integration of virtual and analogue modes of participation (e.g. **Fig. 7**). The workshops face-to-face were each organized in tight cooperation with local partners in order to be able to respond to cultural and social specificities appropriately.

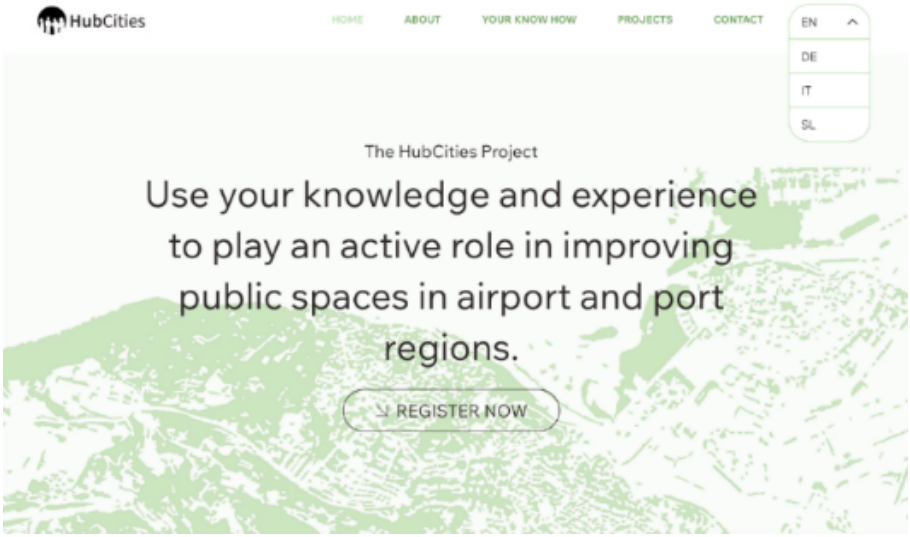

Fig 6. Online-platform HubCities, Graphics: www.hubcities.net

3.3 Comparative analysis and transfer potential

Fig 7. Announcement of workshop in Feldkirchen. Source: https://www.feldkirchen-graz.at/index.php/9-news/608-auftakt-workshop-des-projekts-hubcities,visited 15.06.2025.

Comparative analysis is the third methodology step, where results for Graz, Koper, and Trieste are compared to one another. The comparison shows both general tendencies and local-specific characteristics. The comparative analysis allows one to make general conclusions about sustainable development in port and airport regions outside the individual case studies. A particular focus is put on cultural identity as a basis for social cohesion and as an urban development resource in innovation. The findings demonstrate how infrastructure has not only a functional role but also symbolic significance for the residents, something which can be strategically utilized in planning processes. The lessons learned act as the foundation for guidance that can be applied to other comparable regions with consideration of the specific local context. The HubCities platform makes this possible through enabling the gathering and sharing of local experience and data in an international network thus ensuring effective transfer of knowledge. The combining of: qualitative field studies, participatory public engagement using digital and direct channels, and comparative analysis makes for a full comprehension of the complex dynamics in port and airport area development. By employing modern tools like the HubCities platform, the citizen science dimension is significantly improved, making planning processes more transparent, inclusive, and sustainable.

4. Results

Evaluation of questionnaires and participatory workshops within the three case study regions : Graz, Koper, and Trieste provides differentiated analyses of the potentials and challenges of sustainable development within airport and seaport areas on a local scale. The findings demonstrate the close relationship between ecological, social, and spatial aspects, and highlight the key function active citizen participation (Citizen Science) can assume in such processes. This case studies also identify the capability of online platforms like www.hubcities.net to enable experience sharing, knowledge sharing, and collaborative planning.

Graz-Thalerhof Airport in Graz was chosen for examination with a view to its integration within the urban setting. High environmental awareness of the populace found expression in noise and air pollution issues and general calls for decreases in emissions (e.g. **Fig. 8**).

