# HOW DOES UNDERSTANDING STRESS RESPONSE MECHANISMS IN INHABITANTS HELP US BUILD A RESILIENT CITY?

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Abstract: Long-lasting (chronic) stress leads to many adverse effects in living organisms. In this study, the city is perceived as an organism. Thus, the recognition of physiological mechanisms of stress response and coping with it in an organism will help identify and develop similar defence mechanisms in urban organisms. This study proposes a multidisciplinary approach and is aimed at applying the stress response mechanisms of living organisms to cities in order to build stress resilience in case of threat. The long-term impact assessment effects of the COVID-19 pandemic and the restrictions and lockdowns introduced are of particular interest. In the review, we present a theoretical, multidisciplinary approach to building a stress-resilient city suitable for academics and a global audience, and propose concrete strategies for city policymakers to cope with stressors at the level of its inhabitants as well as regulations and management. Mitigation, re-construction, and new urban governance have been recognised as such strategies and likened to short- and long-term stress responses of living organisms. Thus, we have offered policymakers a solution for building a resilient city. A novel model of environmental governance, propositions of intervention, and recommendations have been created that could be used by local city authorities to rebuild citizens' resilience in post-pandemic times.

Keywords: city resilience, coping strategies, mitigation, re-construction, new urban governance

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## Introduction

Stress, which is an integral part of each organism's life, is understood as a response (reaction) to factors that throw the body off homeostatic balance (stressors) (Carlson, Heth 2007). It is necessary for life and can mobilise towards action and knowledge of extended ways of dealing



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with stressors (Sivilli, Pace 2014). Moreover, the development of adaptation and flexible strategies may cause the future challenges to be easier to cope with (Sivilli, Pace 2014). However, failure to manage stress or not taking appropriate measures lead to a decrease in general resilience, causing illness or even death (McEwen 1998).

The city can be perceived as a living organism as well (an organicist conception of the city); therefore, it is a complex, dynamic system, whose one of the purposes of existence is, like that of any organism, development (Jacobs 1961, Maik 2012, Parysek, Mierzejewska 2013, 2014, Sarr 2019). Cities, like other organisms, also encounter stress as a result of which they may 'get sick' and, thanks to the development of adaptation mechanisms, recover and rebuild resilience (Molder et al. 2024). Principles of adaptation refer to various systems (Kelly 1970, Zautra et al. 2010) in many scientific fields.

Resilience in biology may be understood as the capacity of systems to absorb changes occurring under the influence of external factors and to maintain and control their functions (Holling 1973, Jabareen 2013). A stress-resilient entity is never perceived as passive or deprived of subject treatment, but rather as active and capable of self-transformation (Chandler 2012, Feder et al. 2019). Measures for increasing the system resilience should be geared to (1) minimisation of the consequences of the disturbance and (2) shortening the time needed to regain the condition before the disturbance (Bruneau, Reinhorn 2004); however, the ordinary return to the initial state may turn out to be undesirable (Sivilli, Pace 2014).

The term resilience is also referred to the city, understood as the capability of reducing the risk and mitigating the effects of the stressor at the moment of its occurrence, as well as using measures aimed at minimising disturbances generated by this stressor (Bruneau, Reinhorn 2004). Similarly, urban resilience is defined by Meerow et al. (2016) as the ability of an urban system and its component networks to "maintain or rapidly return to desired functions" and to "adapt to change, and to quickly transform systems that limit current or future adaptive capacity". These stressors can be acute (short) or chronic (long-lasting) (Fastenrath et al. 2019). Short stressors are intense, sudden events or phenomena (such as pandemics) that can cause loss of life, injury and illness, damage urban assets and threaten the ability of cities to function and provide essential services (Acuto et al. 2018, Fastenrath et al. 2019). Chronic stressors, on the contrary, are long-term challenges that undermine a city's structure and ability to function (Acuto et al. 2018, Fastenrath et al. 2019). Desouza and Flanery (2013) emphasise the connections of this concept with other key contemporary goals of urban development such as sustainability, governance, and economic development. They pay particular attention to the adaptability of urban systems and the city as a whole, treating cities as a self-organising complex adaptive system (CAS). They believe that building the capacity for city resilience is difficult, considering the multitude of elements (including the social and physical spheres), processes, and interactions within the city boundaries (Pickett et al. 2001). Strengthening individuals' resilience plays a major role in the process of building resilience, affecting positively the community's resilience (Sivilli, Pace 2014), as well as increasing their capability, concerning the capability approach (Nussbaum, Sen 1993, Shepherd, Dissart 2022). Therefore, the development of city resilience requires proper planning, designing, and urban governance (Desouza, Flanery 2013, Mierzejewska et al. 2020), as well as raising awareness and encouraging participation of all actors in this process (Zautra et al. 2010).

