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Policy impact pathways of climate-related urban health vulnerability – A retrospective analysis

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ABSTRACT

Climate change-related health risks are likely to become more prevalent in cities. Cities are also key actors in adaptation to these risks. Adaptation can take place through intentional measures to reduce vulnerability or exposure and unintentionally through other urban policy processes and outcomes. However, complex and dynamic relations between urban policy impacts and vulnerability development are an understudied phenomena. This limits the understanding of how urban climate-related health risks emerge and evolve. We examine urban policy pathways that influence vulnerability to climate-related health impacts with a most similar - most different case study. With a qualitative retrospective analysis of four urban areas in Finland we unveil the mechanism of how urban policy affects urban environment over time and how these impacts and changes shape vulnerability. Contrasting the most different cases, we show that urban policy impacts set differing preconditions to adaptation between local districts. We conclude by suggesting that to adapt to future challenges in cities with respect to social and ecological justice, it is necessary to mainstream adaptation into urban policies with continuous cross-sector and multi-level dialogue about the development of vulnerability.

1. Introduction

There is a growing body of evidence that climate change is impacting people's health in cities, most often as a result of floods or heatwaves (e.g., Lane et al., 2013; Vicedo-Cabrera et al., 2021). These impacts are likely to worsen as climate hazards are expected to both intensify and become more frequent (IPCC et al., 2021). Studying climate-related health risks in cities is important because cities are centers of population growth, which presupposes a large concentration of people at risk, and the gap between health-related adaptation needs and measures taken is particularly prominent in cities (Ara Begum et al., 2022; Sheehan et al., 2021; Ruth and Coelho, 2007). Moreover, risk development in cities involves complex impact pathways as they are also conditioned by the urban environment and policies (Ellena et al., 2020; Sera et al., 2019).

Adaptation measures to urban climate related risks focus on technical reduction of the severity of hazards and exposure, whilst vulnerability[1] is often addressed superficially in urban adaptation policies (Camponeschi, 2021; Eakin et al., 2022). Other urban policy interventions and urban planning may unintentionally decrease or increase climate vulnerability through changes in physical and social urban environments (e.g., Buzási et al., 2021; Anguelovski et al., 2018; Revi et al., 2014). Moreover, integration of climate adaptation targets to urban planning by applying green and blue infrastructure has proven popular, while there is little evidence on the extent of the impacts of these measures on vulnerability (Goodwin et al., 2023). The interaction between urban planning and adaptation is largely understudied, and urban change overall is considered to be an untapped resource in adaptation planning (Egerer et al., 2021).

The emergence of urban health risks is the result of vulnerability development in interaction with the urban environment. Current urban environment conditions, both physical and social, influence urban

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[1] Vulnerability is defined as "the propensity or predisposition to be adversely affected" by climate change or extreme weather events (Möller et al., 2022: 2927).

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vulnerability largely due to past policy decisions. However, most of current climate vulnerability assessment literature conceptualizes and operationalizes it as a static and detached phenomenon that happens in a social vacuum, overlooking spatiotemporal development of it under the influence of interconnected socio-economic processes (Ebi et al., 2016; Ford et al., 2018; Jurgilevich et al., 2021). In healthcare literature on adaptation, the focus has mainly been on the individual determinants, such as health, education, age, and their interaction with the climate hazards while not accounting for vulnerability influenced by urban environment (e.g., Aylward et al., 2022; Marsha et al., 2018; Phung et al., 2016). Relying on a narrow view of vulnerability as basis of adaptation planning and governance may lead to insufficient and poorly targeted adaptation measures, and consequentially justice concerns (see e.g., Juhola et al., 2022).

Tracking and understanding vulnerability over time is critical to address both in urban and in adaptation planning as it provides insights on the different sectors and stakeholders involved, and on the indirect and cascading effects of socio-economic changes and sectoral measures undertaken (Ford et al., 2018; van den Berg and Keenan, 2019; Jurgilevich et al., 2021). This requires observing changes both in vulnerability indicators and in socio-economic determinants of vulnerability, as well as complex interactions between them (Jurgilevich et al., 2021, 2023; Oppenheimer et al., 2014; Räsänen et al., 2016). So far, there have been few studies that approach vulnerability dynamics as a process, including past (e.g., Fawcett et al., 2017) and future changes (e.g., Jurgilevich et al., 2021; Naylor et al., 2020).

This study bridges research on climate-related health risks, urban environment, and adaptation to increase the understanding of how urban policy affects vulnerability via urban change. We build on the approach that urban policies may decrease or increase vulnerability to harm from climate hazards through changes in the physical and social urban environment (Jurgilevich et al., 2023). We ask the following research question 'How have different urban policies contributed to climate-related urban health vulnerability development?' focusing on the mechanisms and pathways of urban policy impacts. We answer this question with a most similar - most different (MSMD) (Anckar, 2008) case study of four urban areas in Finland using a descriptive *ex post* policy analysis (Patton et al., 2015) of expert interviews and policy documents covering urban development and planning, social and healthcare, climate and environmental policies.

2. Urban health vulnerability

Evidence on environmental determinants associated with urban population health impacts is concentrated on green spaces, mobility and safety (built environment), air quality and noise (natural environment), income and employment, education and racial segregation (social environment), healthcare infrastructures, and health behaviors (Galea and Vlahov, 2005; Salgado et al., 2020). There is a growing body of research that focuses both on the characteristics of urban physical (built and natural) and social environment, and their impacts on people's vulnerability to climate-related health impacts (Giles-Corti et al., 2016; Shen, 2022).