Key findings of the workshops and surveys in Graz are:

1. Residents highlighted the importance of green and park spaces within close proximity to the airport. The spaces are not only considered as biodiversity providers, but also social places that enhance quality of living.
2. The improvement of living conditions in the immediate vicinity of the airport was perceived as a compensatory need for the infrastructure burden.
3. Transparency in dealing with environmental and climate information was repeatedly requested. Immediate emission data was requested to be shared through technological mediums by respondents, who viewed this as essential to the development of public trust among the public, authorities, and airport operators.
4. Involvement of citizens in collecting and interpreting data (citizen science) was identified to increase awareness of technical and planning procedures, and provide greater scope for acceptance of expected changes.

Fig 8. Comparing the current landscape with future scenarios without protection reveals risks of environmental degradation and loss of cultural identity. Graphic: S.Pansinger

Daily break and workplace interaction participants respond better to working conditions within the HubCities region. For lunch break, 47% of them had less than an hour, 18% had 1 to 1.5 hours, 12% had less than 15 minutes, and 23% indicated that they never have a lunch break. Lunch break variations time and workplace interaction demonstrate the degree to which time regimes and conditions at work shape individuals' capacity to participate in citizen science activity. Citizens employed in manufacturing sectors have less opportunity to participate in different activities, demonstrating clearly that participation is mirror of pattern and economic circumstances.

Inquiring about contact with employees of other organizations or residents, 44% reported no contact at all, 22% for less than 15 minutes, 28% for less than one hour, and only 6% for as long as 1.5 hours. This minimal organizational and community contact can be explained as both a consequence of spatial separation and the lack of shared social or collaborative space.

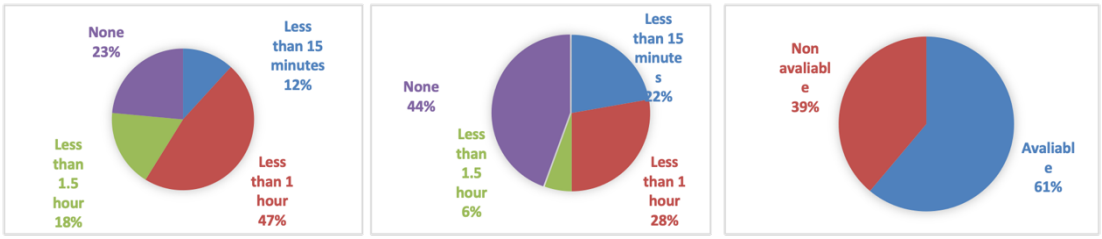

Fig 9. Results of survey analysis - Graz. Graphic: S.Pansinger

To a more positive aspect, 61% of the respondents have confirmed that recreational facilities such as gyms, swimming pools, or sporting fields are available within the HubCities area, while 39% have responded that there are no such facilities. It implies that, even though recreational facilities exist, they may be unevenly located or not fully utilized (e.g. **Fig. 9**).

Similarly, public and green space attitudes reflect socio-economic disparities. Higher availability of free time or cultural capital leads to putting environmental benefits in a different order than for groups whose everyday environment is industrial or logistical in character. It becomes evident from these findings that spatial preference and participation levels are socially organized and reliant on specific urban experiences.

The port city of Koper is defined by a tight economic interdependence with its port facility, a major employer and economic generator for the region. Surveying revealed that while the population is aware of the environmental impacts brought about by the port, its economic importance is strongly appreciated and recognized. The public at large endorsed better spatial integration of the port into the urban tissue. Stakeholders called for multifunctional land use concepts connecting ecological enhancement with social needs such as the creation of public green and leisure spaces that can also function as buffer zones between industry and housing. Participatory processes were viewed as necessary tools to balance complex and perhaps conflicting demands and translate them

into feasible and acceptable planning concepts. The use of the HubCities platform was deemed highly useful by the participants of the workshop in facilitating information flows and enabling early and ongoing citizen participation. The utilization of digital tools was not only applauded for improved communication but also for enabling the easy and clear visualization of emissions, traffic, and environmental impacts (e.g. **Fig.11**).