In recent years, the COVID-19 pandemic turned out to be a new stressor for which neither cities nor their residents were prepared, resulting in considerable human, social, and economic costs (Hagger et al. 2020, Talarowska et al. 2020). The pandemic alongside the restrictions and lockdowns introduced in many countries, which were supposed to limit the spread of the virus, changed the way the world lives. It affected the functioning of cities and their inhabitants, causing fear for one's own health and that of relatives, lack of social interactions, and uncertainty about the future, becoming the source of stress which can lead to various mental disorders (Mumtaz et al. 2018, Carvalho et al. 2022). Social isolation is known to be a very severe psychological stressor. This stressor affects social behaviour, the function of the neuroendocrine system, and physiological, anatomical, and behavioural changes in both animal and humans (Mumtaz et al. 2018).

Therefore, the development of strategies, which help cities and their inhabitants cope with chronic stress during and after the pandemic and thus increase their resilience, has become a priority (Hagger et al. 2020).

Assuming that the city is a complex, dynamic, and adaptive system that functions like a living organism, in this study, we aim to seek analogies in stress response mechanisms between organisms and cities for building their resilience. The city is thus treated as a self-organising system, the homeostasis (understood as dynamic equilibrium), strength and development of which are ensured by resilience mechanisms through adaptability to changing environmental determinants and future challenges (Bristow, Healy 2020).

Such an approach to the research problem expands the organistic conception of a city to include issues of desired responses to stressors, which serves to build resilience with a focus on a stressor such as the pandemic. This work is situated within the context of Goal 11 of the Sustainable Development Goals (SDGs), adopted by the UN in 2015: "Make cities and human settlements inclusive, safe, resilient and sustainable".

## The concept of stress and physiology of the stress response

Stress is a natural physical and mental reaction to life experiences, accompanying daily life, essential for survival, mobilising for action and called eustress (Selye 1975). However, when it is strong or prolonged (so-called chronic stress), it is associated with mental illnesses such as depression or post-traumatic stress disorder (PTSD) (Gold 2015, Godoy et al. 2018).

Selye (1936, 1950), the 'father of stress research', created a complex neurohormonal model of stress, with two main components of the stress response systems: the sympathetic-medullary system and the hypothalamic-pituitary-adrenal (HPA) axis (Gold 2015, Fink 2017).

There are two components of stress response in an organism: a fast (rapid) response and a slow response (Fig. 1). During the rapid response, adrenaline – the hormone of fear, fight, and flight – is released, which allows the body to join the action in a stressful situation. In the second

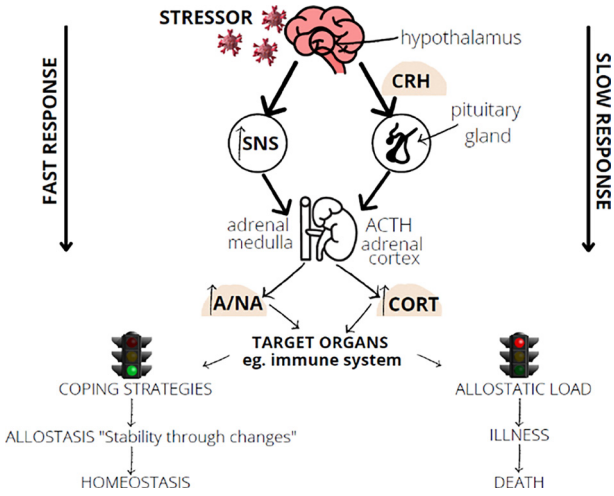


Fig. 1. Stress response, modified from McEwen (1998). ACTH – adrenocorticotropin hormone; A/NA – adrenaline, noradrenaline; CORT – cortisol; CRH – corticotropin-releasing hormone.

phase of the stress response, the HPA axis is the main player. In healthy organisms, the inhibition of the stress response corresponds to the adaptation phase, as mentioned earlier. However, if the stress is very intense and long-lasting (chronic stress), the body 'cannot cope' with the situation, and as a result, the accumulation of too much cortisol could lead to damage to the brain and other organs and illness (McEwen 2007).

In view of the above evidence, there is a need for the organism to develop coping strategies in times of stressful events, for example, during the COVID-19 pandemic, and build resilience. First of all, it is necessary to take into account the occurrence of the body's short- and long-term reactions to stress, and the need to reduce stress as quickly as possible by activating appropriate feedback that promotes faster adaptation. This confirms the thesis that cities familiar with a given stressor (e.g. pandemic) have a greater chance of faster, positive adaptation (Desouza, Flanery 2013).

Below we will discuss the coping strategies which help react in case of stressors.