Characteristics of the urban built environment that create vulnerability to extreme weather events have been identified in several studies. Multiple studies have demonstrated that the relative greenness of an urban area correlates with social vulnerability and health indices within an urban neighborhood in an extreme heat event (e.g., Sabrin et al., 2020; Burbidge et al., 2021). Emerging research on climate-related urban health vulnerability in relation to urban air quality (e.g., Gosztonyi et al., 2023), healthcare access and availability (e.g., Ellena et al., 2020), as well as individual behavior (e.g., Milando et al., 2022) provides tentative evidence on the causal relationships between urban change and vulnerability development among less studied urban environmental health determinants: natural environment, healthcare infrastructure, and health behavior.

There is growing evidence that people's vulnerability to health impacts of climate change in cities is shaped by the urban policy and planning (Jurgilevich et al., 2023). Urban policies may create, decrease or increase vulnerability to different types of harms from climate change through changes in the urban environment (Fig. 1). In the U.S., for instance, discriminatory policies resulting in place-based inequalities increased vulnerability to extreme temperature-related health impacts (Gronlund et al., 2018; Li et al., 2021).

We suggest that climate-related urban health vulnerability,[2] hereon 'urban health vulnerability', is shaped by processes of urban change. Primarily, through urban policy that is constantly changing the physical and social environment of cities (Fig. 2). We argue that the pathways of policy impacts on urban health vulnerability can be identified and explored in retrospect with the focus on i) urban change, i.e. policy impacts that shape urban environment, e.g., improved air quality following traffic regulation, and ii) the impact of urban change on vulnerability, e.g., air quality improvement reduces urban health vulnerability.

3. Materials and methods

We conduct a comparative multi-case study (Yin, 2013) in two types of urban areas in high-latitude European cities located in Southern Finland, Turku and Helsinki, to study vulnerability development at district level nested in the municipal context. We rely on the principles of the most similar - most different (MSMD) system design (Anckar, 2008) in the purposive small-*n* case selection justified by the need for a structured and nuanced comparison (see details on case selection in Appendix B). The two selected case areas from two cities represent most similar (two new and two old) and most different (old vs new) areas within the city in terms of vulnerability, that is the outcome and dependent variable of our analysis (Yin, 2013). The selection of independent variables in the cases is theory-driven and guided by the framework (Fig. 2).

We first elicit and explore the independent variables and their interactions leading to similar vulnerability outcomes by 1) deductively applying the categories from the urban health vulnerability -framework and thus testing the theory, and 2) using inductive reasoning for open categories to develop the theory. Second, since we conduct an exploratory study and reconstruct pathways acknowledging the multitude of variables and their interactions, we use an iterative process of deduction and induction (Kristensen et al., 2008), thus testing and developing theory. In the study, we do not aim to elicit single variables' causalities; therefore, the MSMD design is used to guide the case selection and to structure the comparison (Anckar, 2008).

We use a descriptive *ex post* policy analysis (Patton et al., 2015) of expert interviews and policy documents to establish an understanding of the history of the four local districts with regards to the relevant urban policies' influence on the development of urban health vulnerability in the case areas. Hence, we use an approach on *ex post* analysis for identifying several relevant policies by backtracking them from pre-identified impacts (e.g., Gajjar et al., 2019). We develop a retrospective pathway approach to qualitatively compile a storyline of the policy impact pathways by analysing our material using the urban health vulnerability -framework (Fig. 2).

[2] In our framework (Fig. 2), vulnerability is understood to constitute of (i) enhanced exposure determined by the physical environment, e.g. state of critical infrastructure, sealed surfaces, blue and green infrastructure, (ii) adaptive capacity (to prepare, respond, and recover from climate change impacts) determined also by the social environment, e.g. social organization, social resources, spatial segregation, inequality, and (iii) sensitivity (individual determinants), (Galea and Vlahov, 2005; Jurgilevich et al., 2021; Prasad et al., 2016). Urban environmental determinants associated with sensitivity are not well established in literature (Jurgilevich et al., 2023).

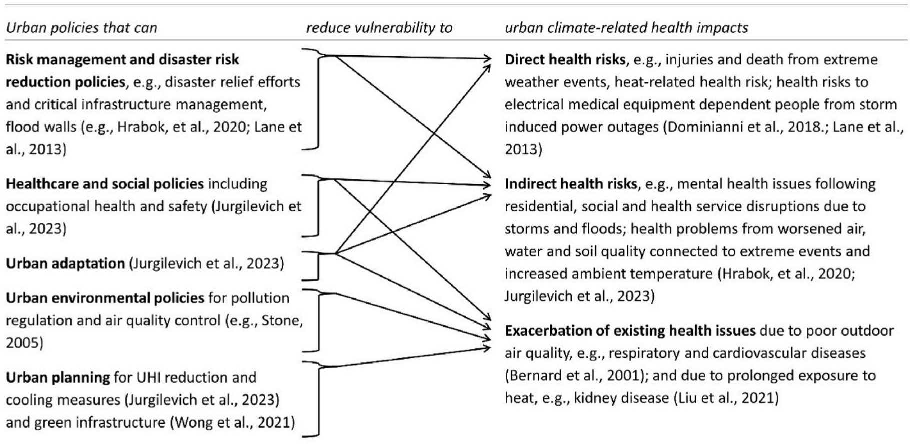

Fig. 1. Urban policies that reduce vulnerability to urban climate-related health impacts (Hrabok et al., 2020; Lane et al., 2013; Jurgilevich et al., 2023; Stone, 2005; Wong et al., 2021; Dominianni et al., 2018; Bernard et al., 2001; Liu et al., 2021).