The findings indicate that 77% of respondents never go to public spaces such as parks or coffee houses during their breaks, indicating limited access to these spaces in daily activities most likely because of time constraints or insufficient provisions. Opinions regarding the proximity of green spaces around the airport and port are divergent, with 39% of them viewing them as being in short supply, 38% as being sufficient, and 23% stating that they are none, indicating skewed access and distribution. Participation in organized social activity is about evenly spread, although conceivably positively, 38% had regular take-up, suggesting that where activities are good value and accessible, there can be high levels of take-up (e.g. **Fig. 10**).

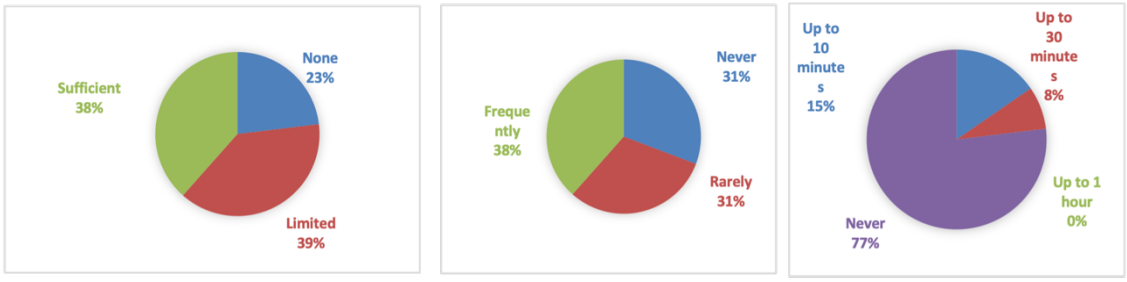

Fig 10. Results of survey analysis - Koper. Graphic: S.Pansinger

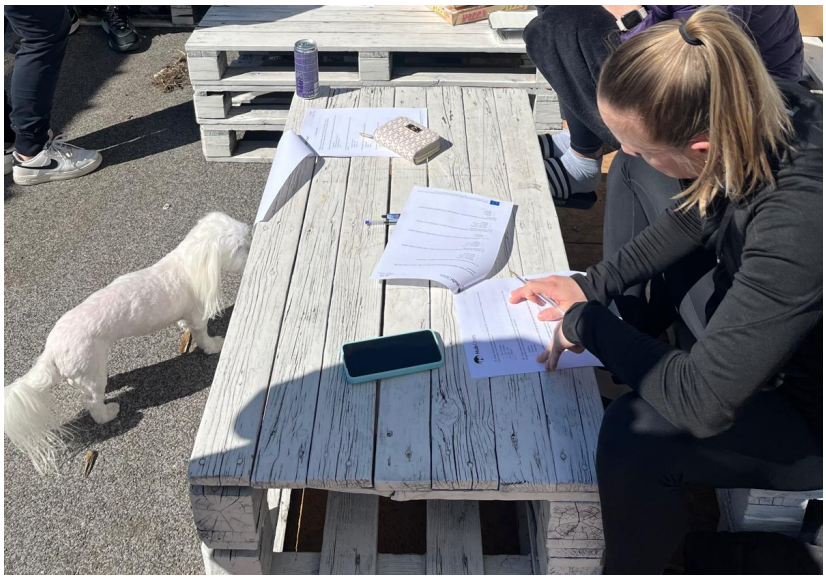

Fig 11. Citizens participation in Koper. Photo by: S.Pansinger

In Trieste, focus is laid more strongly on the social and spatial impact of port activities on the city and its citizens. Public opinions indicate strong interest on the part of the public

in improving public space quality, particularly through opening up and urban regeneration of port areas and transition areas (e.g. **Fig. 12**). Over 70% of interviewees reported limited access to public and green spaces within the port area, which they described as having a detrimental effect on quality of life. While the population acknowledges the economic significance of the port, there is a high desire for improved symbiosis between urban activities and the city. Citizens showed a desire for spatial innovations that respect Trieste's historical identity and cultural values, but at the same time integrate new, mixed-use patterns balancing social, ecological, and economic aspects. HubCities digital platform was again defined as a resource that could be employed enhancing massive stakeholder engagement and allowing participatory decision-making (e.g. **Fig. 13**). The ability to collect, share, and interpret jointly local data was found to be crucial in order to make a transformation process clear and well understood by all stakeholders.

