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RECONSIDERING URBAN RESILIENCE ASSESSMENTS TOWARDS RECOVERY DURING CONFLICT. THE ARTUR FRAMEWORK APPLIED TO UKRAINE

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Abstract

In the face of global crises, resilience is a crucial approach to recovery. Urban resilience frameworks have proliferated in the last three decades, as support for policy-focused guidelines towards sustainable development. However, gaps in the adoption of urban resilience frameworks for local-level urban planning still exist. This study argues whether existing frameworks, despite addressing current global challenges such as climate adaptation or rapid urban growth, are suitable for contexts experiencing conflict. The methodological approach is guided by two themes: 1) How can an urban system be dissected into sub-components, to make it more relatable to resilience approaches? and 2) what qualities of resilience are needed for effective implementation? Both questions support the formulation of a novel urban resilience framework which is integrated into an adaptable digital instrument. A pilot conducted in two Ukrainian cities is presented as the implementation case. The outcome of this study summarises the learnings from implementation and highlights the relevance of integrating resilience assessments into digital platforms focused on local, decentralised planning contexts, to accelerate digital maturity and better prepare against future crises of unprecedented scale.

Keywords:

Urban resilience, digital tools, urban systems, Ukraine, war

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1. Introduction

Ukraine faces the unprecedented challenge of being part of the first contemporary large-scale war of the 21st century in the European context, having fallen victim of invasion by the Russian Federation in February 2022. Strategic thinking based on new technologies, i.e. drones, satellite imagery and artificial intelligence, has evolved, and thus intensifies uncertainties, and vulnerabilities (Clark, 2024). Information and networks demand the need to understand new challenges of territories in conflict, or as Osinga (2021) notes, the conduct of war, in a different way. As the socio-ecological systems of urban contexts have become more complex (Folke, 2006; Walker et al., 2004; Datola et al., 2022), its internal dynamics are consequently highly exposed and more vulnerable. This demands innovative approaches for agile solutions, for fast recovery and long-term, sustainable reconstruction. Learnings and reconsiderations of paradigms in strategic urban planning may be drawn through observation of the developments in Ukraine. The international community, as a larger agent, should support the formulation of effective, agile, and rapid solutions to avoid the consequences of greater impact.

Urban environments are adaptive systems of interconnected flows, materials, and relationships that define urban areas (Alberti, 2016; Batty, 2009; Bettencourt, 2021; Ortman et al., 2020). Cities highlight the concentration and interdependence of assets, dynamics, flows, and dwellers (Folke, 2006). The Russian war in Ukraine has also brought undeniable impacts beyond its borders (Winston, 2023). Sudden shocks in urban areas have demonstrated significant failures and ripple–effects, with consequences on physical, e.g. failing basic infrastructure; economic, e.g. loss of income and workforce; environmental, e.g. territorial degradation, loss of productive land, or flooding; and socio-psychological levels, e.g. loss of homes and displaced population. The displaced population within Ukraine and across Europe has had clear impacts on the social, economic, infrastructural and environmental tissue of the broader territory (World Bank, 2022). New approaches which provide more agile strategic planning must be devised (Kourtit et al., 2020). These must be flexible, dynamic methods that are able to address immediate and long-term challenges; both those that are known and those that are unexpected.

Urban resilience can play a significant role in shifting traditional approaches of planning. Nevertheless, despite the argued relevance of the concept of urban resilience to address recovery, its uptake and integration into operational planning practice at a local level remains fuzzy (Galderisi, 2014). Many existing frameworks are predominantly oriented at policy level and governance. They are strongly focused on indicators and indexes, and address common global challenges such as climate change adaptation, but do not necessarily focus on those challenges which come with the levels of uncertainty and threat that arise during armed conflict. In this case, deeper analysis, e.g. spatial data or mapping approaches, could highlight interdependencies across challenges and provide significant insights to consolidated frameworks. Such an approach might contribute to mitigate effects and enable preparedness for future urban system failures.

This paper identifies key gaps in urban resilience assessment at the planning level and examines whether integrative analytical approaches based on established frameworks can address them. These themes are discussed within the case of an implemented project in Ukraine, launched as part of the response to mounting challenges of recovery in the territory. From this case, learnings were collected from the application of digital tools for resilience assessments towards recovery planning.

The presented Ukraine case can serve as an example for the international community with regard to resilience measures in urban planning practice in this era of interconnected complex urban systems. The outcome of this work paves the way for further research and implementation cases which could streamline the path towards effective urban resilience planning strategies linked to digital tools for contexts undergoing deep transformations grounded in crises.

2. Problem Background

2.1. Urban Resilience as a Suitable Concept for Recovery

Coined in urban ecology (Holling, 1973) and transferred to multiple fields of urban studies, urban resilience can be summarised as the capacity of an urban system to withstand shocks, to recover and to transform from its learning, and be better prepared against future disruptions (Meerow et al., 2016). Resilience highlights a system's preparedness to confront threats and its ability to recover effectively (Ribeiro and Goncalves, 2019; Datola, 2023). This perspective, brought to the realm of urban planning, enhances the understanding of the interconnections and trade-offs that exist between different sub-systems, such as infrastructure, social networks, economic dynamics or natural ecosystems (Derrible et al., 2023; Chelleri, 2012). Urban resilience serves as a pathway towards long-term sustainability, it enables cities to absorb shocks and maintain stability. It is not a concept confined to particular patterns of physical urban forms (Goldschalk, 2003). It highlights patterns related to the flows of a dynamic system. This flexibility allows tailored responses to specific urban conditions, and encourages innovative thinking when becoming resilient. Acknowledging the complex nature of urban systems (Batty, 2009) underscores the utility of a holistic, integrated, and adaptable approach to strategic urban planning based on resilience notions.

2.2. Multi-faceted Concepts of Urban Resilience

The understanding of resilience as a concept varies across disciplines (Meerow et al., 2016). However, within the field of urban development, many definitions support it as a positive concept where systems are prepared to face failures, whether acute shocks or chronic stresses, and thrive through transformation. Still, the question as to whether it should be a unified resilience definition, and whether it is able to adapt on a case-by-case basis is debated. Within existent literature, definitions related to recovery from war is not broadly covered (Elfversson & Höglund, 2023; Rosvold, 2023). Many approaches towards urban resilience measures come from the need to address climate-related challenges, or general global challenges. However, addressing recovery from war has not been directly pinned to specific resilience frameworks (McCandless & Onbargi, 2023; Rosvold, 2023). This case could further revise the considerations of different parameters.

Over recent years, scholars have focused on coining a specific definition for urban resilience based on the situation in Ukraine. Soldak et al. (2024) refer to *emergent urban resilience*, to highlight the importance of differentiating previous definitions against a new one which should acknowledge unforeseen challenges arising in moments of acute crisis. Within this new approach, *emergent urban resilience* separates itself from the previous concepts which are intrinsically embedded in notions of structures and systems and consequently addressed from a predominant governance perspective. Instead, it focuses on the idea that in acute crisis, social cohesion, and local knowledge play a crucial role for recovery. This definition is also closely linked to the principles of poli-crises. Another case (Clark, 2024), suggests that in Ukraine, multiple discourses of resilience are being played at multiple scales. This is defined as *resilience multiple*, a concept that should be understood differently across various domains, such as urban planning, climate adaptation, security, and public health, since each realm brings its own spatial, temporal, and political implications. This multiplicity is not merely a theoretical observation; it has practical consequences on how resilience is implemented and experienced in different settings. Finally, a third study refers to *national resilience* in the Ukrainian context (Goodwin et al., 2023) and, in conjunction with *emergent resilience*, it refers to the role of social cohesion during recovery, and the relationships which exist between state and society. Given that these new concepts have opened multiple approaches, it is also worth challenging the notion that a one-size-fits-all solution to complex societal issues can succeed.