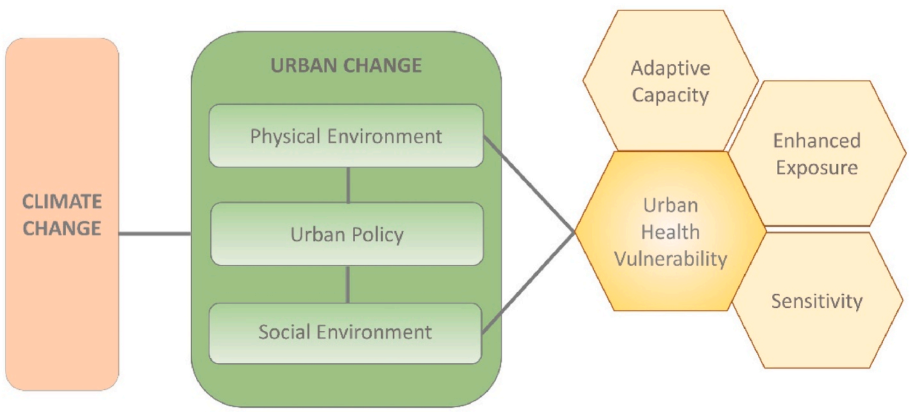

Fig. 2. The urban health vulnerability -framework. Climate change shapes the urban environment by posing adaptation needs. Urban policies shape urban environment and urban environment shapes vulnerability to climate-related health impacts. The figure is adapted from (Jurgilevich et al., 2023) following Jabareen (2009) as a conceptual tool for interpreting reality but not modelling or explaining it.

3.1. Cases

The case areas (Table 1), represent two different types of urban areas: 1) old areas where residents may be relatively vulnerable to the climate related health impacts due to unfavourable social and physical environmental conditions that affect the enhanced exposure and adaptive capacity of the residents; 2) new areas where the physical and social environment contribute to vulnerability less, in comparison to other areas in the city. We use socioeconomic conditions (income, employment) and built environment conditions (housing, green spaces) as the determinants of local urban population health risk and vulnerability determinants (Salgado et al., 2020).

3.2. Interviews and policy document analysis

We constructed a timeline representation of the development of the case areas based on a policy document analysis of the indicators of potential health risk and vulnerability determinants. The documents covered master plans, street plans, and other long-term municipal level policy documents with explicit implications to health and climate risk-related objectives (Appendix A). After the document analysis, to gain further understanding of the health vulnerability development, we conducted 16 expert interviews in small-groups of two to three persons. We selected the small-group format to allow effective material collection, and to strengthen the validity of the interview material (Robson, 2002). The document analysis provided context for interviews on background and historical insights to the case area development (Bowen, 2009). To reduce the bias and subjectivity inherent to interview studies and to provide as all-ecompassing view of stakeholders as possible, we selected the interviewees with diverse functions and backgrounds: city statistics experts, planners, architects, resident organisations, and representatives of the health sector. Additionally, we asked the participants to identify other potentially relevant experts. Participants in each session had similar backgrounds (same organisation or field of work) to promote a sense of cohesiveness, facilitate communication, and encourage an exchange of experiences and potential conflicting concerns (Robson, 2002; Stewart and Shamdasani, 2014). We determined the total amount of interviews by theoretical saturation of the collected material, i.e., repetition in the discussions indicating that the narrative on the vulnerability development in the areas would not change significantly (Timmermans and Tavory, 2012). We coded the transcribed interviews with Atlas.ti (version.9) according to a codebook developed from operationalising the urban health vulnerability -framework (Fig. 2). We used an iterative coding logic and an abductive analysis logic (Timmermans and Tavory, 2012). After the interviews, we analysed the additional 11 policy documents (Appendix A) that were raised by the interviewees and considered relevant for the analysis of the health-related mentions in them. We did the complementary policy document analysis to confirm and bring depth to the statements of the interviewees and contextualize material collected in the interviews

Table 1
Health risk and vulnerability determinants and other case details.

The cases	*Old areas (Kontula and Varissuo)*		*New areas (Skanssi and Kruunuvuorenranta)*	
Local district[a] (district, city), first residents	Kontula (Mellunkylä Helsinki), 1960	Varissuo (Varissuo-Lauste, Turku), 1970	Kruunuvuorenranta (Laajasalo, Helsinki), 2015	Skanssi (Skanssi-Uittamo, Turku), 2017
Population in 2020; aim by 2030 (**Statistics Finland, 2023b**; Helsinki, 2021b, 2023; **Turku, 2023**)	14 288	12 969	3289; 13 500	760; 8000
Physical and social environment conditions (**cf. Galea and Vlahov 2005**)	The development of older residential stock is not guided by policies accounting for climate risks.		The development is guided by policies accounting for climate impacts and risks (e.g., Statute on housing health, 2015; Flood Risk Management Act, 2010).	
	Relatively large proportion of vulnerable groups, i.e., people with low-ranking socio-economic status (incl. unemployment, low-income), aging and immigrant population.		Socio-economic conditions expected to be relatively good due to the socio-economic mixing policy (i.e., mixing different types of housing solutions in area development).	
Apartment values[b] (€/m2)	Among the five lowest ranking local districts in the respective cities		Among the top ten ranking local districts in the respective cities	
Mean income[c]	24852€	24364€	43836€	27415€
Unemployment rate[d]	18,7% in the Mellunkylä district	22,5% in Varissuo-Lauste district	10,5% in Laajasalo district	11,9% in Skanssi-Uittamo district
Other details	The public image/reputation of these neighborhoods is relatively bad in relation to the surrounding areas (Laakkonen, 2022; Tuominen, 2020).			