A strong 70% of respondents believe there is potential to create or improve public spaces to enhance well-being in their work and community environment (e.g. **Fig. 14**). When asked about ideal features, 37% preferred recreational activities with amenities, another 37% supported general recreation, while 21% favored shopping options and 10% chose green spaces, indicating a preference for active and multifunctional spaces. Additionally, 74% expressed a need to use public space during breaks or free time, highlighting demand for accessible and engaging outdoor environments. Together, these responses point to both the desire and opportunity to design human-centered public spaces that go beyond utility and support daily quality of life.

Fig 12. Position of airport and seaport in Trieste. Graphics: Google Earth

Fig 13. Citizens participation in Trieste. Photo by: S.Pansinger

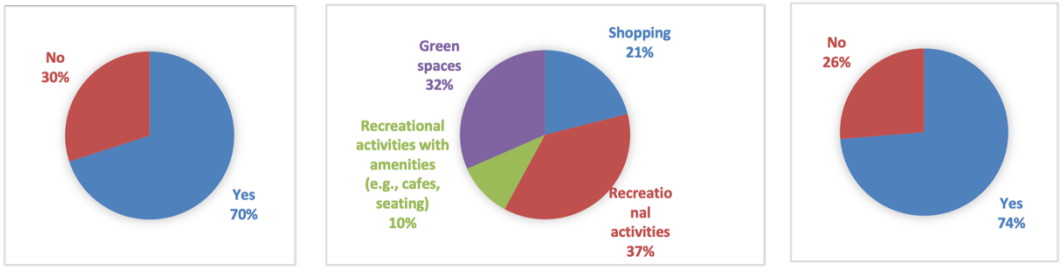

Fig 14. Results of survey analysis - Trieste. Graphic: S.Pansinger

4.1 Cross-Cutting Insights

The cross-site analysis of Graz, Koper, and Trieste reveals that sustainable development of seaport and airport areas is a complex and interconnected issue. Ecological, social, economic, and spatial dimensions are highly interconnected and thus require comprehensive strategies which recognize such complexity. At each of the three case study locations, public participation, specifically through citizen science played an important driver in facilitating various interests and creating public acceptance of the decarbonization processes needed.

Environmental concerns were always ranked a top priority at all places by the citizens. Citizens expressed a prominent requirement of reduced emissions, improved air quality, and noise lowering, which demonstrated a shared environmental awareness and demand for environmental responsibility in planning infrastructure. Besides that, there was a clear and persistent request for open information exchange as well as true participation in planning activities. These findings indicate towards the need for accessible, inclusive modes of participation, facilitated by online platforms such as HubCities.net, making relevant information access available and facilitating collective decision-making.Among the most profiled tensions registered on the sites was one of economic necessity versus ecological sustainability. In Koper, the port's economic function prevailed with emphasis on maintaining it industrial in nature. On the other hand, in Trieste and Graz, public discourse and planning priorities were focused on facilitating

social cohesion and quality of space in dwelling. These are alternative priorities that show the importance of context-sensing planning wherein the local needs and aspirations influence the trends in change strategies.

The third common thread that ran through all three cities was the importance of public and accessible urban space. Citizens demanded more habitable spaces for recreation, cultural life, and social interaction. These were not only essential as an aspect of good urban life, but as protective factors against the impacts of mass-scale infrastructure. Public space thus finds pride of place in social sustainability development and in fostering local attachment to process change. The study shows that online platforms like HubCities are a lot more than they are often portrayed as technical solutions but rather social and communicative drivers. The platform makes valuable planning and environmental data accessible, promotes transparency, and enables broader participation. It unites governance, academia, industry, and civil society stakeholders in one space for collaboration, dialogue, and co-creation. In doing this, it enables the construction of a transdisciplinary community working collaboratively toward sustainable city transformation. The overall findings support the initial objectives of the HubCities project. Participatory planning and Citizen Science combined are not only beneficial but also imperative in addressing the complex ecological, social, and spatial challenges of seaport and airport construction. By using digital technology and collective involvement of citizens, decarbonization processes can be rendered ecologically sound, socially equitable, and spatially balanced. This approach demonstrates that sustainable transformation is not a technical issue but an intensely social and spatial process. HubCities, the model, demonstrates how innovation, participation, and policy come together to promote robust, inclusive, and future-oriented urban futures.