## Psychological ways of coping with stress

According to the conception of Lazarus and Folkman (1984), stress is understood as a type of interaction of the subject with its environment and is perceived as the state that overburdens

or threatens its resources, causing internal tension. When an individual interprets a given stimulus as a stressor, what follows is the state of psychophysiological tension accompanied by relevant emotional correlates. It is worth emphasising that in the conception discussed emotions are secondary in relation to cognitive processes that induce them (Heszen-Niejodek 2002). The following three categories of stressors are mentioned alongside: (1) harm or loss, (2) threat, and (3) challenge (Lazarus, Folkman 1984). The first concerns a real, difficult situation that has already happened. The second relates to the anticipation of an imminent threat, whereas the last category pertains to the resources of an individual for managing a stressful situation. During the pandemic, all the above-mentioned categories of stress have been seen.

Therefore, one may notice that psychological stress results from external requirements surpassing the individual's resources. Ratajczak (2002) defined those requirements as the person's perceived need to take action while performing the following three functions: (1) prevention, (2) intervention, and (3) positive expansion (Table 1). Thus, in each case the primary assessment affects the intensity and type of emotions occurring during the subject's transaction with the environment.

Table 1. Functions of external requirements in stress response based on Ratajczak (2002).

| Function | Typical features |
|---|---|
| Prevention | Prevention of threat |
| Intervention | Taking remedial measures combating effects of stressful situation |
| Positive expansion | Possibility of using opportunities that occur |

A relatively stable trend in the actions taken by an individual towards stress reduction is termed the style of coping with stress and is understood as the generalised repertoire of an individual's behaviour, tailored to various situations (Strelau 2002).

On the basis of factor analysis, Endler and Parker (1990) distinguished three styles of coping with stress (1) task-oriented coping (TOC), (2) emotion-oriented coping (EOC) and (3) avoidance coping (AC). Moreover, the latter may take two forms: engaging in replacement activities (ERA) and seeking social contacts (SSC) (Strelau et al. 2005). The first of the styles mentioned is characterised by undertaking activities for solving the problem, which may include the situation analysis, determining the priorities, and the choice of the best solution available in a given situation. Thanks to those activities, the subject can make cognitive re-evaluations that are helpful in interpreting difficulties as challenges (Endler, Parker 1990). Conversely, the emotion-oriented style implies excessive focus on internal emotional states giving them too much importance. This is manifested by self-blame or despair over the lost comfort, often accompanied by excessive concentration on one's own physiological ailments, exaggerating their intensity (Gołuch 2011). The last of the coping styles mentioned manifests itself in avoiding the problem by denying it, or dispersing responsibility for solving it. This style may take the form of ERA, not related to the existing stressful situation. Another way of expressing the above-mentioned style is SSC, to get away from problems and receive support (Endler, Parker 1994). This indicates the importance of social contact in coping with stress, which was significantly limited during the pandemic. Individuals usually employ one dominating style, which does not mean that they cannot also use the others in specific circumstances (Strelau et al. 2005).

Active and functional coping with stress is more common in situations perceived to be under control (Gelhaar et al. 2007). Effective coping with stress relates to greater life satisfaction (Bodnar 2022) and reduces the risk of serious diseases (Folkman, Moskowitz 2004). Therefore, one may assume that 'good stress management' is key to building a unit's or social groups' resilience.

It is important to notice that coping strategies are typically considered conscious cognitive or behavioural strategies, whereas the default stress response is largely considered an unconscious phenomenon (Brosschot 2010, Brosschot et al. 2010). Wishing to avoid the negative consequences of stress (illness and even death), it is therefore necessary to adopt a specific coping strategy. It seems worth using this knowledge even in the process of building the resilience of a city, which can also be treated as a living organism.

In the face of potentially stressful challenges, the activation of neural, neuroendocrine, neuroendocrine-immune, and physiological mechanisms (coping strategies) leads to adaptation. This

is called 'allostasis' or 'stability through change', which is an essential component of maintaining homeostasis. When the above systems work properly, the body can cope effectively with challenges (stressors). However, in cases of 'allostatic load', allostatic systems may either be overstimulated or not perform normally, which may lead to illness or even death.

## Stress response mechanisms of cities: Analogies with organisms

The recognition of stress response mechanisms of living organisms for building resilience makes it possible to seek analogies for cities. In this study, we propose a new concept in which we adopt the well-known functional mechanisms that exist in organisms and are responsible for the stress response to the structure within the city. Firstly, according to our concept, we identified the main, leading centres for both organisms and cities. In living organisms, the brain plays a leading role in building resilience.