[a] Helsinki is divided to 8 districts and 60 local districts, and Turku to 8 districts and 87 local districts (Helsinki, 2021b; Turku, 2023b).
[b] We used the single room apartment prices as a standard for all case areas except Skanssi where no information was available for single room apartment prices. For Skanssi, we based the ranking on triplet prizes. (Statistics Finland, 2023c).
[c] Mean income in Helsinki is 41804€; Mean income in Turku is 28701€ (Statistics Finland, 2023a).
[d] Unemployment data is not openly available for the local district level, hence, unemployment rate (share of the unemployed work force from the total work force) is calculated for sub-district level. Total unemployment rate in Helsinki is 11% and in Turku 13,2%. (Statistics Finland, 2023b).

(Bowen, 2009). Detailed information of participants, process and operationalisation is in Appendix B.

4. Results

4.1. Old areas

The physical environment exacerbates vulnerability to climate-related health impacts in the old case areas, Varissuo (Turku) and Kontula (Helsinki), via limited mobility and transportation options and limited municipal maintenance in the area. The building codes of the time resulted in relatively narrow walkways and corridors that are hard to access with ambulances and other vehicles. Also, practices of construction fifty years ago differ from those of today. For instance, few of the buildings in the old areas have elevators which can create difficulties for the physically impaired. Poor maintenance of mobility infrastructure (e.g., sidewalks, bus stops) is an issue of municipal policy that can also challenge vulnerable groups in the event of increased precipitation (snow and water) and slippery weather. Access to health services is limited due to inadequate maintenance (Int. 2) particularly in the winter:

> [3]Some of the paths and walkways that people use regularly are not maintained in the winter while others are. That's where they need to then, all of a sudden, figure out how to pass a 10-meter way that is not maintained in the winter. For example, the park area in the mall where there are those dirt tracks is not maintained in the winter and the way to the bus stop is basically blocked because they plow the snow just there [on the dirt tracks].[4] — The mall is also tricky because it is privately owned, as I understand it, and they are not obliged to maintain their surroundings. (Int. 2)

Enhanced exposure to heat in the case areas is reduced by relatively spacious building density and green space, both of which provide a cooling effect. This is particularly prominent in Kontula due to the 60's building style emphasizing these design elements (Int. 4). However, interviewees expressed concern with the performance of natural air ventilation systems as compared to mechanical ventilation during prolonged heat waves (Int. 6). Natural ventilation is more typical for older buildings, while newer buildings rely on mechanical air ventilation. It was raised in one interview that the architects of the older neighborhoods did not consider the need for summertime cooling (Int. 5). Cooling devices may not be physically compatible with older apartments (Int. 13) nor accessible for the low-income households as illustrated in the following excerpt from the urban change expert (Int. 5).

> — in Kontula three out of four children live in a family that belongs to the lowest ranking quarter of households per income. These types of households are not likely to afford cooling devices. The apartments are not necessarily designed to fit a cooling device. There might not even be that sort of windows that could fit an exhaust air pipe. (Int. 5)

The social environment conditions related to lower overall vulnerability (low socio-economic status, relatively large proportion of senior citizens and people with immigrant background) are not perceived to exclusively negatively affect urban health vulnerability. For example, opportunities for community supported adaptive capacity building were discussed. Autonomous resident activity (e.g., arranging hobby groups, events etc.) is considered relatively high in the old case areas (Int. 5, 13, 14) and related to the idea of caring for one's community, as reflected by a youth worker (Int. 14):

> [In the case area] there is this communality among the people that are from so many various cultural backgrounds and still consider it "a thing" to be from there [appeciating the local identity] — and, in my opinion, this involves a certain aspect of communality, like, "have you seen this or that [person], and how are they". (Int. 14)

Participation in local democracy and decision-making (i.e., municipal council activity, voting activity) is nevertheless relatively low in the areas, which was perceived to have a direct impact on the well-being and health-related matters negotiated in the municipal administration (Int. 5).

Attractiveness, reputation and image of the older local districts was often raised to have indirect consequences to residents' health and social

[3] Transcript excerpts are translated from Finnish to English by the authors.
[4] Brackets [] are used to indicate text that is added by the authors for clarification.

well-being as it largely affects the quality of the social environment and it may affect the quality and quantity of different health services via the negative effects related to segregation. The relatively negative image of these areas is considered to have a negative influence on the value of apartments in the areas (Int. 13). The respondents consider that the negative images are partly based on false assumptions and individual negative events that have stuck and continue to harm the areas' appeal to investors and service providers, and the social environment quality. Whilst attractiveness is partly a subjective matter, the existing enhanced exposure reducing determinants in the old neighborhoods, such as green areas and spacious design, are often considered to be essential part of these areas' attractiveness. In Kontula, the city has planned to increase infill development, among other measures, e.g. renovations and a new shopping mall, to increase the attractiveness of the area (Viljakainen et al., 2020) which may have negative implications for green areas and spaciousness.