2.3. A Broad Spectrum of Resilience Frameworks

The concept of resilience for societal balance is a relatively recent approach in urban development. The transfer of applied concepts from other fields of study, i.e. ecology, physics and psychology; and the proliferation of urban resilience frameworks has only developed in the last three decades (Bautista-Puig et al., 2022). Driven by the emergence of sustainable urban development approaches, there is currently a broad number of resilient frameworks which make significant contributions to the mitigation of the common challenges that societies

face worldwide. These have been developed by governmental bodies or international development agencies (Krishnan et al., 2023; Sharifi & Yamagata, 2018). Starting in the 1990s, when the concept of *sustainable development* was coined, the first initiatives of this nature emerged (WCED, 1987). This was followed during the 2000s by those which were adapted to disaster risk management (ICLEI. org, n.d.) and, thereafter, in the 2010s by a higher trend of frameworks (the Rockefeller Foundation, 2013; UNISDR, 2015; United Nations, 2015; the Rockefeller Foundation and ARUP, 2015) and agreements such as the Paris Agreement, which consolidated the term of resilience linked to urban development. In recent years, initiatives have become even more focused on global impacts, such as the global pandemic or the EU Green Deal (e.g. UNDRR, 2021; World Bank Group, 2024), and have been applied to multiple locations with a strong-community based approach. They have sought to enhance measures such as energy transition, digital infrastructures, risk, security, investment, health, and social cohesion.

It can be argued that this spectrum of instruments has, rather than accelerated the effective uptake of a more streamlined methodology of practice, instead made its effective operationalisation cumbersome. The reliance of many of these frameworks on complex metrics and rigid standards (Datola et al., 2022; Figueiredo et al., 2018; Meerow et al., 2016; Arup International Development, 2013; Jabareen, 2013) might hinder their tailoring capacities to specific cases, slow down implementation, and limit their flexibility with regard to guiding future planning and projects from a generalised to a local scale.

2.4. Implemented Resilience Frameworks in Ukraine

In Ukraine, resilience measures have, over the last three years, been implemented at two levels: 1) those from international aid agencies and 2) national-level projects and measures. In both cases, the resilience measures have been carried out in an acupunctural manner, and have sought to tackle different cities in dialogue with individual local-level authorities.

At International Level:

- *The MCR2030* initiative has engaged with cities such as Lviv, Mykolaiv, Ostroh, Vinnytsia, and the Rivne region, and has implemented the UNDRR's Disaster Resilience Scorecard to assess vulnerabilities and plan for enhanced urban resilience. Facilitation activities by the MCR2030 Resilience Hub have been executed using a workshop-oriented approach (UNDRR.org, 2024).

- *The Ukraine Recovery Roadmap*, from ICLEI, is a roadmap that was launched in 2024 to assist Ukrainian cities in post-conflict recovery and sustainable development. It emphasizes decentralisation, climate neutrality, and integration with the European Local Green Deal. Consequently, it guides resilience assessments and adaptive risk governance. The efforts of ICLEI in Ukraine are mostly related to support energy transitions (Iclei-europe.org, 2022).

- *The Resilience, Recovery and Reconstruction Plan 2023-2026* was launched by the Council of Europe as an action Plan for Ukraine. It is focused on supporting issues pertaining to democracy, the rule of law and human rights. It has been delivered via webinars, conferences and training sessions (Council of Europe, 2024).

- *The Eurocities Sustainable Rebuilding Project* was initiated in 2023 as a pilot project to promote sustainable urban reconstruction and it involves 10 Ukrainian cities and 34 European counterparts. The project focuses on integrated planning, clean energy, disaster risk reduction, and circular economy principles. This content, which seeks to guide recovery efforts, has been compiled into a toolkit released in May 2024. The project is focused on capacity-building measures for sustainable development and climate neutrality practices and contains a strong governance approach (Eurocities, 2023).

- The *Strengthening Urban Resilience in the Areas of Supply Infrastructure and Housing* Project from the GIZ-UA is supported by the German Federal Ministry for Economic Cooperation and Development. This program (2023–2027) collaborates with external partners and Ukrainian cities to restore municipal infrastructure and housing. It also enhances local capacities through training and transfer of digital systems for damage assessment and urban planning. The approach of this specific project is more directly oriented at supporting the enhancement of integrated planning and physical infrastructure (GIZ, 2025).

At National Level:

National executive measures have focused strongly on the decentralisation of administrative power to assign more control to cities at community level. One example of this is the case of decentralised energy solutions to mitigate the impact of infrastructural failures (IEA, 2025). Another significant measure is the nationwide project *Points of Invincibility*, which was initiated in November 2022. It is now established in over 4,300 centres across Ukraine, and provides essential services such as heating, electricity, water, and communication during infrastructure outages; thereby enhancing community resilience amid ongoing hostilities. The initiative has been coordinated by the Ministry of Internal Affairs with support from local authorities and international donors (Kitsoft, n.d.).

The identified international measures applied in Ukraine since the beginning of the war, have the use of the term *resilience* in common. However, many of them aim at governance level measures, such as climate mitigation, energy transition, sustainable development goals, and EU compliance; making them less directed at local-level planning or tailored to conflict situations. In contrast, national level measures, although not explicitly linked to the term *resilience*, are a valuable approach, as they incorporate spatial-based strategies, e.g. the location of secure points over the territory or the decentralisation of critical infrastructure. Geographical exposure has a strong impact on notions of vulnerability (Turner et al., 2003). Both terms are spatial conditions that contribute to the identification of overlapping challenges as well as interdependencies that exist over a territory. These can support the design of urban planning strategies to prioritise the implementation of adequate plans at the city-scale. However, exposure and vulnerability are only a part of the parameters needed to monitor the different stages of urban resilience. According to the definition from the National Academy of Sciences, the path towards resilience is comprised of preparation, absorption, recovery and adaptation (Connelly et al., 2017). A more holistic assessment of urban resilience which monitors optimal state across all stages alongside spatial considerations has not been sufficiently explored.

2.5. The Advantage of Crowd-sourced Data

Data that is gathered by population, on a daily basis, from a combination of routine behavioural patterns and *IoT* devices has proven to be a valuable data asset when it comes to rapidly collecting immediate information from cities. It has the potential to complement historical or statistical data because it provides short-term and large-scale insights into the status of urban systems and their dynamics. This is especially important during emergency situations when cities are faced with sudden shocks and emergency operators must react fast (Qiu et al, 2022, Chaves et al, 2019). In Ukraine, since 2022, several crowd-sourced platforms have been implemented so that residents are aware of upcoming attacks from drones or other sources, and can seek shelter promptly. The *ePPO* app is just one of many examples that have activated Ukrainian citizens to act as spotters, and report sightings of missiles and drones. Citizens submit reports through the app, which aides air defence systems in tracking and responding to threats (Eppoua, 2023).