However, the brain is built from different parts and nuclei. Similarly, for cities, it is local authorities who could vie as the brain as formally empowered entities representing the residents, with their greater or limited participation (Klijn, Koppenjan 2000, Noworól 2011, Pratama et al. 2023). It should be emphasised that city authorities (just like the brain) are the main, but not the only, 'decision-making centres'. They do not have complete autonomy in making decisions, because city management is related to other organisational levels of governance. Their jurisdiction is also limited with regard to the various entities operating within the city, and in the case of informal settlements. The scope of local authorities' autonomy is very diverse due to cultural/institutional aspects and models of city management. It is worth noting that social, economic, political, and cultural institutions play a significant role in shaping the resilience capacity of cities (Lang 2012, Aligica, Tarko 2014, Profiroiu, Nastacă 2021, Gherghina et al. 2023).

Secondly, we compared the possible worst outcomes that could be observed as an effect of chronic stress in organisms and in cities. The impact of stress (in the case of a pandemic) on the body results in weakening the immune system. In the case of a prolonged stress response, a general overload and exhaustion of the body's energy resources occur, and as a consequence, there is a greater likelihood of somatic and mental illnesses (Mumtaz et al. 2018, Hagger et al. 2020). By analogy, cities when encountered with stressors (e.g. restrictions, lockdowns) and their residents exposed to stress, go through a specific crisis. These could be manifested by disturbances in their functioning (e.g. an unexpected change in inhabitants' lifestyles and work, inability to satisfy multiple needs), which lead to the depletion of resources. It is also important to note that during the pandemic of COVID-19, restrictions and lockdowns were actually introduced in cities as a coping mechanism to mitigate viral spread, which was especially important in densely populated areas. However, they caused a strong stress response in residences of cities. As mentioned above, social isolation is a strong stressor and social connection is one of the coping strategies in the case of crisis, and may facilitate post-traumatic growth. Thus, city authorities should implement interventions to foster compassion and feelings of social safeness and reduce experiences of social disconnection (Matos et al. 2021).

Thirdly, we propose mechanisms via which cities could cope with stressors based on those present in living organisms. In response to stressors in living organisms, in the first phase there is an activation of emergency reactions, using available physiological mechanisms, which are unconscious and lead to the secretion of adrenaline (a fast or rapid response to stress). As a result, fight, flight, or freeze reactions occur, enabling survival. In the second phase (slow response), the HPA axis is activated, and cortisol is produced. After a cognitive re-evaluation and evaluation of one's resources, living organisms adopt specific coping strategies in stressful situations. The above strategies are needed to prevent exhaustion and allow adaptation to changing environments, and build resilience (Figs 1 and 2).

Cities should develop similar adaptation mechanisms. Thus, we propose, similar to the response to stressors in organisms, two steps and actions, via which cities could regain control. In the first step, when stressors emerge (acute, in relation to cities, they are often called 'shocks', or later chronic), primary interventions should be taken to ensure the survival of the city and its