5. Discussion

The three case studies of Graz, Koper, and Trieste yield results that emphasize the complex challenges and transformational opportunities of airport and seaport area sustainable development. Such so-called HubCities, while functioning as vital logistics and economic centers, are also enormous resource consumers and CO_2 emitters. Decarbonization in such an environment can only be successful if overall there is a response to ecological, social, economic, and spatial considerations simultaneously. One of the essential findings in all the sites is the importance of active public participation. The study demonstrates that citizens show great interest and enthusiasm to be involved in designing and implementing sustainable solutions. Citizen Science engagement consolidates the public's awareness of complex interdependencies as well as initiates trust and acceptance. Citizens become active co-producers instead of passive observers, participating significantly in warranting the long-term embedding of decarbonization strategies. Being an airport city, Graz demonstrates how environmental and social efforts

in enhancing quality of urban life in neighboring districts can be successfully implemented. Citizens especially emphasized the need for: more sports and green areas, better air quality, and social spaces that break down barriers between residential and industrial zones. Such interaction of environmental and social factors illustrates the idea of how technical solutions must be compatible with human needs.

The Koper case illustrates a highly sensitive equilibrium among industrial purpose, economic value, and social integration. The port is not only an economic hub but a marker of local identity. Participatory processes managed to establish constructive conversation among the parties involved public administration, industry, and citizens. Sustainability is neither conceived as a solely environmental imperative nor as an environmental imperative in itself but as a way to strengthen social justice and economic resilience. The findings show that decarbonization will be effective only if it is integrated into the local social and economic setting. As a border city, Trieste introduces an additional aspect of refinement with its international link and cross-border collaboration. While environmentally sustainable transformation is encouraged by the populace, they also have genuine concerns regarding competitiveness and jobs. The challenge thus calls for innovative and collaborative solutions that reconcile ecological aspirations with economic stability. In this aspect, collaboration with adjacent regions and cities, assisted through online platforms such as HubCities.net, becomes crucial.

In every location, the HubCities digital platform was a significant facilitator of: knowledge and experience sharing, enhanced transparency, and an engaged citizen participation, including on local borders. together on sustainable solutions, while sharing best practices and success stories

From the perspective of Science and Technology Studies (STS), the use of digital participation tools such as the HubCities platform cannot be regarded as neutral. While the platform facilitated interaction, openness, and transboundary communication, its use also revealed social and digital asymmetries among participants. Better educated citizens with flexible work schedules and reliable internet access were likely to be active, where as industrialand shift workers, particularly those in port settings, had greater limitations on their participation. These dynamics trace out the ways in which infrastructures of digitality, although designed to democratize planning, are prone to reproduce existing class-based, labor-divided and technological-accessed inequalities. The variation between the three cities also reflects their different economic and social profiles. Graz's service and research-oriented economy allowed for more widespread and diverse civic engagement. Conversely, Koper's industrial-strength and Trieste's blended logistic and heritage setting produced more selective and issue focused engagement. These variations underscore that sustainable transformation citizen involvement is not merely a question of motivation but also of social status, economic livelihood and local institutional habit. On a broader level, the findings resonate with conventional STS arguments about the non-neutrality of technological systems. Seaports