However, crowd-sourced data from the population is seldom integrated into existing resilience frameworks, although they could potentially serve as real-time learning mechanisms that anticipate situations and better prepare citizens and emergency operators after immediate failures. Soft data such as citizen knowledge and their behavioural patterns, are inputs that could balance quantitative approaches and authoritative knowledge, e.g. statistical data, historical data, or indexed data; it could also serve as a counterpart in urban resilience measures (Tavra, Racetin, and Peroš, 2021). Despite obvious setbacks, e.g. lack of validation or data privacy, the use of crowd-sourced data could significantly complement historical or statistical data, and provide more local-bound and real-time information (Albuquerque et al., 2016). This argument supports the previously presented concepts of *emergent* or *national resilience*, and the relevance of social cohesion and emotional distress during crises.

3. Methodological Approach

The study is guided by the conceptual framework depicted in Figure 1, and is based on the collected knowledge and identified gaps presented in section 2. It presents two guiding questions defining the research scope. Firstly, on the understanding of urban systems: How can urban system be dissected into sub-components, to make it more relatable to resilience approaches? Secondly, on the understanding of resilience: Which constituent qualities of the concept of resilience are needed to bring it to operational measures in planning strategies? Both guiding themes converge to formulate a novel urban resilience framework.

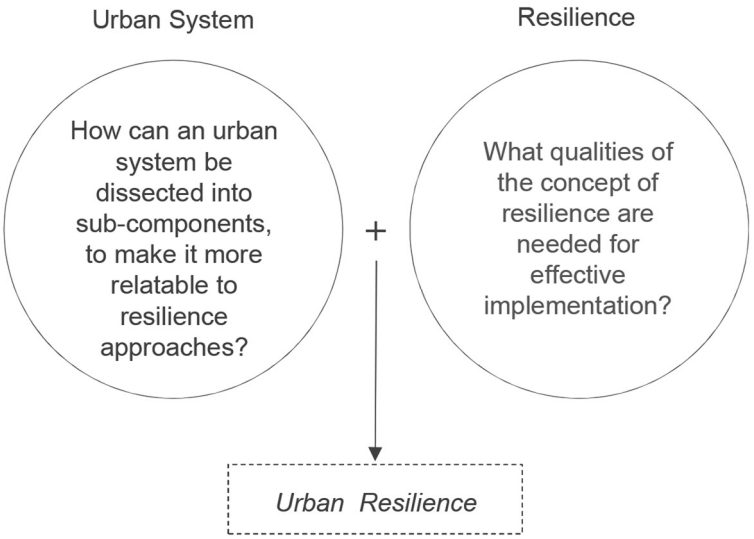

Fig. 1. Conceptual framework guiding the methodological approach.

The conceptual framework underpins the methodological approach that uses a qualitative framework synthesis approach that combines document analysis and thematic interpretation to inform the necessary parameters for the creation of a novel integrative resilience assessment framework. The document analysis focused on reviewing scientific literature and empirical reports. The thematic interpretation was based on a comparative framework analysis that sought to identify patterns and singularities from a sample of selected resilience frameworks.

3.1. Comparative Analysis of Resilience Frameworks

A comprehensive comparative review of relevant urban development resilience frameworks was conducted as part of the thematic interpretation of this study. The selection criteria for the considered frameworks were based on their relevance to the research problem, geographical coverage, and recent implementation. The selected frameworks were: The *Disaster Resilience Scorecard for Cities* (UNDRR, 2017), the *City Resilience Index* (the Rockefeller Foundation and ARUP, 2015) the *City RAP Tool* (UN-Habitat, 2020), and the *City Strength Diagnostic* from the World Bank (Lynch, 2018). From the identified resilience-related framework implemented in Ukraine, only the *UNDRR Disaster Resilience Scorecard for Cities* is considered in this study's comparative analysis. The other identified frameworks implemented to date in Ukraine were beyond the scope of this study's analysis, as they are either based on the collection of best practice from existing cases, i.e. ICLEI, Eurocities; or do not focus specifically on urban planning approaches, i.e. the Council of Europe.

The criteria for comparing the selected frameworks were determined as follows: 1) background, 2) method of application, and 3) output. The selected frameworks were subjected to document analysis as a method of qualitative inquiry. The key features, principles, and components of each framework were extracted from the developing agencies' public repositories´ documentation and organised into a comparative matrix[1] (Table 1).

1 An extended table of the comparative analysis can be consulted in Appendix 1.1 and 1.2.

Through conducting thematic analysis, the recurring patterns (commonalities), gaps, and unique elements (distinctions) were identified across the different frameworks. This enabled capture of both the shared foundations and distinctive contributions of each case. The insights collected in the performed comparative analysis are considered in this study's novel proposed framework (Fig. 2).

Table 1. Summary of the comparative analysis of the consulted frameworks.

Compared Resilience Frameworks		
1) Disaster Resilience Scorecard for Cities (UNDRR); 2) City Resilience Index (CRI); 3) City Resilience Action Planning Tool (City RAP); 4) City Strength Diagnostic (CSD)		
	Commonalities	**Distinctions**
Background		
Developing agency	All are aid agencies or organisations with an international scope.	
Year of creation	All created within the last two decades, where common goals are focused on global impacts, e.g. climate adaptation.	The CSD is the most recently developed framework, after 2020.
Contexts where applied	3 out of 4 (UNDRR, CRI and CSD) are involved in 4 continents: Africa, Asia, Europe, America. All refer to city-level applications.	Only City RAP is focused primarily in Sub-Saharan Africa. It is still relevant for its consideration of small and medium-sized cities.
Purpose	All focus on supporting prioritisation and drafting of action plans towards resilience.	Only CRI explicitly suggests monitoring over time. Only CityRAP targets an audience with low technical expertise and limited resources. UNDRR focuses on disaster risk reduction.
Target / End-user	The end-user is usually focused on governance-sector actors.	CityRAP focuses in small and medium-sized cities of developing countries. The CSD focuses in cities of low and middle-income countries. Urban planners is not explicitly mentioned, except in the CRI as part of the multi-stakeholder approach.
Methods		
Method of application	CityRAP and CSD involve a guided process. UNDRR Scorecard and CRI refer to self-assessment methods. / All refer to QUAL and QUAN methods of application.	UNDRR suggests a two-fold (rapid and thorough) method of application. CityRAP offers a bottom-up approach.
Data collected / Used	CityRAP and CSD focus on analog methods of data collection, via participatory approaches.	CRI focuses on expert level assessments. It is the only instrument offered fully online. UNDRR is offered online but executed offline.
Output		
Output	2 of 4 (UNDRR and CRI) are based on scoring from indicators. / 2 of 4 (CiyRAP and CSD) are focused on thematic clustering. / All offer best-practice recommendations.	None of their outputs produce spatial-based analytics.
Considered urban domains (areas, sectors, dimensions, pillars)	Common urban dimensions mentioned in the different frameworks: Economic (3 of 4), Social (4 of 4), Institutional (2 of 4) and Physical (4 of 4). Environment and Infrastructure are mentioned as different areas of actions.	Terms vary across the different frameworks. CRI is the only framework which adds a bridging layer of urban components between the four main urban dimensions and their indicators.
Considered resilience capacities (categories, qualities)	CSD and the CRI focus on similar resilience capacities. The term used varies but refers mainly to the characteristics of resilience which should be achieved to a certain extent, and thus should be considered and measureable.	UNDRR and CityRAP do not focus on specific resilience capacities to address, but consider an open approach for drafting recommendations.