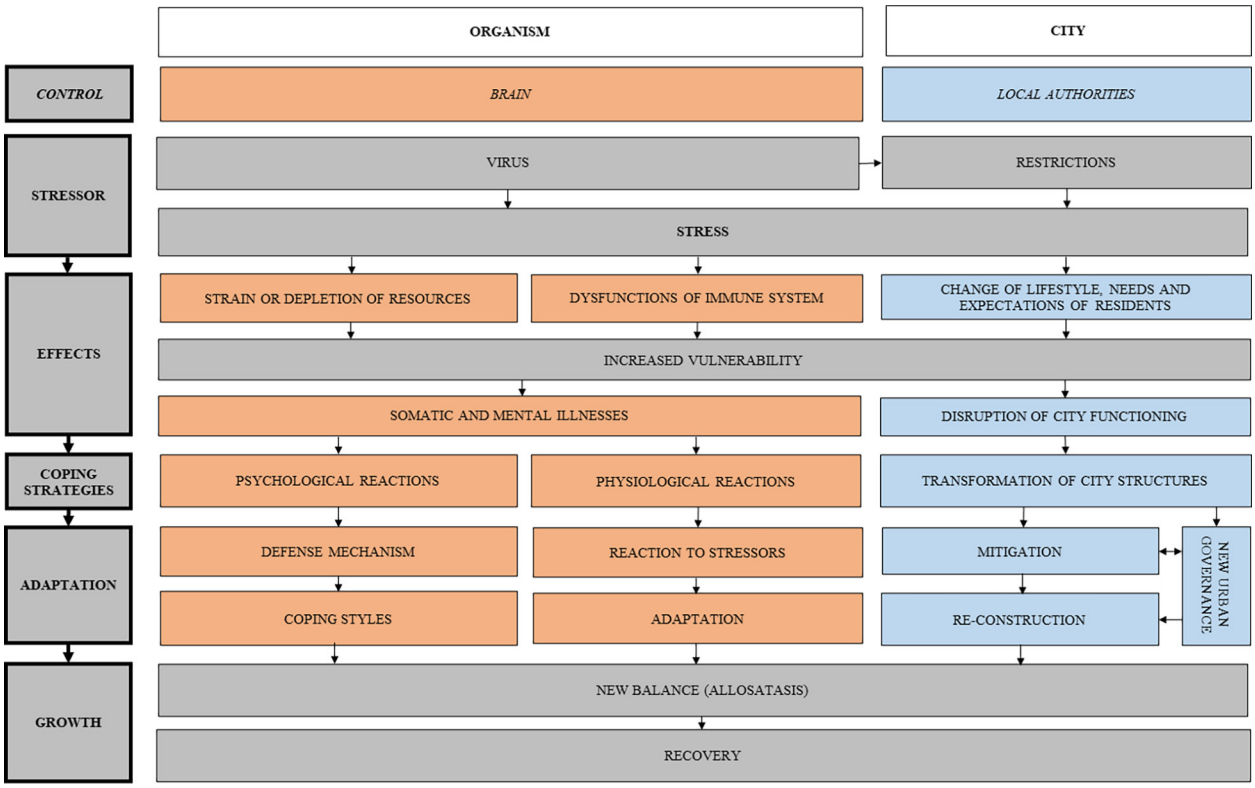


Fig. 2. Analogies of stress response mechanism of a living organism and a city.

residents, aiming at minimising their adverse effects (mitigation), which represents fast responses to stressors.

In the next step, measures are directed at adapting the city's system to new conditions by reducing the vulnerability of the city system to pandemic-caused stress and thus creating healthy, safe conditions for living and further development (reconstruction of the urban system). The mitigation of negative effects will thus fulfil the intervention function – one of the three functions of the activities undertaken as part of the psychological stress response mechanism of the body. Conversely, the reconstruction of the city has a preventive role (prevention of danger) and it is a positive expansion, based on new circumstances, interpreted as favourable opportunities for building resilience of an urban organism.

While seeking an analogy with the physiological stress response of the living organism, one may discover that mitigation measures taken in the COVID-19 era in cities resembled the first phase of the organism response, that is the activation of the sympathetic nervous system resulting in adrenaline rush. They were to limit the virus transmission and to protect people against the threat (restrictions, lockdowns) (Caevallo, Godwin 2020, Hagger et al. 2020, Talarowska et al. 2020). However, long-term restrictions led sometimes to loss of resources and stress intensification, upsetting the equilibrium of an urban organism. Similarly, activation of the HPA axis and cortisol rush, and its continued high level in the body, may lead to negative health consequences and even death. However, the scope of the mitigating and intervention activities varied in cities in different parts of the world, depending on the pandemic, socio-economic, cultural, and institutional conditions (OECD 2020, United Nations 2020).

In the body's response to stress, a pivotal role is played by the way the brain 'governs' the functioning of various systems. Whether and when the organism achieves new equilibrium and resilience to the stressor depends primarily on this way of 'governance'. This is also the case for the city. In analogy to the body's psychological response to stress, the way the city is managed determines, among other things, the following: (1) the primary assessment of whether the situation should be perceived as a stressor, (2) the secondary assessment of the stressor (whether the stressor induces

harm or loss, a threat, or can become a challenge), (3) the response to the stressor, i.e. taking specific actions (initially interventional, then preventive, fostering positive expansion) for coping with a given stressor (stress coping styles), and then (4) the effectiveness of the fight against the stressor in both the intervention and prevention phases. In the case of cities, in response to a stressor, task focus is desirable (analogous to the kind of style adopted in psychology), while emotion focus is the least preferred. Focus on the task in the intervention phase should be directed at minimising the loss and damage caused by the stressor, while in the prevention phase it should be directed at precautionary measures to reduce the risk of a given stressor in the future and reduce vulnerability to it.