Segregation was often brought up in the discussions of vulnerability. Public policy tools to target social segregation in the old areas with low socio-economic ranking are considered limited (Helsinki, 2021a). These include monitoring of the socio-economic index (Helsinki), programs for segretation prevention in schools (Oittinen et al., 2023; Turku, 2021) and programs to increase attractiveness of the areas. In Helsinki, for instance, positive discrimination is one of the guiding principles of the segregation prevention policy. It is applied in the program for the schools in the socio-economically lower ranking areas (Int. 5) as well as in the recently implemented "suburban regeneration model" (Int. 4) piloted in the Mellunkylä local district to increase attractiveness of the area for private and municipal investments, e.g., through affordable wood-constructed apartments (Int. 1). Furthermore, experiments and initiatives that have activated residents of both areas were raised in the discussions with some being autonomously led by the residents and some municipality-led. These activities were considered to have a positive impact on the self-identity as well as on the public image of the area.

Unequal distribution of negative health impacts from the COVID-pandemic was raised as an analogous example of the mechanisms of climate related health impacts on working population that is vulnerable due to their occupation. Bus-drivers and mobile health care professionals were raised as examples of critical occupations where enhanced exposure to heat during heatwaves, for example, is difficult to avoid. COVID exposure statistics were relatively high, for instance, in East-Helsinki where Kontula is located because people there have occupations that do not allow them to do remote work (Int. 4):

> People were hospitalized in Kontula. In a way, people's chances to protect themselves due to their occupation and their household [type] have been worse [than in other areas]. And this shows the complex relation between the social, health and all other factors as well as the resources people have for protecting themselves from such risks [as COVID and climate change]. (Int. 4)

4.2. New areas

In the new areas in Turku (Skanssi) and Helsinki (Kruunuvuorenranta), the physical environment exacerbates vulnerability to climate-related health impacts via the undeveloped infrastructure of the newly built or under construction areas, including lack of transportation options and access to healthcare services.

The discussed key adaptation measures that are being implemented or have already been implemented include novel building surface material, ground floor design, and urban planning instructions on shorelines that are used to secure healthy living and working conditions (Flood Risk Management Act, 2010) green and blue adaptation infrastructure, such as water retention ponds and parks, that have beneficial mental health impacts. Compared to the old areas, some of the modern building codes, such as the obligatory elevator in buildings with three stories or more (Ministry of Environment, 2005), may reduce the severity of the health impacts enabling easy access to health care. Mechanical air ventilation to secure sufficient ventilation in all weather became mandatory under the updated construction standards in 2003 for new buildings (Ministry of Environment, 2003). However, one interviewee raised a concern that there is always a risk of technologies breaking down or becoming unaffordable (Int. 5).

The case areas follow the trend of building small and one-sided apartments, partly due to densification policy (Int. 1, 3), and the heat-prone south and west directions are often preferable for aesthetic reasons and natural light, whilst heat is rarely considered in the apartment design (Int. 7). In addition, the insulation in Finnish buildings, primarily designed to protect from cold, performs well also in cooling in cases of short heat events, but in case of prolonged heatwaves it may increase enhanced exposure to heat (Int. 5) and this effect is exacerbated in the newer thick-walled energy efficient buildings' apartments and shared spaces (Int. 7). Furthermore, it was raised that the surrounding areas are often planned without shade-providing constructions or routes (Int. 7).

> [I]t is seldom that the yards have shading. Usually, when constructing those community park structures, there are a few about one-and-half meter high young trees, but no actual shading is constructed. At least in Kruunuvuorenranta there are no such routes that would allow direct passage to shade. — And many of the balconies are still positioned south [as they have been traditionally], so, the points of compass are not considered, and the street level plan also dictates the direction of the balcony and others [elements of the plan]. (Int. 7)

Some enhanced heat exposure related trade-offs, compromises and unintended negative effects were reflected by the planners and the developers. In Kruunuvuorenranta, it was discussed that the recent changes in transportation planning (adding broader sidewalks to allow car parking next to tramlines) have led to the removal of shading green elements (street trees) from the plan (Int. 3). In Skanssi area development, preserving the valuable natural environments was an important planning principle (Turku, 2013), which led to building the residential area to a valley with low natural environmental value (Int. 11). The valley provides a natural cooling effect that was considered as sufficient heat management measure in the planning phase. Later, experts have been considering the possible formation of an urban heat island in the area, if the area is built full and the skyline level rises. In addition, there is yet no district cooling system in Skanssi even while the heating infrastructure, based on low temperature system, would allow implementation of district cooling to the area. The developers considered the low temperature system as a less ambitious solution regarding heat and energy self-sufficiency in comparison to a geothermal system, questioned the current policy and its legitimacy, and hence have been reluctant to proceed with the implementation of the district cooling system (Int. 15, 16).