3.2. The proposed novel ARTUR framework

3.2.1. Adopted Urban Dimensions

Datola et al., (2022) summarise five dimensions within urban systems from a socio-ecological perspective: physical, natural, economic, institutional, and social. For the proposed framework, the natural dimension is assumed to be part of the physical dimension; understanding this as inclusive of all elements of the physical environment, i.e. the natural, built, infrastructural, and technological realms of urban systems. The term *dimension* is also addressed differently across the consulted frameworks. For the proposed framework, the term *dimension* refers to the overarching four categories which organise the subcomponents of the urban sphere and allow assessment of urban resilience. The SETS theoretical platform (Mc. Phearson, et al., 2022), understands urban systems as social-ecological-technological systems, and serves as an additional disaggregation that is required to better reclassify the different indicators that the referenced frameworks provide. For that, the implementation-oriented framing for evaluation of urban resilience that Datola proposes, brings forward the institutional element that is required to complete an overview of urban dimensions. This sets the basis on which the urban resilience indicators are integrated. The following four urban dimensions organise the integration of urban resilience (UR) indicators: Social, Economic, Physical, and Institutional.

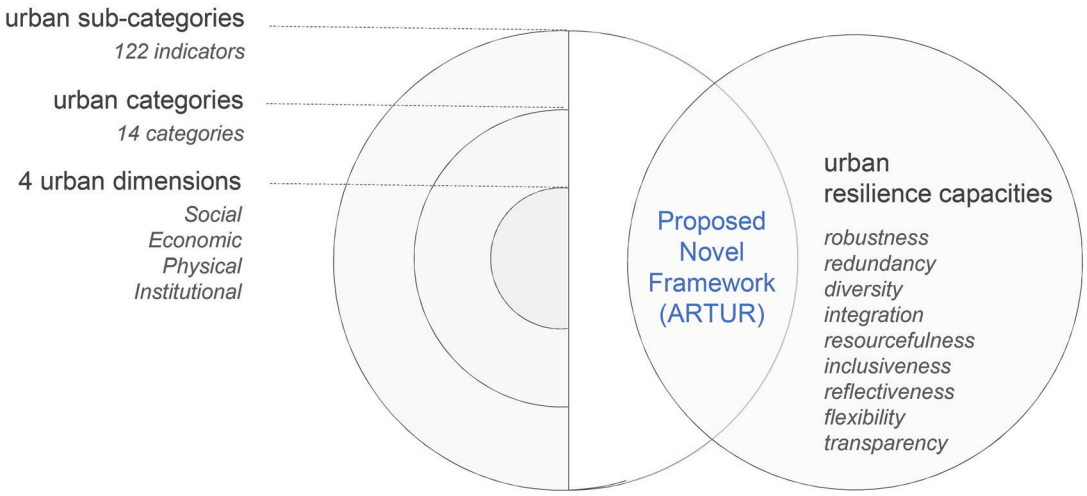

Fig. 2. Diagram of the proposed novel integrated resilience framework: ARTUR.

3.2.2. Adopted Categories

An intermediate categorisation step is necessary both to organise the indicators within each urban dimension, and to guide the selection of measures required as a consequence of the specific needs reported by individual cities. These categories are based on the definition of the goals or components of urban resilience that the consulted frameworks propose, for instance, the *core module* from the *City Strength Diagnosis*; the urban resilience *goals* from the *City Resilience Index*; and the *priority issues* from the *City RAP*. The set of proposed categories under the defined urban dimensions that are used to sort the adopted urban resilience indicators are detailed in Table 2.

Table 2. Urban resilience dimensions, categories distribution, and total indicators.

Urban Dimensions	Categories	Total Indicators
Economic	Economic activities	4
Economic	Economic impact	12
Institutional Physical	Governance	19
Economic Physical Social	Planning for resilience	24
Institutional Physical	Land use	3
Institutional Physical	Planning for risk and disaster	13
Institutional	Public health systems	4
Institutional Social	Security services	3
Physical	Communication	2
Physical Social	Ecosystem services	4
Physical	Major infrastructure	11
Social	Basic necessities	5
Social	Capacity building and public awareness	3
Social	Community support	15

3.2.3. Integration of Indicators

The compiled indicators were sorted into the four proposed urban dimensions and the sub-layers of corresponding categories using a thematic clustering approach based on existent literature (Datola, 2023, Galderisi, 2014). To ensure clarity and avoid duplicating measures of the same construct, a defined criterion which was focused on thematic relevance and non-redundancy clustering was adopted. Additional criterion, such as clarity, actionability, and conceptual consistency were assumed as givens, due to the ample implementation of the consulted frameworks. Table 3 illustrates the distribution of adopted indicators according to their corresponding sources.

Table. 3. Distribution and source of the adopted indicators for the ARTUR framework.

Number of indicators considered in consulted frameworks (*or questions; if not referred to as indicators)			Number of indicators adopted into ARTUR framework
Disaster Resilience Scorecard for Cities (UNDRR)	117+	>>	43
City Resilience Index (CRI)	150+	>>	43
City Resilience Action Planning Tool (CityRAP)*	75	>>	11
City Strength Diagnostic (CSD)*	92	>>	25
			122

3.2.4. Adopted Resilience Capacities

The need to integrate resilience capacities into resilience assessment frameworks, and the small number of existing methods that presently integrate them has been underlined (Datola, 2023). The adopted resilience capacities are partially based on the comparative analysis outlined in Section 3.1. Galderisi (2014) summarised 13 resilience capacities from four overarching fields of study: ecology and sustainability, risks and disasters, climate change and economy. From these, nine resilience capacities were assumed for our proposed resilience framework; six of which were identified as common capacities in Section 3.1. The adopted resilience capacities for this study are: robustness, redundancy, diversity, integration, resourcefulness, inclusiveness, reflectiveness, flexibility, and transparency.

The complementary value of local knowledge was garnered from expert discussions, in regards to how resilience in Ukraine has assumed particular significance. These pertain to the specific parameters that they perceive as having the ability to strengthen the resilience capacities of their cities. The work presented by scholars from the Kyiv National University of Construction and Architecture (KNUCA) in an online workshop, referred to the capacities of decentralisation, diversification and alternativity, multifunctionality, accessibility, and community cohesion as the most relevant for Ukrainian cities and their recovery (Apostolova-Sossa, 2024). When compared to the ARTUR framework, similar capacities are considered to be the most relevant (Fig. 3). Nevertheless, standardisation remains a challenge with regard to both the adoption of terms and the implementation measures.