In order to take appropriate decisions on the emerging risk in a crisis situation, caused, for example, by the pandemic, and identify accurately expectations and needs of residents in post-pandemic circumstances, appropriate governance is essential. It is about such a form of governance in which local powers act transparently for residents and with their participation, and the residents cooperate and undertake bottom-up initiatives (e.g. neighbourly assistance, which is a type of coping strategy). Additionally, a wide range of experts from various fields take part in the decision-making process (for the pandemic not only virologists, but also specialists in economics, psychology, sociology, ecology, city planning, etc.), including entities of territorial and institutional management. A team of experts would act as a buffer between city dwellers and urban authorities in a process which can be called new urban governance. It should also be adaptive governance, characterised by flexibility, experimentation, creative problem-solving, social learning, democracy, participation, and a diversity of methods, approaches, and actors (Armitage 2007, Huitema et al. 2009, Chaffin et al. 2014, DeCaro et al. 2017). This kind of new urban governance may become, in relation to mitigation and reconstruction, a coping strategy of cities for pandemic-caused chronic stress, and may lead to building city resilience. One may assume, however, that the way the city is governed will vary in both phases mentioned. In the phase of mitigation of the effects of acute stress (shock), owing to the importance of reaction time to the stressor, the possibility of inhabitants being involved in city governance is likely to be limited as compared to the reconstruction phase, aimed at reducing the effects of long-term stress and building resilience to similar stressful situations. It is worth emphasising that in the case of catastrophic events, decision-making and mitigating actions go beyond the jurisdiction of city authorities and are often the responsibility of crisis home management teams at various levels.

The physiological mechanism described above refers to a non-specific reaction to stress. This does not mean that a specific city can, or even should, take individual actions that allow for local specificity.

As a result of adaptation measures, both cities and their residents (living organisms) reach the state of equilibrium – allostasis via a dynamic process of changes, denoting some kind of recovery and city resilience to stressors. Thus, a city, like an organism, acquires the ability to attain allostasis, i.e. to maintain the state of balance by making multisystem changes (Figs 1 and 2).

Below are described coping strategies for pandemic-caused stress implemented in cities, referring to responses to stressors observed in living organisms.

## Mitigation

Mitigation measures should be taken as soon as possible from the moment a stress-inducing factor emerges (one of a shocking nature in particular), which is analogous to the activation of the body's sympathetic nervous system in the physiological aspect and the intervention phase in the psychological aspect. The measures aim to mitigate unfavourable effects, most often violent ones, as quickly as possible. The character of emergency measures, usually taken by crisis management teams, depends primarily on the type of stressor, its intensification, and spatial extent, and often varies in time; these are usually short-lived actions the efficiency of which needs to be monitored (Feder et al. 2019, Hagger et al. 2020).

Such measures were employed after the outbreak of the COVID-19 epidemic. In the face of a global threat to human health and life from the new virus, public authorities at various levels (mainly governments) implemented numerous

urgent measures, intended to limit the virus transmission (analogous to the stress management style of focusing on a task). These measures covered a series of orders and prohibitions (as part of restrictions and so-called 'lockdowns'), mainly aimed at limiting social contacts and the functioning of many business entities (OECD 2020, Szpyt 2021). But actions such as limiting social contact are another stressor affecting the inhabitants, because people are social creatures. However, there are also examples of countries (e.g. Finland) where no specific action was taken at the outbreak of a pandemic (analogous to an avoidance-focused style) (Korppi 2022). Yet one can also point to examples of mitigation measures that helped limit the spread of the virus and had positive effects that turned out permanent. These include, among others, the development of e-government as well as remote or hybrid working where this is reasonable (Kuzior et al. 2021, Ilawagbon, Ajisebiyawo 2024).

In the pandemic situation, what was also taken were mitigation measures as part of local bottom-up initiatives and social organisations (e.g., neighbourly help), and also in the form of material support, aimed at reimbursements to various types of entities (mainly business) for losses incurred as a result of the restrictions imposed (Poli et al. 2020).

Although the restrictions were well-meaning, they were often introduced over the top or delayed in relation to dynamically changing needs, exacerbating and prolonging the state of chronic stress, and aid was not always directed to those most in need (Mierzejewska et al. 2023, Wdowicka et al. 2024). Therefore, it seems that there was no proper secondary cognitive assessment of the threat. Consequently, in many cases the restrictions resulted in disturbance in the functioning of selected urban systems, changing the inhabitants' lifestyle and could lead to 'allostatic load', deteriorating the health of inhabitants (Hagger et al. 2020, Carvalho et al. 2022). This should make city authorities aware of the need to introduce mitigation measures that would fit local conditions, and also well-thought-out, long-term preventive procedures that would require transformation of urban structures and alterations in the way a city is governed, involving more participants in this process (new urban governance).

**Reconstruction**

Coping strategies of cities and their residents with long-lasting stress in the long term include measures in the area of reconstruction. They focus on the adaptation of cities to dealing with negative consequences of changes, including those resulting from the pandemic (Erfani, Bahrami 2022) (minimisation of resource consumption in analogy to physiological stress response), but also on using opportunities which occur because of those changes (by analogy with preventive measures, fostering positive psychological expansion). Modern urban structures should be both prepared to absorb stress-inducing factors and to return quickly to normal functioning, and building resilience through developing new models of contemporary cities is to reduce vulnerability to pandemic-caused stress. Reconstruction embraces the strategies of the measure aimed at modifying urban structures in spatial, economic and social terms. These actions are intended to relate to the needs, expectations and inhabitants' aspirations changed by the stressor and to develop healthy (improving the organism's resilience) living conditions, limiting the virus transmission and alleviating the inhabitants' stress (Mierzejewska et al. 2021). Examples of desirable measures in this regard, including conditions for the formation of mental health, are presented in the United Nations (2020) report, among others.