Stormwater management infrastructure in Skanssi is based on a projected 100-year flood return period. The decision was guided by the green-blue factor tool, similar to the 'green-factor' tool also in use in Helsinki, and supported by favorable politics due to its cost-effectiveness (Int. 16). It was raised by the developers that the applied green-blue solution-based infrastructure is much cheaper for the municipality than a conventional one and, due to the remote location, there was room for it in the plan (as it takes more space than conventional stormwater management infrastructure) (Int. 16).

Climatic models are used in planning the new areas. However, the models used in planning the case areas have not involved all climatic characteristics, e.g., wind conditions. In addition, they were considered insufficient regarding more complex impacts even in short-term, e.g., creating heat island impact conditions when raising the groundlevel of the valley-based naturally cool area (Int. 12). They are done only for the final constructed area, i.e., they do not consider the construction phase which may increase, for instance, enhanced exposure to strong wind-related health hazards (accidents, dusty air) (Int. 7) and uncontrolled puddling and other problems due to extreme weather events that may involve health risks (Int. 7). Usually, climatic modelling is done only on special request, except for obligatory wind simulations to buildings above 8 stories high. Moreover, it was raised that the implementation of a wind simulation altogether and the quality of it is dependent on the skills and resources of the planners (Int. 7). The integration of climate simulations into planning is not yet often applied, and there are several reasons for that, as the following discussion between the two housing production officials discussing the Kruunuvuorenranta area development shows:

> [Person a:] Despite the changes in wind conditions etc., the street plans still guide to make blockhouses that don't have eaves or anything to block the slanting rain, and the wall structures are still made in ways that allow their peeling in strong wind, even with the storm panels and others. I do not think that the street planning has clearly addressed that this is a windy area.
>
> [Person b:] That is true. In our plan, we then address what is possible within the limits of the street plan. Even if we would propose solutions based on that some structures were, for example, more durable in windy and rainy conditions, they would not pass if they depart from the street plan. The image, the townscape is nevertheless the priority. (Int. 7)

The social environment in the new case areas does not increase vulnerability of the current population that is relatively heterogeneous and not determined by any single feature. This may obviously change over time. The climate adaptation measures, mainly green and blue infrastructure, are considered to increase or be an essential part of an area's attractiveness. As discussed above, attractiveness is related to the reputation and image of the areas, which was raised often in the discussions as something that urban developers nowadays pay more attention to with deliberate "attractiveness building" (Int. 1). In addition, the planners considered their work on avoiding segregation development through urban design as a way to reduce vulnerability. This involves, for instance, a planning criterion of equal distribution of apartments with different ownership and funding models, and in some cases, also different building types in Helsinki (Int. 5; Helsinki, 2021a).

4.3. Summary of results

Mechanisms of vulnerability development through urban policy impacts on the urban environment in the two cases are the same (Figs. 3 and 4), while differences between them occur in the causal relations between policies and outcomes (Table 2). For instance, the lack of transportation options and access to health care services in the new and old areas is similarly exacerbating vulnerability but their causal relations to policies are different. In the new areas, the transportation system is undeveloped, whereas in the old areas it is underdeveloped.

5. Discussion

The urban health vulnerability development-related variables were similar in all studied cases and confirm the hypothesis we make that urban policies contribute to urban health vulnerability development. Moreover, our results bring novel understanding to the links between the variables by showing two mechanisms of policy impacts via the urban environment on health vulnerability.

First, policies have an impact on general health risk determinants such as socio-economic conditions and access to healthcare, e.g. via limited transport options. These determinants may exacerbate or reduce overall vulnerability to climate-related health impacts. The results highlight that even relatively recent urban development has not explicitly addressed multiple potential climate related health risks and that some of the contemporary decisions have even increased vulnerability.

Second, our results suggest three types of policy impact pathways on the vulnerability determinants: i) impacts via the social environment on sensitivity, ii) impacts via the physical environment on enhanced exposure, and iii) impacts via both types of environments on adaptive capacity. In the urban adaptation policies, vulnerability altogether is not in focus which has also been emphasized in previous studies (e.g., Camponeschi, 2021). Both previous and current urban policies create environmental determinants of vulnerability to climate related health impacts and, hence, conditions for adaptation also in the future. Previous studies on the urban policy impacts on urban environment and further affecting vulnerability development have focused on individual policies, e.g. land use and related gentrification (Anguelovski et al., 2018) and shorter time-scales of change. Our approach broadens the understanding of policy-impact pathways on urban vulnerability development because of a longer temporal analysis of multiple policies.

Social environment factors such as attractiveness of neighborhood as a determinant in vulnerability development are less obvious than the physical environment factors and have rarely been raised in literature (e.g., Gronlund et al., 2018; Ellena et al., 2020; Li et al., 2021). While our case selection was based mainly on quantifiable socioeconomic indicators, our results point towards the relevance of qualitative factors in vulnerability reduction such as social networks and attractiveness beyond economic criteria. The policy impact pathways behind these factors relate mainly to autonomous and bottom-up initiatives which implies that to enhance adaptation via social environment changes, urban planning should engage with citizen-led initiatives, and they should be properly assessed and monitored for vulnerability and justice impacts (see, e.g., Juhola et al., 2022).