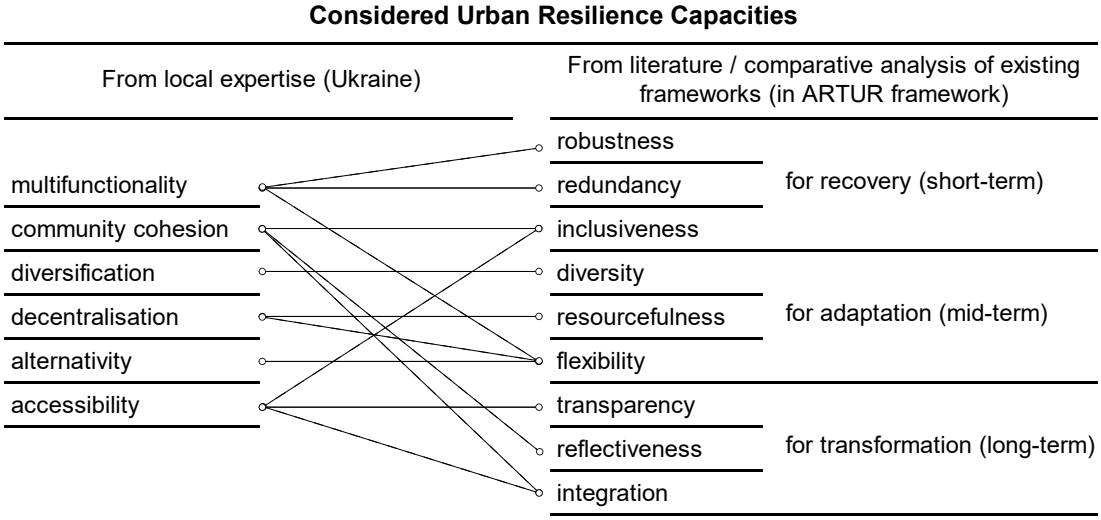

Fig. 3. Alignment of framework´s resilience capacities to local expertise

3.2.5. Calculation Method

The workflow noted in Figure 4 operationalises the cross-connection of components from the proposed integrated framework that are required to obtain a resilience score. The first step involved a second thematic clustering to link the set of indicators collected from the referenced frameworks to each of the nine urban resilience capacities. The workflow ensures the possibility of dissecting a specific problem that is cross-connected from each urban dimension to its corresponding urban resilience capacities by a specific set of indicators. Each indicator measures several urban resilience capacities, and each resilience capacity is affected by a selected group of indicators. A scoring system was established to transfer qualitative inputs to a quantitative scoring output. Each indicator is assessed through a questionnaire based on a four-level, best-worst scaling system. Each answer assigns a quantitative value as a score to each resilience capacity from the related indicator. Figure 4 details the sequential steps followed to perform the calculation method that was used to obtain an urban resilience score.

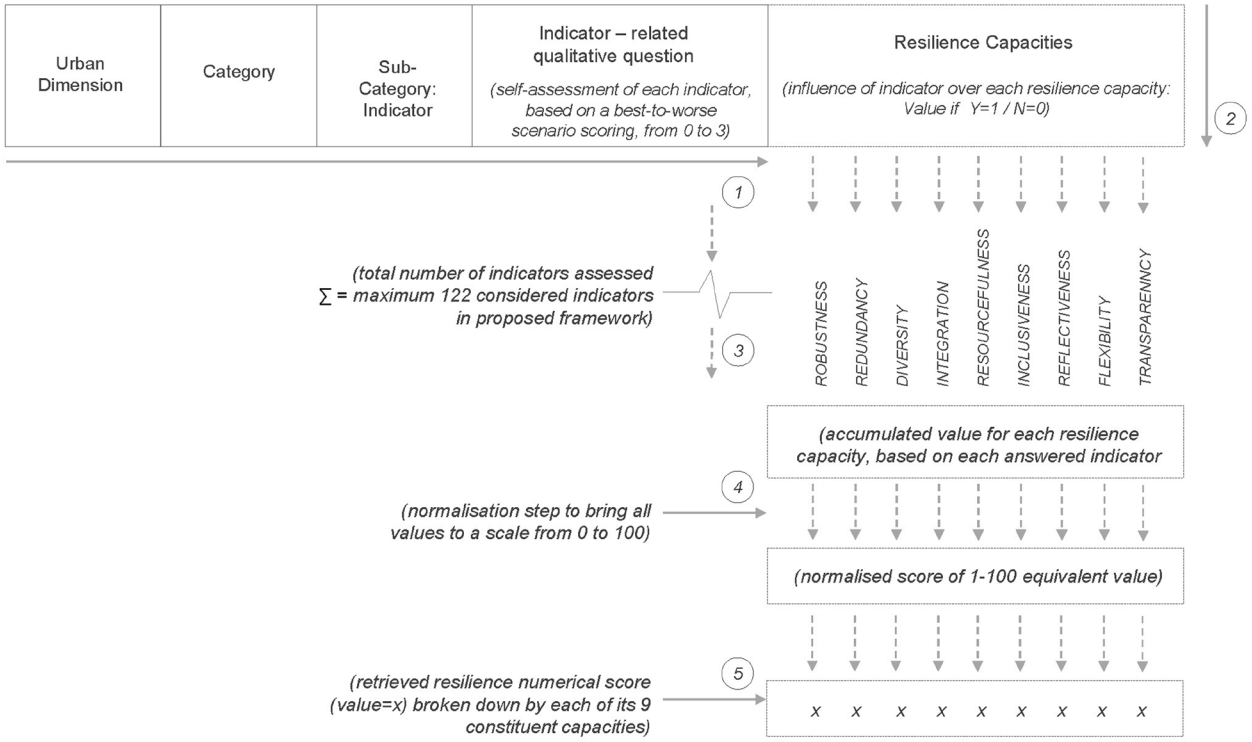

Fig. 4. Operational diagram of the calculation of a resilience score in the ARTUR framework.

In Figure 5 an example of one indicator, showcased in blue, is added into the calculation, to illustrate steps 1 and 2 from Figure 4. The highlighted grey cell illustrates the user's input in the self-assessment questionnaire and how this affected the score linked to this specific indicator. The process would then be repeated, considering as many indicators as required according to the type of challenges that the specific case demands. There is a maximum of 122 indicators embedded in the framework. The accumulated values and normalisation steps 3, 4 and 5 (from Figure 4) are not illustrated in this example.

Urban Dimension	Category	Sub-Category: Indicator	Indicator – related qualitative question				Resilience Capacities (9)								
Social	*Basic Needs*	*Safe and Affordable Housing*	*To what extent does the city have an adequate supply of safe and affordable housing?*				*ROBUSTNESS*	*REDUNDANCY*	*DIVERSITY*	*INTEGRATION*	*RESOURCEFULNESS*	*INCLUSIVENESS*	*REFLECTIVENESS*	*FLEXIBILITY*	*TRANSPARENCY*
			There is an acute shortage of affordable housing in the city. People lack security of tenure and property rights are not acceptable. There are large parts of the city where informal (unplanned) settlements have established unsuitable to live in.	*20 – 40% level of service (incl. Quality)*	*40 – 60% level of service (incl. Quality)*	*The supply of affordable housing meets demand. Requirements of residents (space and quality) are met. There is effective funding to provide safe housing. There are incentives and affordable financing mechanism to help upgrade the standard of existing housing stock.*									
			score 0 factor: 0.00 (lowest: worst)	score 1 factor: 0.33	**score 2 factor: 0.66**	score 3 factor: 1 (highest: best)	*0*	*0*	*0*	***1***	***1***	***1***	*0*	***1***	***1***
			value for each affected resilience capacity, based on one answered indicator >>							*0,66*	*0,66*	*0,66*		*0,66*	*0,66*

Fig. 5. Example, in blue, of one indicator calculated into the ARTUR framework.