Reconstruction measures require a multi-scale strategic approach at various levels (Wilkinson, Wagenaar 2012), however their common denominator is time. Thus, reconstruction measures are long-term actions (like a long-term stress response in an organism). What is interesting is that short-term solutions (mitigation – an equivalent to quick response to stress), being first an element of crisis management, started to shape long-term reconstruction strategies towards more inclusive, ecological, and intelligent cities (Erfani, Bahrami 2022). Short-term measures that worked at the onset of the pandemic have been picked up and arranged in a legislative and organisational framework by local authorities, enterprises, and the inhabitants themselves, becoming not only an element of building the city's resilience, but also a New Normal (Hagger et al. 2020), like online meetings or hybrid working. It

is the reconstruction in response to the city residents' needs changed by the pandemic that will make it possible to build city resilience also to other epidemic threats in the future.

When it comes to stress coping strategies, long-term strategies (reconstruction) may take place at four main levels (UN-Habitat 2021): urban economy (means), form and function of the city (resources), social policy (relations), and legislation and urban governance (management) (Fig. 3). Provided that these changes are introduced to governance and organisation relatively easily (urban governance), physical changes in the spatio-functional structure (form and function of the city) seem the most difficult, time-consuming, and costly. However, building cities' resilience to pandemic stress requires such changes. It will be primarily about transforming those structural elements that intensify this stress and developing those that reduce it (Wdowicka et al. 2024). Changes to strengthen the physiological immunity of residents and improve access to essential goods and services near places of residence will also be essential to minimise the possibility of virus transmission. In the case of large cities, this will mean developing a polycentric spatial structure and improving residents' accessibility to urban green areas (Mierzejewska et al. 2023).

Within each level that demands long-term action (reconstruction), one may define a series of urban factors/features typical of a given city

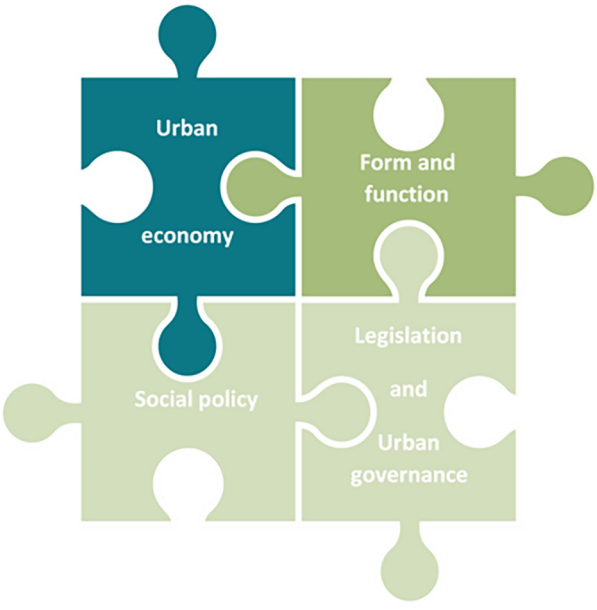


Fig. 3. Four levels of strategic measures for coping with pandemic-caused effects.

(Cheshmehzangi 2020), which require subject treatment in building its resilience strategies.

The long-lasting stress of an urban organism, analogically to a human organism, reduces its resilience. Therefore, it seems that the individual features of a city (such as size, population density, spatial-functional structure, economic structure, etc.), as in people, may play an important role in mitigating pandemic effects and in the adaptation process. To achieve this, one needs to first identify urban stressors as well as the expectations and needs of inhabitants changed by the pandemic, and also acquire expert knowledge in the field of building healthy and effective cities.

## New urban governance

The COVID-19 pandemic, whose main focal points (and restrictions) embraced cities, has demonstrated the weaknesses of currently accepted models of urban governance and urban policy (Clark 2020).The pandemic generally highlighted the unpreparedness of public administration to fight this type of threat (Christensen, Laegreid 2023, Moon et al. 2023). It has led to a resurgence of state intervention and state power in infection control, public health, and differentiated social and economic support (McGuirk 2021). It also demonstrated the ineffectiveness of conventional public management methods in dealing with the implications of a pandemic (Alqutob et al. 2020, Cave et al. 2020).