Our results show that a compilation of several policy impacts on the social and physical urban environment create conditions for exacerbated vulnerability in the old case areas, through factors such as the poor maintenance of streets and walkways, access problems of medical staff and vehicles, limited access to health care services, including novel applications such as heat warnings. These findings contribute to the

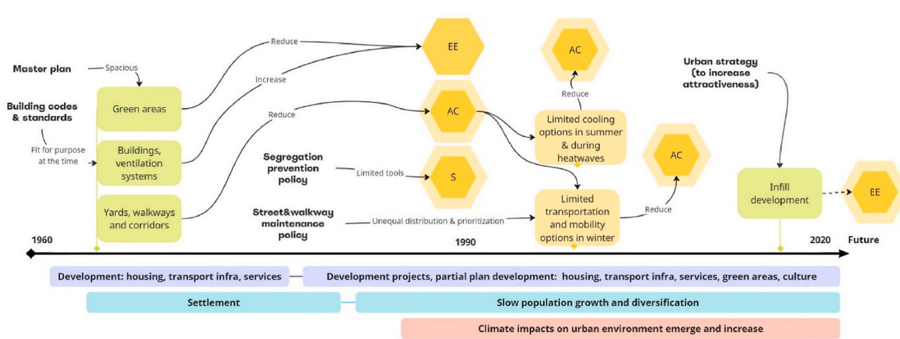

Fig. 3. Timeline of the old case area development and emergence and changes in health risk and vulnerability determinants. EE refers to enhanced exposure, AC to adaptive capacity and S to sensitivity.

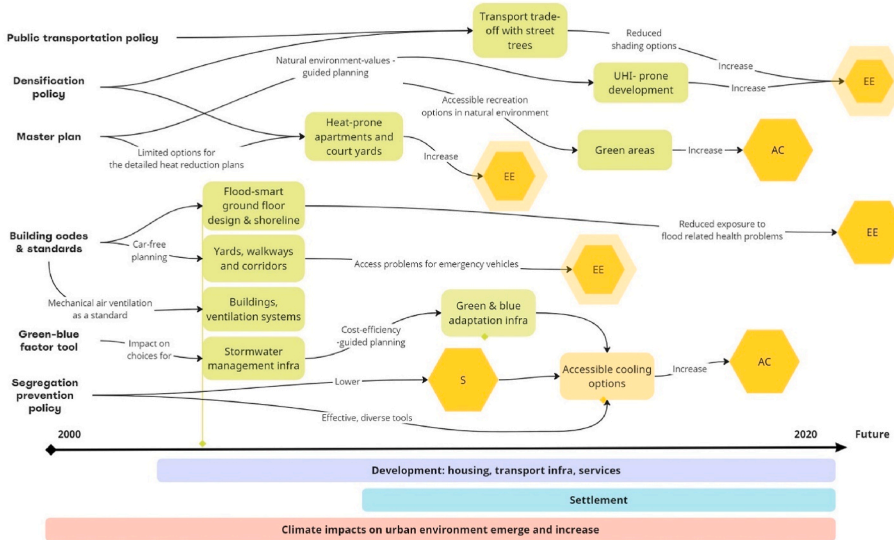

Fig. 4. Development of the new case areas and emergence and development of health risk and vulnerability determinants. EE refers to enhanced exposure, AC to adaptive capacity and S to sensitivity.

limited literature on understanding on healthcare access and availability as environmental determinants associated with urban population health impacts (Ellena et al., 2020; Salgado et al., 2020). Furthermore, the results show that adaptation measures that have mitigation synergies, such as green and blue infrastructure, shading and insulation of apartments, are currently a highly policy-relevant way of addressing exposure through physical environment changes. However, due to higher retrofitting costs in the old areas, the likelihood of the application of the climate resilient options is expected to be lower than in the new areas without sufficient subsidization. This finding exemplifies the importance of cost-efficiency and profit-seeking as drivers of vulnerability development. The findings broaden the understanding on potential inequalities, path dependencies and lock-ins of urban adaptation policies in cities (e.g. Buzási et al., 2021) by showing pathways as preconditions of vulnerability development also at the local district level.

Our results show that there is a challenge between contradictory policies and planning practices and the underlying assumptions of what is expected, possible and needed from different actors, in horizontal as well as in vertical perspectives. This is a widely recognized issue by the governance literature on urban adaptation and related responsibilities (e.g., Eakin et al., 2022; Juhola, 2019). Solutions proposed in literature to address this challenge include alternative governance approaches such as multilevel governance, and mainstreaming of adaptation (Dodman et al., 2022). In European comparison, Finland has been relatively effective in horizontal mainstreaming of adaptation, i.e., national level adaptation policies have resulted in widespread local level dedicated adaptation plan adoption (Reckien et al., 2019). However, our results suggest that horizontal mainstreaming does not reach to the city organization and vertical mainstreaming has not yet been effective as adaptation is not integrated into the urban planning even in the largest Finnish cities that are generally considered to be more advanced in their adaptation policy than smaller cities. We argue that a more robust structure to adaptation governance is needed to ensure that the critical needs are timely addressed in urban policies and planning. Furthermore, while our multi-case study provides a representative sample of MSMD high-latitude European urban areas in terms of vulnerability, further research is needed on the vertical mainstreaming and multilevel governance of adaptation effectiveness in European cities.