3.3. From the framework to the interactive tool

Based on the principle of *boundary object* (Star & Griesemer, 1989; Meerow et al., 2016) applied in the fields of knowledge transfer (Carlile, 2002), information systems (Bowker & Star, 1999) and collaborative approaches (Trompette & Vinck, 2009), the ARTUR framework was transferred to a digital instrument that compounds both the notions of complex urban systems and resilience. This adaptation ensures its suitability for multiple contexts, while also providing the possibility to translate the framework into an operational tool.

The ARTUR digital prototype facilitates its remote take-up in diverse operational contexts, through a series of operational features. A GIS-based interface, or map-view allows consultation and the uploading of spatial data related to each case. The sunburst diagram (Fig. 6, top-left) showcases the indicators for prioritisation and selection. An online self-assessment questionnaire based on the selected indicators collects qualitative input from the user. The spider diagram (Fig. 6, top-right) presents a quantitative resilience score, from the questionnaire´s input. The Sankey diagram (Fig. 6, bottom-left) showcases the connection of the resilience capacities to each urban dimension. An urban resilience dictionary (Fig. 6, bottom-right) was integrated into the tool. It links related concepts and best-practice examples to be consulted with regard to how they translate to measures in the urban form. The complete toolkit is controlled via a user-interactive sidebar.

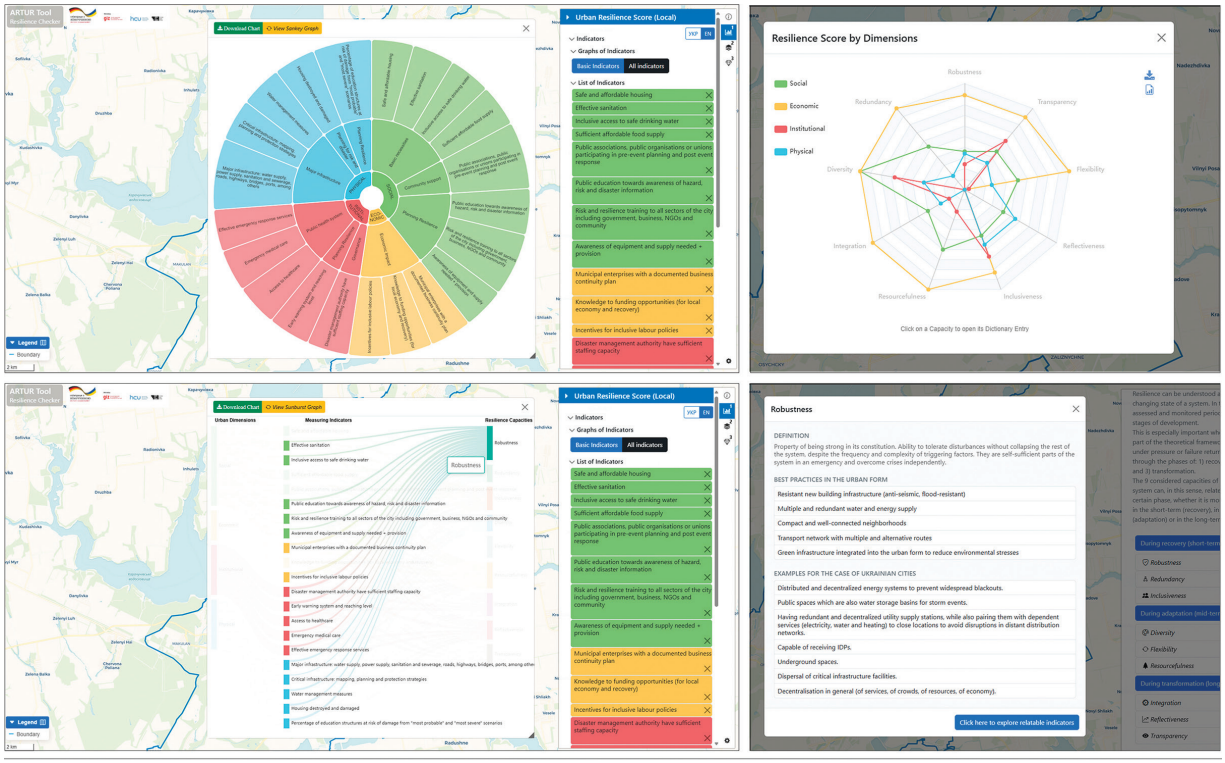

Fig 6. ARTUR interactive prototype tool.

4. Implementation

To test the ARTUR tool, two Ukrainian cities were part of the pilot activities: Nikopol and Kryvyi Rih. The activities linked to this study are based on the work carried out by the HafenCity University (HCU) Hamburg, between November 2023 and February 2025 as part of the German transitional development assistance which was commissioned by the Federal Ministry for Economic Cooperation and Development (BMZ), and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH within the framework of the project `Strengthening of Urban Resilience in the Areas of Supply Infrastructure and Housing in Ukraine (SUR)´.

The pilot consisted of a remote collaboration with the two selected cities. During the initial stage, input data was collected via online workshops and individual discussions with members of each city council. This enabled identification of the specific challenges faced by both cities as well as their individual technical capacities and data availability. Thereafter the tool was further adapted to the two local contexts. The tool´s interface and content were prepared so as to be available in both English and Ukrainian languages. A first review of the indicators was conducted to adapt them further to local demands and constraints; including accuracy of terms used during translation.

The second phase focused on preparing guidance documentation on the methodology of use. The documentation was designed to enhance understanding of the ARTUR Framework with regard to its application using the prototype tool through a series of steps which would guide its users, in this case city representatives. The documentation supported cities not only in performing a resilience scoring, but also in monitoring progress over time. The developed methodology focused not only on the necessary technical steps needed to use the tool, but also on methodological recommendations, e.g. who should participate, and how often should the methodology be practiced for successful monitoring of prioritised measures.

The final phase was the hand-over of the digital tool to both cities. To ensure data protection, the tool was adapted so that each city had independent access; ensuring privacy of uploaded data. The time given to the cities to test the tool, conduct the exercise on their own and provide a feedback report to the research team was four weeks. At the end of the implementation phase, the two pilot cities retained permanent access to the online version of the ARTUR prototype tool.

5. Discussion

The outcome of the pilot implementation provided generally positive feedback from the city representatives with regards to the potential that this instrument has to address recovery measures in Ukraine. The feedback highlighted its advantage of use, as well as what features could be improved further before resilience assessment interactive tools such as ARTUR are fully adopted into existent local-level planning workflows.

An important observation from the pilot was the need to further streamline the adopted indicators in the proposed framework when adapting them to specific local contexts. The Ukrainian partners argued that the indicators should be more contextual-bound, and more adaptable to existent current administrative, legal and technical terms. These findings are in line with the argument presented at the beginning of this paper pertaining to the importance of understanding cities as complex systems, as well as the difficulty of making resilience frameworks a one-for-all solution. Nevertheless, the potential brought by the use of a digital platform is considerable when it comes to addressing this limitation. Digital platforms ease the ability to constantly update input data, e.g. new layers of information, and this can make resilience checks more accurate as cities evolve and change.

Another productive reaction from users was their interest in becoming full administrators of such a tool. This would accelerate a sense of ownership and independence when it comes to drafting strategies to support decisions based on local-data-based evidence, and also further enable planning for development without long-term dependence on international aid. For this, users also manifested the need to receive more technical training to ensure data-update and management; and shared their interest in its use to ensure more transparency in their local governance, as well as supporting the prioritising of investment measures.