At the same time, the pandemic has accelerated trends in urban innovation, enabling an expansion of the repertoire of governance mechanisms, including using digital tools (McGuirk 2021). It also triggered a resurgence of civic action through mutual aid and 'pandemic solidarity' (Sitrin, Sembrar 2020). Such bottom-up initiatives were designed to address government and market failures, demonstrating civil society's willingness and ability to co-govern (McGuirk 2021). The COVID-19 pandemic resulted in the mobilisation of new, local, spontaneously formed action centres and political decisions, as well as the emergence of a unique 'new decision-maker' taking part in new forms of democracy through the following: social networks, digital participation, or civil budgets, implemented with modern technologies and the Internet (Smart City 2017).

Moreover, the chronic stress situation caused by the pandemic also activated behaviours related to dissatisfaction and distrust of the authorities, as reflected in the numerous mass protests by residents against the restrictions imposed. This public reaction showed the need to engage not only inhabitants (participatory governance model), but also professional, highly qualified, interdisciplinary experts in governance processes (decisions during the pandemic were made primarily at the dictates of epidemiologists). Their role would be to prepare and present development scenarios, both short- (mitigation) and long-term (reconstruction). There is also a need to allow for current data, local specificity of the situation and place (city), and also the exposure of favourable and unfavourable (financially, health-wise, socially, etc.) results of the development paths suggested. Experts have at their disposal many informal negotiation tools (soft-power), and the ability to formulate visions and influence through specific instruments (Cheshmehzangi 2020).

Thus, the pandemic has vividly revealed the need to develop new ways of managing cities in an emergency, with proper recognition of the stressor and the appropriate response to it in short (mitigation), and long terms (reconstruction), but also the need to adopt new mechanisms, structures, processes, and tools of urban governance (Masik et al. 2021, Masik, Stępień 2021, Wereda et al. 2024). These need to be more decentralised, adaptive, and flexible based on new technologies and intelligent data (smart governance) as well as forces and possibilities of fast and accurate reaction to crisis, using the knowledge and experience of a wide range of experts.

Communication plays an important role in the entire governance process for adaptation and building resilience – the flow of information about problems, ways of solving them, and their possible consequences (Mosera, Ekstrom 2010). Feedback in urban governance (from both social and physical parts of the system) can be treated as feedback occurring in living organisms (Chaffin et al. 2016), which is conducive to reducing stress levels positively and, as a result, leads to faster and better adaptation. Leadership is no less important (not only formal and certainly not limited to one person). The lack of high-level leadership and guidance may weaken the ability and willingness to make adaptive decisions (Mosera, Ekstrom 2010).

The problems of city functioning and development during a pandemic cannot be solved without taking into account multilevel governance (Vogel 2008, Daniell, Kay 2017). However, the influence of supra-local actors should be significantly reduced compared to what took place during the COVID-19 pandemic.

Therefore, new urban governance, in general, should incorporate the principles of good urban governance and combine the advantages of participatory and expert models of governance, multi-level governance models, smart governance, and adaptive governance (Folke et al. 2005, Folke 2007). Such new urban governance would help increase the effectiveness of actions taken (focus on the task) to reduce the risk of the stressor and the effects it causes (creating conditions for positive expansion). It would thus foster the city's resilience to stress at the individual (individual residents), social (city residents in general), and general (the city as a living organism) levels. The concept of new urban governance is more widely described in Mierzejewska et al. (2024).

## Conclusions

In summary, this paper shows that the COVID-19 pandemic could be viewed as an acute, and later as a chronic stressor, which may lead to difficult life events, illnesses, and even traumas. Since resilience is defined as the ability to bounce back from difficult life events, building-up global resilience in cities in the post-COVID times seems necessary. Therefore, we adopted physiological strategies used by organisms in response to chronic stressful events. We also discussed coping strategies known in the field of psychology. Finally, we presented the analogy between coping with stressors and building resilience in the organism and the city. By making such analogies, we have offered propositions of intervention, conducive to rapid adaptation of cities to the effects of the stressor and recommendations that could be used by local city authorities to rebuild citizens' resilience in post-pandemic times. The analogies presented may also serve to devise new development models of contemporary, resilient cities.

However, it should be noted that the analogies presented are general and considerably simplify reality. Significant differences in the way crisis situations are coped with, as well as in building urban resilience, may occur in particular between cities operating under different political conditions, with different governance systems, or of varying sizes, which translates into providing access to services at different levels. The development of the mechanisms of reaction to stress outlined in the article and building the city's resistance to stress in analogy to the functioning of a living organism opens new, engaging, interdisciplinary research fields. Moreover, a novel model of environmental governance, propositions of intervention, and recommendations have been created that could be used by local city authorities to rebuild citizens' resilience in post-pandemic times.

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### Authors' contributions

All authors contributed equally to the text production.

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