Reasons for the poor integration of adaptation into urban plannign include that, on the one hand, the politically determined city strategies that change every four years along with the municipal council direct the focus of urban planning and power relations between the different sectors, i.e. horizontal level. The political power is particularly central in deciding how to finance or incentivise urban adaptation while planning for urban development that supports other goals of the city (Eakin et al., 2022). On the other hand, our results show that the hierachical order of planning in Finland is strict and the planners consider it to be more or less unquestionable. The town, housing, and land use plans dictate the broader boundary conditions of where to build and what the broader goals for urban development are several decades in advance. Our results demonstrated the tension between these three levels and the lack of cross-level discussion on the potential long-term negative impacts to vulnerability as the higher level plans create path dependencies for the urban planning even if the political leadership changes. Consequentially, we argue, the urban planners and decision-makers in the larger cities, in particular, should be engaged in more active and open discussion across the city organization to identify and address the potential long term vulnerability trade-offs of current urban planning decisions.

We observed that urban policies that benefit adaptation usually aim to decrease the exposure to hazards in the urban physical environment and increase the adaptive capacity of people in the urban social environment. Surprisingly, a sensitivity decreasing impact of segregation prevention policy was also identified, which is a finding that contributes to the gap in literature on the sensitivity impacts of urban policies (Jurgilevich et al., 2023). The largest and fastest growing cities in Finland have more advanced policies to address social vulnerability in general than majority of Finnish municipalities. The value of urban segregation policies in climate vulnerability prevention should be considered at national level to ensure its full potential. National level regulation of urban development covers only some aspects of exposure (e.g., ground-floor flooding and indoor temperatures) in new areas. For more effective adaptation to urban climate-related health risks, we argue that urban planning and governance should contribute more prominently to climate vulnerability reduction through promoting social, health, and economic equity and welfare. To help targeting these measures, further research is needed on the multiple policy impact pathways to future, which was beyond the reach of this *ex post* policy study.

6. Conclusions

We analysed policy documents and expert discussions for the interactions between the urban policies, urban change, and climate change-induced health risk in two cases with an MSMD systems design.

Table 2
Most different case comparison (two old areas vs. two new areas).

	Old areas	New areas
Policy impacts via physical environment to vulnerability	Building codes: narrow walkways and corridors hinder access with ambulance and other vehicle, buildings without elevators lower the mobility options for physically impaired; buildings have inadequate ventilation systems for summertime heat prevention; cooling devices are physically incompatible with the older apartments Street and walkway maintenance policy: prioritization/resources/public-private responsibility division cause access problems to health and well-being services in winter Spacious urban planning including much green space reduces enhanced heat exposure Infill development (to increase attractiveness/real estate value) reduces green areas and spaciousness	Building codes and standards: ground floor design, urban planning instructions on shorelines to prevent flood exposure; mechanical air ventilation (during long heatwaves) Green-blue factor tool/cost-efficiency guided planning: green and blue stormwater management infrastructure Densification policy: heat-prone apartments and court yards Car-free planning and public transportation infrastructure: access problems for emergency vehicles Public transportation policy: trade-off with street trees (cooling effect) Natural environment values guided planning and underestimated natural cooling effect: creating conditions for urban heat island
Policy impacts via social environment to vulnerability	Segregation prevention policy tools are less diverse and hence less effective; cooling devices may be unaffordable	Green and blue adaptation infrastructure such as water retention ponds and parks also work as cooling spots Segregation prevention policy tools are more diverse and hence can be more effective
Policy impacts on climate-related health risks (undetermined pathway)	Social policy in the early phases of the area development have resulted in a social environment that contributes to population vulnerability via relatively low attractiveness of neighborhood, socio-economic status, and large proportion of senior citizens and people with immigrant background Green infrastructure and natural environments that are built/reserved in the areas for other than climate risk reduction purposes (recreational use, spacious urban planning) have positive health impacts	The drivers of densification policy are numerous (climate change mitigation, urbanization, nature conservation, etc.) and the impacts on vulnerability can also be positive Building codes and standards are lacking construction time standards for addressing climate vulnerability, and incorporation of climate modelling in planning (e.g. wind conditions) Climate risk expertise not incorporated to the skillset of all relevant actors in the planning and construction

Key findings show two mechanisms of vulnerability development that are the same in the two cases, i.e., i) policy impacts on general health risk determinants, that may or may not contribute to, ii) the policy impacts on health vulnerability determinants. These constitue of three types of policy impact pathways: i) impacts via the social environment on sensitivity, ii) impacts via the physical environment on enhanced exposure, and iii) impacts via either environment on adaptive capacity. Differencies between the two cases occur in the causal relations between policies and outcomes.

This study responds to the criticism of climate vulnerability literature having little influence on adaptation planning and contributes to the recent discussion of urban change as an untapped opportunity for climate adaptation by linking the mechanisms of policy impacts on urban environment and vulnerability. The retrospective analysis of urban policy impact pathways provides novel evidence on climate change-related urban health vulnerability development as a process that is shaped by different urban policies, and thus identifies specific points for possible adaptation interventions. The results highlight the need in current urban and adaptation planning to consider complex socio-economic interactions and longterm horizons of past and present decisions on future vulnerability development through shaping urban environment, and avoiding path dependencies and lock-ins.

CRediT authorship contribution statement

Janina Käyhkö: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Alexandra Malmström (nee Jurgilevich):** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Aleksi Räsänen:** Writing – review & editing, Conceptualization. **Saara Pörsti:** Writing – review & editing, Visualization, Investigation, Formal analysis, Data curation. **Sirkku Juhola:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

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Appendix A. Supplementary data

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