and airports are not merely transport or logistics infrastructure but socio-technical systems that embody political agendas and economic hierarchies. Within such globally networked and large-scale contexts, local participatory processes such as those stimulated through HubCities can make open discussion, increase transparency, and disrupt planning trends, but must be constrained by the very character of acting upon global economic systems. Regardless, these participatory spaces are critical spaces of negotiation, in which collective awareness and small-scale interventions can collectively reorder institutional practices towards more sustainable and equitable possibilities. Despite these positive outcomes, there are still challenges to be addressed, assuring long-term participation procedures, security of the data, and electronic access, as well as the construction of political and bureaucratic institutions that institutionalize participatory methods and ensure their effectiveness. This research provides significant findings of relevance to many other urban regions confronting similar sustainability issues. It offers a vision of the possibilities of technological innovation, participatory planning, and social mobilization in facilitating socially equitable and sustainable urban change. HubCities demonstrates how technological systems are socio-technical articulations with definite interests and power relations. Through the demonstration of such underlying dynamics, the project relocates decarbonization away from being merely a technical issue but as one of social and spatial negotiation whereby sustainability is co-produced in the course of relations among citizens, planners, and institutions. HubCities can therefore be a driver in achieving climate goals while concurrently building sustainable, inclusive, and resilient cities for their citizens.

6. Conclusion

The present research being conducted as part of the HubCities project represents a valuable contribution to the research and utilization of sustainable development strategies for energy-intensive urban centers — i.e., airport and seaport areas. The entirety perspective, in turn, grounded on unifying the ecological, social, economic, and spatial elements of decarbonization, points to the multifaceted nature as well as the necessity of multidisciplinary examination of such urban regions. First and foremost, the empirical evidence confirms that effective decarbonization of HubCities can be achieved only through active involvement by local communities and suitable stakeholders in the future as well. Not only does citizen science present itself as a participatory tool, but also as a methodological interface between science, planning, and society. Public engagement has an extremely important role in guaranteeing increased transparency, acceptance of climate protection measures, and urban change in a socially equitable manner. This is particularly important in view of the large size of airport and port infrastructures and multi-dimensional stakeholder interests involved. Second, the case studies of Graz, Koper, and Trieste highlight the need for a strategy that builds on an

integrated approach that goes beyond narrowly technical or economic thinking. The close interrelation between social quality of life, ecological compatibility, and economic competitiveness becomes all the more important. The results reveal that reduction measures and efficiency measures for emissions are only effective in the long term when complemented with socio-spatial strategies enhancing residents' well-being as well as inclusive social engagement. Multifunctional, accessible, and high-quality public spaces developed in HubCities lead to social cohesion and enhance public support for necessary infrastructural and technical change. Third, the study shows that intermunicipal cooperation and spatial connectedness are preconditions for success in decarbonization. Intra-border cooperation like in the case of Trieste puts more pressure on government and coordination systems, but also opens new innovative possibilities. Websites like www.hubcities.net have an important role to play by promoting knowledge transfer, facilitating participatory processes, and building a transnational community of practice. The systematic use of such tools makes it possible to collect experiences, good practices, and knowledge to be accumulated beyond territorial boundaries and adaptively incorporated into decision-making. Fourth, the project emphasizes the need to strengthen institutional infrastructures to the sustainable development of HubCities. This entails: Developing legally binding processes of participation, Institutionalizing citizen science, and Designing flexible and adaptive planning tools that respond to multidimensional requirements. Such systems require revamping planning and administration — towards collective and learning-oriented systems of administration capable of handling complexity and ensuring long-term flexibilities. In conclusion, HubCities provide a versatile model of integrating decarbonization, social integration, and spatial sustainability in energy-dense urban systems. The interplay between participatory science, technological innovation, and social integration is a model which can be replicated in other urban networks. The project, thus, not only contributes to addressing climate targets but also increases societal resilience and promotes future-proof urban environments. This multi-perspective approach will become increasingly important in the years ahead, as cities confront growing challenges from climate change, urbanization, and social inequality. Further explore the interplay between technological innovation, participatory processes, and institutional frameworks, and Assess the scalability and transferability of the developed concepts to other urban infrastructures and regions. It is only by taking such an integrative and adaptive strategy that the long-term security of the sustainable transformation of HubCities can be guaranteed and made a model for other energy-consuming urban agglomerations.

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