In both cases, the pilot allowed users to reflect on their low-performing indicators, as well as the dimensions, and capacities of their cities. The outcome of the exercise exposed the ability to identify areas to focus upon with regards to planning and developing actionable implementation strategies based on the results retrieved from the ARTUR resilience scoring. In the longer-term, the outcome of this capacitation exercise would be a city's independent capacity to reassess its progress by iterating the assessment process, once certain implementation outcomes have emerged from scenario planning. The expected impact should be an enhanced urban resilient system, in which cities can further evaluate and monitor their performance, while adopting other indicators and urban dimensions.

With regards to the methodological approach of this study, beyond the pilot, the contribution of the prototypical interactive tool can be discussed. The proposed framework and tool were developed within the scope of a fast-paced, agile project which contains significant data access issues due to the security concerns associated with an ongoing war. Nevertheless, the tool was developed up to a level beyond proof-of-concept. The practical implementation carried out in Nikopol and Kryvyi Rih allowed the ARTUR resilience tool to reach a technology-readiness level that is high enough to be considered a novel resilience assessment prototype with potential for further development. The pilots demonstrated operationalisation of the framework, its ability to be transferred to external users, and the identification of limitations. The pilot testing allowed users to identify vulnerable areas in their cities, such as shelter accessibility, closeness to public health sites by walking or driving distance, population coverage analysis, and the criticality of the water distribution network. The possibility to enhance the framework's potential through deeper spatial-based analytics directly linked to the framework's indicators and capacities could potentially overcome other implementational gaps identified at the beginning of this paper.

6. Conclusion

This paper elaborated on the relevance of urban resilience as a means to adopt new assessment approaches for urban planning at a local level. The study argues that certain identified gaps hinder effective urban resilience assessment methods for planning-practice; and presents an integrated urban resilience framework which holds some of the identified limitations as novel features. The two Ukrainian case studies served not only as pilots for the implementation of the proposed framework and instrument, but also as lighthouse examples for the larger development landscape of how urban systems should embrace urban resilience approaches to prepare against future unprecedented challenges that are both of larger scale and unpredictable.

The proposed methodology involved the synthesis of identified thematic insights into a coherent and integrative framework. A novel framework combined the strengths of the reviewed frameworks while addressing identified blind spots. The result intends to contribute to a more context-responsive and comprehensive structure that can guide future research and practice in resilient and sustainable development. This approach aligns with established practices in qualitative meta-synthesis and conceptual modelling, particularly in interdisciplinary fields where theoretical clarity and practical utility are equally important.

Throughout the pilot in the two Ukrainian cities, empirical learnings were collected with regard to how local communities and organisations play critical roles in resilience implementation. Ukraine´s measures of decentralisation already seem to point towards the right path. Effective resilience planning must further engage multiple stakeholders, i.e. authorities, experts, and vulnerable populations, to ensure comprehensive and adaptable strategies. This research-backed consultation project provides Ukrainian cities with a structured framework to assess resilience, develop strategies, and promote sustainable urban development.

With the increasing complexity of urban systems, it is relevant to seek solutions that can address the cascading effects upon impact of an affected urban system. Digital tools model complex, dynamic systems, enhance data usage, and synthesise the knowledge needed for planning and decision-making. These instruments accelerate the generation of new output data in the form of analysis for concrete planning activities, and thereby facilitate agile and iterative evaluations such as scenario comparison. The pilot implementation of the proposed ARTUR resilience framework illustrated how integrating digitalisation into an urban resilience framework can enhance such needed analysis, iterations, and decision-making activities toward greater transparency and digital maturity for contexts that need rapid measures and long-term sustainable recovery.

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Appendix 1.1. Extended Table of Comparative Analysis of consulted Resilience Frameworks, showcasing Background-related Criteria.

COMPARED FRAMEWORKS		BACKGROUND				
		Developing Agency	Year of Creation	Contexts where applied	Purpose	Target / End-user
Disaster Resilience Scorecard for Cities (UNDRR)		UNDRR, based on the Sendai Framework for DRR. With the support of USAID, European Commission, IBM, AECOM	2014, updated in 2017.	Over 200 cities worldwide. Strong uptake in: Asia-Pacific (Philippines, India, Indonesia); Africa (Uganda, Tanzania, Mozambique); Europe (Italy, Portugal); Latin America (Peru, Mexico).	Helps cities assess disaster resilience and align with the Sendai Framework for Disaster Risk Reduction (2015-2030).	Supports the following areas: governance, risk identification, infrastructure resilience, and disaster response planning.
City Resilience Index (CRI)		Rockefeller Foundation / ARUP	2015	Part of the 100 Resilient Cities initiative research cities: North America (New York City, Los Angeles); Europe (Rotterdam, Thessaloniki, Paris); Africa (Kigali, Cape Town, Durban); Asia (Surat, India; Bangkok, Thailand); Latin America (Medellín, Colombia; Rio de Janeiro, Brazil). Tested in 5 cities: Shimla (India), Concepcion (Chile), Arusha (Tanzania), Hong Kong (China) and Liverpool (UK).	Enable cities to measure and monitor the multiple factors that contribute to resilience. It supports diagnosis of strengths and weaknesses and measure relative performance over time.	Oriented at city-level actors, both governmental and non- governmental, i.e. authorities, decision-makers, planners, community. Focused on measures against natural and man-made pressures, e.g. rapid urbanisation, climate change, terrorism and natural hazards risks.
City Resilience Action Planning Tool (CityRAP)		UN-Habitat	2016	Primarily Sub-Saharan Africa, including: Mozambique: Chokwe, Mocuba, Madagascar, Comoros, Zambia, Senegal, Cabo Verde, Malawi, Somalia.	To build resilience with limited technical expertise. Enabling local authorities and communities to develop resilience action plans.	Targeted at small and intermediate cities (local governments), particularly in low-income and developing regions with limited technical expertise.
City Strength Diagnostic (CSD)		World Bank	2024	Africa (Accra, Ghana; Addis Ababa, Ethiopia; Nairobi, Kenya), South Asia (Dhaka, Bangladesh; Kathmandu, Nepal), East Asia (Can Tho, Vietnam; Ulaanbaatar, Mongolia), Latin America (Medellín, Colombia; Santiago, Chile), Middle East (Amman, Jordan), Europe & Central Asia (Belgrade, Serbia; Tbilisi, Georgia).	Support for diagnostics and investment prioritization. Reduce impact of rapid urban growth.	Typically applied to city-level, from low- and middle-income countries.
THEMATIC CLUSTERING	**Commonalities**	All are aid agencies or organisations with an international scope.	All developed within the last two decades, where common goals are focused on global impacts, e.g. climate adaptation.	3 out of 4 frameworks (UNDRR, CRI and CSD) are involved in 4 continents: Africa, Asia, Europe, America. All of them refer to city-level applications.	All focus on supporting for the assessment, prioritisation and drafting of action plans towards resilience.	All focus on supporting for the assessment, prioritisation and drafting of action plans towards resilience.
	Distinctions		The CSD is the most recent developed framework, after 2020.	Only CityRAP is focused primarily in Sub-Saharan Africa and not in other contexts. It is however a relevant case due to its consideration of small and medium-sized cities.	CRI is the only framework which suggest monitoring over time. CityRAP is the only framework targeting an audience with low technical expertise and limited resources. UNDRR is focused on disaster risk reduction.	CRI is the only framework which suggest monitoring over time. CityRAP is the only framework targeting an audience with low technical expertise and limited resources. UNDRR is focused on disaster risk reduction.
Considerations into proposed ARTUR Framework		Enough empirical knowledge collected from the compared frameworks can be assumed, as they all work in multiple continents.	All frameworks with recent research and implementation cases can be considered relevant enough for the topic	All consulted frameworks present a ample contextual coverage to serve as a valid reference from previous implementation cases. 3 of the 4 frameworks have been implemented across 4 continents.	The majority focus on overarching global challenges, e.g. disaster risk reduction, climate mitigation, rapid urban growth. The term `conflict´ is mentioned on some frameworks but not as a core focus challenge, or directly related to war scenarios	City-level application and multi-stakeholder approach is most adequate to address the problem of resilience with manageable strategies. Most have a higher tendency toward governance-oriented measures. None mention explicitly, urban planning targets, instead higher level (governance) targets.

Appendix 1.2. Extended Table (part 2) of Comparative Analysis of consulted Resilience Frameworks, showcasing Methodology and Output Criteria.

COMPARED FRAMEWORKS	METHODOLOGY		OUTPUT		
	Method of Application	**Data Collected / Used**	**Output**	**Considered urban domains (areas, sectors, dimensions, pillars)**	**Considered resilience capacities (categories, qualities)**
Disaster Resilience Scorecard for Cities (UNDRR)	Self-assessments at two levels: Level 1, as a two-days workshop, based on 47 indicators, each with a 0–3 score; and Level 2, as a multi-stakeholder exercise of 1–4 months that can be a basis for a detailed city resilience action plan.	A downloadable excel tool for off-line use, to retrieve a score linked to indicators, and based on a self-assessment questionnaire. Includes 117 indicators, each with a score from 0 to 5.	A self-retrieved resilience score and action plan is produced. / Additionally, best practices and a glossary to improve disaster preparedness and recovery capacity are available in their platforms.	(4 areas) infrastructure, health, environment, and society.	This framework does not define specific capacities, categories or qualities of resilience. It rather focuses on resilience goals.
City Resilience Index (CRI)	Applies qualitative and quantitative conducted questionnaires or self-assessments in a digital platform that provides a resilience-index score which can be monitored over time, via iterations.	Via the online Platform, a self-assessment is conducted, as qualitative and quantitative prompt questions (1 to 5 scale). An index score is retrieved.	A digital resilience profile for cities, allowing them to benchmark their strengths and weaknesses and track progress over time.	(4 Dimensions) health and well-being, economy and society, infrastructure and environment, leadership and strategy. Overall the framework includes: 4 dimensions, 12 goals and 52 indicators).	Robust, Flexible, Redundant, Resourceful, Reflective, Inclusive, Integrated.
City Resilience Action Planning Tool (CityRAP)	Analog and participatory Bottom-up Planning Approach: engages local stakeholders through training and workshops, using a step-by-step approach to identify vulnerabilities, prioritize actions, and co-develop a city resilience action plan.	Data is collected via a self-assessment questionnaire (1 to 4 scale) and a mapping activity of threats and challenges in participatory sessions with communities.	A City Resilience Framework for Action Plan outlining short- and long- term strategies to enhance urban resilience, focsued on climate change, safety, inclusiveness, growth.	(5 pillars) governance, disaster-risk management, infrastructure and basic services, economy and society, planning, environment.	This framework does not define specific capacities, categories or qualities of resilience.
City Strength Diagnostic (CSD)	Uses a structured diagnostic approach with a qualitative, multi-sectoral guidelines, involving stakeholder engagement, workshops, and data analysis to identify vulnerabilities and opportunities for improving resilience.	Analog Process: stakeholder mapping, sectorised interviews, prioritisation of challenges, mapping of vulnerable areas in a participatory session, filling an interdependency matrix.	A prioritized list of interventions and recommendations for enhancing city resilience.	(4 Sectors) economic, infrastructural, social, environmental.	Robustness, Coordination, Reflective, Redundant, Inclusive
THEMATIC CLUSTERING **Commonalities**	CityRAP and CSD involve a guided process. UNDRR Scorecard and CRI refer to self-assessment methods. / All refer to QUAL and QUAN methods of application.	CityRAP and CSD focus on analog methods of data collection, via participatory approaches.	2 of 4 (UNDRR and CRI) are based on scoring from indicators. / 2 of 4 (CiyRAP and CSD) are focused on thematic clustering. / All offer best-practice recommendations.	Common urban dimensions mentioned in the different frameworks: Economic (3 of 4), Social (4 of 4), Institutional (2 of 4) and Physical (4 of 4). However, Environment and Infrastructure are mentioned as different areas of actions but for this study both are assumed as part of the physical realm of urban systems.	Both the CSD and the CRI focus on similar resilience capacities. The term used varies but refers mainly to the characteristics of resilience which should be achieved to a certain extent, and thus should be considered and measureable.
Distinctions	UNDRR Scorecard suggest a two-fold (rapid and thorough) method of application. / CityRAP is the only one with a bottom-up approach. / CRI and CSD provide more in-depth resilience analysis.	The CRI is focused on expert level assessments. It is the only instrument offered fully online. The UNDRR-Scorecard is offered online but is to be executed offline.	None of their outputs produce spatial-based analytics.	The terms to refer to their areas of action are not unified across the different frameworks. / CRI is the only framework which adds a bridging layer of urban components between the 4 main urban dimensions and their indicators.	UNDRR and CityRAP do not focus on specific resilience capacities to address, but consider an open approach for drafting recommendations.
Considerations into proposed ARTUR Framework	Workshop-based participatory approaches are a basis in 2 of the 4 consulted frameworks, intended for those contexts with lower technical expertise and income. Nevertheless, self-assessment methods can be adopted, for contexts where expert-level stakeholders are usually expected. This is accompanied by the right guidelines for proper independent use.	2 of the 4 Frameworks, those oriented at small, medium-sized cities or developing cities focus on analogue processes of data collection. Only 1 of the 4 consulted frameworks is available on a fully-online platform and suggests periodical monitoring of the retrieved score over time. This can suggest that when instruments are provided with a digital basis, they might enhance ease of monitoring for progress.	Indicators-based scoring as outputs is usually assumed for the self-assessment methods, and involve collected of mixed (qualitative and quantitative) data, via questionnaires. None of the identified outputs from the consulted frameworks offer spatial- based analytics, rather thematic-clustered output strategies, or indicators- based scoring.	Output is framed within 3 to 5 areas of impact. There are no unified terms to define these areas of action, also referred to as sectors, domains, pillars or dimensions. For this study, we assume the term Dimensions to refer to the most overarching realms of an urban system. Common Urban Dimensions mentioned in the different frameworks are: Economic (3 of 4), Social (4 of 4), Institutional (2 of 4) and Physical (4 of 4). Environment and Infrastructure are mentioned as additional areas of an urban system, but for this study both are assumed as part of the Physical Dimension.	This term is not unified across frameworks These can be referred to as qualities, capacities or characteristics. For this study, we assume the term Capacities, to refer to what constitutes an urban system to enhance and maintain their resilience. These capacities are grounded in a socio-ecological perspective. Common urban resilience qualities in 2 of the 4 consulted frameworks are: Robustness, Reflectiveness, Redundancy, and Inclusiveness.